Results from a long term rootstock trial with the apple cultivar 'Topaz' according to organic production conditions in Eastern Austria

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Abstract

In autumn 2008, in the research orchard of the University of Natural Resources and Life Sciences in Vienna, the apple cultivar 'Topaz' was planted on the rootstocks M9 (clone T337) with and without Rubinola as interstem, M26, M7 grafted at 25 cm and at 55 cm respectively, M111 and Bittenfelder seedling. The trees were trained as spindles and tested for eight years according to organic production rules. The trees on seeding grew very vigourously, followed by MM111 and M7 normally grafted; the M7 highly grafted trees showed less vigour, comparable with M26, while the trees on M9 with and without interstem grew very weakly. Tree losses were only observed on M9 without interstem. The highest yields per hectare were found on M7 normally grafted, followed by M26, M7 highly grafted and M9 without interstem. M7 highly grafted showed the highest single fruit weights, followed by MM111, the lowest were found on M9 with and without interstem and M26. The rootstock M7 grafted at 55 cm combines a medium growth with high yield and good fruit quality and therefore can be recommended for dry areas like our site. M9 without interstem showed a higher specific yield and fruit firmness after storage compared to the variant with interstem. Whether these advantages for 'Topaz' on M9 can be combined with a higher grafting height as effective preventive method to control Phytophthora cactorum*, has to be examined in further research.*

Keywords: M9, interstem, M26, M7, M111, Seedling

Introduction

The last years, the use of more vigourously growing apple rootstocks, especially for extensive and organic production and for recultivation has been discussing (Ruess, 2010, Hornig & Paul, 2011). They dispose of a stronger root system compared to M9, are less sensitive to voles (*Arvicola terrestris*), and furthermore, they are more tolerant to dry stress (Keppel *et al.,* 1998). In the context of the climatic change they can gain more importance in future, because their more intensive root system allows a better water and nutrient supply. This is very important in organic production, where no slightly soluble nutrients are available. Thus, the influence of some medium and strong growing rootstocks to the vegetative and generative characteristics of the apple cultivar 'Topaz' compared to the standard rootstock M9 was examined in an organically managed perennial field trial on a dry site.

Material and Methods

The trial was established in the research orchard of the University in the North-East of Vienna. The mean yearly temperature at the site is around 10 °C, the yearly rainfall about 550 mm. The soil is a chernozem with a pH of 7.6 and a high lime-content (15%). After the

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second and then after the fourth year each year, always in March, it was fertilized with Biofert (30 kg N/ha).
The cultivar ‘Topaz’ was grafted on the following rootstocks: M9 (clone T337) without and with interstem (cv. ‘Rubinola’ between 20 and 65 cm), M26, M7 (grafted normally=25 cm over the soil and highly=55 cm over the soil), MM111 and seedling ‘Bittenfelder’. In autumn 2008, 20 (5 repetitions with 4 trees) mainly unbranched trees were planted for each combination. Each repetition block was bordered on both sides by a random tree (cv. ‘Opal’ on M9). The planting distance between the rows was 4 m, and varied in the row between 1.0 m (M9 and M26), 1.5 m (M7) and 1.8 m (MM111 and seedling). The trees were trained as spindle, the orchard management was done according the organic production rules. The tree strip was opened mechanically several times per year, the grass between the rows was mulched. The plant treatments were done according the organic production rules using Neem and Quassia, and after blossom mainly Sulphur and Granulosevirus. The water supply was done when required with a mobile overhead irrigation. All other treatments (pruning, mulching) were done in a similar way on all rootstock. At harvest, for each tree weight and fruit number were registered. Since the plant distance differed depending on the expected vigour, the yield was calculated as kg per ha. In winter, the stem circumference was measured on each tree at 40 cm height. The assessment of the rosy apple aphid (*Dysaphis plantaginea*) was done every year in June, with a rating scale from 0 (no symptoms) up to 5 (extreme highly infested). The specific yield was calculated by dividing the accumulated yield per hectare with the stem cross section after the vegetation period 2015. In 2013 and 2015, immediately after harvest, a quality rating of all harvested fruits was done. In 2015, one box per variant and repetition was used for a color rating of the fruits.
From 2013-2015, 25 fruits per rootstock-variant were analysed in the lab after a short and a longer storage at 4 °C. We measured fruit weight, total soluble solids in °Brix at 20°C (Khazaei et al., 2008). Titratable acid was measured according to Wurm et al. (2005), where 10 ml sample were titrated up to pH 8.1 with a 0.1 mol/l NaOH (Thybo et al., 2006). Acid content was calculated as follows: [g/l] malic acid = [ml] NaOH * 0.67. The sugar-acid-relation was calculated using the formula: Brix * 10 / [g/l] malic acid (OECD, 2005).
The statistical analysis was done in SPSS version 19. After testing for homogeneity of variances and normal distribution we did an analysis of variance including an F-test. The means were subsequently evaluated using post-hoc Student-Newman-Keuls test ($p<0.05$).

Results and Discussion

Tree losses

In the observation period three trees (15%) on the rootstock M9 Standard without interstem were dying, all other variants had no losses.

Pests and diseases

Despite a yearly treatment with Neem before blossom, each year between 2013 and 2016 a slight attack with the rosy apple aphid (*Dysaphis plantaginea*) could be found on the trees (data not shown). At the rating no distinctive differences between the rootstocks could be found. No other important pests or diseases could be detected.

Growth

In the first years, only little differences could be observed. After the end of the third year (2011), the seedlings showed the highest vigour. The trees on MM111 were relatively weak at the beginning, and only after five years they showed the second highest vigour. After

seven years, the normally grafted trees on M7 were on third position, growing less than MM111. The trees on M7 were growing very strong at the beginning. However, especially the higher grafted ones were growing distinctly less in the following years. After seven years, they were at the same level as M26, significantly weaker than the M7 normally grafted. Both M9-variants grew significantly weaker than all other variants with no difference whether the trees had an interstem or not (figure 1).

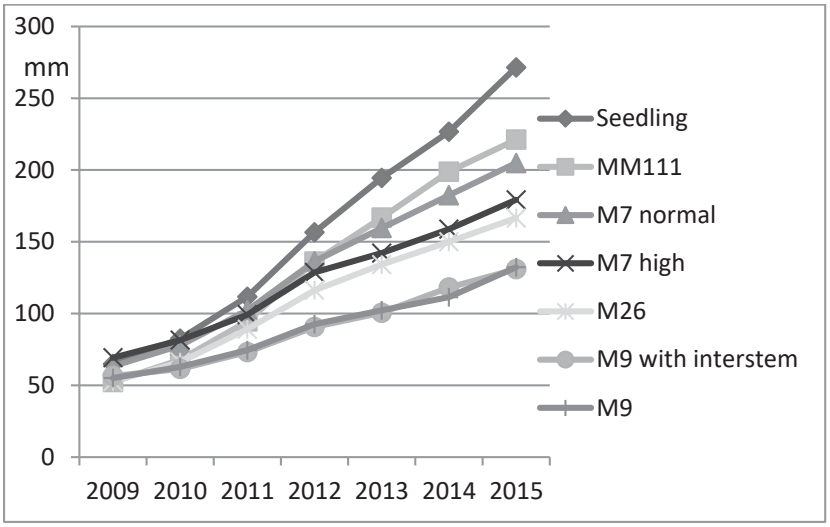

Figure 1: Results of the growth measuring (mm circumference on 40 cm height) from 2009 to 2015, always done at the end of the year.

Yield

In 2010 and 2011, we had the very first and small yields on the weakly growing rootstocks M9 and M26. The first nameable yields were in 2012 on trees of M9, M26 and both variants of M7. The strongly growing rootstocks MM111 and Seedling started even later with bearing (figure 2).

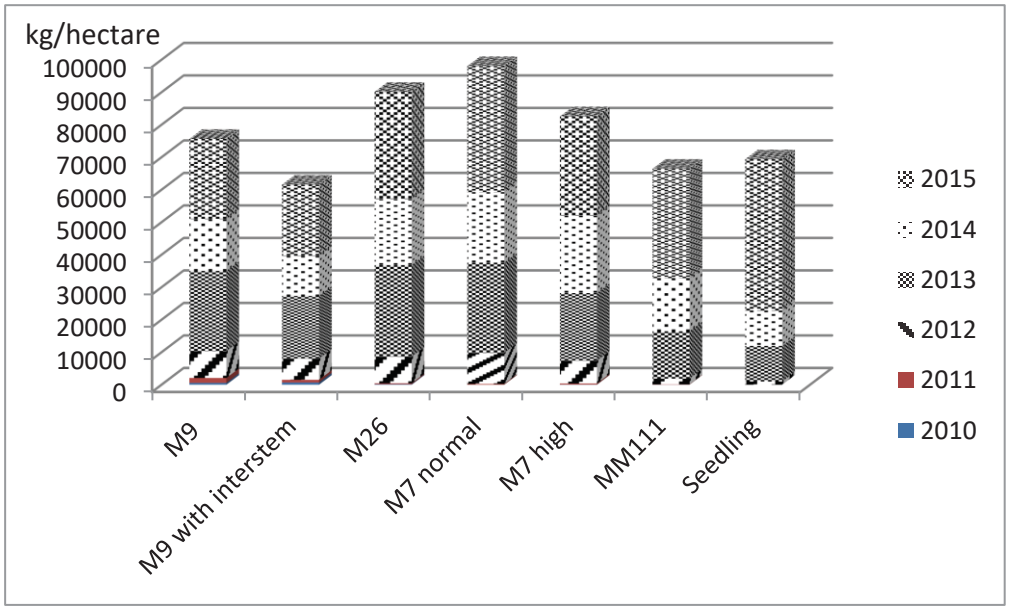

Figure 2: Yearly single tree yield (calculated as kg/ha) 2010-2015 on the different rootstocks.

Summing up the years, M7 normal and M26 had the highest yields per hectare, followed by M7 highly grafted. M9 with interstem had the lowest total yield, but was not significantly different from Seedling, MM111 and M9 Standard (table 2).
If the growth is also taken in consideration, the weakly grown rootstock M9 showed the highest specific yield, the once grafted trees (M9 Standard) could statistically not be differentiated from those with interstem. Behind M9, there was ranking M26, followed by the two variants of M7. MM111 and Seedling were clearly beneath (table 1).

Table 1: Sum of the yields in kg/ha from 2010-15, stem cross section at the end of the season 2015 and specific total yield of 'Topaz' on various rootstocks.

	Sum of yield 2010-15		Stem area end 2015	Specific total yield 2010-15	
	kg/ha	*	cm^2	kg ha/cm^2 2015	*
M9	75630	ab	14.14	5349	f
M9 with interstem	61541	a	13.57	4534	e
M26	90102	cd	22.57	3992	d
M7 normal	98012	d	33.61	2916	c
M7 high	82538	bc	25.98	3177	c
MM111	66439	a	39.86	1667	b
Seedling	69358	a	59.46	1166	a

* different letters indicate significancy (ANOVA with post-hoc SNK-test, p<0.05)

In 2013, MM111 (152 g) and M7 highly grafted (153 g) showed a significant higher fruit weight compared to M9 standard (135 g) and M26 (139 g); M7 normally grafted (148 g) and seeding (148 g) had also larger fruits than M9 standard. M9 with interstem (143 g) could not be differed from the others. In 2014 the fruits were larger, and there were no differences between the variants. In 2015 seedling (151 g), M7 highly grafted (150 g) and MM111 (144 g) showed higher values than M9 (123 g), M9 with interstem and M26 (both 129 g). M7 normally grafted (140 g) had a higher medium fruit weight in this year than M9 standard, however, it was not distinguishable from the other variants.

There were no differences between the variants in the quality rating of the harvested fruits in 2013 and 2014 (data not shown). In 2015, a higher percentage of too small fruits (8%) was found in both M9 variants, on M26 there were less (4%), hardly no small fruits were found on the more vigourosly growing rootstocks (table 2). The amount of apples with aphid (*Dysaphis plantaginea*) damage was much higher on M7 (9.4 and 7.8%) and seeding (7.4%) compared to M26 (2.0%) and M9 (1.9 and 3.5%, respectively). On seedling (2.2%) also more fruits with bitter pit were found than on M9 (0.1%), M26 (0.2%) and MM111 (0,7%) (table 2).

Table 2: Results of fruit quality rating at harvest in 2015.

	marketable fruits		*Cydia pomonella*		*Dysaphis plantaginea*		bitter pit		too small	
	%	*	%	*	%	*	%	*	%	*
M9	88,0	a	0,3	a	3,5	a	0,1	a	7,9	c
M9 mit Zwischen	87,4	a	0,9	a	1,9	a	0,1	a	8,8	c
M26	92,6	a	0,6	a	2,0	a	0,2	a	4,0	b
M7 normal	88,0	a	1,0	a	9,4	c	1,1	ab	0,2	a
M7 hoch	88,8	a	0,8	a	7,8	bc	1,4	ab	0,4	a
MM111	93,4	a	0,4	a	5,2	ab	0,7	a	0,0	a
Sämling	88,2	a	0,6	a	7,4	bc	2,2	b	0,7	a

* different letters indicate significancy (ANOVA with post-hoc SNK-test, p<0.05)

Fruit quality

The rating of colouring in 2015 showed a significant higher amount of well coloured fruits on both M9 variants compared to the seedling. All other rootstocks were in between and did not differ from each other. The strong and dense growth of the seedlings had a negative effect on the fruit colour (table 3).

Table 3: Results of the rating of fruit colouring in 2015

	% covering colour				
	< 25	25 - 50	50 - 75	> 75	*
M9	1,8	10,9	22,1	65,2	b
M9 with interstem	3,8	9,0	22,4	64,8	b
M 26	1,3	17,1	35,1	46,4	ab
M7 high	8,1	13,3	21,5	57,1	ab
M7 normal	15,3	21,3	24,9	38,5	ab
MM 111	5,4	13,9	26,8	53,9	ab
Seedling	16,6	24,9	31,4	27,1	a
* different letters indicate significancy					
(ANOVA with post-hoc SNK-test, p<0.05)					

The lab analyses after two months of storage in November did not show any significancies (data not shown).

After five months, in February, the fruit firmness was differing. M9 standard showed significant higher values (5.10 kg/cm²) than M7 high (4.87 kg/cm²) and M9 with interstem (4.84 kg/cm²). The significant lowest values were found on the seedling (4.65 kg/cm²). All other variants were not distinguishable between M9 standard and M9 with interstem.

All other characteristics, like fruit form index, soluble dry matter, ascorbic acid, malic acid and sugar-acid ratio were not differing between the variants.

Discussion and Conclusions

Both variants of M9 (with and without interstem) showed comparable results in many parameters (growth, pests, fruit quality, fruit colouring). However, the tree mortality was different: 15% of the trees on M9 standard were lost, none of the trees on M9 with interstem. ‘Topaz’ is known to be very sensitive to crown rot (*Phytophthora cactorum*), because of its property to build air roots on the stem, which easily can be infested by zoospores of *P. cactorum* from the soil (Lindner, 2009). Therefore, it is recommended to use a higher grafting point (minimum 40-70 cm over the soil line) or a tolerant cultivar (e.g. ‘Summerred’, ‘Rubinola’) as interstem (Lindner, 2009). Our observations confirm the susceptibility of ‘Topaz’ on M9 and the recommendation to use an interstem.

On the other hand, the trees with interstem had a lower specific yield compared to the standard trees and a lower fruit firmness after five months of storage. Also Köksal (1973) described a negative influence of an interstem on apple trees to the yield. Since ‘Topaz’ on M9 is very sensitive to crown rot, but also shows a higher specific yield and fruit firmness after storage without intergrafting, it has to be clearified, if a higher grafting point, as Lindner (2009) mentioned beside the intergrafting as another option to prevent crown rot, could be a cheaper alternative to the use of an interstem.

The trees on M26 grew more intensely and showed a higher yield per hectare compared to M9. In all other characteristics, also in the mean fruit weight, no diferences could be found compared to M9. In contrast to M7, despite the more intense growth, the fruit size could not be increased, this rootstock is no alternative for M9.

The first two years the trees on M7 grew very intensely. After the third year with the first fruits, the growth diminished. After, seven years, the vigour of the normally grafted trees was between MM111 and M26. In contrast, the highly grafted trees grew weaker, comparable to M26. Despite the later start of bearing compared to M9, after seven years, the summed single tree yield of the normally grafted trees was the highest of all variants. The highly grafted trees showed a slightly weaker growth and were not differing in the specific yield from the normally grafted ones. They were showing also good values regarding colouring and fruit quality, only the fruit firmness after five months of storage was less than on M9 standard. Sotiropoulos (2006) highlighted also the positive yield characteristics on M7 (beside MM 106) in a rootstock trial in Northern Greece. Therefore, on our rather dry site, the rootstock M7 highly grafted can be recommended for 'Topaz' because it combines a reduction of growth compared to the normally grafted one with a high yield and fruit weight.

On both, MM111 and seedling, a later start of fruit bearing was observed. MM111 showed a higher specific yield than the seedling, however, both were considerably lower compared to all other tested variants. Although the fruit colour and the fruit firmness were much better on MM111 than on seedling, both rootstocks are not suitable for an intensive apple production. The well-known disadvantages of the seedling, a strong growth and the late start of yielding, a low specific yield were found also in our trial. Furthermore, on this rootstock many fruits with bitter pit and damage of aphids were found, and after five months of storage a significant lower fruit firmness compared to all other variants.

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