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# Aspects influencing the rootstock-scion performance during long term evaluation in pear orchard

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**Abstract**: During 1999–2016, the performance of 'Red Bartlett', 'Conference' and 'Beurré Alexander Lucas' grafted on four pear (*Pyrus*) rootstocks OH × F 69, OH × F 87, OH × F 230, OH × F 333 and on quince (*Cydonia*) rootstock BA 29 was evaluated at the RBIP Holovousy Ltd. For each combination, trunk cross-section area, cumulative yield, yield efficiency and mean fruit weight were assessed. The growth vigour of the scion cultivars on OH × F rootstocks was similar or slightly higher comparing to the growth on BA 29. Throughout the years, the growth vigor and productivity of the rootstock combinations may change. Less vigorous combinations of rootstock/scion were linked with higher yields in young trees, but usually with just moderate yields in later seasons. By contrast, combinations with higher growth vigour had usually higher yields in the later seasons. This balance is genotype specific, where aside of rootstock an important role is played by the scion cultivar vigour. The bearing precocity may be influenced by the cultivar as well. The results can vary with different climatic conditions and orchard management.

**Keywords**: *Pyrus*; *Cydonia*; growth; yield; bearing precocity

The use of different rootstock and scion combinations in fruit growing has a long tradition. Beside of other factors, rootstocks are widely used for their ability to control tree size, production, orchard uniformity and tolerance to stress factors influencing scion cultivar. Under European conditions, pear orchards are usually planted on quince rootstocks, which control the growth and bring early yields of high quality fruits. Since the 1980's, the use of pear (*Pyrus* spp.) rootstocks from several breading programs (Brooks 1984; Jacob 2002; Fischer 2007; Brewer, Palmer 2011) has become popular. Among others, the series of Old Home × Farmingdale (OH × F) *(P. communis)* rootstocks appeared to bring promising results (Dietz 1997; Wertheim 1998; Iglesias, Asin 2005; Kosina 2008; Massai et al. 2008; Alonso et al. 2011; Elkins et al., 2011), keeping the desired qualities of quince rootstocks, but less susceptible to their weakness's (Kosina 1997; Webster 1998; Wertheim 1998; Brewer, Palmer 2011; Maas 2015). Nevertheless, experiences of the various authors varied greatly. The differences can mainly be attributed to growth vigour and productivity (Massai et al. 2008, Iglesias, Batlle 2011), which usually depends on the differences in the tree architecture and it's development under certain environmental conditions (Lauri et al. 1997; Costes et al. 2006; Costes, García-Villanueva 2007), as well as with different orchard management (Webster 1995). Such trials bring usually a global overview of the rootstocks performance in certain conditions resulting to local or global recommendations for fruit growers (Mészáros et al. 2013). However, little is known about the reasons of the changes of the rootstock performance in time (Mészáros et al. 2015). In

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this context, the role of the cultivar is also poorly understood (Webster 1995).

The objective of this study was to evaluate the long term growth and productivity of selected OH × F pear rootstocks compared to standard quince rootstock in combination with three pear cultivars, with focus on describing some specific aspects influencing tree development, as well as possible effects of the cultivar.

## MATERIAL AND METHODS

Pear cultivars 'Red Bartlett', 'Conference' and 'Beurré Alexander Lucas' (all *Pyrus communis*) were grafted on the four Old Home × Farmingdale (OH × F) pear (*Pyrus communis*) rootstocks OH × F 69, OH × F 87, OH × F 230, OH × F 333 and standard quince (*Cydonia oblonga*) rootstock BA 29 as a control. The trees were planted in spring 1996 at the Research and Breeding Institute of Pomology Holovousy Ltd., (North East Bohemia region of the Czech Republic, 50.3761164N, and 15.5814056E). Average annual precipitation over the last 30 years was 666.0 mm (370.6 mm from April to September) and annual average temperature was 8.9°C with substantial fluctuations over the years. The non-irrigated orchard was situated on loamy brown soil with neutral pH and medium fertility. There was no hand or chemical thinning of the fruits accomplished. The weed control in 1.5 m wide strips was maintained by herbicides. Grass grown in inter-rows was periodically mowed. Plant protection followed standard integrated pest management practices and fertilization followed local recommendations for commercial orchards. The experiment was laid out in a randomized block design with three replications, each with two trees. Planting distance was 5 × 2.1 m and the 2.5 m high trees were trained to a central leader without permanent support. Data were collected from single trees during the years 1999–2016. The assessed variables were yield (kg/tree), trunk cross sectional area (TCSA) calculated from trunk circumference measured 10 cm below the first branching once per 1–3 years, yield efficiency (kg/cm$^2$) calculated as yield/TCSA, and average fruit weight evaluated from 25 fruits (randomly picked) per tree starting in 2001., because of more balanced yields (i.e. fruit weight) within the cultivar/rootstock combinations. Data were analysed using the statistical software 'R' (version 3.4.2; Agricolae, Felipe de Mendiburu, 2017) using one-way ANOVA. Further separation of the means was performed using Fisher's LSD test. The effect of cultivar, rootstock and year as well as their interactions were analysed using multi-factorial ANOVA test.

## RESULTS AND DISCUSSION

### Tree Growth

After 21 years of growth, the overall trees growth was highest in cultivar 'Alexander Lucas' (Table 1) followed by 'Conference' (moderate vigour) and 'Red Bartlett' (weakest vigour). Significant differences in final TCSA among rootstocks were recorded in cultivars 'Alexander Lucas' and 'Red Bartlett' (Table 1). For 'Alexander Lucas', the most vigorous trees were on rootstocks OH × F 69, OH × F 230 and OH × F 333. The least vigorous were on BA 29, which were of similar size as those on OH × F 87. 'Red Bartlett' trees were the smallest overall. 'Red Bartlett' trees were slightly more vigorous on the OH × F rootstocks than on BA 29 with only OH × F 230 significantly larger than the other OH × F rootstocks. There were no differences in TCSA among rootstocks of 'Conference' (Table 1). These results are partly in contrast to the foreign experiences (Webster, 1998; Massai et al. 2008; Alonso et al. 2011). While the vigour of 'Red Bartlett' on OH × F rootstocks was similar to that reported by Webster (1998), the other authors reported higher vigour of 'Conference' on all OH × F rootstocks compared to BA 29. Possible explanations for the varying performance of the same scion/rootstock combination are different climatic conditions and orchard management (Wertheim 1998). The higher mean temperatures (i.e. longer vegetation period) of Spain and the use of irrigation could enhance tree growth comparing to trees in the trial orchard, subsequently increasing rootstock vigour (Webster 1995). Rootstock performance in TCSA may also change through time (Fig. 1, Table 2). In the first half of the observed period of the trial, we reported significantly better growth of 'Conference' on OH × F 69 and OH × F 230, 'Red Bartlett' trees on all OH × F rootstocks comparing to BA 29 and 'Alexander Lucas' on OH × F 230 and 333 (Kosina 2003, 2008). In 'Conference' and 'Red Bartlett', the decline in statistical significance among individual scion/rootstocks combinations for each cultivar

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Table 1. Trunk cross sectional area, cumulative yield, yield efficiency, average fruit weight and suckering of 'Alexander Lucas', 'Conference', and 'Red Bartlett' pear on different rootstocks

| Rootstock | TCSA 2016 ($cm^2$) | Cumulative yield* (kg/tree) | Cumulative yield efficiency ($kg/cm^2$) | Average fruit weight* (g) | Suckering* (pieces/tree) |
|---|---|---|---|---|---|
| BA 29 | $232.4^{c}$ | $506.1^{a}$ | $2.17^{a}$ | $203.2^{ab}$ | $6.2^{a}$ |
| OH × F 69 | $290.9^{a}$ | $423.3^{a}$ | $1.46^{b}$ | $211.5^{a}$ | $0.0^{b}$ |
| OH × F 87 | $247.8^{bc}$ | $473.0^{a}$ | $1.91^{a}$ | $206.6^{ab}$ | $0.0^{b}$ |
| OH × F 230 | $284.0^{ab}$ | $427.4^{a}$ | $1.51^{b}$ | $197.0^{b}$ | $0.0^{b}$ |
| OH × F 333 | $273.9^{ab}$ | $435.8^{a}$ | $1.59^{b}$ | $203.9^{ab}$ | $0.4^{b}$ |
| 'Alex. Lucas' – mean | $267.4^{x}$ | $451.1^{x}$ | $1.71^{y}$ | $223.3^{x}$ | $1.2^{y}$ |
| BA 29 | $208.1^{a}$ | $401.0^{ab}$ | $1.93^{a}$ | $159.5^{a}$ | $19.2^{a}$ |
| OH × F 69 | $227.8^{a}$ | $411.4^{a}$ | $1.88^{a}$ | $155.3^{a}$ | $1.8^{b}$ |
| OH × F 87 | $204.7^{a}$ | $400.3^{ab}$ | $1.97^{a}$ | $154.0^{a}$ | $1.6^{b}$ |
| OH × F 230 | $231.8^{a}$ | $332.6^{c}$ | $1.44^{b}$ | $148.4^{a}$ | $1.6^{b}$ |
| OH × F 333 | $200.7^{a}$ | $351.2^{bc}$ | $1.77^{ab}$ | $146.1^{a}$ | $1.0^{b}$ |
| 'Conference'– mean | $215.0^{y}$ | $383.1^{y}$ | $1.81^{y}$ | $146.5^{z}$ | $5.5^{x}$ |
| BA 29 | $114.7^{b}$ | $435.0^{bc}$ | $3.82^{a}$ | $177.3^{b}$ | $11.3^{a}$ |
| OH × F 69 | $135.9^{ab}$ | $457.5^{ab}$ | $3.45^{ab}$ | $193.8^{a}$ | $0.8^{b}$ |
| OH × F 87 | $134.3^{ab}$ | $500.7^{a}$ | $3.81^{a}$ | $187.7^{a}$ | $0.6^{b}$ |
| OH × F 230 | $144.0^{a}$ | $463.4^{ab}$ | $3.24^{ab}$ | $178.4^{ab}$ | $0.0^{b}$ |
| OH × F 333 | $132.6^{ab}$ | $397.4^{c}$ | $3.03^{b}$ | $171.5^{b}$ | $3.8^{b}$ |
| 'Red Bartlett'– mean | $131.3^{z}$ | $448.0^{x}$ | $3.47^{x}$ | $163.8^{y}$ | $3.5^{xy}$ |

different letters represent significant differences at $P \leq 0.05$ by the LSD test; x, y, z – significant differences among cultivars; *1999–2016; OH – Old Home pear rootstocks; F – Farmingdale pear rootstocks

seem to reflect more the increased variation of TCSA within individual combinations as the trees become older. However, aside of the increasing variation, final TCSA differences among rootstocks of 'Alexander Lucas' were significantly affected by several fluctuations along the time. In 2006 and 2013, the cultivar positively affected the TCSA of trees on OH × F 69 and 87 compared to the other combinations (Fig. 1a). This was likely linked with the significant interaction between the rootstock and year (Table 2). In both cases, the increase was connected with alternating bearing or late frost occurrence, as well as with good conditions for growth (e.g. actual rainfall 145.9/305.0 mm during May–July in 2006/2013) during the period of intensive growth. Similar situation was found by authors Iglesias and Batlle (2011), who showed increase in TCSA of 'Conference' on Pyriam rootstock connected with low yields in previous years. Seasonal variation in productivity due to late frost or alternate bearing corresponds with fluctuation in the growth and can negatively modify TCSA. We can

Table 2. The effect of cultivar, rootstock, year and they interactions on TCSA, yield, cumulative yield, yield efficiency and cumulative yield efficiency (1999–2016)

| Effect/interaction | TCSA | Yields | Cumulative yield | Yield efficiency | Cumulative yield × Efficiency |
|---|---|---|---|---|---|
| Cultivar | *** | *** | *** | *** | *** |
| Rootstock | *** | “ | *** | *** | *** |
| Year | *** | *** | *** | *** | *** |
| Cultivar × Rootstock | *** | ns. | *** | ns. | *** |
| Cultivar × Years | *** | ns. | *** | *** | *** |
| Rootstock × Years | *** | ns. | *** | * | *** |
| Cultivar × Rootstock × Years | * | ns. | *** | ns. | * |

significant difference at “$P \leq 0.10$, *$P \leq 0.05$ , **$P \leq 0.01$ , and ***$P \leq 0.001$

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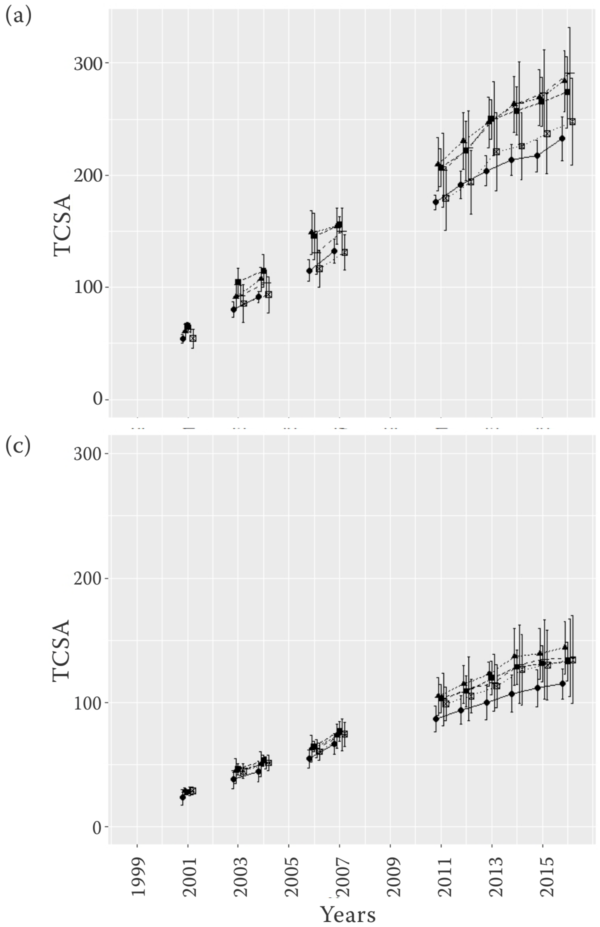


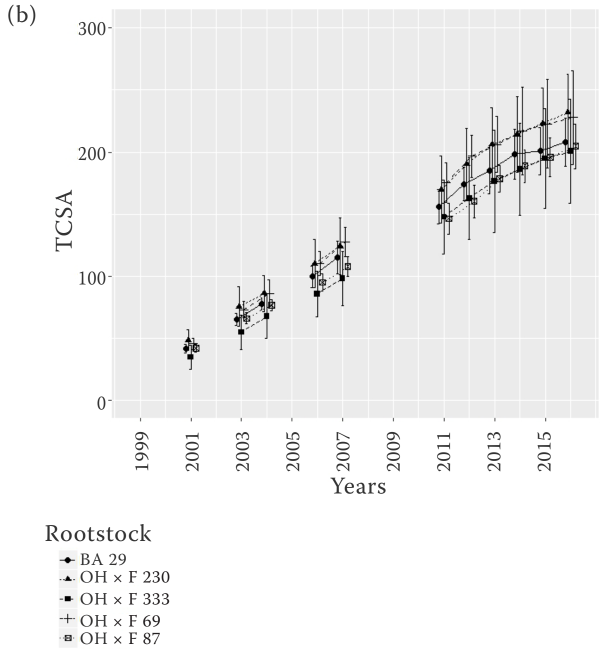


Fig. 1. Trunk cross-section area (TCSA; $cm^2$) with confidential intervals ($P$ = 0.05) of (a) cv. 'Alexander Lucas", (b) cv. 'Conference', and (c) cv. 'Red Bartlett' pear trees on analysed rootstocks, (2001–2016)

thus assume, that the changes were more pronounced in vigorous scion cultivar 'Alexander Lucas'.

## Suckering

Regardless of cultivar, the highest number of suckers per tree was on rootstock BA 29 (Table 1), ranging from 6.2 ('Alexander Lucas') to 19.2 ('Conference'). The number of suckers on OH × F rootstocks was negligible.

## Productivity

Cultivars 'Alexander Lucas' and 'Red Bartlett' brought higher yields (Table 1) on most of the rootstocks comparing to 'Conference'. The highest numerical cumulative yields among the rootstock combinations for 'Alexander Lucas' were on BA 29 and OH × F 87 (Table 1), but the results were not significant. 'Conference' cumulative yields were significantly higher on rootstock OH × F 69, BA 29 and OH × F 87, followed by OH × F 333 and OH × F 230 (Table 1). Cumulative yields for 'Red Bartlett' were higher on OH × F 69, OH × F 230 and 87 (Table 1), followed by BA 29 and OH × F 333. These results are similar to that of other authors (Webster 1998; Carrera et al. 2005; Massai et al. 2008; Alonso et al. 2011), but do not fully correspond with the previous results of this rootstock trial (Kosina 2003, 2008). In the first three years, 'Alexander Lucas' had the highest yields on OH × F 87 and OH × F 230 (Fig. 2a). In 2002, yield on OH × F 230 dropped, while BA 29 increased. After 2011, the yield on OH × F 87 started to decrease as well. For 'Conference', the best yields during the first five years were on OH × F 87 (Fig. 2b). After reaching of full bearing (2005), this combination remained just similar or slightly less productive than on BA 29 and OH × F 69. 'Red Bartlett' had the highest mean yields on BA 29, OH × F 69, 87 and 230 during the first five years (Fig. 2c). From 2004, yields on BA 29 were less and by the end of the trial this decrease was significant versus trees on OH × F 87, the most productive combination during the observation period. The expected year effect (Table 2) was affected by two events. The first was connected with the trees entering to full bearing (Fig 2). The second event was linked

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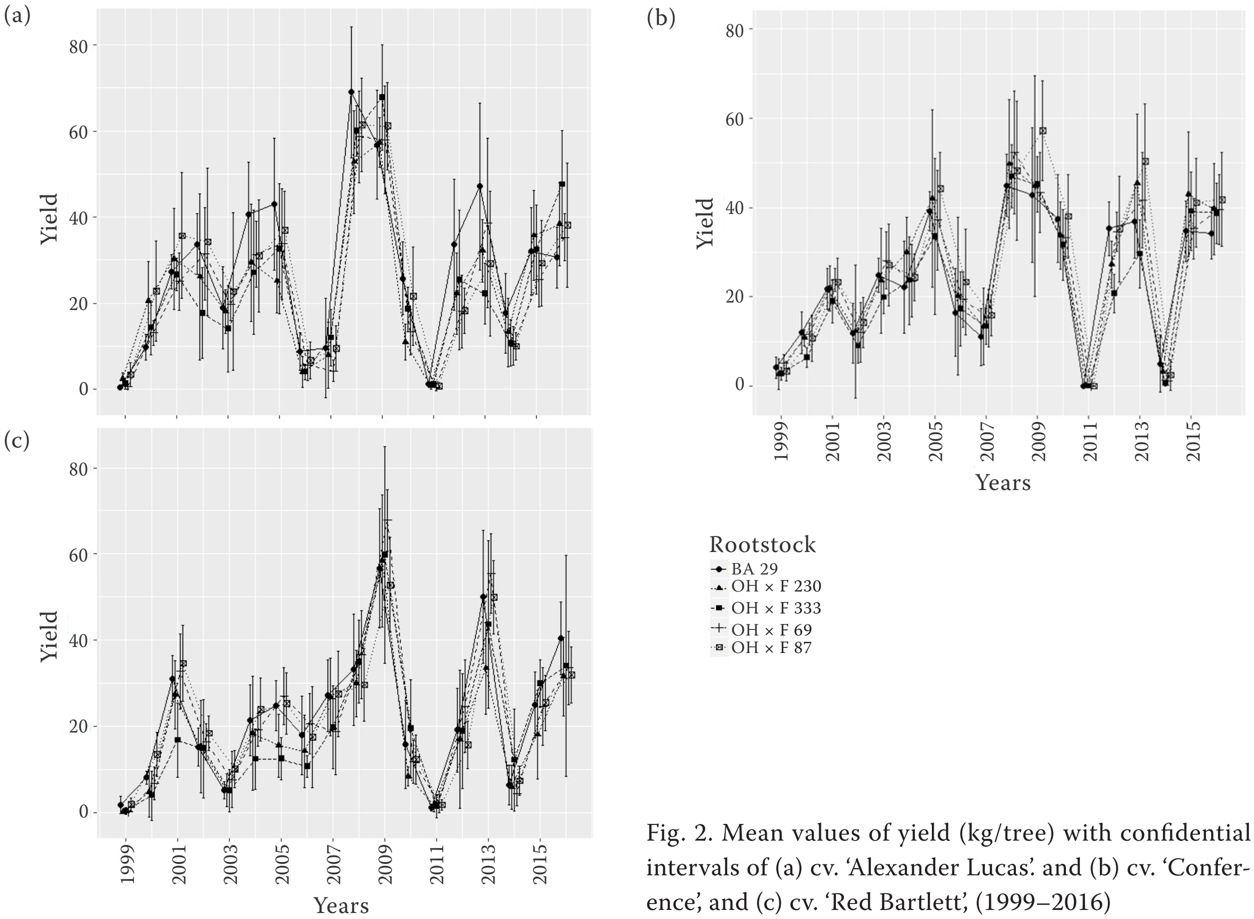


Fig. 2. Mean values of yield (kg/tree) with confidential intervals of (a) cv. 'Alexander Lucas'. and (b) cv. 'Conference', and (c) cv. 'Red Bartlett', (1999–2016)

with substantial fluctuation in yields among the years, partially caused by the absence of thinning treatments during all years and partially by some late frost occurring mainly in 2011 and 2014 (Fig. 2). The effect of the rootstock on annual yield was present rather as trend, but resulting to significant influence of the rootstocks on cumulative yield (Table 2). The interaction, found between the rootstocks and years, confirms the ability of the rootstocks/scion combinations to change the productivity observed among certain periods of the trial (Kosina 2003, 2008). These results confirms, that the stress conditions (like drought, late frost or overcropping of the trees) may negatively affect the cultivar performance in productivity according to the used rootstock (Webster 1995). Moreover, we can suggest, that the occurrence of the stress conditions may affect the various scion/rootstock combinations in different intensity according to the trees age.

Evaluation of the long-term productivity among the rootstocks suggests that differences in the vigour of the scion cultivars play an important role in individual rootstock/scion combination performance (Tables 1 and 2). The vigorous cultivar 'Alexander Lucas' had the highest productivity on rootstocks with less vigour (BA 29, OH × F 87), which were, however, significant in trees younger than 10 years only. The significance of the relative high difference in cumulative yields among the rootstocks with 'Alexander Lucas' could be affected with the increased variability among the trees within particular scion/rootstock combinations. In contrary, the cultivar 'Red Bartlett' had the highest yields mainly on OH × F rootstocks, which were more vigorous comparing to BA 29. It is likely, that combinations of vigorous cultivar with less vigorous rootstock, as well as vigorous rootstock with less vigorous cultivar may lead to higher crops, even when their annual productivity starts to decline in the later seasons (Mészáros et al. 2015). The combining of a vigorous or less vigorous scion and rootstock on the same tree can brings inverse performance (Alonso et al. 2011; Mészáros et al. 2015). The exception of the performance of the cultivar 'Red Bartlett' on OH × F 333 was linked with the overall lower productivity and small fruit weight, which are considered as normal (Webster 1998; Carrera et al. 2005; Kosina 2008). However, while the data shows lower

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yields for 'Red Bartlett', yields of 'Alexander Lucas' on 333 were statistically equal to the other stocks. Fruit weight of 333 was equal to that of BA 29, OH × 87, and OH × F 230 for 'Alexander Lucas' and to BA 29 and 230 for 'Red Bartlett'. We suggest, that if there is no other problem, like incompatibility, environmental or other kind of stress factors, the productivity can be linked to certain balance consisted with the growth vigour of the scion and rootstock. This balance is genotype specific and can vary with different climatic conditions. This conclusion is consistent with the observed modification of architectural traits with use of dwarfing rootstocks in apples (Costes, García-Villanueva 2007). These authors found that cultivars grafted on a dwarfing rootstock M9 were characterized with different shoot type composition, containing higher proportion of medium and short shoots comparing to own-rooted trees. The trees had higher proportion of shoots with terminal as well as axillar flowering and higher return bloom combined with higher reduction of the number of axes in consecutive years due to extinction (Lauri et al. 1997). Enhanced competition between the vegetative and reproductive growth in the early seasons have an important impact on further vegetative growth and performance of the trees (Costes et al. 2006). In this trial, the more precocious rootstocks were usually linked with just moderate yields (e.g. 'Red Bartlett'/BA 29, OH × F 69, 'Alexander Lucas'/OH × F 87 and 230) in the later seasons, while those with a slow start and poor yields in the initial years may perform better in the later seasons ('Conference'/OH × F 69 'Alexander Lucas'/BA 29) (Fig. 2). This likely confirm the idea, that high yields in the first years of the trees growth may negatively influence their crown development and subsequently their further yields (Webster 1995). Although the precocity of bearing is often linked with use of less vigorous rootstocks (Wertheim 1998; Iglesias, Batlle 2011; Mészáros et al. 2013, 2015), this cannot be considered as a rule (Webster 1995). In our trial, there was no evidence about the precocious bearing of trees on less vigorous rootstocks only. However, the cultivar seems to plays an important role in the precocity of particular scion/roostock combinations as well as their further development along the years. While each cultivar did promote the precocity in different scion/rootstock combinations, the intensity of the difference among the combinations in first years yields was found to increase with the cultivar vigour.

**Yield efficiency**

The highest cumulative yield efficiency of 'Alexander Lucas' were on BA 29 and OH × F 87 (Table 1), whereas the other OH × F rootstocks were significantly less productive. Cultivar 'Conference' had the highest cumulative yield efficiency on BA 29, OH × F 69 and 87 (Table 1). The worst results were found with OH × F 230. The highest cumulative yield efficiency with 'Red Bartlett' was on BA 29 and OH × F 87 (Table 1). The lowest cumulative yield efficiency with this cultivar was on OH × F 333. Because of the variation in cumulative yields and TCSA in time, the cumulative yield efficiency have changed as well. While in annual yields, the influence by the rootstocks was found just as a trend, annual yield efficiency was significantly different by the rootstocks (Table 2), interacting also with the year and cultivar. In cultivar 'Alexander Lucas', the highest cumulative yield efficiency were at the beginning recorded on OH × F 87 (Fig. 3a) through an early entrance to the bearing. After 2004, the cumulative yield efficiency of the cultivar on BA 29 became similar to OH × F 87 because of increased yields. However, after 2013, the cumulative yield efficiency of OH × F 87 slowly decreased due to the enhanced TCSA. In the first half of the seasons, 'Conference' had the highest cumulative yield efficiency in OH × F 87 and BA 29 (Fig. 3b). In the later seasons, the cumulative yield efficiency of OH × F 69 and 230 increased approaching the first two combinations. The high start of OH × F 87 was again due to an early entrance to the bearing and higher yields in the first half of the observed period. Interesting history of the cumulative yield efficiency was found in 'Red Bartlett' (Fig. 3c). The cultivar begun with the highest values in combination with BA 29 and OH × F 69. After 2004, the cumulative yield efficiency among BA 29, OH × F 69, 87 and 230 were compensated. Moreover, after 2008, the cumulative yield efficiency of the four combination had again split up and the cultivar had the highest values on BA 29 (because of the less vigour) and OH × F 87 (because of higher yields). From the results it is obvious, that the increase of cumulative yield efficiency in less vigorous scion cultivar 'Red Bartlett' is more progressive reaching higher efficiency comparing to other two cultivars. However, while the cumulative yield efficiency of vigorous cultivar 'Alexander Lucas' on less vigorous rootstocks BA 29 and OH × F 87 is higher through almost the whole bearing period of the trees, higher efficiency of less vigorous cultivars 'Red Bartlett' and 'Conference' on less vigorous

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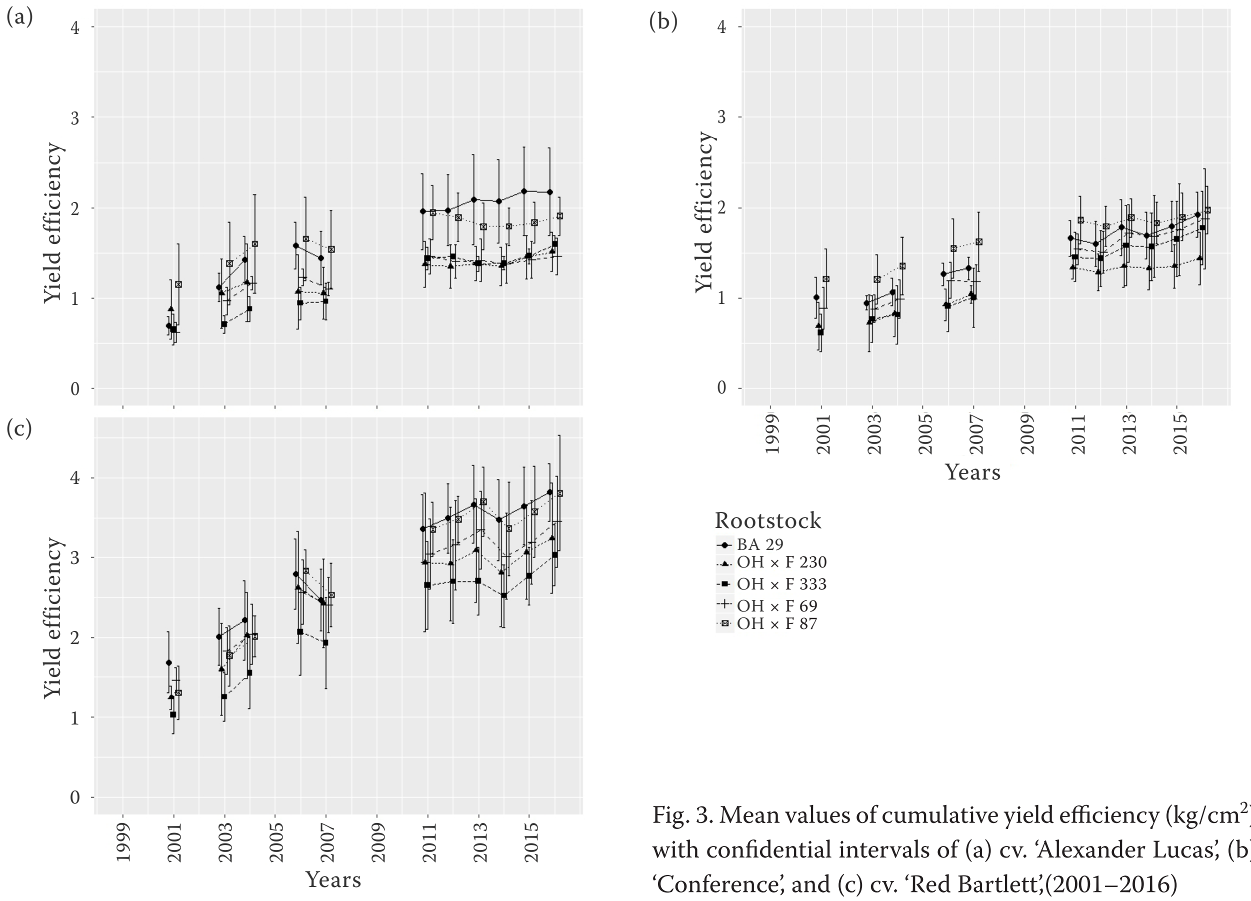


Fig. 3. Mean values of cumulative yield efficiency (kg/cm$^2$) with confidential intervals of (a) cv. 'Alexander Lucas', (b) 'Conference', and (c) cv. 'Red Bartlett',(2001–2016)

rootstocks BA 29 and OH × F 87 can be observed in the first few seasons only. The slow start of the 'Red Bartlett' on OH × F 87 comparing to BA 29 was due to higher TCSA, explainable trough better compatibility of the cultivar with *Pyrus* rootstocks. However, it can be suggested that the less vigorous rootstocks provide better chance to keep higher efficiency comparing to vigorous rootstocks with rising scion cultivar vigour.

**Fruit weight**

At the end of the trial, the mean fruit weight (Table 1) of 'Alexander Lucas' ranging between 197.0 to 211.5 g, which is overall higher than in 'Red Bartlett' (171.5–193.8 g) and 'Conference' (146,1–159.5 g). The mean fruit weight of 'Conference' is not usual and can be seen as very small (Massai et al. 2008). Possible reason is the lack of irrigation and fruit thinning in the orchard. The mean fruit weight of 'Alexander Lucas' was higher in combination with OH × F 69 and lowest with OH × F 230 (Table 1). The cultivar ha+d similar fruit weight on all OH × F rootstocks as with quince rootstock BA 29. 'Conference' proved similar fruit weight on all rootstocks (Table 2). 'Red Bartlett' had the highest mean fruit weight on rootstocks OH × F 69 and 87 (Table 3). In this cultivar, the worst result was found with OH × F 333 and BA 29. This is partly in contrast with the previous results of this trial (Kosina 2003, 2008), as well as with some experiences from other authors (Carrera et al. 2005; Massai et al. 2008; Alonso et al. 2011), where the quince rootstock BA 29 had better fruit weight than OH × F rootstocks. Possible explanation is that the BA 29 provides significantly better fruit quality mainly on the younger trees. Moreover, the rootstocks OH × F 9 and 87 had a good fruit quality, comparable with the quince.

**Long-time performance of the evaluated OH × F rootstocks**

In this trial, the long-time experience indicates that OH × F 87 brought good productivity among the OH × F rootstocks, which is in agreement with foreign experience (Webster 1998; Carrera et al. 2005; Massai et al. 2008). Moreover it demonstrates early entrance to bearing bringing higher yields in

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young orchards and in combination with slower growing scion cultivars ('Red Bartlett') promote the yield in later seasons as well. This is ensured by a good balance in growth and productivity. Although slightly more vigorous, the cultivars on OH × F 87 brings, through higher yields, similar yield efficiency to BA 29. This rootstock also provides good quality of fruits. The cultivars on rootstocks OH × F 69 and 230 were just moderately productive. Their yield performance was more (in case of OH × F 230) or less (in case of OH × F 69) promoted with use in combinations with less vigorous scion cultivars. However, even though good size of fruits in OH × F 69, the performances of OH × F 69 and 230 were not as good as that on OH × F 87. The use of rootstock OH × F 333 is according to the results not recommended. In conclusion, clone OH × F 87 is good substitute to medium growing quince rootstocks, where the conditions are not suitable for quince rootstocks, especially for 'Red Bartlett'.

## References

Alonso J.M., Gómez-Aparisi J., Ansón J.N., Espiau M.T., Carrera M. (2011): Evaluation of the OH × F selections as an alternative to quince rootstocks for pear: Agronomical performance of 'Conference' and 'Doyenné du Comice'. Acta Horticulturae (ISHS), 903: 451–456.

Brewer L.R. and Palmer J.W. (2011): Global Pear breeding programmes: goals, trends and progress for new cultivars and new rootstocks. Acta Horticulturae (ISHS), 909:105–120

Brooks A.L. (1984): History of the Old Home × Farmingdale pear Rootstocks. Fruit Varieties Journal, 38: 126–128.

Carrera M., Aspiau T.M. and Gómez-Aparisi J. (2005): Pear rootstock trial: Behavior of 'Conference' and 'Doyenné du Comice' on two quince and five OH × F selections. Acta Horticulturae (ISHS), 671: 481–484.

Costes E., Lauri P.E., Regnard J.L. (2006): Analyzing fruit tree architecture: implications for tree management and fruit production. Horticultural Reviews, 32: 1–61.

Costes E., García-Villanueva E. (2007): Clarifying the effects of dwarfing rootstock on vegetative and reproductive growth during tree development: A Study on apple trees. Annals of Botany, 100: 347–357.

Dietz J.H. (1997): Neue Probleme bei Birnen-Unterlagen. Deutsche Baumschule 5: 278–279.

Elkins R.B., Castagnoli S., Embree C., Parra-Quezada R., Robinson T.L., Smith T.J., Ingels C.A. (2011): Evaluation of potential rootstocks to improve pear tree precocity and productivity, Acta Horticulturae (ISHS), 909: 183–194.

Felipe de Mendiburu (2017): Agricolae: Statistical Procedures for Agricultural Research. R package version 1.2-8. Available at https://CRAN.R-project.org/package=agricolae

Fischer M. (2007): New pear rootstocks from Dresden-Pillnitz. Acta Horticulturae (ISHS), 732: 239–245.

Iglesias I., and Asin L. (2005): Performance of 'Conference' pear on self-rooted trees and several Old Home × Farmingdale, seedling and quince rootstocks in Spain. Acta Horticulturae (ISHS), 671: 485–491.

Iglesias I., Batlle L. (2011): Agronomical performance and fruit quality of 'Conference' on some *Cydonia* and *Pyrus* rootstocks. Acta Horticulturae (ISHS), 909: 195–200.

Jacob H.B. (2002): New pear rootstocks from Geisenheim, Germany. Acta Horticulturae (ISHS), 596: 337–344.

Kosina J. (1997): Effect of quince rootstocks on growth and yields of some pear cultivars in the first years after planting. Vědecké práce ovocnářské, 15: 33–39.

Kosina J. (2003): Evaluation of pear rootstocks in an orchard. Horticultural Science (Prague), 30: 56–58.

Kosina J. (2008): Evaluation of selected OH × F pear rootstocks in the orchard. Acta Horticulturae (ISHS), 800: 691–694

Lauri P. É., Lespinasse J. M. and Térouanne É. (1997): Vegetative growth and reproductive strategies in apple fruiting branches: an investigation into various cultivars. Acta Horticulturae (ISHS), 451: 717–724.

Maas F. (2015): Evaluation of yield efficiency and winter hardiness of quince rootstocks for ´Conference´ pear. Acta Horticulturae (ISHS), 1094: 93–101.

Massai R., Loreti F. and Fei C. (2008): Growth and yield of 'Conference' pears grafted on quince and pear rootstocks. Acta Horticulturae (ISHS), 800: 617–624.

Mészáros M., Kosina J., Laňar L., Náměstek J. (2013): Evaluation of growing characteristics of four pear cultivars on selected rootstocks. Vědecké práce ovocnářské, 23:179–188.

Mészáros M., Kosina J., Laňar L., Náměstek J. (2015): Long-term evaluation of growth and yield of Stanley and Cacanska lepotica plum cultivars on selected rootstocks. Horticultural Science (Prague), 42: 22–28.

Webster A. D. (1995): Rootstock and interstock effects on deciduous fruit tree vigour, precocity and yield productivity. New Zealand Journal of Crop and Horticultural Science, 23: 373–382.

Webster A. D. (1998): A brief review of pear rootstock development. Acta Horticulturae (ISHS), 475: 135–141.

Wertheim S.J. (1998): Rootstock Guide: Apple, Pear, Cheery, European Plum. Wilhelminadorp, Fruit Research Station.

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