Results from a long term trial with pear rootstocks under organic production conditions in Eastern Austria

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Abstract

In spring 2006, the pear cultivars 'Bosc's', 'Williams Christ' and 'Uta' were planted on the rootstocks 'Kirchensaller Mostbirne' (Seedling), Pyrodwarf, Farold 69, Quince Adams (with intercropping 'Conference') and own rooted from in vitro culture in the research orchard of the University of Natural Resources and Life Sciences in Vienna, and tested for eight years under organic production rules. The own rooted 'Williams'- and 'Bosc's'-trees had many tree losses in the first year, they grew medium and started with fruiting later than the grafted trees. The trees on rootstock Quince Adams were growing very weakly in the high lime containing soil at the site, with the consequence of chlorosis, tree losses and small fruits, but also a higher brix-, vitamin C- and apple acid-content in the fruits. 'Bosc's' showed low yields on all rootstocks in the observing period. 'Williams' on Farold 69 and Seedling had good yield and fruit quality, while the weakly growing cultivar 'Uta' showed low tree losses and high yields on Seedling. Pyrodwarf had very few tree losses and similar growth and yield compared to Farold 69 and Seedling, however smaller fruits on 'Williams' and 'Bosc's'.

Keywords: Farold 69, Seedling, Pyrodwarf, Quince Adams, own rooted

Introduction

The demand for organically produced pears has been increasing. According to this, in the last 15 years, also the production area in Austria raised, especially in the area around St. Pölten in Eastern Austria (Rueß, 2007). Due to a high lime content of the soil in the region, the dwarf growing quince (*Cydonia oblonga*) rootstocks (C, A, Adams) are not suitable for this region. Rootstocks from the species *Pyrus communis* are generally well adapted to high lime content in the soil. However, the pear seedling grows intensely and, like quinces, also susceptible to pear decline and fire blight (*Erwinia amylovora*). Other interesting pear rootstocks are the OHF clones (e.g. OHF 69, 87) bred from Old Home with Farmingdale. They are tolerant to fire blight, but also growing vigorously (Monney & Evequoz, 1999, Weber 2001, Einhorn *et al*., 2013). Other pear rootstocks with a more moderate growth (Fox 11, Pyrodwarf) are not studied well so far. In Northern Italy besides the seedling, own rooted scions are used in the organic production, because they are more resistant against stress compared to those grafted on quinces (Tibiletti, 2001). The trees are propagated in vitro and they are similar to seedling in growth. Like the seedlings, especially in the first years, the own rooted trees have to be cut not too much to bring them as early as possible into production (Tibiletti, 2001).

The aim of this long term field trial was to find out, which rootstocks could be suitable for organic production in Eastern Austria and if own rooted pears could be an alternative to grafted trees.

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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 7.5 and a high lime-content (15 %).

Three cultivars ('Bosc's', 'Williams' and 'Uta') on five rootstocks were tested: Seedling ('Kirchensaller Mostbirne'), Pyrodwarf, OHF(=Farold) 69, Quince Adams (with 'Conference' as interstem) and own rooted scions from in vitro propagation. The trees were all one year old and came (Seedling, Pyrodwarf, Quince) from an Austrian nursery (Schreiber, Poysdorf), Farold 69 and the own rooted scions from Italy (Calderoni, Solarolo). In spring 2006, 5 repetitions with 5 trees (in total 25 trees) for each combination were planted at 4 x 2 m distance. The own rooted 'Uta'-trees were available only one year later, and therefore planted in autumn 2006. The trees were trained as spindles, the orchard management was done according the organic production rules.

At harvest, which was done specifically on time for each cultivar, for each tree weight and fruit number were registered. The specific yield was calculated from the summed yearly yields, divided with the stem area, calculated from tree circumference measured at 40 cm height in autumn 2013. The assessment of pests and chlorosis was done every year from 2010-2013 at the End of May, with a rating scale from 0 (no symptoms/chlorosis) up to 5 (extreme highly infested/chlorotic). The symptoms of pear rust (*Gymnosporangium sabinae*) were assessed in the same way every year in August.

From 2011-2013, 25 fruits per cultivar-rootstock-combination were harvested from different trees of all repetitions and left at room temperature for a short period to fully maturate prior to lab analysis. We measured fruit weight (balance FA-200S, Sartorius, Germany), total soluble solids (refractometer, Atago, Japan) in °Brix at 20 °C (Khazaei *et al*., 2008). Titratable acid was measured (TitroLine alpha plus, Schott, Germany) according to Wurm *et al*. (2005), where 10 ml sample were titrated up to pH 8.1 with 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, IBM, Austria). 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 ($p<0.05$). The fruit quality data was evaluated separately for each cultivar.

Results and discussion

The own rooted trees of 'Williams' and 'Bosc's' showed 48 % of tree losses, all in the planting year. The reason for that could be the rarely existing fine roots of these trees combined with a late planting time and a very dry spring period in 2006. The own rooted Uta-trees, which were planted in autumn 2006 had only 4 % of loss at all.

The Quince trees, which had many fine roots when planting, did not show tree losses in the first two years. However, after the following five years many trees (up to 48 % on 'Uta') on this rootstock died, certainly due to the high lime content in the soil of the site. High losses could be found also on 'Uta' on Farold 69 (8%), 'Bosc's' and 'Williams' on Seedling (16 and 8 %). After all years, all trees of 'Uta' on Seedling and Pyrodwarf as well as 'Bosc's' on Pyrodwarf were healthy (figure 1).

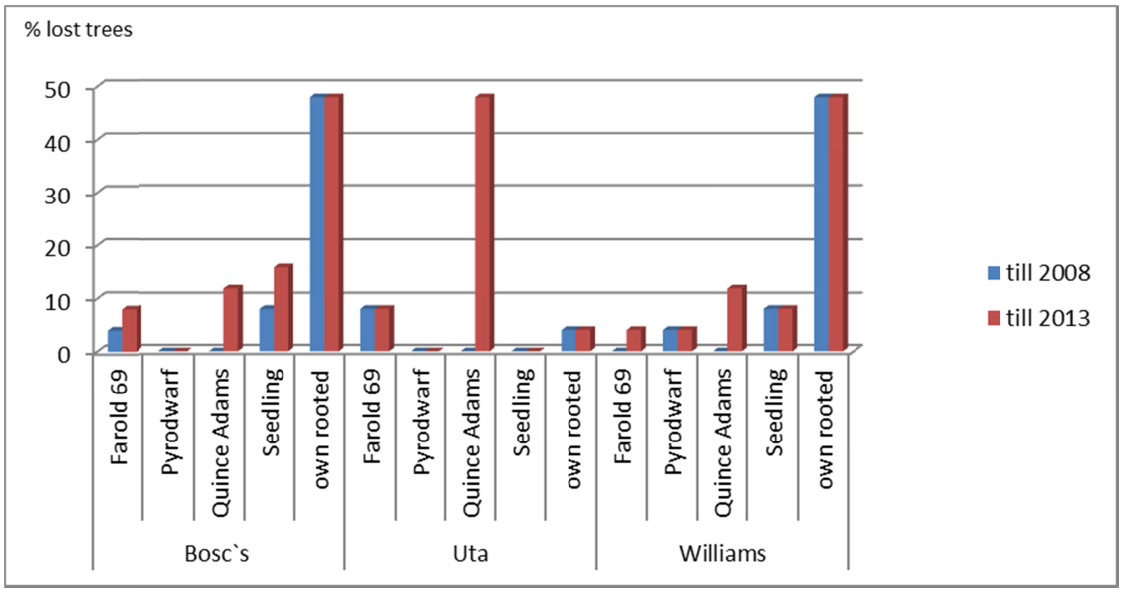

Figure 1: Lost trees in the trial till the years 2008 and 2013.

No differences between the variants could be found in the infestation with *Psylla pirisuga, Psylla piri, Eriophyes piri* and *Gymnosporangium sabinae* (figure 2). For the wolly pear aphid (*Dysaphis pyri*) differences between the variants were obvious. The combination 'Bosc's' on Pyrodwarf was hardly attacked; the weakly growing trees on Quince Adams showed much less infestation compared to the other rootstocks, also regarding symptoms of *Janus compressus*. Nevertheless, a higher rating of chlorosis was found on Quince, more on 'Uta' compared to 'Williams' and 'Bosc's' (data not shown). Regarding symptoms of chlorosis, similar results were found at on another site in Austria with the same trial in an integrated management system (Wurm *et al*., 2014).

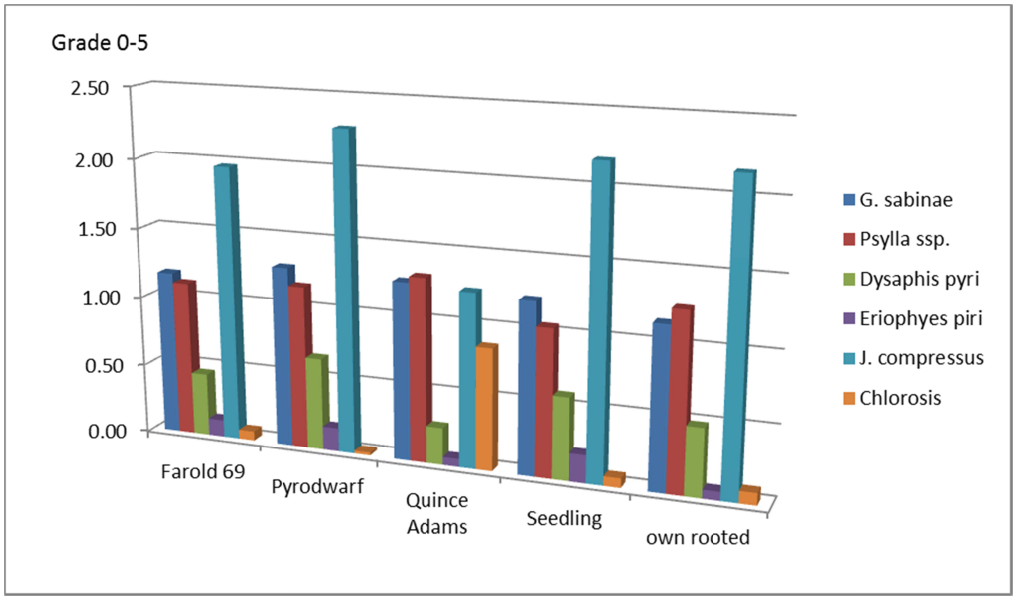

Figure 2: Results of the assessments of pests, diseases and chlorosis (Mean of the years 2010-2013, Rating scale from 0 = no infestation/chlorosis to 5 = extreme highly infested/chlorotic.

For the cv. ‘Bosc’s’, which generally showed a lower yield compared to ‘Williams’ and ‘Uta’, the yield on Pyrodwarf, Farold 69 and Seedling was higher compared to Quince Adams and the own rooted trees. On ‘Uta’, the trees on Seedling showed the highest yield, followed by Pyrodwarf and Farold 69, Quince Adams was lowest. The own rooted trees, which were planted one year later, showed a later start of bearing, however, it was hardly comparable to Farold 69 and Pyrodwarf in the last two years. On ‘Williams’, Farold 69 had the highest yield, followed by Seedling and Pyrodwarf. The own rooted scions showed only a slight difference especially in the first years due to a later start of bearing.

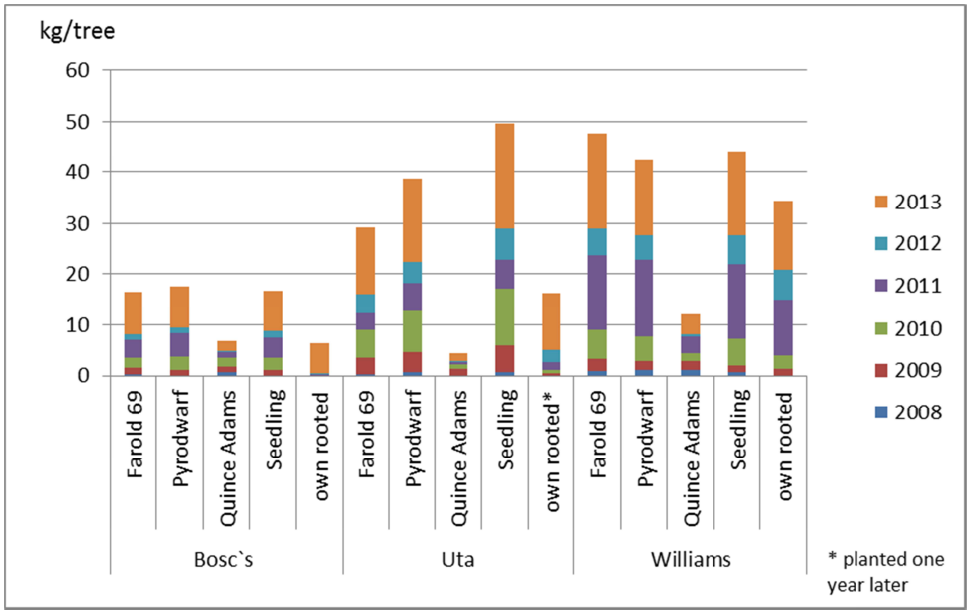

Figure 3: Yearly yield per tree from 2008 to 2013

The trees on Quince Adams showed the weakest growth with all three cultivars. The own rooted trees, of all three cultivars, were growing medium. With the scion ‘Bosc’s’ the trees on Pyrodwarf were the most vigorous, followed by Seedling and Farold 69.

With ‘Uta’, Seedling was the most vigorous, followed by Pyrodwarf and Farold 69.

With ‘Williams’, Farold 69, Pyrodwarf and Seedling were closed together, the first two significantly stronger grown than the own rooted. The weaker growth of ‘Uta’ compared to ‘Bosc’s’ and ‘Williams’, and Quince Adams compared to the other rootstocks and the own rooted ones has a strong influence to the specific yield: ‘Uta’ on Seedling (1.16 kg/cm²) had the highest cumulated specific yield, ‘Bosc’s’ own rooted (0.21 kg/cm²) the lowest. The own rooted trees of all cultivars were less fertile than the grafted ones.

For ‘Bosc’s’ the most fertile rootstock was Quince Adams (0.77 kg/cm²), all other variants were very low between 0.21 and 0.33 kg/cm². On ‘Uta’, as above-mentioned, the Seedling was the most fertile, followed very closed by Pyrodwarf and Farold 69, the one year later planted own rooted trees and Quince Adams at the end. On ‘Williams’ hardly all variants were in a similar range, with 0.87 kg/ cm² the own rooted were here competitive (table 1).

The fruits of the cultivar ‘Bosc’s’ on Quince Adams showed the lowest mean fruit weight (133 g), the fruits on Pyrodwarf were bigger (182 g), and those found on Farold 69 (197 g) and Seedling (201 g) again significantly bigger. The biggest fruits (216 g) were found on the own rooted ‘Bosc’s’ trees. Mean total soluble solids (19.5 °Brix) and malic acid (2.43 g/L) were significantly higher on Quince Adams compared to the other rootstocks. The relation of sugar to acid ranged between 84.15 (Quince Adams) and 101.06 (Pyrodwarf, table 2).

Table 1: Sum of yields 2008-13, trunk diameter and specific yield.

		Sum of yields 2008-13		Stem trunk area autumn 2013		spec. yield	
		kg/Baum	*	cm^2	*	kg/cm^2	*
Bosc`s	Farold 69	16.06	b	50.48	ef	0.33	a
	Pyrodwarf	17.60	b	58.01	f	0.29	a
	Quince Adams	6.56	ab	8.88	a	0.77	bc
	Seedling	15.89	b	52.41	ef	0.30	a
	own rooted	6.27	ab	32.10	bc	0.21	a
Uta	Farold 69	29.29	c	31.65	bc	0.93	cde
	Pyrodwarf	38.59	de	38.59	cd	1.02	de
	Quince Adams	3.82	a	7.78	a	0.60	b
	Seedling	49.72	f	44.59	de	1.16	e
	own rooted**	16.16	b	25.72	b	0.63	b
Williams	Farold 69	47.57	ef	45.69	de	1.02	de
	Pyrodwarf	42.46	def	44.24	de	0.93	cde
	Quince Adams	11.51	ab	11.03	a	1.06	de
	Seedling	44.15	def	40.36	cde	1.05	de
	own rooted	34.26	cd	35.50	c	0.87	cd

* ANOVA with post hoc (S-N-K) test; p<0.05, ** planted one year later

Fruits of the cultivar ‘Uta’ on Quince Adams were likewise remarkably smaller (138 g) compared to the fruits on other rootstocks (201-213). Furthermore fruits on Quince Adams showed higher values for total soluble solids and malic acid (19.4 °Brix, 3.96 g/l) as also seen in ‘Bosc’s’. ‘Uta’ on Seedling showed the least amount of total soluble solids and malic acid (17.4 °Brix, 2.99 g/l).

For the cultivar ‘Williams’, fruits on Quince Adams were significantly smaller than on Pyrodwarf and both of them had a significantly lower mean fruit weight (133 g, resp. 161 g) compared to the other rootstocks. The Malic acid was significantly lower in ‘Williams’ fruits of own rooted (3.69 g/l) and on Seedling (3.57 g/l) compared to Farold 69 (4.11 g/l) and Quince Adams (4.01 g/l). ‘Williams’ on Quince Adams additionally showed higher total soluble solids than on Seedling and own rooted (16.4 °Brix vs. 15.3 resp. 15.4 °Brix).

Table 2: Summary of selected fruit quality measurements from 2011-2013 (data of three years).

cultivar	rootstock	Fruit weight		Total soluble solids		Malic acid		sugar/acid	
		g	*	° Brix	*	g/l	*		*
Bosc`s	Farold 69	197	c	18.2	a	1.93	ab	95.1	ab
	Pyrodwarf	182	b	18.1	a	1.82	a	101.1	b
	Quince Adams	133	a	19.5	b	2.43	c	84.1	a
	Seedling	201	c	17.7	a	1.88	a	95.9	ab
	own rooted	216	d	18.7	ab	2.14	b	87.8	a
Uta	Farold 69	205	b	18.1	ab	3.25	ab	56.6	a
	Pyrodwarf	201	b	17.7	ab	3.08	ab	59.4	a
	Quince Adams	138	a	19.4	c	3.96	c	54.8	a
	Seedling	213	b	17.4	a	2.99	a	59.0	a
	own rooted	204	b	18.5	b	3.71	bc	54.5	a
Williams	Farold 69	172	c	15.8	ab	4.11	b	42.7	a
	Pyrodwarf	161	b	15.7	ab	3.69	ab	47.3	a
	Quince Adams	133	a	16.4	b	4.01	b	46.4	a
	Seedling	181	c	15.3	a	3.57	a	47.0	a
	own rooted	183	c	15.4	a	3.34	a	48.8	a

* ANOVA with post hoc (S-N-K) test; p<0.05

Discussion

Our results concerning the high tree losses of the own rooted trees are inconsistent with Tibiletti (2001), who attested seedlings and own rooted pear trees a high tolerance to stress. At the site Klosterneuburg, not far from Vienna, where the same trees were cultivated under integrated management conditions, similar tendencies with low tree losses on Pyrodwarf and high losses on own rooted trees, Seedling and Quince Adams were found (Wurm *et al*., 2014). However, the variant with the highest tree losses in Klosterneuburg was 'Uta' own rooted, which in our trial did not show so many died trees. In contrast to our site in Vienna, the trees from this variant at the site in Klosterneuburg were planted only in spring 2007. This permits the conclusion that for the own rooted trees, and for other pear rootstocks, which also often show a lack of fine roots in the plant material, it is very important to plant them in autumn to ensure a good start of growing.

The assessment of pests and diseases did not give many differences between the rootstocks. However, it was obvious that more vigorously grown trees were more affected by some pests (*Dysaphis pyri*, *Janus compressus*) compared to the weaker growing Quince.

The own rooted trees were growing more intensely compared to Quince Adams, however clearly less than the other pear rootstocks. Nevertheless, because of the juvenile plant material from in vitro propagation, they showed a later start of yield. Therefore, the own rooted trees were significantly lower in yield on 'Bosc's' compared to the grafted variants, but more competitive on 'Williams'. A comparison is difficult on 'Uta', because of the later planting time of the own rooted variant. Similar results regarding the fertility of the own rooted trees were obtained by Wurm *et al*. (2014).

All cultivars showed an extremely weak growth on Quince Adams. Besides, especially on the cultivar 'Uta', very heavy symptoms of chlorosis were found, which was also seen on the site in Klosterneuburg (Wurm *et al*., 2014). The fruit weight was lower with Quince Adams in all three cultivars. At the same time those fruits showed higher levels of total soluble solids and malic acid compared to the other rootstocks. The lower fruit size possibly causes a higher concentration of these substances in the fruit. Nevertheless, on our site with a high lime content (15 %), the rootstock Quince Adams is not suitable for production. The more vigorously grown and lime tolerant rootstock Quince BA 29 could be a better option. This rootstock performed better on an arid site compared to Quince A and C (Ikinci *et al*., 2014).

The Seedling ('Kirchensaller Mostbirne') showed a more vigorous growth than Farold 69 only in combination with the weakly growing cultivar 'Uta'. With 'Bosc's' and 'Williams', it was about the same as Pyrodwarf and Farold 69 or even slightly less. It performed well in yield, especially on 'Williams' and 'Uta'. Similar observations were done by Wurm *et al*. (2014) and even under the acid soils in Styria, the highest yields were harvested on 'Uta' as well on Seedling and Farold 69 and not on the Quinces, predominant at this site (Steinbauer, 2013 a). The since 2004 at the organic farms in Niederösterreich in highly lime containing soils planted 'Uta' trees, were also grafted on Seedling, which in view of this results was a good choice.

Pyrodwarf showed in sum over all cultivars the least losses of trees. The growth and yield characteristics were comparable to the other two grafted rootstocks from pear species. However, the mean single fruit weight on 'Bosc's' and 'Williams' was significantly lower compared to Seedling and Farold 69, why this rootstock is not suitable for our site with organic production.

Farold 69 showed the highest growth and single tree yield with ‘Williams’ and the highest specific yield of the rootstocks from pear species with ‘Bosc’s’. Growth and yield of Farold 69 with ‘Uta’ were definitely lower than on Seedling and Pyrodwarf, while the specific yield was not significantly different compared to Seedling and Pyrodwarf. This rootstock had many tree losses with ‘Uta’, however also important with the other cultivars. Fruit size was higher on ‘Bosc‘s’ and ‘Williams’ compared to Pyrodwarf, not different compared to the Seedling. The high performance of ‘Bosc’s’ and ‘Williams’ on Farold 69 was also seen in Klosterneuburg (Wurm *et al*., 2014), and Farold 69 resulted also at the trial site in Styria as the best of the pear native rootstocks (Steinbauer, 2013 b). Therefore, a further use of this rootstock in combination with medium or more intensely growing cultivars is suitable on highly lime containing soils.

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References

Einhorn, T.C., Castagnoli, S., Smith, T.J., Turner, J. & Meilke, E. (2013). Summary of the 2002 Pacific northwest of USA pear rootstock trials: performance of 'd'Anjou' and 'Golden Russet Bosc' pear on eight Pyrus rootstocks. *Journal of the American Pomological Society* **67**: 80-88.

Ikinci, A., Bolat, I., Ercisli, S. & Kodad, O. (2014). Influence of rootstocks on growth, yield, fruit quality and leaf mineral element contents of pear cv. ‘Santa Maria’ in semi-arid conditions. *Biological Research* **47**: 71.

Khazaei, J., Chegini, G. & Bakhshiani, M. (2008). A novel alternative method for modelling the effect of air dry temperature and slice thickness on quality and drying kinetics of tomato slices: Superposition technique. *Drying Technology* **26**: 759.

Monney, P. & Evequoz, N. (1999). OHF- und Quttenunterlagen für Birnen im Vergleich. *Schweiz. Z. Obst- und Weinbau* **26**: 634-637.

OECD (2005). Leitfaden zu objektiven Testmethoden zur Bestimmung der Qualität von Obst und Gemüse sowie Trocken- und getrockneten Erzeugnissen.

Rueß, F. (2007). Birnensorten für den ökologischen Anbau. *Öko-Obstbau* **1**: 20-23.

Steinbauer, L. (2013 a). Beständigkeit bei Birnensorten. *Besseres Obst* **10-11**: 9-10.

Steinbauer, L. (2013 b). Unterlagen, Pflanzmaterial und Erziehung – die Qual der Wahl. *Besseres Obst* **9**: 8-9.

Thybo, K., Edelenbos, M., Christensen, L., Sørensen, J. & Thorup-Kristensen, K. (2006). Effect of organic growing systems on sensory quality and chemical composition of tomatoes. *LWT Food Science and Technology* **39**: 835.

Tibiletti, E. (2001). Pero, dall`impianto alla raccolta. *AZ Bio* **2**: 44-48.

Weber, H.-J. (2001). Birnenunterlagen für den Intensivanbau. *Erwerbsobstbau* **43**: 99-105.

Wurm, L., Harmer, A., Darnhofer, P. & Lippitz, M. (2005). Leistungsprüfung verschiedener Apfelsorten bei biologischer und integrierter Produktion unter Berücksichtigung unterschiedlicher Baumstreifenpflege, Teil 3: Innere Fruchtqualität und Lagerverhalten. *Mitteilungen Klosterneuburg* **55**: 162-176.

Wurm, L., Spornberger, A., Gantar, E.-M. & Kieler, M. (2014). Vergleich von selbstbewurzelten mit auf gängige Unterlagen veredelten Birnbäumen. *Mitteilungen Klosterneuburg* **64**: 137-147.