RESEARCH ARTICLE

Yield and profitability of 'Conference' pear in five training systems in North East of Spain

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Abstract

Training systems are key to manage the tree canopy to take advantage of the tree productivity potential. Assessment of yearly cropping, labor requirements, fruit quality, and orchard profitability were studied. The experiment was organized in a randomized complete block design with three replications. Five different training systems on Quince EMC rootstock and 'Conference' as the scion cultivar were compared. The results of this study show that the use of preformed highly feathered trees is an improvement for both, early cropping and profitability. Planting cost, trellis, and labor requirements had a large impact on the economic viability of each system. Tatura produced high yields, but the strong initial investment that needs to be done at planting makes this system a risky investment. Axis 2 seems to be the most suitable system for early cropping while maintaining intermediate plantation costs and an appropriate level of production efficiency.

Additional keywords: axis; crop value; fruit quality; fruit size; planting density; *Pyrus communis*; Tatura.

Abbreviations used: BYCF (break-even year to cash flow); IRR (internal rate of return); NPV (net present value); THSD (Tukey honestly significant difference)

Introduction

Low prices for apples over the last years have increased the plantings of new pear (*Pyrus communis* L.) orchards in Europe (Vercammen, 2011b). Moreover, yield efficiency, fruit size and quality will need to be improved in order to justify those investments (Webster, 2002). The adoption of high-density orchards for pear production has resulted in a significant improvement in yield and fruit quality. However, early cropping is often not achieved, and remains one of the main challenges when planting a pear orchard (Webster, 2002). A positive correlation exists among yield, light interception and tree density (Palmer *et al.*, 1992). While several studies have reported a positive relationship between tree density and yield (Vercammen, 1999; Kappel & Brownlee, 2001; Elkins & DeJong, 2002; Sansavini & Musacchi, 2002; Robinson, 2008); Wagenmakers & Tazelaar

(1997) observed an increase about 2.3 t/ha over 8 years when light interception was increased by 1%. However, Lakso *et al.* (1989) and Musacchi *et al.* (2005) reported that if orchard efficiency is not maintained, an excessive yield increase can also reduce fruit quality.

Training systems, as a way to manage the tree canopy, can play a key role in order to take advantage of the tree productivity potential (Lakso & Robinson, 1997). Numerous studies on pear training systems have been carried out around the world (Deckers, 1992; Sansavini & Musacchi, 1993; Corelli-Grappadelli, 2000; Wertheim *et al.*, 2001; Elkins & DeJong, 2002; Musacchi, 2008; Robinson, 2008; Sosna & Czaplicka, 2008; Turner *et al.*, 2008; Monney & Evéquoz, 2009; Vercammen, 2014; Heijerman *et al.*, 2015), but research shows that no system is optimum for all conditions (Barritt, 1987). Therefore, it is necessary to conduct exhaustive studies to find the best training system for each

particular situation: cultivar, rootstock, climate, and economic conditions.

Italy and Spain are the most important pear producing countries in Europe (Deckers & Schoofs, 2008). While 'Conference' is the second most important cultivar grown in Italy (Deckers & Schoofs, 2008); it is the most important cultivar grown in Spain (Iglesias & Casals, 2013), and in Northern Europe, with 80% of the acreage in Netherlands (Heijerman *et al.*, 2015), and 85% in Belgium (Vercammen, 2014). 'Conference' is a very fertile cultivar that tends to crop on spurs, but with significant smaller sizes when crop is bore on old branches (Sansavini & Musacchi, 1993). Therefore, training system is key not only to increase yield, but also to increase profitability through bigger fruit sizes. Regarding that, Sansavini & Musacchi (1993) recommend that 'Conference' must be well pruned yearly, eliminating one-third of the fruiting spurs and their branches.

A good tree establishment after planting will help to achieve precocity (Heijerman *et al.*, 2015). Regarding that, rootstocks are crucial for tree establishment but also to make trees more manageable through vigor control (Sansavini & Musacchi, 2002). Pear orchards in North America are mostly planted on *Pyrus* seedling rootstocks, as Quince (*Cydonia oblonga* Mill.) rootstocks routinely suffer from winter damage, fire blight (*Erwinia amylovora* Burill) infections and pear decline (Westwood & Lombard, 1983; Lind *et al.*, 2003; Mitcham & Elkins, 2007; Robinson, 2011). However, clonal pear rootstocks generally delay cropping with respect to Quince (Sansavini & Musacchi, 2002). Therefore, while most of the studies done in North America are done with *Pyrus* and 'Old Home' × 'Farmingdale' (OH×F) rootstocks (Elkins & DeJong, 2002; Turner *et al.*, 2008; Robinson & Dominguez, 2015), EM Quince A and C are the most widely planted pear rootstocks in Europe (Mitcham & Elkins, 2007). As a result, the better early cropping of Quince compared to pear clonal rootstocks, plus the milder winter temperatures in southern Europe like Italy and Spain compared to North America, make the use of quince EMC more suitable for such areas, ensuring optimum yield and fruit quality. This justifies why Quince Adams, MC, and Sydo are the most used rootstocks for trials in Europe (Deckers, 1992; Sansavini & Musacchi, 2002; Musacchi, 2008; Vercammen, 2014).

Aim of this study was to evaluate five training systems on a Quince EMC rootstock with 'Conference' that involved the use of feathered trees and increased densities, which thereby permitted more intensive production. Assessment of yearly and early cropping, labor requirements and fruit quality were studied.

In addition, orchard profitability through different economic factors was also evaluated.

Material and methods

A field trial was planted at the experimental station of IRTA (Institute of Research and Technology, Food and Agriculture) in Mollerussa, Spain (41°36′51.13″N; 0°52′ 22.75″E) in 1999. The experiment was organized in a randomized complete block design with three replications. Training system was the main plot factor with each main plot consisting of 2 rows 10 m long. Five different training systems on Quince EMC rootstock and 'Conference' as the scion cultivar were compared. Training systems descriptions are given in Table 1. Foliar GA3 sprays (1.5 g/ha) to promote early cropping were applied at full bloom during the first three years. Trees were drip-irrigated (climate is semi-arid Mediterranean, with a mean annual rainfall of 350 mm), and received 100 kg N/ha, 40 kg P, and 120 kg K_2O each year.

Axis 1 and 2 were supported by a 4-wire trellis (2.5 m), whereas Tatura systems were supported by 4-wire trellis (0.5 and 2 m) with 2 wires on each side.
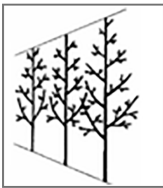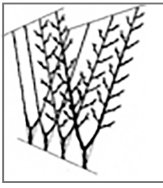
The Axis 1 system was the standard system grown by the farmers. A non-preformed tree without feathers (whip) was used in this case (Table 1), heading the leader at 80 cm right after planting. A strong vertical shoot arising near the heading cut was tied to the wires and trained as the leader. The remaining shoots were selected as scaffold branches and tied to 40° above the horizontal, encouraging light penetration. Due to the branching ability of 'Conference', most of the branches were kept uncut during the early years after planting, to encourage formation of laterals along the axis and discourage apical dominance.

A preformed tree (two-year-old tree with feathers) was used for the Axis 2 system (Table 1). Trees were developed by leaving the leader un-headed at planting and selecting the more vertical feather as the leader. Then, similarly to Axis 1, the remaining feathers were tied to 40° above the horizontal and kept uncut to encourage the growth of more laterals along the axis.

Two-year-old preformed trees with 4 or 2 tiers were used for Tatura 4 and Tatura 2, respectively (Table 1). Tatura 2 and Tatura 4 systems were developed by tying at planting each axis (2 or 4) to the wires of the trellis (as V). These systems were trained to short limbs and spurs that were periodically renewed.

A 1-year-old preformed tree was used for the Tatura 1 (Table 1). With this system, trees were tied to a tilted structure to a 15° angle from vertical.

Table 1. Training systems

System	Tree characteristics	Spacing (m)	Planting density (tress/ha)	Layout
Axis 1	1-year-old non-preformed tree without feathers (whip)	3.75 × 1.25	2,133	
Axis 2	2-year-old preformed tree with feathers	3.75 × 1.0	2,667	
Tatura 4	2-year-old preformed tree with 4 tiers	3.75 × 1.0	2,667	
Tatura 2	2-year-old preformed tree with 2 tiers	3.75 × 0.5	5,333	
Tatura 1	1-year-old preformed tree with feathers	3.75 × 0.5	5,333	

Overall for the different systems, during the early years tree training was based on encouraging development of new branches to quickly fill the space assigned to the trees. In the first through the second year, dormant pruning was minimal for the preformed trees (Axis 2 and Taturas), promoting and keeping all the fruiting structures that were developing. Large diameter limbs (> 3 cm) were removed back to the trunk with an angled cut to grow replacement limbs. In the case of Axis 1, the main goal for the first 3 years was to establish the central axis structure.

For all the systems, once trees filled the allotted space, a balance pruning to promote fruiting wood was developed. Cuts were made on >1-year-old wood, promoting fruiting spurs. Leaders were cut to a side shoot when they reached its maximum height of 3.3 m. Once a branch diameter exceeded 3 cm it was cut back to its point of origin and renewed. The rest of the cuts were made to a side branch to keep growth balance and fruit quality.

Yield, fruit size, fruit quality (flesh firmness, soluble solids, and acidity), and required time to prune (dormant and summer) and harvest were recorded each year. A ≥50 kg-fruit sample from each elemental plot was collected for fruit quality, fruit size, and caliper distribution assessments. The sample was graded for fruit size and caliper distribution by a weight sizer machine (MAF RODA Iberica, Alzira, Spain). From this data we calculated a simulated packout. Firmness was measured at two opposite sides on the fruit equator using a digital firmness tester (Penefel; Ctifl, France). Soluble solid content (°Brix) and titratable acidity (malic acid g/L) were determined using the freshly prepared juice of the whole subsample. Soluble solid content was measured using a digital temperature compensated refractometer (model PR-101, Atago Co. Tokyo Japan), and titratable

acidity (expressed as malic acid) was determined by titrating 10 mL of juice with 1.0 M NaOH to pH 8.2 (Torres *et al.*, 2017). Crop value and economic return were calculated using 100% packout (€/ha) predicted from the average fruit price and the fruit size distribution recorded during the 10 years of the trial. Costs included planting (soil preparation, trees, trellis, fertilization, annual interest of capital, and labor); drip irrigation and fertigation installation; yield protection insurance, equipment rentals (mechanized machine for pruning and harvest, 4 €/h), administration, taxes, and land lease. Labor cost was categorized for unskilled (7.5 €/h), and skilled (pruning, 9.5 €/h) tasks. Net present value (NPV), internal rate of return (IRR) and break-even year to cash flow (BYCF) for each system over 10 years were calculated (Casler *et al.*, 1993). NPV is the sum of discounted annual cash flows over 10 years using a fixed discount rate. The discount rate is determined by subtracting the rate of inflation from the current interest rate to arrive at a real rate of interest. IRR is the return on the cash flow stream generated over a certain number of years (in this case 10) (Casler *et al.*, 1993; Robinson, 2011). We have used an interest rate of 5.5%, and a 4.5% rate discount for our basic comparisons. BYCF is the year when the accumulated NPV reaches zero, which equals to the year in which the investment has been recouped with interest. It can also be considered the year that an orchard can be removed or replanted in our case. A repeated-measures MANOVA was used to analyze yield and labor cost evolution along the seasons. Contrast tests were used to compare among training systems. Linear mixed models including training system as fixed factor and block as a random factor were built to separate treatment effects for the cumulative labor requirements, firmness, soluble solids, acidity, fruit weight, and caliper distribution at harvest. A linear mixed model including training system as fixed factor and block and year as random factors was built to separate treatment effects for the average efficiency rates. With all the models, the Tukey Honestly Significant Difference (THSD) post hoc test was used to compare training systems. Statistical significance was set at $p \leq 0.05$. Data were analyzed using the JMP statistical software package (vers 11; SAS Inst. Inc., Cary, NC, USA).

Results

Training system, time and the interaction of both was highly significant regarding yield and labor cost over the years (Fig. 1). Axis 1 had the lowest yields, followed by Axis 2 and then the Taturas. No significant differences were observed within the three different Tatura systems

and with the Axis 2 (contrast tests, $p > 0.05$). Axis 1 had significantly lower yields than Axis 2 (contrast test, $p < 0.028$), and the Taturas (contrast tests, $p < 0.05$).

Labor cost followed a similar pattern as the yield, with lowest values for Axis 1, followed by Axis 2, and Tatura 2 as the highest-labor-requirement system (Fig. 1). Significant differences were observed between Tatura 1 and Tatura 2 (contrast test, $p < 0.0373$), whereas no differences were observed between Tatura 2 and Tatura 4, and Tatura 4 *vs* Tatura 1 (contrast tests, $p > 0.05$). Axis 2 required significantly less labor cost than the three different Tatura systems (contrast tests, $p < 0.05$), and higher than Axis 1 (contrast test, $p < 0.0085$).
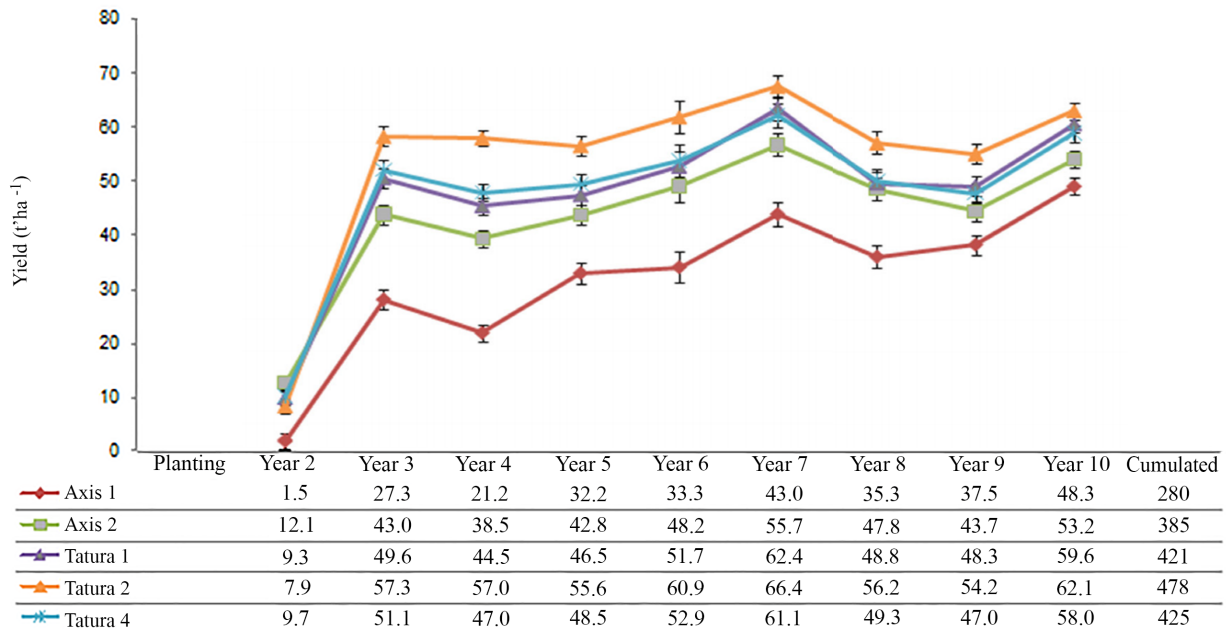
Along the 10 years, Tatura 2 with over 1,200 h/ha, was the system that required more dormant pruning, followed by Tatura 1 and 4, Axis 2, and Axis 1 with less than 500 h/ha (Fig. 2). Summer pruning was mainly important on Tatura 2, with about 70 h/ha. Significantly higher amount of harvest time was required for the Tatura compared with the Axis systems.

Efficiency rates about 150 kg/h were observed for the Axis systems, whereas Taturas were significantly lower with values about 130 kg/h (Fig. 2).
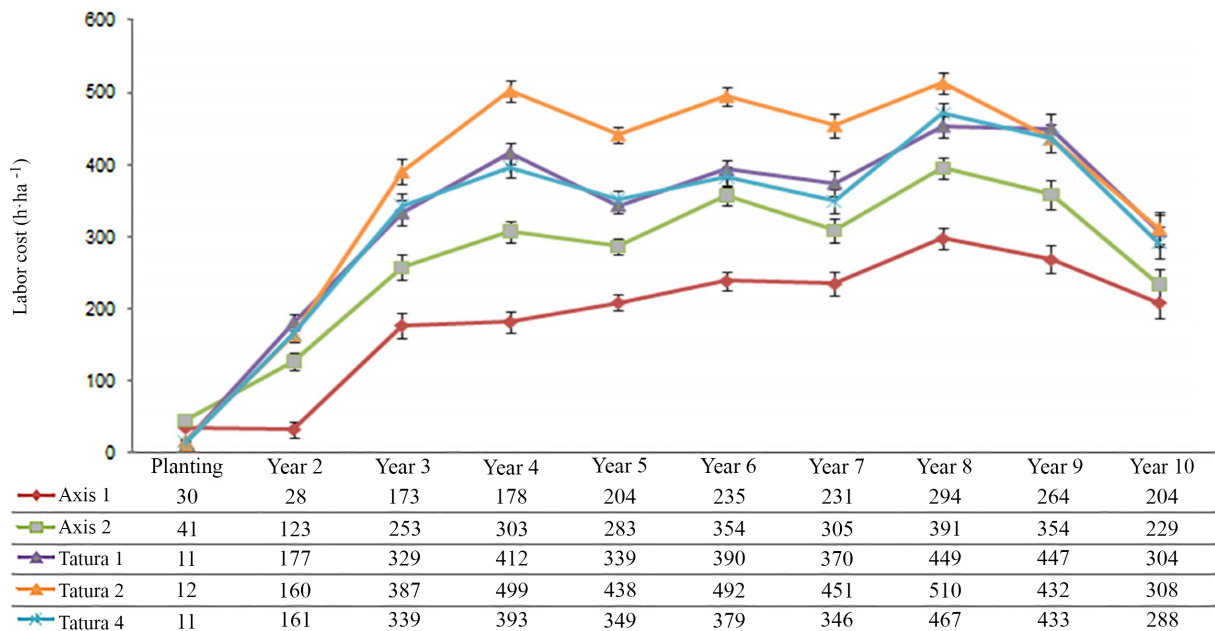
Axis systems tended to have higher fruit firmness (0.1 kg) and sugar content than Taturas; however, no significant differences among systems were observed (Table 2). Average firmness was 5.7 kg, 15.4 °Brix, and 1.6 g/L of acidity. No significant differences among training systems were observed either for fruit acidity, fruit size, or caliper distribution. With an overall fruit size of 190 g, about 70% of the harvest had 65 mm or more for all the different systems.

Great differences regarding the establishment cost (total investment at the end of year 1) were observed among systems (Table 3 and Fig. 3). Tatura 2 with 47,000 €/ha was the most expensive system, followed by the other two Taturas (4 and 1) (~35,600 €/ha), Axis 2 (19,149 €/ha), and Axis 1 (15,040 €/ha) as the cheapest option at planting (Table 3 and Fig. 3). Differences among systems were also observed regarding the yearly and cumulative cash flow, especially in how negative the cumulative cash flow curve dipped and became positive (Fig. 3). Axis 2 had the highest cumulated cash flow, near to 80,000 €/ha, followed by the Tatura 4 and 2 (~62,000 €/ha), Tatura 1 (53,000 €/ha), and Axis 1 (41,000 €/ha) (Fig. 3). With 5 years, Axis 2 was the system to reach first the break-even point, followed by Tatura 2 and 4 (6 years), and Tatura 1 and Axis 1 (7 years) (Table 3 and Fig. 3).

All of the assessed training systems in this experiment had a positive IRR and NPV values after 10 years (Table 3 and Fig. 3). With a value near to 30%, Axis 2 had the highest IRR, doubling the one observed for the Taturas overall (~15%) (Table 3). The highest NPV (50,437

	Planting	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Cumulated
Axis 1		1.5	27.3	21.2	32.2	33.3	43.0	35.3	37.5	48.3	280
Axis 2		12.1	43.0	38.5	42.8	48.2	55.7	47.8	43.7	53.2	385
Tatura 1		9.3	49.6	44.5	46.5	51.7	62.4	48.8	48.3	59.6	421
Tatura 2		7.9	57.3	57.0	55.6	60.9	66.4	56.2	54.2	62.1	478
Tatura 4		9.7	51.1	47.0	48.5	52.9	61.1	49.3	47.0	58.0	425

*MANOVA test results: Prob> F (system) <0.0001; prob> F (time) <0.0005; prob> F (time*system)< 0.0285

	Planting	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Axis 1	30	28	173	178	204	235	231	294	264	204
Axis 2	41	123	253	303	283	354	305	391	354	229
Tatura 1	11	177	329	412	339	390	370	449	447	304
Tatura 2	12	160	387	499	438	492	451	510	432	308
Tatura 4	11	161	339	393	349	379	346	467	433	288

*MANOVA test results: Prob> F (system) <0.0001; prob> F (time) <0.0001; prob> F (time*system)< 0.0006

Figure 1. Evolution of yield (t/ha) and labor cost (h/ha) along years for every training system. Values are the calculated treatment means for selected years.

€) was also observed for Axis 2. Conversely, Axis 1 showed the second best IRR (18.4%), but the lowest net present value (24,250 €) (Table 3). Regarding the Tatura systems, Tatura 4 had the highest IRR (16.7%) and NPV (35,699 €) values (Table 3). On the other hand, Tatura 2 had higher NPV than Tatura 1 (32,926 € *vs* 28,930 €), but for the IRR value the opposite was observed (13.4% *vs* 14.4%) (Table 3).

Discussion

Time to reach full crop production is key on the profitability of each training system. Yields at 2nd leaf were very low (1.5 t/ha) on Axis 1, compared to the other Axis 2 and Tatura systems, with yields about 10 t/ha. Similarly, at 3rd and 4th leaf, production of Axis 1 was 63% lower than its average production (5th to
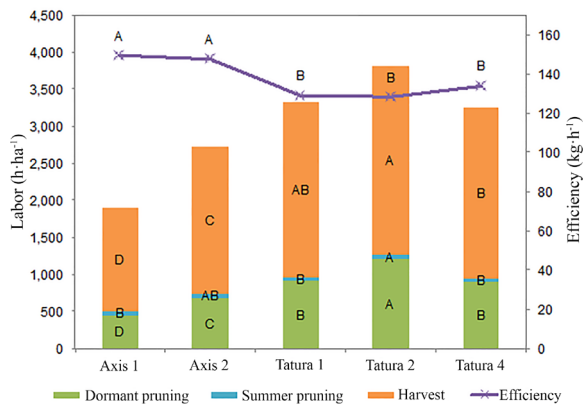
Figure 2. Cumulative labor requirements for pruning and harvest (h/ha), and average efficiency rate (yield per working hour, kg/h) for each training system. For every response variable (labor task and efficiency rate), training systems with the same letter are not significantly different according to Tukey's honestly significant difference test at $p \leq 0.05$

10th leaf). Among all the systems tested, Axis 1 was the one with the lowest planting density (2,133 trees/ha). The positive relationship between tree density and crop value through the cumulative yield have also been reported in several studies comparing rootstocks and training systems for pear (Vercammen, 1999; Kappel & Brownlee, 2001; Elkins & DeJong, 2002; Sansavini & Musacchi, 2002; Elkins *et al.*, 2008; Robinson, 2008, 2011; Robinson & Dominguez, 2015). Non-preformed trees (one-year-old whips) were used for Axis 1. In addition, tree training for that system consisted of heading the leader at 80 cm right after planting, starting the new tree structure the following year. This management technique is clearly a delay in regard to two-year-old preformed trees (Axis 2, Tatura 2-4), or even to one-year-old preformed trees with feathers but without heading the leader (Tatura 1). Sansavini *et al.* (2007) and Heijerman *et*

al. (2015), already reported the importance of using highly feathered trees and reducing heading cuts in order to achieve high precocity to increase orchard profitability. However, low yields and delay to reach full production on Axis 1 was not only observed at the 2nd leaf, but it kept up to the 3rd and 4th.

Although differences in planting density ranged from 2,667 trees/ha on Axis 2 and Tatura 4, *vs* 5,333 trees/ha on Tatura 2-1, no significant differences regarding yield over the 10 years were observed among those systems. Other studies about training systems with 'Conference' have been conducted by Vercammen (2002, 2005, 2011a, 2014) reporting the V-system, with 367 t/ha after 10 years, as one of the most productive. Comparable to the Tatura 2 system that we tested, Musacchi *et al.* (2005) observed that a V-shape with 5,555 trees/ha was the highest productive system (181 t/ha, over 7 years). However, it is hard to make comparisons with the Axis system that we tested. For instance, Musacchi *et al.* (2005) used central leader trees but with different planting densities (Vertical Axis 7,936 trees/ha; Slender Spindle 3,968 trees/ha) and even with different rootstocks (Spindle bush 1,984 trees/ha – Sydo). Whereas Vercammen (2014) used a Long Pruning and Bush Spindle systems (1,714 trees/ha), and Spindle training (5,625 trees/ha). After 10 years, the cumulated yield of our Axis 2 system was 385 t/ha. Similarly, Robinson & Dominguez (2015) tested a Tall Spindle system with 2,243 trees/ha, reporting after 11 years, cumulated yields of 299 and 341 t/ha with 'Bosc', and 'Barlett' respectively.

With a nice fruit size of 190 g on average, no significant differences regarding size and fruit quality among systems were observed in our experiment. On the other hand, differences in fruit size among systems have been observed by other authors. For instance, larger pears were harvested by Vercammen (2014) on the V-system; and on the Spindle Bush by Musacchi *et al.* (2005). Most likely, fruit size variances can be

Table 2. Average fruit quality variables (flesh firmness, soluble solids (SS), and acidity), fruit size and caliper distribution at harvest for each training system. No significant differences among training systems were observed at *p* value ≤ 0.05.

| | Firmness (kg) | SS (°Brix) | Acidity (g/L) | Fruit size (g) | Caliper distribution (%) | | | |
					≥ 60 mm	≥ 65 mm	≥ 70 mm	≥ 75 mm
Axis 1	5.8	15.6	1.7	186.3	93	68	28	9
Axis 2	5.8	15.5	1.6	192.8	93	71	30	11
Tatura 1	5.7	15.4	1.6	183.9	92	65	23	8
Tatura 2	5.7	15.2	1.5	192.2	93	70	30	12
Tatura 4	5.7	15.4	1.6	189.7	93	68	29	11

Table 3. Planting cost, average annual balance (years 6-10), break-even year to cash flow (BYCF), internal rate of return (IRR), and net present value (NPV) for each system.

Interest rate 5.5%			55-60	60-65	65-70	>70	Fruit caliper (mm)	
Discount rate 4.5 %			0.136	0.340	0.476	0.527	Fruit price (€/kg)	
	Planting cost		**Annual balance**		**BYCF**	**IRR (%)**	**NPV**	
	(€/ha)	**%**	**Average 6-10 (€/ha)**	**%**			**(€)**	**%**
Axis 1	-15,040	100	9,052	100	7	18.4	24,250	100
Axis 2	-19,149	127	12,549	139	5	28.9	50,437	208
Tatura 1	-35,694	237	11,933	132	7	14.4	28,930	119
Tatura 2	-47,326	315	14,208	157	6	13.4	32,926	136
Tatura 4	-35,529	236	12,316	136	6	16.7	35,699	147

explained by the differences in yield depending on the system (Robinson, 2008). In addition, different systems can induce a greater intensity of light that could affect the quality and size of the fruit. Hence, since light interception is more limiting in Belgium than in Spain, this may explain why we did not see differences among systems, while V-systems were reported to have larger fruits in Belgium (Vercammen,

2014). V-systems are reported to intercept more light than conic shapes in northern North America (Robinson & Lakso, 1989; Robinson, 2007).

Reasonably, time devoted to harvest showed a direct relationship with the production of each system. It is important to examine to what point one system is more or less efficient than another, as expressed in terms of yield harvested per working hour (harvest, dormant and
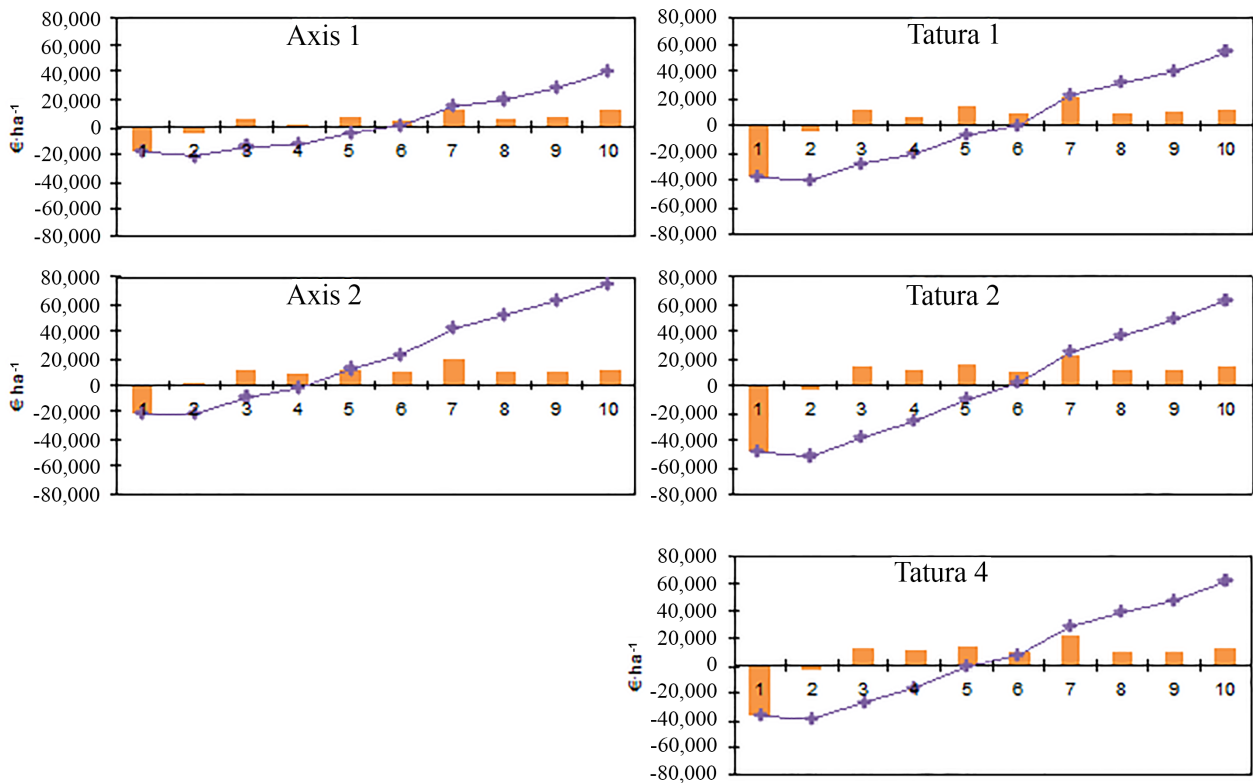

Figure 3. Effect of training system on yearly (bars) and accumulated (lines) cash flows per unit of land area (€/ha) over 10 years. Crop value and economic return were calculated using 100% packout (€/ha) predicted from the average fruit price and the fruit size distribution of the trial. Costs included planting (soil preparation, trees, trellis, fertilization, annual interest of capital, and labor); drip irrigation and fertigation installation; yield protection insurance, equipment rentals (mechanized machine for pruning and harvest, 4 €/h), administration, taxes, and land lease. Labor cost was categorized for unskilled (7.5 €/h), and skilled (pruning, 9.5 €/h) tasks.

summer pruning). Differences among the efficiency rate were observed in our trial. The Axis systems had an average of 148 kg/h, whereas the Tatura systems had a lower rate of 130 kg/h. Higher differences were observed regarding the pruning time required for each system. Tatura systems required considerably more hours of pruning, especially Tatura 2, which tripled the requirements of the Axis 1. In addition, the open structure of the Axis system facilitates harvest labor. Similar results were observed by Vercammen (2005), where after ten years the V-systems were the most labor intensive compared to Spindle and Long Pruning systems. Management and training differences among single-stem systems as the Axis, and the V-systems (Tatura), were also reported by Sansavini & Musacchi (2002).

Great differences were observed for planting cost, which was highly influenced by the tree type, density and trellis used for each system. The yearly activity costs showed that the most expensive systems at planting required higher annual cost of activity as well, mainly due to an increased need in the time of harvest, but also for pruning. If we examine the overall results, systems based on high planting densities and double production plan as the Tatura, have been able to achieve great yields. Nevertheless, its strong cost at planting hinders a quick investment pay off. That is, even in the case of great fruit prices, Tatura cannot beat the Axis 2, which had similar yields. As Robinson *et al.* (2007) pointed out, the greater the level of initial investment, the greater the risk in achieving expected profits. Thus, if two systems produce about the same NPV but one has much lower investment requirements, it is the preferred investment. Regarding that, Vercammen (2005) also suggested that a system that requires high management and planting cost as the Tatura is only an option if adequate reserves are available.

From a theoretical point of view, profitability of the Tatura could be improved by reducing the planting cost and/or increasing the production. In the first case, and based on the fact that the tree density should not be amended, there would only be two ways: (1) simplify the trellis; (2) reduce the labor cost. The other option (yield increase) could achieve economic returns similar to Axis 2, however, it does not seem that this may be continuously achievable year after year.

The results of this study show that the use of two-year-old preformed highly feathered trees is an improvement for both, early cropping and profitability. Within intensive systems, Axis 2 was the most profitable. Planting cost, trellis, and labor requirements had a large impact on the economic viability of each system. In addition, the low prices that growers are getting for the fruit, plus the increase of labor costs, enhance the need

for simple training systems, with low labor input and highly productive. Tatura systems produced high yields, but the strong initial investment that needs to be done at planting makes these systems a risky investment. Axis 2 seems to be the most suitable system for early cropping while maintaining intermediate plantation costs and an appropriate level of production efficiency.

References

Barritt BH, 1987. Orchard systems research in decidious trees: A brief introduction. HortScience 22: 548-549.

Casler GL, Anderson BL, Aplin RD, 1993. Capital investment analysis; using discounted cash flows, Grid Publ. Co., Columbus, OH, USA. 147 pp.

Corelli-Grappadelli L, 2000. The palmette training system. Acta Hortic 513: 329-336.

Deckers T, 1992. Training systems of young pear trees with or without chemical growth regulation. Acta Hortic 322: 21-28. https://doi.org/10.17660/ActaHortic.1992.322.2

Deckers T, Schoofs H, 2008. Status of the pear production in Europe. Acta Hortic 800: 95-106. https://doi.org/10.17660/ActaHortic.2008.800.8

Elkins RB, Dejong TM, 2002. Effect of training system and rootstock on growth and productivity of Golden Russet Bosc' pear trees. Acta Hortic 596: 603-607. https://doi.org/10.17660/ActaHortic.2002.596.104

Elkins RB, Dejong TM, Klonsky K, Demoura R, 2008. Economic evaluation of high density versus standard orchard configurations; case study using performance data for 'Golden Russet Bosc' pears. Acta Hortic 800: 739-746. https://doi.org/10.17660/ActaHortic.2008.800.101

Heijerman G, Roelofs P, Groot M, 2015. Profitability of the Dutch growing system of 'Conference'. Acta Hortic 1094: 233-238. https://doi.org/10.17660/ActaHortic.2015.1094.29

Iglesias I, Casals E, 2013. Evolución de la producción de pera en España y análisis del mercado. Vida Rural 367: 36-43.

Kappel F, Brownlee R, 2001. Early performance of 'Conference' pear on four training systems. HortScience 36 (1): 69-71

Lakso A, Robinson T, Pool R, 1989. Canopy microclimate effects on patterns of fruiting and fruit development in apples and grapes. In: Manipulation of fruiting, 47th Nottingham Easter School; Wright CJ (ed). Butterworths, London. https://doi.org/10.1016/B978-0-408-02608-6.50022-9

Lakso AN, Robinson TL, 1997. Principles of orchard systems management optimizing supply, demand and partitioning in apple trees. Acta Hortic 451: 405-415. https://doi.org/10.17660/ActaHortic.1997.451.46

Lind K, Lafer G, Schloffer K, Innerhofer G, Meister H, 2003. Choice of rootstocks and cultivars in organic fruit

production. In: Organic fruit growing; Lind K *et al.* (eds.). CABI Publ, Cambridge, MA, USA. https://doi.org/10.1079/9780851996400.0039

Mitcham EJ, Elkins RB, 2007. Pear production and handling manual, UCANR Publ, Davis, CA, USA. 215 pp.

Monney P, Evéquoz N, 2009. Modes de conduite du poirier: premiers résultats d'un essai dans la région lémanique avec la variété Conférence. Revue Suisse de Viticulture, Arboriculture et Horticulture 29 (3): 147-154.

Musacchi S, 2008. Training systems and soil management for southern European pear orchards. Acta Hortic 772: 447-457. https://doi.org/10.17660/ActaHortic.2008.772.76

Musacchi S, Ancarani V, Gamberini A, Gaddoni M, Grandi M, Sansavini S, 2005. Response of training system planting density and cultivar in pear. Acta Hortic 671: 463-469. https://doi.org/10.17660/ActaHortic.2005.671.65

Palmer J, Avery D, Wertheim S, 1992. Effect of apple tree spacing and summer pruning on leaf area distribution and light interception. Sci Hortic 52 (4): 303-312. https://doi.org/10.1016/0304-4238(92)90031-7

Robinson TL, 2007. Effects of tree density and tree shape on apple orchard performance. Acta Hortic 732: 405-414. https://doi.org/10.17660/ActaHortic.2007.732.61

Robinson TL, 2008. Performance of pear and quince rootstocks with three cultivars in four high density training systems in the Northeastern United States. Acta Hortic 800: 793-801. https://doi.org/10.17660/ActaHortic.2008.800.108

Robinson TL, 2011. High density pear production with *Pyrus communis* rootstocks. Acta Hortic 909: 259-270. https://doi.org/10.17660/ActaHortic.2011.909.28

Robinson TL, Demarree AM, Hoying SA, 2007. An economic comparison of five high density apple planting systems. Acta Hortic 732: 481-489. https://doi.org/10.17660/ActaHortic.2007.732.73

Robinson TL, Dominguez L, 2015. Yield and profitability of high-density pear production with *Pyrus* rootstocks. Acta Hortic 1094: 247-256. https://doi.org/10.17660/ActaHortic.2015.1094.31

Robinson TL, Lakso AN, 1989. Light interception, yield and fruit quality of 'Empire' and 'Delicious' apple trees grown in four orchard systems. Acta Hortic 243: 175-184. https://doi.org/10.17660/ActaHortic.1989.243.21

Sansavini S, Ancarani V, Neri D, 2007. Overview of intensive pear culture: planting density, rootstocks, orchard management, soil-water relations and fruit quality. Acta Hortic 800: 35-50.

Sansavini S, Musacchi S, 1993. Canopy architecture, training and pruning in the modern European pear orchards: an overview. VI Int Symp on Pear Growing 367: 152-172.

Sansavini S, Musacchi S, 2002. European pear orchard design and HDP management: A review. Acta Hortic 596: 589-601. https://doi.org/10.17660/ActaHortic.2002.596.103

Sosna I, Czaplicka M, 2008. The influence of two training systems on growth and cropping of three pear cultivars. J Fruit Ornam Plant Res 16: 75-81.

Torres E, Recasens I, Lordan J, Alegre S, 2017. Combination of strategies to supply calcium and reduce bitter pit in 'Golden Delicious' apples. Sci Hortic 217: 179-188. https://doi.org/10.1016/j.scienta.2017.01.028

Turner J, Seavert CF, Auvil T, 2008. Preliminary results of pear rootstock and competitive orchard systems trials. Acta Hortic 800: 611-615. https://doi.org/10.17660/ActaHortic.2008.800.81

Vercammen J, 1999. Dossier Poire (2eme partie). Systèmes de plantation et de taille pour le poirier Conference. Fruit Belge 67 (479): 70-80.

Vercammen J, 2002. Influence of the plant and pruning system on pear cv. Conference. Acta Hortic 596: 615-620. https://doi.org/10.17660/ActaHortic.2002.596.106

Vercammen J, 2005. Financial result of different planting systems for 'Conference' pears. Acta Hortic 671: 471-475. https://doi.org/10.17660/ActaHortic.2005.671.66

Vercammen J, 2011a. Comparison among different planting systems for 'Conference'. Acta Hortic 909: 271-275. https://doi.org/10.17660/ActaHortic.2011.909.29

Vercammen J, 2011b. Different planting systems for 'Conference' pear. Acta Hortic 903: 701-706. https://doi.org/10.17660/ActaHortic.2011.903.97

Vercammen J, 2014. Comparison of different planting systems for 'Conference'. Acta Hortic 1058: 37-43. https://doi.org/10.17660/ActaHortic.2014.1058.2

Wagenmakers PS, Tazelaar M, 1997. Planting systems and light utilization. Annual Report Research Station for Fruit Growing Whilhelminadorp, pp: 17-18.

Webster A, 2002. Factors influencing the flowering, fruit set and fruit growth of European pears. Acta Hortic 596: 699-709. https://doi.org/10.17660/ActaHortic.2002.596.121

Wertheim S, Wagenmakers P, Bootsma J, Groot M, 2001. Orchard systems for apple and pear: conditions for success. Acta Hortic 557: 209-227. https://doi.org/10.17660/ActaHortic.2001.557.28

Westwood MN, Lombard PB, 1983. Pear rootstocks - Present and future. Fruit Var J 37 (1): 24-28.