Corvinus Univesity of Budapest

Increased intensity of sweet and sour cherry growing using dwarfing rootstocks

Ph.D thesis

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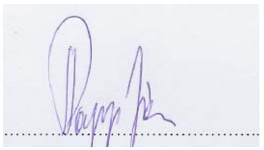

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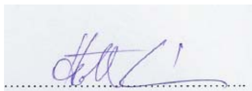

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1. Introduction

The intensive growing technology is spreading more and more over the last 2-3 decades among the stone fruit species. It isn’t easy to define concept of the intensive growing system because the intensity is a relative notion. According to Long et al. (2005) in the United States of America an orchard where the density is minimum500 trees/ha or more is considered as intensive one. After Papp (1997) we have to choose elements of the growing system so that we can reach the biggest yield and the best fruit quality within the biological and oecological potential of the site.

Size of the fruit trees in intensive orchard is smaller an in „traditional” orchard. The smaller tree size gives a lot of advantages for the growers: it is more easy and fast to prune, to harvest the orchard, 70 % of the fruits can be picked by hand from the ground so the labour cost, which is a big part of the production costs can be reduced by 50-60 % compared to „traditional” orchard (Treutter et al. 1993). As well as the „easy built” canopy is walked through sun light better than in the canopy of „traditional”sized trees so the fruit diameter and the coloring of the fruit can increase. The bearing periode starts in the 3rd or 4th leafes after planting, which means 4 or 5 leafes earlier bearing periode compared to fruit trees grafted on vigorous rootstocks. The smaller tree size needs less chemichals as well as there are no infection centres within the canopy because covering by chemichals is complete in the canopy (Hrotkó, 1999, 2003, 2005).

Reducing the canopy of fruit trees can be reached by using phytotechnical methods (Gonda and Király 2005), as well as using dwarfing rootstocks (Robinson 2005).

In the frame of my Ph.D work we studied effects of some foreign bred dwarfing rootstocks on Hungarian bred sweet and sour cherry cultivars:

- we examined the tree growth of the rootstocks-scion combinations,
- we evaluated the effects of dwarfing rootstocks on the blooming time, ripening time, yield and fruit quality of the scion varieties,

- we set up spacing models in the row and between the rows based on our results in order to calculate the orchard efficiency at the potential intensity.

Our aim was to develop the Hungarian sweet and sour cherry rootstock-usage, and to select foreign bred dwarfing rootstocks which have good results among the Hungarian climate conditions.

The important publications of the author in the frame of Ph.D tesis

Articles in reviewed journals

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2. Literature

2.1. Dwarfing rootstocks of the sweet and sour cherry

„For the fruit grower the rootstocks mean those fruit spieces on which we graft our scion cultivars because of aim of propagation, yielding and consumption." (Horn 1918).

Breeding of dwarfing cherry rootstocks started in the 1960s, 1970s. During this work many research institutes bred an own rootstocks series (Table 1.)

2.2. Rootstocks-scion interactions

According to the literature the rootstock inducing 0-30 % dwarfing effect on the growth of the grafted varieties compared to Mazzard 'F 12/1' is called vigorous rootstock. Rootstocks with 30-50 % dwarfing effect are considered medium vigorous, and rootstocks with 50-70 % dwarfing effect are semidwarf. Rootstocks with dwarfing effect on the growth of grafted cultivars than more than 70 % are considered dwarf.

There are differences between the generative properties of the varieties grafted on dwarfing rootstocks. After Lichev and Lankes's (2004) as well as Blazkova and Hlusickova' s (2004/a) data the blooming time of varieties on dwarfing rootstocks started some days later than on control, while Pfannenstiel and Schulte (2000) and Stehr (2003) obtained some days earlier blooming time. The majority of sweet cherry cultivars are self sterile so they need pollinator for the fruitful pollination. If the main blooming times of scion variety and that of pollinator aren't the same, the yield can increase completely.

Table 1. Growth reducing rootstocks and its breeing institutes (Wolfram 1989; Hrotkó 1993; Vogel 1994; Franken-Bembenek 1996; Callesen and Jorgen 1997; Bargioni et al. 1998; Mladin et al. 1998; Sansavini and Lugli 1998; Eremin and Eremin 2002; Blazkova and Hlusickova 2004/b; Rozpara and Grzyb 2004/b; Moreno 2004)

Country	Name of the research instutute	Rootstock
Belgium	Centre de Recherches Agronomiques, Gemblox	'Camil', 'Inmil', 'Damil'
Czech Republic	Reseach and Breeding Institute of Pomology Holovousy, Holovousy	'P-HL' series
Denmark	Danish Institute of Agricultural Sciences, Department of Fruit, Vegetable and Food Science, Aarslev	'DAN' series
France	INRA, Bordeaux	'Tabel Edabriz'
Great-Britain	Horticultural Research Institute, EastMalling	'Colt'
Germany	University of Giessen	'GiSelA' series
	University of Technical Munich, Institute for Fruitgrowing, Weihenstephan	'Weiroot' series
	Federal Centre for Breeding on Cultivated Plants, Institute for Fruit Breeding, Dresden-Pillnitz	'Pi-KU' series
Hungary	University of Horticulturae and Foodindustrie, Budapest	'Magyar', 'Bogdány', 'Korponay', 'Prob'
Italy	University of Bologna, Bologna	'CAB' serie
	Vivai Battistini dott. Giuseppe, Martorona di Cesena	'Victor'
Poland	Research Institute of Pomology and Ornamentals, Skierniewice	'Frutana'
Romania	Fruit Research institut Pitesti-Marachineni	'IP-C' serie
Russia	Krymsk Breeding Station, Krasnodar Region	'VC-13', 'LC-52', 'L-2', 'VSL-2'
Spain	Department of Pomology, Estacion Experimental de Aula Dei, Zaragosa	'Adara', 'Reboldo, Stockton', 'Morello', 'Masto del Montana'
United State of America	Oregon State University, Oregon	'Brokforest', 'Brokgrow'

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2.3. Importance of rootstocks evaluation under different conditions

The climate of Hungary are consinderably different from that of Western European. Our home climate is dryer and the fluctuation of temperature are bigger than the Western European. This is the reason why it is important to evaluate the dwarfing rootstocks bred in Western Europe.

The „star rootstock" of Western Europe is 'GiSelA 5' divided most the growers' community. This is now the standard rootstock in Northern half of Europe mainly in Germany (Stehr 2004). The researchers complain about weak growth of scion variety on 'GiSelA 5' in neighbourcountry of Germany in Poland that's why the polish growers give preference to using 'Frutana' interstock on seedlings and 'P-HL-A' rootstocks. It is good experience about 'GiSelA 5' rootstocks in our neighbour in Austria, also before Alps in Burgenland where the influence of the Pannon climate is large (Modl 2004). The 'GiSelA 5' rootstock still can't be used under irrigated conditions in South part of Europe in Italy and Spain because it induces very low vigor and low fruit quality (Iglesias et al 1998).

2.4. Calculating method of spacings on a unit surface with biggest density planted in the intensive orchard

To establish the largest intensity of the conical-shaped free spindel sweet cherry orchards we have to reach the biggest canopy covering-inedx. The maximum canopy covering-index can be made model simply mathematical with the circle which has the biggest radius into square.

According to Cain (1970) the canopy covering-index quotient of area under the canopy and spacings (spacing in the row x spacing between the rows). If the

canopy diameter corresponds to spacing in the row (the canopies reach each other,
canopy diameter = spacing in the row) we can calcutale the canopy covering-index by the Winter (1986 cit. Hrotkó 2002/a) formula.

6. New scentifical results

1. On the base of our results we can rank the dwarfing cherry rootstocks according to its growth: the strongest vigor resulted on *Cerasus mahaleb* 'Cema', which were continued by *Cerasus avium* 'C. 2493', 'Weiroot 13', 'P-HL-A', 'Weiroot 158', 'Weiroot 154', 'Weiroot 72', 'Weiroot 53' and 'GiSelA 5'.

2. We recommend to achieve highest density planting distances for rootstock/scoin combinations.

3. Based on our observations can be started that the dwarfing cherry rootstocks have a singnificant effect on blooming time of grafted scion varietes. The blooming time is influenced by flower density.

4. The scion varietes on foreing bred dwarfing cherry rootstocks turned to bear in the 4-5th leaves after planting. Except on control, on Cerasus avium 'C. 2493', and on 'P-HL-A' which induced the bearing periodstage of the grafted cultivars in the 7-8 leaves after planting.

5. All rootstocks/scion combinations induced higher cumulated yield than control except grafted cultivars on Cerasus avium 'C. 2493' and 'P-HL-A'. The fruit diamter of all observed cultivars decreased year by year except 'Germersdorfi 3' sweet cherry cultivar.

6. Dwarfing rootstocks caused significant differences in the fresh and dry specifics weight of the leaves of scion varieties but it needs further investigation to make the connection clear.

The ’Weiroot 13’ and *Cerasus avium* ’C. 2493’ rootstocks induced strong vigour so on the base of its growth and canopy size it wasn’t out of question by planting of an intensive orchard.

In contrast to both strong vigorous rootstocks the ’Weiroot 72’ and ’Weiroot 53’ rootstocks induced too dwarf vigour. Characteristic of both rootstocks 50-70 % drawfing effect of the grafted cultivars was too much among Hungarian climate conditions. Because of dry and outstanding characters of the Hungarian climate there wasn’t suitable regeneration capacity of the fruit variety grafted on both rootstocks.

The ’Weiroot 154’ and ’Weiroot 158’ reduced the canopy of grafted cultivars 40-50 % compared to control in our trial. The cultivars on both rootstocks produced good yield as they yielded 10-115 % more. The ’Germersdorfi 3’ and ’Linda’ sweet cherry cultivars were the most productive on ’Weiroot 154’ the ’Katalin’ sweet cherry cultivar and ’Piramis’ sour cherry cultivar on ’Weiroot 158’.

Cultivars on at least mediumvigorous rootstocks should be planted in the Hungarian intensive orchards among Hungarian climate conditions. Use of mediumdwarf rootstocks can be reached the suitable regeneration capacity so unbroken developing of generative items can be guaranteed. Next to its regeneration capacity the mediumdwarf rootstocks have tolerant to Hungarian climate conditions, they have less sensitivity to drought and produce high yield and good fruit quality. The ’Weiroot 158’ and ’Weiroot 154’ rootstocks had mediumdwarf growth in our trial were the most suitable for growing between the observed rootstocks among Hungarian climate conditions.

3. Material and method

3.1. Dwarfing rootstocks as test material in the Ph.D thesis

All foreing bred rootstocks were set up our trial were propagated by soft wood cutting in the nursery of University of Technical Munich, Institute for Fruitgrowing. The Hungarian bred rootstocks were propagted by seeds at the Reserach Instituet for Fruitgrowing Cegléd.

3.2. Introduction of the rootstocks

Cerasus mahaleb ‘Cema’ (syn.: C. 500) rootstock: According to Vogel (2000) vigour of sweet cherry cultivars grafted on ‘Cema’ is 5-10 % less than on *Cerasus avium* ‘F 12/1’. The yielding periode of cultivars on ‘Cema’ starts in the 5^{th}-6^{th} leaves after planting, this rootstock induces big yield and good fruit quality. According to Nyujtó’s (1971) data there is small differences in blooming time and ripening time of cultivars grafted on ‘Cema’ (Sebőkné and Hrotkó 1988).

Cerasus avium ‘C. 2493’ rootstock: The growth of the trees on *Cerasus avium* ‘C. 2493’ are vigorous – very vigorous, its trees on it show not to strong vigour after planting but its growth will be stronger from the 13.-15. leaves. The yielding periode of the cultivars on *Cerasus avium* ‘C. 2493’ starts in the 7^{th}-8^{th} leaves after planting (Nyujtó 1971; Hrotkó 1999).

‘GiSelA 5’ rootstock: The ‘GiSelA 5’ dwarfing rootstock is the hybrid of *Cerasus vulgaris* Mill. ‘Schattenmorelle’ x *Cerasus canescens* Mill. The canopy size of the cultivars gratfed on ‘GiSelA 5’ rootstock is reduced by 30-70 % less in the first 6 leaves after planting compared to *Cerasus avium* ‘F 12/1’. Later it can show 30-40 % dwarfing effect due to stronger vigour of the cultivars on 'GiSelA 5' (Franken-Bembenek 1995; Vogel 2000). The first fruits appeared on 'GiSelA 5' 's combinations in the 2^{nd} – 3^{rd} leaves after planting but the yielding periode starts in the 4^{th}-5^{th} leaves (Franken-Bembenek 1995; 2004/a; Pfannenstiel and Schulte 2000). After Lichev's data (2001) the blooming time of cultivars on 'GiSelA 5' starts 3-10 days earlier than on control *Cerasus avium* 'F 12/1'. According to Pfannenstiel and Schulte (2000) cultivars's blooming time on 'GiSelA 5' is some days earlier than on control. The 'GiSelA 5' combinations yield 72-363 % more than the control combinations (Franken-Bembenek 1998; Blazkova and Hlusickova 2001/c; Hilsendegen 2004; Sitarek et al. 2005). This big yield influences the fruit quality negative so after Franken-Bembenek's (1998) and Sitarek et al's. (2005) data the fruit diameter increased 10-20 %. Siegler (1996) and Vogel (2000) obtained good fruit quality.

P-HL-A rootstock: The 'P-HL-A' rootstock was selected among the natural hybrids of *Cerasus avium* L. Mill x *Cerasus vulgaris* Mill. The dwarfing effect of 'P-HL-A' rootstock on the grafted sweet cherry cultivars is 40-55 % compared to *Cerasus avium* 'F 12/1' (Blazkova and Hlusickova 2001/c, 2004/b). The cultivars on 'P-HL-A' start yielding a bit later after Blazkova and Hlusickova (2001/c) but Bargioni et al. (1998) obtained early yielding periode, in the 3^{rd}-4^{th} leaves after planting. The blooming time of grafted cultivars delayed 4 days than on control (Blazkova and Hlusickova 2004/a). After Grzyb et al's. (1998) and Blazkova and Hlusickova's (2004/a) data the cultivars on 'P-HL-A' rootstock yield three times more than the cultivars grafted on 'F 12/1' among Polish climate conditions.

Introduction of 'Weiroot' rootstocks: The 'Weiroot' rootstocks are selected *Cerasus vulgaris* Mill. types from the flood area of Danube part between Passau and Regensburg.

5. Conclusions

Between the fruit growers they can stay on their feet in the big competation of the present fruit market who can produce high fruit quality with low cost of production. The intensive fruit growing technology has a big role in the decrease of cost of production.

The site selection has an important role in the sucess of intensive sweet and sour cherry orchard. An intensive orchard in good site guarantees the good fruit quality. Important standpoint of choosing site because roots of the mediumdwarf and dwarf rootstocks are in higher 30-50 cm layer in the soil that's why they are sensitive to drought. The fruit qulaity goes off among dry climate conditions. This is the reason the irrigation of Hungarian intensive orchards is indispensable.

If we have chosen the suitable fruit site it is an important role of choice of the rootstocks next to choice of varieties. About a lot of rootstock trials can be read in the literature. In all casts it is important to take climate conditions of the trial's place into consideration. It's by no means certain we can receive some results among Hungarian climate conditions like e.g. northward or southward from Hungary.

On the base of literatural data the 'GiSelA 5' rootstock is the standard rootstock north part of Europe (Bujdosó and Kállayné 2004). Its 30-70 % dwarfing effect on grafted cultivars compared to control *Cerasus avium* 'F12/1', early, bearing periode (it starts in the 2nd-3rd leaves after planting), extremly high productive capacity and fruit quality on it are praised. Its effect on the fruit quality wasn't managed to document.

The effect of 'P-HL-A' rootstock on the yield of grafted cultivars couldn't be proved among Hungarian climate conditions. The reason of it is the climate conditions according to Hrotkó's (2002/a) oppinion.

Table 10. Calculated yield per hectar next to actual and modelled density (Érd-Elvira major, 2005)

Rootstocks	'Germersdorfi 3'		'Linda'	
	Actual t/ha	Modelled t/ha	Actual t/ha	Modelled t/ha
Cerasus mahaleb 'Cema'	1,5	5,2	4,3	16,6
Cerasus avium 'C. 2493'	1,5	4,9	5,6	19,7
'Weiroot 13'	3,1	13,5	7,8	32,0
'P-HL-A'	4,2	11,5	12,9	36,0
'Weiroot 158'	6,5	18,4	7,3	22,0
'Weiroot 154'	6,7	20,0	11,8	31,2
'Weiroot 72'	6,5	22,7	5,9	17,7
'Weiroot 53'	7,2	25,0	13,2	49,6
'GiSelA 5'	8,1	26,1	9,0	34,0

Continue of the Table 10.

Rootstocks	'Katalin'		'Piramis'	
	Actual t/ha	Modelled t/ha	Actual t/ha	Modelled t/ha
Cerasus mahaleb 'Cema'	8,9	44,0	2,1	9,2
Cerasus avium 'C. 2493'	2,3	9,2	2,7	12,2
'Weiroot 13'	9,4	41,0	3,9	23,5
'P-HL-A'	12,2	33,3	3,2	10,2
'Weiroot 158'	18,5	52,0	5,6	22,7
'Weiroot 154'	13,8	38,8	4,8	17,9
'Weiroot 72'	13,9	44,6	-	-
'Weiroot 53'	8,3	25,0	3,3	10,7
'GiSelA 5'	10,5	36,5	1,4	5,9

'Weiroot 13' rootstock: The dwarfing effect of 'Weiroot 13' rootstock on growth of grafted sweet cherry cultivars is 30-50 % compared to 'F 12/1'. According to Lichev and Lankes (2004) and Heyne (1994) the blooming time of grafted cultivars on 'Weiroot 13' let delay 2 days compared to control combination. Bearing periode of the 'Weiroot 13' combinations starts in the 3rd leafes after planting, its yield is 2-3 times higher than on control 'F 12/1'. After Heyne (1994) the fruit size of cultivars grafted on 'Weiroot 13' is smaller than on control.

'Weiroot 53' rootstock: The dwarfing effect of 'Weiroot 53' on the growth of grafted cultivars is 50-70 % compared to control. Blooming time of 'Weiroot 53' combination's let delay 3-8 days (Lichev and Lankes 2004). The cultivars on 'Weiroot 53' turn to bear in the 2nd – 3rd leafes after planting, this rootstock induces 7 % bigger yield and good fruit quality than on control.

'Weiroot 72' rootstock: The dwarfing effect of 'Weiroot 72' rootstock on the growth of grafted cultivars is 50-70 % compared to *Cerasus avium* 'F 12/1'. According to Vogel's (2000) data the grafted cultivars on this rootstock turn to bear very early, in the 2nd-3rd leafes after planting and it induces good fruit quality. Blooming time of cultivars on 'Weiroot 72' starts 2-7 days later than on control. The yield of 'Weiroot 72'-combinations is 70 % higher than on control *Cerasus avium* 'F 12/1'.

'Weiroot 154' rootstock: The dwarfing effect of 'Weiroot 154' rootstock on the growth of grafted cultivars is 40-50 % compared to control *Cerasus avium* 'F 12/1'. The cultivars on 'Weiroot 154' turn to bear in the 3rd-4th leafes after planting, this rootstock induces big yield next to good fruit quality.

'Weiroot 158' rootstock: The dwarfing effect on grafted cultivars of 'Weiroot 158' is 25-50 % compared to *Cerasus avium* 'F 12/1'. According to Pfannenstiel and Schulte's (2000) data the cultivars on 'Weiroto 158' turn to bear in the 2nd leafes after planting but it can appear ageing symptons still in the 5th leafes after planting. The trees on ’Weiroot 158’ react well on renewal pruning in the interests of ageing. The yield on ’Weiroot 158’ is few according to Hilsendegen’s data (2004) but after Lichev and Lankes’s (2004) results the yield is good among Bulgarian climate conditions in Plovdiv compared to control *Cerasus mahaleb* combinations.

3.3. Cultivars in our trial

We set up ’Germersdorfi 3’ sweet cherry cultivar which is the standard cultivar in the Hungarian sweet cherry growing and two relativ new bred hybrid cultivars (’Linda’, ’Katalin’). Among the sour cherry cultivars we chose a new bred, precocious cultivar (’Piramis’). All cultivars were grafted close to the soil level of the rootstock.

3.4. Trial site and its climate conditions

The Research Institute for Fruitgrowing and Ornamentals set up a rootstock trial at the Experimental Fields in the spring of 1997. At Érd-Station between 1970 and 2005. average number of yearly sunny hours was 1981 hours, the mean yearly temperature was 10,7 ˚C, the average temperature of growing periode was 16,6 ˚C, average yearly precipitation was 515 mm. The soil was pseudomyceliar calcareous chernozem soil (pH=8, total content of $CaCO_3$ in the over 60 cm of the soil 5%, content of humus 2,3-2,5 %) (Ambrózy and Kozma 1990; Szűcs 2001).

Table 8. Density per hectar of ’Katalin’ sweet cherry cultivar calculated on the base of actual canopy size (Érd, Elvira major, 2005)

Rootstocks	’Katalin’			
	Actual spacing (m)	Actual density (db/ha)	Modelled spacing (m)	Modelled density (db/ha)
Cerasus mahaleb ’Cema’	6 x 6	277	4 x 1,9	1361
Cerasus avium ’C. 2493’	6 x 6	277	4,6 x 1,9	1122
’Weiroot 13’	6 x 6	277	4,2 x 2	1205
’P-HL-A’	6 x 3	555	4,1 x 1,6	1512
’Weiroot 158’	6 x 3	555	4 x 1,6	1562
’Weiroot 154’	6 x 3	555	4 x 1,6	1562
’Weiroot 72’	6 x 3	555	4 x 1,4	1785
’Weiroot 53’	6 x 3	555	4 x 1,5	1666
’GiSelA 5’	6 x 3	555	4 x 1,3	1923

Table 9. Density per hectar of ’Piramis’ sour cherry cultivar calculated on the base of actual canopy size (Érd, Elvira major, 2005)

Rootstocks	’Piramis’			
	Actual spacing (m)	Actual density (db/ha)	Modelled spacing (m)	Modelled density (db/ha)
Cerasus mahaleb ’Cema’	6 x 6	277	4,7 x 1,8	1215
Cerasus avium ’C. 2493’	6 x 6	277	4,1 x 2	1244
’Weiroot 13’	6 x 6	277	4 x 1,5	1666
’P-HL-A’	6 x 3	555	4 x 1,4	1785
’Weiroot 158’	6 x 3	555	4 x 1,1	2272
’Weiroot 154’	6 x 3	555	4 x 1,2	2083
’Weiroot 53’	6 x 3	555	4 x 1,4	1785
’GiSelA 5’	6 x 3	555	4 x 1,1	2272

Table 6. Density per hectar of 'Germersdorfi 3' sweet cherry cultivar calculated on the base of actual canopy size (Érd, Elvira major, 2005)

Rootstocks	'Germersdorfi 3'			
	Actual spacing (m)	Actual density (db/ha)	Modelled spacing (m)	Modelled density (db/ha)
Cerasus mahaleb 'Cema'	6 x 6	277	5 x 2,1	965
Cerasus avium 'C. 2493'	6 x 6	277	4,8 x 2,3	920
'Weiroot 13'	6 x 6	277	4,3 x 1,9	1219
'P-HL-A'	6 x 3	555	4,1 x 1,6	1513
'Weiroot 158'	6 x 3	555	4 x 1,6	1562
'Weiroot 154'	6 x 3	555	4 x 1,5	1666
'Weiroot 72'	6 x 3	555	4 x 1,3	1923
'Weiroot 53'	6 x 3	555	4 x 1,3	1923
'GiSelA 5'	6 x 3	555	4 x 1,4	1785

Table 7. Density per hectar of 'Linda' sweet cherry cultivar calculated on the base of actual canopy size (Érd, Elvira major, 2005)

Rootstocks	'Linda'			
	Actual spacing (m)	Actual density (db/ha)	Modelled spacing (m)	Modelled density (db/ha)
Cerasus mahaleb 'Cema'	6 x 6	277	4,3 x 2,2	1061
Cerasus avium 'C. 2493'	6 x 6	277	4,3 x 2,4	972
'Weiroot 13'	6 x 6	277	4 x 2,2	1136
'P-HL-A'	6 x 3	555	4 x 1,6	1562
'Weiroot 158'	6 x 3	555	4 x 1,5	1666
'Weiroot 154'	6 x 3	555	4 x 1,7	1463
'Weiroot 72'	6 x 3	555	4 x 1,5	1666
'Weiroot 53'	6 x 3	555	4 x 1,2	2083
'GiSelA 5'	6 x 3	555	4 x 1,2	2083

3.5. Orchard desing of the trial

Planting material of our trial was one-year old non-feathered trees we produced them in the nursery of Experimental Flieds of Reseach Institute for Fruitgrowing and Ornamentals. 'Germersdorfi 3', 'Linda', 'Katalin' sweet cherry and 'Piramis' sour cherry cultivars were grafted on *Cerasus mahaleb* 'Cema', *Cerasus avium* 'C. 2493', 'Weiroot 13', 'P-HL-A', 'Weiroot 158', 'Weiroot 154', 'Weiroot 72', 'Weiroot 53' and 'GiSelA 5'. The cultivars grafted on control 'Cema', Mazzard (*Cerasus avium*) stock and 'Weiroot 13' were planted to 6 x 6 m, the other combinations to 3 m in the row and 6 m between the rows. The trial design consists of 3 trees per treatment in 2 replications. The canopy form of all trees were spindel with strong central leader.

3.6. Introduction of the obtained characteristics and calculated indexes were used during evaluation of the trial

During the research work (between 2001-2005) the observed characteristics contained the table 2. Trunk diameter of the rootstock/scion combinations was measured 20 cm over the budding at the end the vegetation periode (in November). Trunk cross sectional area was calculated from the trunk diameter with the following formula:

$$\text{Trunk cross sectional area (TCSA)} = (\text{trunk diamter}/2)^2 \times \pi$$

Among the generative items beginning of the blooming time was assessed when the 5 % of the buds were open. The main time of blooming was when

Table 2. Obtained data and time of its examination during the research work of the tesis

Obtained data	Time of examination (year)				
	2001	2002	2003	2004	2005
Trunk diameter	X	X	X	X	X
Water and dryed substance content of the leaves					X
Blooming time	X	X	X	X	X
Ripening time	X	X	X	X	X
Yield	X	X	X	X	X
Fruit diameter	X	X	X	X	X

80 % of flowers were open. We considered end of blooming, when the petals started to fall down. The ripening time was observed when 80 % of the fruits were in ripening stadium. The yield was estimated the average fruit diameter was determinated by measuring 60 fruits/combination.

The effect of the rootstocks on productivity of scion varieties is shown by a cumulated yield efficiency index (CYEI) which is the ratio of cumulated yield and the trunk cross sectional area.

To determinate dryed substance of the leaves 10 pieces leavesdisces/combination were made with using 24 mm diameter punch one week after ripening time. After processing weight of leavesdisces was measued immediately as well as when its weights remained permanent. During the evaporation water steams from the leavesdisces, after the remeasuring was become the weight of dryed substance. The differences between total weight and weight of dryed substance gives the weight of watercontent of the leaves.

4.3. Reach the highest orchard density

The calculated orchard density differ from the literatural data. It can be observed that the spacing in the row and between the rows are 1 m smaller than Heyne's (1994); Vogel's (1995) and Franken-Bembenek's (2000) recommendations (Tables 6.-9.).

The biggest density on orchard unit surface results biggest yield per hectar compared to „traditional" orchard. The yield per trees is lower in the intesive orhcard than in the extensive orchard but the smaller yield per tree is compensated by biggest tree density on unit surface (Hrotkó 1999).

On the base of our results the 'Germersdorfi 3' sweet cherry cultivar produced 170-340 % more yield by our calculation in the model density by biggest density than the actual one. This ratio is 181-310 % by 'Linda', 173-392 % by 'Katalin' and 220-503 % by 'Piramis' (Table 10.).

Fig. 11. The CYEI of 'Katalin' sweet cherry cultivar on different dwarfing rootstocks
(Érd-Elvira major, 2001-2005, SzD5%= 0,2)

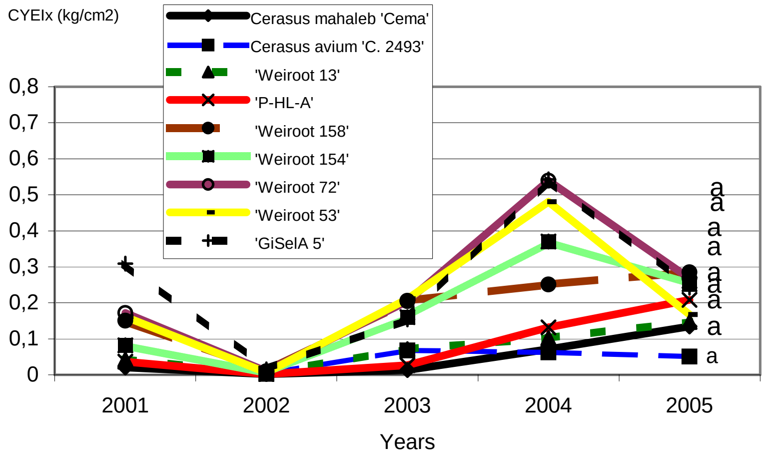
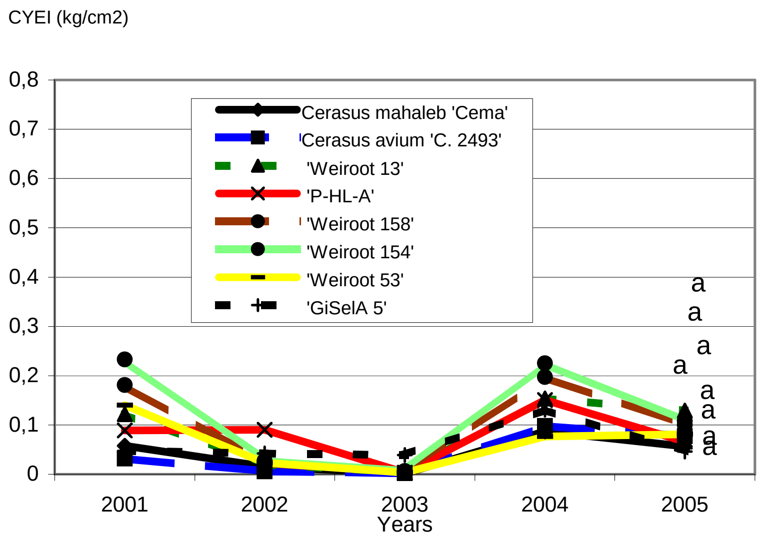


Fig. 12. The CYEI of 'Piramis' sour cherry cultivar on different dwarfing rootstocks
(Érd-Elvira major, 2001-2005, SzD5%= 0,08)



We calculated the CYEI on the base of actual and potential spacing. The potential spacing was calculated on the base of canopy covering index the following way: in our trial the canopies meet (canopy diameter = spacing in the row), the high of the trees can determinate on the base of tree height (Winter 1986 cit. Hrotkó 2002/b):

$$\text{Canopy covering} = = \frac{r^2\pi}{2\,(Mf-1)2r} = \frac{r\,\pi}{4(Mf-1)}$$

r = radius of the canopy Mf = tree height

The mean separation of rootstock/scion combinations were made by Ducan's Multiple Range Test of StatFig.ics ver. 5.1 programme (SD level was 5%). We determinated the relation of examinated charcateristics using regressio analyse of SPSS11 programme. The missing data was added the average of the mass of facts.

4. Results

4.1. Vegetative characteristics

4.1.1. The trunk cross sectional area

Based on our results we can rank the examined rootstocks according to its growth vigor: the strongest was the control *Cerasus mahaleb* ’Cema’ followed by *Cerasus avium* ’C. 2493’, ’Weiroot 13’, ’P-HL-A’, ’Weiroot 158’, ’Weiroot 154’, ’Weiroot 72’, ’Weiroot 53’ and ’GiSelA 5’.

The control ’Cema’, *Cerasus avium* ’C. 2493’, ’Weiroot 13 were classified strong, ’P-HL-A’, ’Weiroot 158’, ’Weiroot 154’ are medium vigorous while Weiroot 72’, ’Weiroot 53’ and ’GiSelA 5’ were semidwarf roostocks (Fig 1.-4.) The dwarfing rootstocks reduced the canopy size of fruit trees according to the with tree height.

4.1.2. Total weight of the leavesdisces, water and dryed matter content of the leaves

The tree size is smaller on the dwarfing rootstocks and there is less leaf surface on the trees. The bigger weight of leaves of the cultivars grafted on dwarfing rootstocks indicates that the rootstock may influence the specific fresh weight of the leaves. On the base of our results it can be stated that the bigger weight of the leaves doesn’t result bigger dryed substance of leaves (Tables 3. and 4.).

Fig. 9. The CYEI of 'Germersdorfi 3' sweet cherry cultivar on different dwarfing rootstocks
(Érd-Elvira major, 2001-2005, SD5%=0,3)

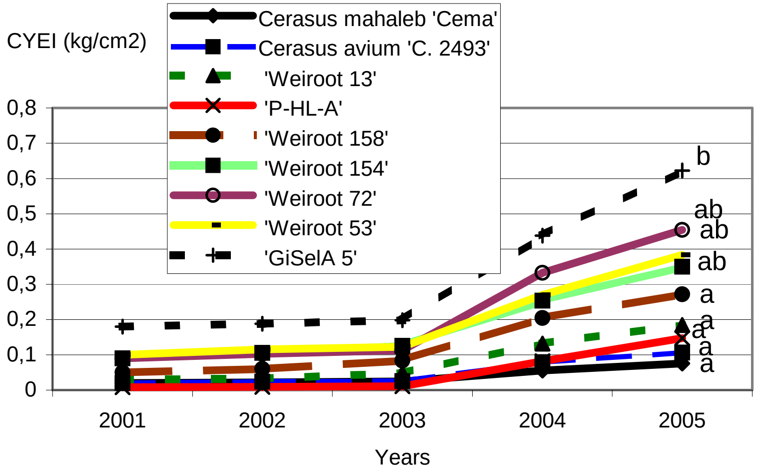
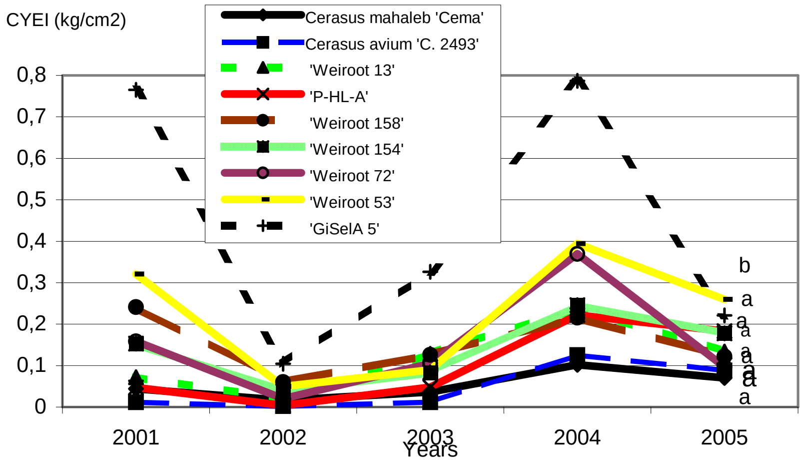


Fig. 10. The CYEI of 'Linda' sweet cherry cultivar on different dwarfing roostocks
(Érd-Elvira major, 2001-2005, SD5%= 0,17)



4.2.4. Fruit diameter

The dwarfing rootstocks affected diversely not only the yield but fruit quality too. Between the sweet cherry cultivars one of the wrongest fruit quality was produced by ’GiSelA 5’/combinations which is related to Franken-Bembenek’s (1998) and Sitarek et al.’s data. On the base of their data the ’GiSelA 5’ rootstock reduced fruit diameter of grafted cultivars by 10-20 %. The reason of it is the Hungarian climate as well as the early ageing and the strong tendency for balding.

After Vogel’s (2000) observation „the ’Weiroot 53’ and ’Weiroot 72’ rootstocks induced the best fruit quality” it isn’t true among Hungarian climate conditions. We proved Vogel’s (2000) observation by mediumdwarf rootstock (’Weiroot 154’, ’Weiroot 158’) among Hungarian climate conditions that both rootstocks induced good fruit quality.

4.2.5. The cumulated yield efficiency index

Sweet cherry cultivars on dwarf rootstocks produced the biggest CYEI. By all sweet cherry cultivars the ’GiSelA 5’ can found on the first and the strong rootstocks (control, *Cerasus avium* ’C. 2493’, ’Weiroot 13’) on the last places. By ’Piramis’ sour cherry cultivar the ’Weiroot 154’ combination reached the biggest, the control and *Cerasus avium* ’C. 2493’ the smallest CYEI (Figs 9.-12.).

Fig. 1. The trunk cross sectional area of 'Germersdorfi 3' sweet cherry cultivar on different dwarfing rootstocks (Érd-Elvira major, 2001-2005, SzD5%=49,7)

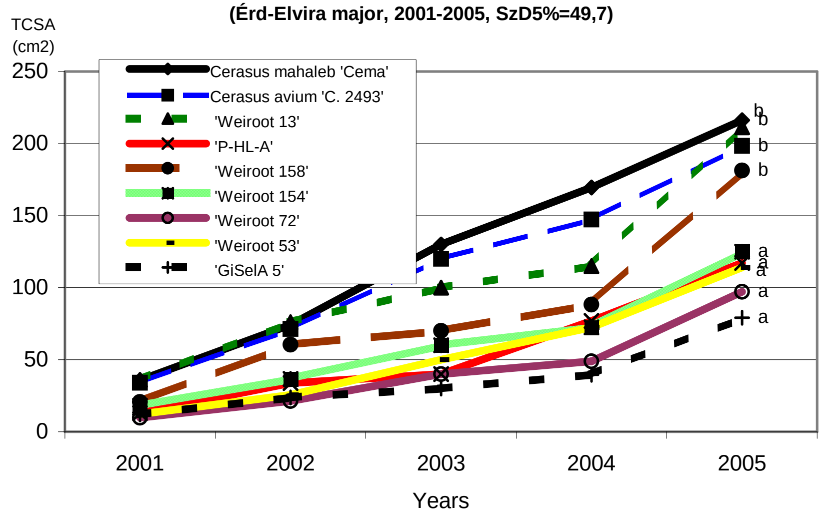


Fig. 2. The trunk cross sectional area of 'Linda' sweet cherry cultivar on different dwarfing rootstocks (Érd-Elvira major, 2001-2005, SzD5%=35,1)

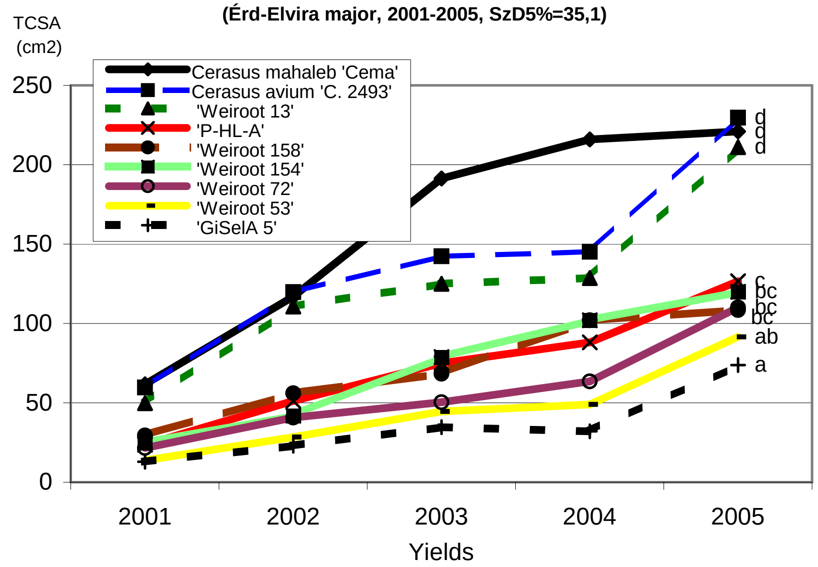


Fig. 3. The trunk cross sectional area of 'Katalin' sweet cherry cultivar on different dwarfing rootstocks (Érd-Elvira major, 2001-2005, SzD5%=41,6)

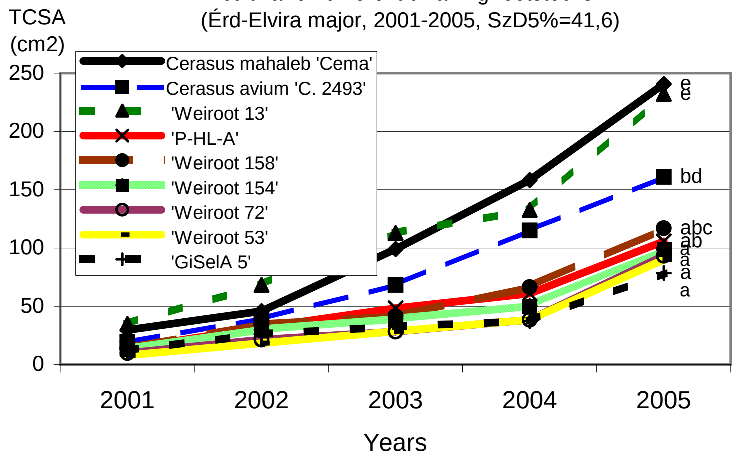


Fig. 4. The trunk cross sectional area of 'Piramis' sour cherry cultivar on different dwarfing rootstocks (Érd-Elvira major, 2001-2005, SzD5%=15,6)

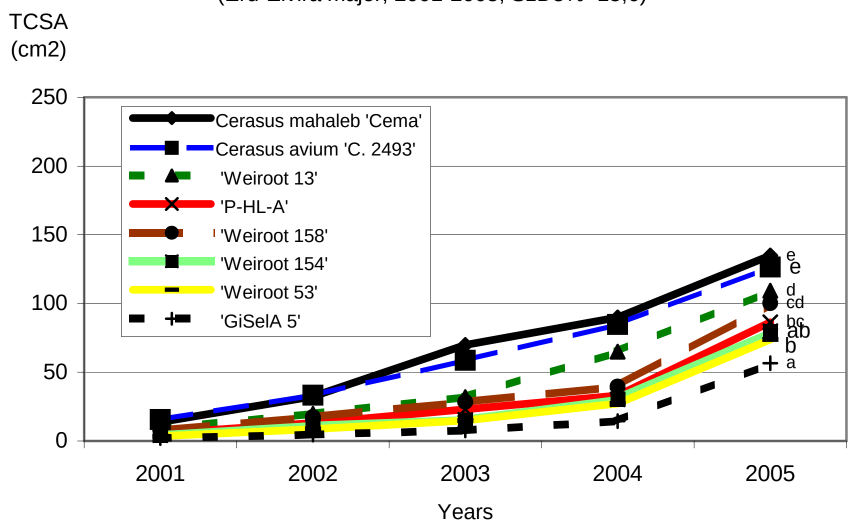


Fig. 7. Cumulated yiels of A 'Katalin' sweet cherry cultivars on different dwarfing rootstocks (Érd-Elvira major, 2001-2005, SD 5%= 12,3)

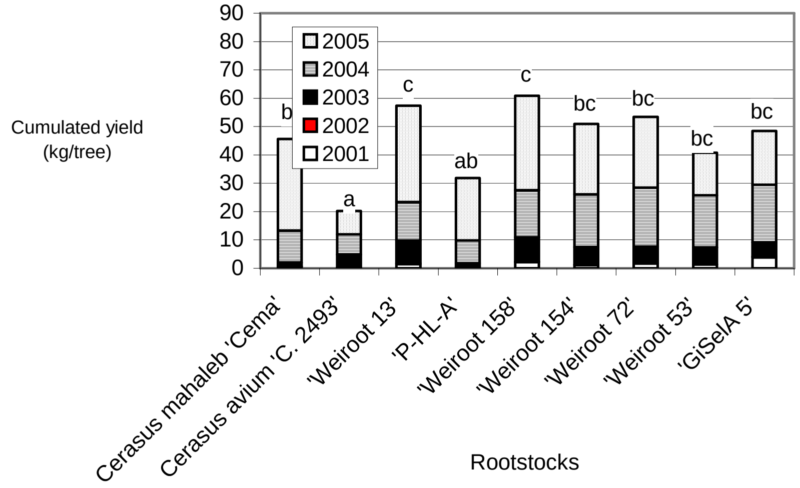


Fig. 8. Cumulated yield of 'Piramis' sour cherry cultivar on different dwarfing rootstocks (Érd-Elvira major, 2001-2005, SD 5%= 4,7)

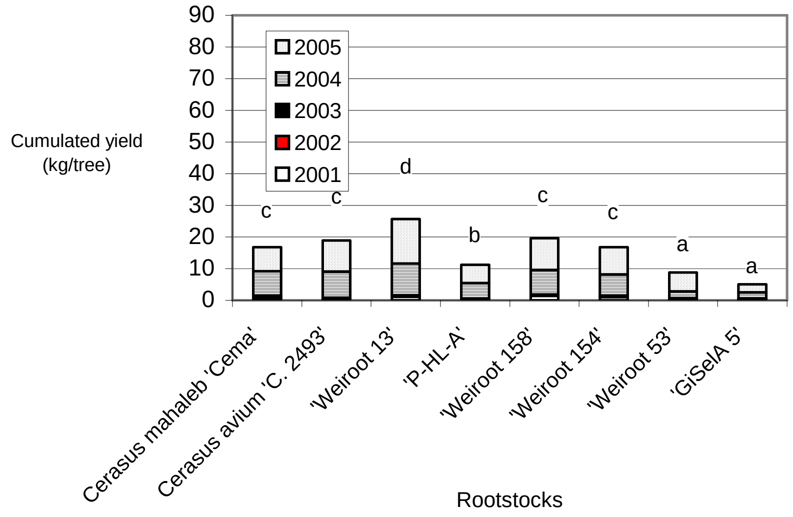


Fig 5. Cumulated yield of 'Germersdorfi 3' sweet cherry cultivar on different dwarfing rootstocks (Érd-Elvira major, 2001-2005, SD 5%= 5,9)

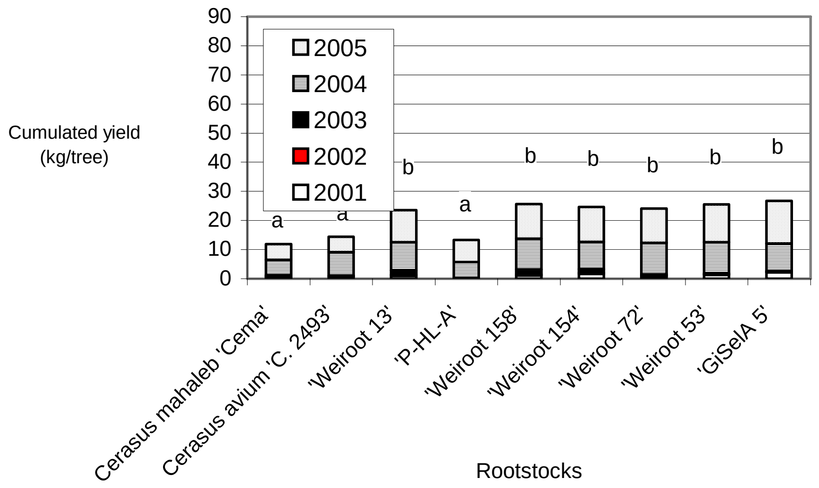


Fig. 6. Cumulated yield of 'Linda' sweet cherry cultivars on different dwarfing rootstocks (Érd- Elvira major, 2001-2005, SD 5%= 12,6)

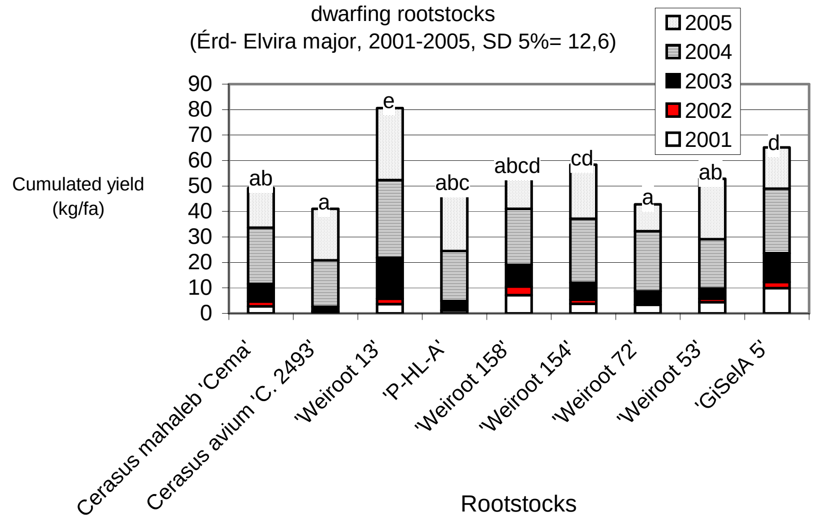


Table 3. Dry matter content of unit surface (452,16 mm^2) leavesdisces of 'Germersdorfi 3', 'Linda', 'Katalin' sweet cherry cultivars and 'Piramis' sour cherry cultivar compared to total weight on different rootstocks (Érd-Elvira major, 2005)

	'Germersdorfi 3' (%)	'Linda' (%)	'Katalin' (%)	'Piramis' (%)
Cerasus mahaleb 'Cema'	56 b	44 a	50 a	53 a
Cerasus avium 'C. 2493'	52 ab	50 a	48 a	55 a
'Weiroot 13'	40 ab	49 a	48 a	57 b
'P-HL-A'	45 ab	47 a	42 a	57 b
'Weiroot 158'	38 ab	49 a	45 a	54 ab
'Weiroot 154'	35 a	48 a	47 a	48 a
'Weiroot 72'	41 ab	60 a	45 a	-
'Weiroot 53'	54 b	60 a	60 a	54 ab
'GiSelA 5'	49 ab	60 a	44 a	58 b
SD5%	17	18	20	9

Table 4. Water content of unit surface (452,16 mm^2) leavesdisces of 'Germersdorfi 3', 'Linda', 'Katalin' sweet cherry cultivars and 'Piramis' sour cherry cultivar compared to total weight on different rootstocks (Érd-Elvira major, 2005)

	'Germersdorfi 3' (%)	'Linda' (%)	'Katalin' (%)	'Piramis' (%)
Cerasus mahaleb 'Cema'	44 a	56 a	50 a	47 ab
Cerasus avium 'C. 2493'	48 ab	50 a	52 a	45 ab
'Weiroot 13'	60 ab	51 a	52 a	43 a
'P-HL-A'	55 ab	53 a	58 a	43 a
'Weiroot 158'	62 ab	51 a	55 a	46 ab
'Weiroot 154'	65 b	52 a	53 a	52 b
'Weiroot 72'	59 ab	40 a	55 a	-
'Weiroot 53'	46 a	40 a	40 a	52 b
'GiSelA 5'	51 ab	40 a	56 a	42 a
SD5%	18	18	20	9

4.2. Generative characteristics

4.2.1. Blooming time of fruit trees on different rootstocks

Based on our results the main blooming time of the cultivars on ’Weiroot 13’ and on ’Weiroot 154’ was usually earlier than on control. At cultivars on ’Weiroot 72’ it isn’t clear whether the earlier blooming time is induced by of this German rootstock or not. The *Cerasus avium* ’C. 2493’ rootstock induced „delaying” effect on the blooming time when grafted with ’Germersdorfi 3’, ’Linda’, ’Katalin’ sweet cherry and ’Piramis’ sour cherry cultivars. The other rootstocks in our trial induced same effects on blooming time of the grafted cultivars like the control (Table 5.).

Table 5. Effect of the rootstocks on the main blooming time of grafted ’Germersdorfi 3’, ’Linda’, ’Katalin’ sweet cherry and ’Piramis’ sour cherry cultivars (Érd-Elvira major, in the average of 2001-2005 years)

Rootstocks	Sweet cherry cultivars			Sour cherry	Σ
	’Germersdorfi 3’	’Linda’	’Katalin’	’Piramis’	
Cerasus mahaleb ’Cema’	O	O	O	O	O
Cerasus avium ’C. 2493’	O	-	-	O	-
’Weiroot 13’	+	+	+	O	+
’P-HL-A’	O	-	+	O	O
’Weiroot 158’	O	+	O	O	O
’Weiroot 154’	+	O	+	+	+
’Weiroot 72’	-	+	+	O	O ill. +
’Weiroot 53’	-	O	O	O	O
’GiSelA 5’	-	+	O	O	O

+: earlier blooming time, O: average blooming time, -: late blooming time (compared to cultivars grafted on control *Cerasus mahaleb* ’Cema’)

4.2.3. The yield

Our data correspond to statment of Sebőkné and Hrotkó (1988) for *Cerasus mahaleb* ’Cema’ and *Cerasus avium* ’C. 2493’ because the cultivars on both rootstocks turned to bear in the 7th –8th leaves after planting. We proved observation of Blazkova and Hlusickova (2004/a) that the ’P-HL-A’ rootstock induced later yielding stage of the grafted cultivars than the control. This later bearing periode meant 7th-8th leaves after planting depend on the cultivars.

The cumulated yield of ’GiSelA 5’ rootstock reached the level knownfrom literature only at ’Germersdorfi 3’ sweet cherry cultivars (Franken-Bembenek 1995; 2004/a; Pfannenstiel and Schulte 2000), other combination’s yield remained lower. We could not prove results of Vogel (2000) the cultivars on ’Weiroot 13’, which yielded 2-3 times more among Hungarian climate conditions than on control. Yield of the cultivars grafted on ’Weiroot 72’ and on ’Weiroot 53’ was substantial by less in our trial than the Vogel’s data. The results of ’Weiroot 158’ were the same like Lichev and Lankes’s (2004) data but it was less at the ’Piramis’ sour cherry cultivar (Figs 5.-8.).

The differences compared to data of foreing authors can account for more factors. First of all the Hungarian climate conditions can be mentioned. The Hungarian climate conditions are dyer than Western and Northern European, that can’t be toleranted by dwarfing rootstock.

Next to the climate conditions the adverse weather decreased the yield in our trial. In the beginning of blooming time in 2002 a frost of –2 degree damaged the orchard. In 2003 it was 25-30 degree during the blooming time which hindered the pollination. In 2005 it was rainy during the blooming time meant hindrance of the optimal pollination.