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Rootstock Efficiency in Nutrient Uptake and Utilization in a High Density Cherry Orchard Experiment: A preliminary report from the results of three years findings of the use of the cultivar 'Petrus' on four rootstocks with special reference to potassium

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'Rita' trees on Gisela 6 rootstock. In background 'Petrus' on vigorous P. mahaleb. Hungary. Photo by K. Hrotkó.

Introduction

Maintaining optimal potassium (K) supply is important in cherry orchards (Hanson and Proebsting, 1996), because this nutrient plays an important role in carbohydrate transport. The cherry fruit accumulates relatively large amounts of potassium and it is for this reason that inadequate supply in cherry orchard soils may lead both to low yield and quality of fruit. The current trend in increased planting of high density orchards (Hrotkó *et al.*, 2007; Musacchi 2010), emphasizes the importance of maintaining optimal nutrition.

In high density orchards the young trees planted are heterografts. These are composite trees which consist of two different parts, in which the scion of one cultivar is grafted to the rootstock of another. The rootstock, which forms the root system of the tree, is responsible for the uptake of mineral nutrients from the soil. From the literature, rootstocks may be selective in nutrient uptake and transport, whereas the scion may influence the xylem flux, which results in different concentration of nutrients reaching the leaves and fruits. For example, Ystaas and Frøynes (1995, 1998) found that the leaves of trees on *Colt* rootstock had lower nitrogen (N) and K, and significantly higher calcium (Ca) and magnesium (Mg) contents than those of trees on control *Mazzard* rootstock. Also the leaf phosphorus (P) content in seven out of nine rootstocks (*Colt*, *Camil*, *Inmil*, *Weiroot 10*, *Gisela 1*, *Gisela 5*, and *Gisela 10*) was significantly lower than those from trees on control *Mazzard* rootstock. Hrotkó *et al.* (1997) found higher N, P and K contents in leaves of trees on moderately vigorous *M x M 14*, *M x M 97* rootstocks, compared to vigorous *Mahaleb SL 64* and *Colt*. Ca and Mg leaf contents were also higher in trees on vigorous rootstocks. Data from Roversi *et al.* (2008) also confirms the importance of rootstock in determining leaf mineral composition of sweet cherry trees. Large differences in leaf mineral composition of sweet cherry trees were also reported by Seker *et al.* (2008). In the region in which the present study was carried out, trees on *P. mahaleb* and *Gisela 6* rootstocks proved to have high content in N, P, K, Mg and Iron (Fe).

In order to predict fertilizer requirements for high density sweet cherry orchards in which new hetrographs are being grown, several aspects have to be considered:

- possible variability in mineral composition of leaves and fruits of cultivars (Roversi *et al.*, 2008);
- rootstock differences in mineral uptake and mineral composition of wood, leaf and fruit;
- data on nutrient quantities taken up and incorporated by the tree are not available; tree mass, and amounts of pruning wood are different compared to traditional orchards;
- the fertilizer need of grass in the alleyway as well as that of the trees must be taken into account.

Our investigation aimed to study the mineral composition of leaf, fruit, root and wood of sweet cherry trees budded on different rootstocks in order to establish their mineral uptake, distribution and utilization in high density orchards in Hungary. As well as providing information for possible

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different mineral nutrient features of these rootstocks, our results may also contribute to improving fertilizer recommendations specifically for sweet cherry orchards. In this publication we give an overview of the results of experiments carried out during 2007-2009 using different rootstocks and cultivars and provide a preliminary report of the findings of one cultivar ‘Petrus’ grafted on four different rootstocks. We acknowledge, with thanks, the support of the International Potash Institute (IPI).

Table 1. Soil characteristics and nutrient level measured in the research plot.

Parameter	Value				
Soil depth (cm)	0-20	20-40	40-60	Mean	Optimum*
pH (KCl)	7.68	7.74	7.77	7.73	
Compactness index (K_A)	24	24	24	24	
Total salt content (%)	<0.02	<0.02	<0.02	<0.02	<0.1
$CaCO_3$ (%)	2.21	2.62	2.80	2.54	>1
Organic humus (%)	0.94	0.88	0.81	0.87	0.71-2.0
NO_2+NO_3-N (mg kg^{-1})	2.80	5.29	4.12	4.07	
P_2O_5 (mg kg^{-1})	424	339	309	357	100
K_2O (mg kg^{-1})	206	137	99	147	100
Mg (mg kg^{-1})	70	64	66	67	60

*Szűcs, 2003. *Source*: Soroksar, 2007.

Materials and methods

The experimental orchard is planted at Soroksar Station, the experimental farm of the Faculty of Horticultural Science, Corvinus University of Budapest. The farm is located southeast of Budapest. The soil is calcareous and sandy with a lime content around 2.5 percent and a pH of 7.7. Soil compactness index (K_A) is 24 (low). The climate is typical of the central Hungarian plain, meteorological characteristics on average for the fourteen years (1991-2004) were as follows: Yearly temperature is 11.3°C, total sunshine is 2,079 hours in a year, and rainfall is 560 mm year^{-1}. Trees were planted in the orchard in spring 2004.

The trees were planted at a spacing of 4 x 2 m, i.e. a density of 1,250 trees ha^{-1} (Photo 1). Each experimental plot consisted of three trees. Each plot was from different rootstock/scion combination, and replicated six times. The setup was randomized. The trees are trained to Hungarian Cherry Spindle (Hrotkó *et al.*, 2007; Photo 1); in the alleyway naturally grown grass is managed by mowing. Drip irrigation was installed in the orchard providing 60-120 mm water during fruit growing until ripening, the quantity varying depending on the rainfall.

In autumn 2007 (September) soil samples at nine points within the orchard were taken and measurements made according to Hungarian guidelines (MSZ – 08 0202-77). The following parameters were measured: pH (in KCl), soil compactness index (K_A), organic humus content, KCl-soluble nitrate and ammonium, Al-soluble P, K, and micronutrients. From the literature, P and K contents at upper soil depth (0-20 cm and 20-40 cm) were higher than optimum, while Mg content was around optimum (Szűcs, 2003). The decreasing P and K levels at different soil depth may be attributed to the slow movement of these nutrients in this soil. Even the deepest soil layer (40-60 cm) contained optimal nutrient levels of P, K and Mg, according to Szűcs (2003; Table 1). From these data it can be concluded that soil fertility conditions were optimal for cherry trees.

Leaf samples were collected from six trees from each rootstock at the end of the months of May, June, July and August, the samples being taken from the middle of long shoots (50-70 cm) from four sides of the tree.

Leaf N, P, K, Ca, Mg and Fe contents were measured using ground dry leaf samples. N, P and K were determined after digesting the dried samples (0.5 g) with 5 cm³ concentrated sulphuric acid (H_2SO_4) at 150°C. After cooling to room temperature, 5 cm³ 30% solution of hydrogen peroxide (H_2O_2) was added and boiled until clearing. For Ca, Mg, Fe, the ground dry leaf samples were digested at 105°C with 10 ml concentrated nitric acid (HNO_3) plus

Photo 1. *View of the sweet cherry orchard trained to Hungarian Cherry Spindle. 2008. Photo by K. Hrotkó.*

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4 ml 30% solution of H_2O_2, which was boiled until clearing. The N content of the digestion solution was measured using a Tecator spectrophotometer with FIAstar flow injection system. The contents of the other mineral nutrient elements in the two digestion solutions were measured using ICP atomic emission spectroscopy (ICP Thermo Jarrell Ash ICAP 61E equipment).

Cultivars and rootstocks involved in the trial

During 2007-2009, thirty-two types of cultivar/rootstock combinations were tested (Table 2). ‘Petrus’ was tested on all eleven rootstocks, while the cultivars ‘Rita’, ‘Vera’ and ‘Carmen’ were tested only on seven of the rootstocks. Rootstock SL64 was tested only on ‘Petrus’.

Some information about the cultivars and rootstocks is given below:

Cultivars (four):

1. ‘Petrus’®; patented new Hungarian cultivar, ripens early (second cherry week), self fertile.
2. ‘Rita’®; patented new Hungarian cultivar, ripens very early (first cherry week), needs pollinator.
3. ‘Vera’®; patented new Hungarian cultivar, ripens medium to early (third cherry week), needs pollinator.
4. ‘Carmen’®; patented new Hungarian cultivar, ripens medium to early (third-to-fourth cherry week), needs pollinator.

Rootstocks (eight):

1. Mazzard (*Prunus avium* L.); seedlings of selected virus-free seed tree clone C 2493.
2. SL 64 (*Prunus mahaleb* L.); selected clonal rootstock from France, widespread sweet cherry rootstock used all over the world. Vigorous, very productive, performs well on sandy soils.
3. Cemany (*Prunus mahaleb* L.); seedlings of selected seed tree.
4. Érdi V. (*Prunus mahaleb* L.); seedlings of selected seed tree.
5. Bogdány (*Prunus mahaleb* L.); clonal rootstock selected in Hungary, vigorous, very productive, more hardy than SL 64, performs well on light sandy soil.
6. Magyar (*Prunus mahaleb* L.); clonal rootstock selected in Hungary, moderate vigorous, very productive, more hardy than SL 64, performs well on light sandy soil.
7. Gisela 6 (*Prunus cerasus* x *P. canescens*, Gi 148/1); clonal rootstock from Germany, semi-dwarf, precocious, requires fertile soil and irrigation.
8. Prob (*Prunus fruticosa* Pall. *forma aucta* Borb.); clonal rootstock from Hungary, dwarfing, precocious, early senescence of trees is typical on this rootstock.

Table 2. Scion/rootstock combinations involved in the investigations.

Cultivar	‘Petrus’			‘Rita’		‘Vera’	‘Carmen’
Year	2007	2008	2009	2008	2009	2009	2009
Rootstock							
Gisela 6	$\underline{X}$	$\underline{X}$	$\underline{X}$	X	X	X	X
Érdi V.			X	X	X	X	X
Cemany			X		X	X	X
Korponay			X		X	X	X
Egervár			X		X	X	X
SM 11/4			X		X	X	X
Mazzard	X		X	X	X	X	X
Prob	$\underline{X}$	$\underline{X}$	$\underline{X}$				
Magyar	$\underline{X}$	$\underline{X}$	$\underline{X}$				
Bogdány	$\underline{X}$	$\underline{X}$	$\underline{X}$				
SL 64	X						

Note: $\underline{X}$ represents combinations from which leaf samples were taken.

The investigations were carried out in 2007 on leaf samples of ‘Petrus’/Gisela 6, Prob, Magyar and Bogdány taken from May to August in every month. These were extended in 2008 with ‘Rita’ on three rootstock combinations (Table 2) and in 2009 with additional four rootstock combinations. In 2009, samples in all combinations were taken in August only, from trees of four cultivars (Petrus, Rita, Vera and Carmen) on 10 (for ‘Petrus’) and seven (for Rita, Vera and Carmen) rootstocks (Table 2). In this overview we have restricted the presentation of data to selected scion – rootstock combinations and years. Results of leaf analysis are presented for the cultivar ‘Petrus’ only (Table 2, Fig. 1 and 2).

Applied mineral nutrition

The fertilizing program applied in the orchard and the nutrient supply capacity of soil was uniform during the trial, matched with expected crop (Szűcs 1997, 2003). The following fertilizer quantities were applied in spring 2008 and 2009: N - 30 kg ha^{-1}, P_2O_5 - 10 kg ha^{-1} and K_2O - 50 kg ha^{-1}. The very low amounts of nutrients used were because the soil has a relative high nutrient status.

Results and discussions

Our results confirmed the literature data that there are significant differences in leaf mineral composition between trees on different rootstocks, however these differences are inconsistent and may alter depending on sampling date, and on year of growth. Furthermore, similar large differences are found between cultivars budded on the same rootstocks.

Changes in leaf mineral content during the season

Seasonal changes in leaf mineral contents on all rootstocks showed typical nutrient patterns as reported in the literature. Highest N contents were found in May, which gradually decreased towards the end of the growing season (Fig. 1) as also reported by Hanson & Proebsting (1996). Trees on dwarf *Prunus fruticosa* Prob showed the lowest leaf N-content, while higher N contents were present in leaves of

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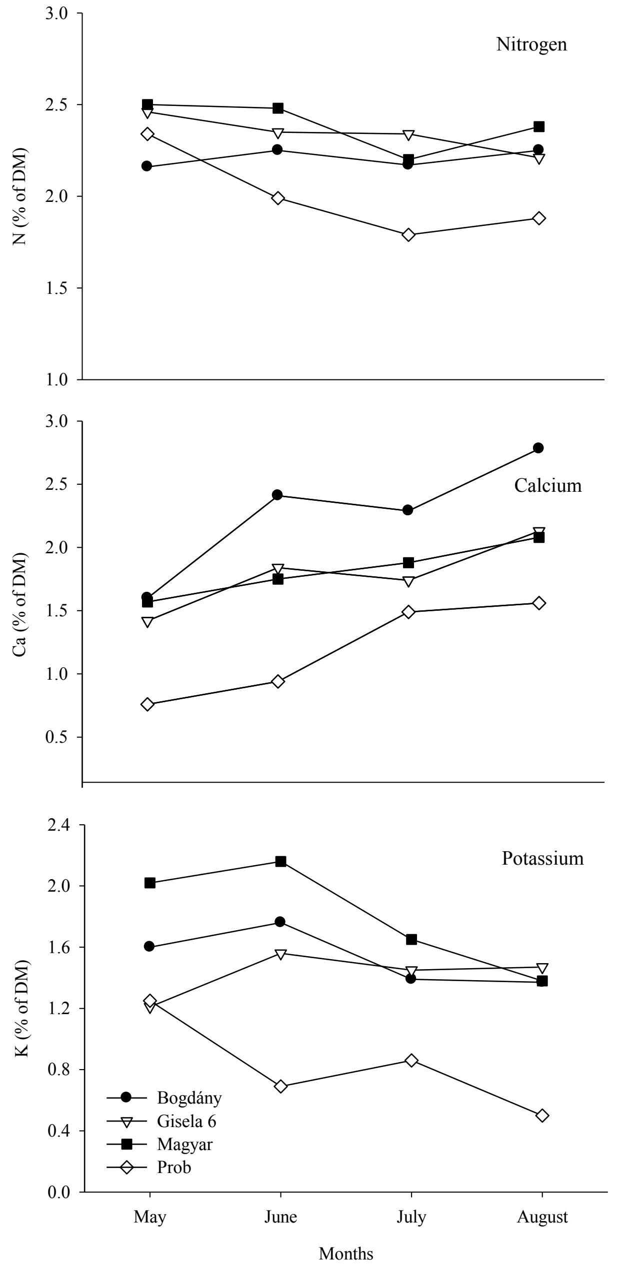

Fig. 1. N, K and Ca concentrations (% of DM) in leaves of 'Petrus' x four rootstocks in 2008 from May to August.

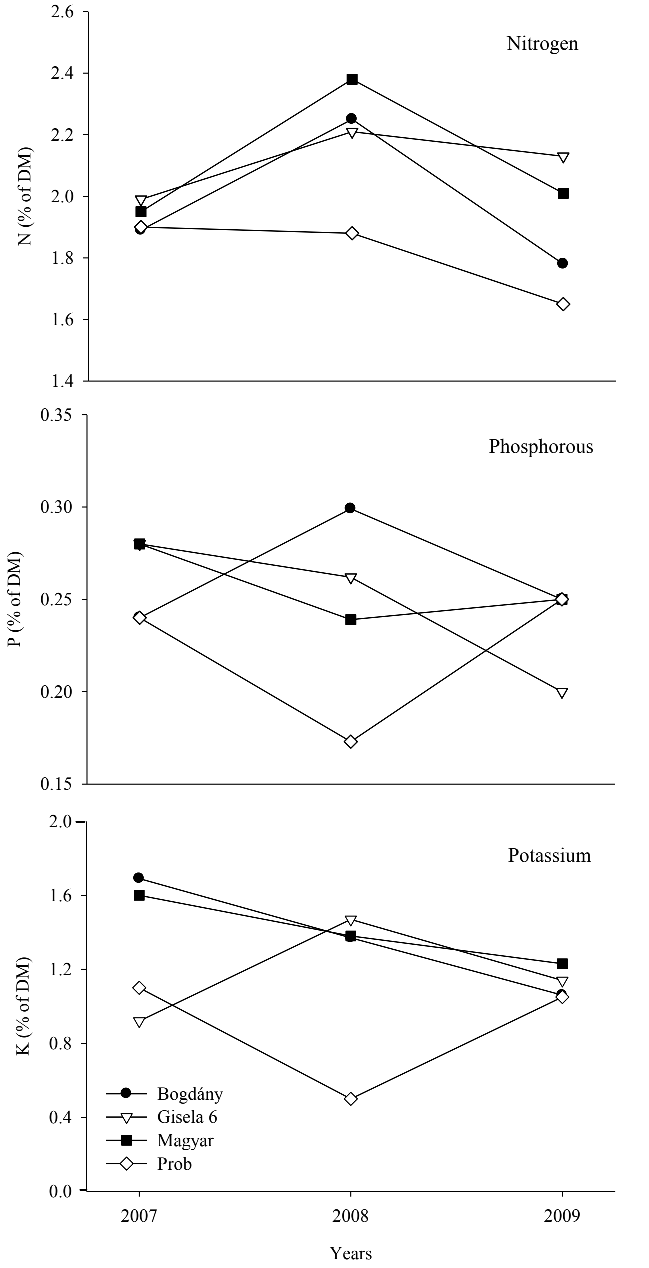

Fig. 2. N, P and K concentrations (% of DM) in leaves of 'Petrus' x four rootstocks in 2007-2009, leaves sampled in August of each year.

trees on vigorous *Prunus mahaleb* rootstocks. P contents were fairly constant from May to August. The leaf K content decreased, while Ca content increased during the growing season (Fig. 1) as might be expected because of the high mobility of K (like N) and the virtual immobility of Ca within plants. These data are important in terms of fertilizer practice because recommendations based on leaf analysis are made at the end of August when K leaf contents are at their lowest.

Effect of rootstocks on leaf mineral composition

Rootstocks might be expected to play an important role in determining leaf mineral content of grafted trees because to a large extent they control the nutrient uptake of the tree. However, in comparing leaf mineral composition of the same cultivar (Petrus) with 4 different rootstocks (all growing on the same soil), there was a lack of consistency between rootstocks and between years of sampling (Fig. 2). In the experiment as a whole, three conspicuous rootstocks, or rootstock groups showed more or less consistent performance. The leaves of trees on dwarf *Prunus fruticosa* Prob regularly

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Table 3. Leaf mass production in the 'Petrus' orchard (kg tree^{-1}; with 1,250 tree ha^{-1}) in 2008.

Rootstock	Fresh leaf mass	Dry leaf mass	Fresh leaf mass	Dry leaf mass
	--------*kg tree^{-1}*--------		--------*kg ha^{-1}*--------	
Gisela 6	2.71	0.70	3,387.5	875.0
Magyar	8.15	2.11	10,187.5	2,637.5
Bogdány	15.69	3.84	19,612.5	4,800.0

Table 4. Nutrients (kg ha^{-1}) used by trees to produce leaf mass (August samples) of 'Petrus' cherry orchards on different rootstocks at 1,250 trees ha^{-1} density in 2008.

Nutrient	Rootstock		
	Bogdány	Magyar	Gisela 6
	-----------*kg ha^{-1}*--------------		
Nitrogen	108	62.8	19.3
Phosphorus	14.3	6.4	2.3
Potassium	65.8	36.4	12.9

show the lowest mineral contents (N, P, and K), whereas those of trees on *Prunus mahaleb* rootstocks usually have mineral contents typical of well supplied trees, although large differences may occur from one year to another. Leaf samples of trees on Gisela 6 rootstock regularly contain the highest mineral levels (N, P, K), except for K (Fig. 2) in the first year 2007. We suppose that these trees had not developed their full root capacity at this stage. These results confirm Seker (2008), who also found higher mineral content of sweet cherry leaves on Gisela 6 in Turkey. It would appear that this rootstock is more efficient in mineral uptake and utilization and is similar to some *mahaleb* rootstocks.

Our results confirm the effect of rootstocks on leaf mineral content but further factors, including the degree of vegetative growth and crop load of the current year may modify mineral nutrient utilization and so too leaf mineral content.

In 2009, four trees on different rootstocks 'Petrus' (on Gisela 6, Magyar and Bogdány) and 'Rita' (on Gisela 6, Mazzard and Érdi V) received a double dose of fertilizer in spring. From the leaf samples collected in August from these trees only, Gisela 6 showed significantly higher nitrogen content which again confirms the higher uptake efficiency of this rootstock.

Nutrient use by trees on different rootstocks

The fertilizing program has a much larger impact on the rootstock usage in intensive sweet orchards when the nutrient use in biomass production is considered. Here we present only the leaf nutrient use for leaf mass production calculated for 2008.

Calculating the leaf mass produced on trees on different rootstocks showed differences much larger than those known from the literature when comparing the vigor by trunk cross-sectional area. The dry weight of leaf mass produced on vigorous Bogdány trees is more than five times larger than that of trees on dwarf Gisela 6 rootstock (Table 3).

Since the differences between rootstocks in leaf nutrient content are much smaller than those in the leaf mass production, nutrient use per hectare follows the trend of leaf mass production (Table 4). Note that this calculation does not consider the nutrient quantities taken up and incorporated by the tree (the tree mass, and pruning wood), which differs in trees depending on rootstock.

Of the K taken up by trees, large differences occur between rootstocks in distribution between leaves and fruits (Table 5). K use efficiency, as described in terms of the ratio between the yields produced (kg ha^{-1}) and the K used in leaves and fruit flesh (kg ha^{-1}), is also highly dependent on rootstock. Petrus trees on dwarf Gisela 6 produced 127 kg fresh fruit with 1 kg K taken up by leaves and fruits, whereas the comparative figure for trees on Bogdány were 43.5 kg. In this respect, an orchard planted with trees on Gisela 6 is three times more efficient. Since leaf analysis data are from the orchard in fifth leaf, this ratio is valid at the stage of development just as fruit bearing is beginning to take place.

We would like to emphasize that orchard efficiency also depends on economic considerations. Trees on dwarfing rootstocks like Gisela 6 should be planted at four-to-five times higher density (Lugli and Musacchi 2010) in order to achieve the same bearing surface, which implies a similar leaf mass per hectare, but less wood and root mass compared to vigorous rootstocks. On the other hand, the yield is relatively low with no more than 10-15 mt ha^{-1} in contrast to larger crops on vigorous rootstocks with good fruit size. Furthermore, under our site conditions, the general performance of these trees on dwarfing rootstocks is unsatisfactory. In our conditions the nutrient requirements of orchards on vigorous rootstocks, which tend to waste nutrients, should be considered.

Nevertheless the data achieved in our research project should provide a useful basis for establishing fertilizer programs for high density sweet cherry orchards.

Table 5. K use efficiency of 'Petrus' trees on different rootstocks at 1,250 trees ha^{-1} density in 2008.

Rootstock	K use in leaves	K use in fruit flesh	K use Σ in leaves and fruit flesh	Yield	Efficiency: Produced yield
	-------------------------*kg ha^{-1}*-------------------------				*kg kg^{-1}K used*
Bogdány	65.80	6.42	72.22	3,137.5	43.45
Magyar	36.40	7.34	43.74	3,400.0	77.74
Gisela 6	12.90	5.62	18.52	2,350.0	126.91

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Conclusions

Nowadays planting of high density orchards is becoming more common which emphasizes the importance of optimal nutrition. The cherry fruit accumulates relatively large amounts of K, and for this reason lack or low level of K in soils of cherry orchards may lead to low crop and low quality fruit. For high density orchards different rootstocks are preferred, the trees used being heterografts, or composite trees consisting of two different species. From the literature, rootstocks may be selective in nutrient uptake and transport, so that rootstock usage should be considered when planning fertilizing programs.

Our results confirm literature reports that there are significant differences in leaf mineral nutrient content between trees on different rootstocks. However these differences are inconsistent, with differences at specific sampling dates and variations from year to year. Furthermore, similarly large differences are found between cultivars budded on the same rootstocks. However, our results confirm the effect of rootstocks on leaf mineral content, although additional factors, such as vegetative growth and crop load of the current year, may modify mineral utilization and so too leaf mineral content.

The fertilizing program has a much larger impact on the rootstock usage in intensive sweet orchards when the nutrient use of biomass production is considered. Calculating the leaf mass produced on trees on different rootstocks showed differences, much larger than those, known from comparisons of vigor by trunk cross-sectional area. In this respect an orchard planted with trees on Gisela 6 is more efficient in nutrient utilization. However, under our site conditions, the general performance of trees and fruit size on dwarfing rootstocks is unsatisfactory.

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The paper "Rootstock Efficiency in Nutrient Uptake and Utilization in a High Density Cherry Orchard Experiment: A preliminary report from the results of three years findings of the use of the cultivar 'Petrus' on four rootstocks with special reference to potassium" appears also at:

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