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COMPARISON OF TWO PLANTING SYSTEMS FOR SEVERAL PEAR CULTIVARS

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ABSTRACT

Choice of orchard system is one of the major factors, on which pear crop size and quality depend. The purpose of this research was to assess the influence of two training systems involving trees trained to different number of leaders on growth, yield, and fruit quality of three pear cultivars. The study was conducted in 2001–2012 near Wrocław (south-western Poland). One-year-old trees of 'Carola', 'Dicolor' and 'Erika' cultivars on the Quince S_1 rootstock were planted in the spring 2001 using 3.5 m between rows and a variable in-row spacing: 1.7 m (Drilling form with 3 leaders) and 1.2 m (Güttingen – V system with 1 leader). More vigorous growth was observed from more sparsely planted trees under the Drilling form. The total per-tree yield during 2002–2012 was decreasing as the planting density increased. No differences were observed on yield per hectare between the tested systems. The Drilling trees produced significantly heavier and larger fruit than the trees trained to the V-Güttingen system.

Key words: *Pyrus communis*, training method, canopy shape, yield, growth, fruit quality

INTRODUCTION

The need to develop training and pruning strategies that would better fit the natural growing and fruiting habits of the tree has become a challenging issue [Lauri 2009]. The pursuit to make most of the available orchard space and to increase the per-unit-area efficiency motivates the search for productive methods of tree training. Modern pear orchard management systems strive for optimal yielding that preserves good fruit quality. Increased efficiency can be attained by planting dwarf trees grafted on various quince clones and by employing the spindle crown system [Sosna 2006, Buler et al. 2008]. A wire support combined with a multiple-leader system enable even stronger canopy shape modification. Studies on such systems have been focusing primarily on apple and pear trees [Maas and Steeg 2001, Widmer 2005, Bianco et al. 2007, Uselis et al. 2007, Rutkowski et al. 2009, Kwon et al. 2011, Jajo et al. 2014, Choi et al. 2017, D'Abrosca et al. 2017, Sosna 2017]. However, V-shaped crowns may be suitable also for stone fruit cultivation [Rabcewicz et al. 2017].

The most popular V-shaped canopy systems, recommended as an alternative for orchards with high tree densities, are the Güttingen-V system (Tatura-1), the Y-system (Tatura or Tatura-2), the Drilling (triple system, Tatura-3), and the Mikado system (Tatura-4) [Robinson 2000, Lordan et al. 2017]. The open forms with slender elements, which characterize these systems, allow for optimal light interception and promote good yield of high-quality fruits [Monney and Evéquoz 1999, Hampson et al. 2002, Buller and Mika 2006, Hassan et al. 2010]. The optimum angle from vertical for a leader to maximize the fruit size is about 60 degrees. In case of fruit color, best results are obtained with leaders growing vertically. V-systems tend to perform better than vertical tree systems under

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conditions of extreme light intensity (by limiting the extent of fruit sunburn), in high winds, as well as in orchards where all fruits have to be collected near the floor [Gandev and Dzhuvinov 2014].

According to Widmer [2005], an important advantage of these new systems lies in reducing the planting expenses compared with currently used spindle single-row system. In particular, the low planting densities of multiple-leader trees result in reduced costs of acquiring the nursery material [Uselis et al. 2007, Sosna 2017]. The large within-row spacing between the trees contributes to improved fruit quality. As demonstrated by numerous studies, dense planting of spindle trees suppresses their vegetative growth and enables high yields, but simultaneously it tends to impair their quality in terms of fruit average weight, size and coloration [Platon 2007, Dorigoni et al. 2011, Robinson and Dominguez 2015, Ozkan et al. 2016, Pereira and Pasa 2016, D'Abrosca et al. 2017, Lordan et al. 2018]. Other authors highlight high costs of wire supports and the necessity of laborious tree pruning and training as major drawbacks of V-shape systems [Gandev and Dzhuvinov 2014, Vercammen 2014, Lordan et al. 2017]. It does not take much time before these investments become amortized, however [Elkins et al. 2008].

The aim of the present study is to compare the growth, flowering, as well as fruit yield and quality of pear trees maintained under two orchard planting systems based on V-shaped canopies in the climatic and soil conditions of the Lower Silesia (south-western Poland).

MATERIAL AND METHODS

The experiment was established in the spring 2001 at the Fruit Experimental Station in Samotwór near Wrocław (51°06'12"N; 16°49'52"E) in Poland. The orchard was located on a fawn soil consisting of slightly sandy, light clay over medium clay and representing the 3rd class of the Polish economical soil classification. The research was carried out on the one-year-old trees of 'Carola', 'Dicolor' and 'Erika' (*Pyrus communis* L.) pear cultivars budded on Quince S_1 rootstock. The planting pattern followed the randomized split-plot design with four replications and 7 trees per plot (the main plot was training system; the split-plot was cultivar). The in-row tree spacing was 1.7 m (Drilling form – 3 leaders, 1681 trees ha^{-1}) and 1.2 m (Güttingen – V system – 1 leader, 2381 trees ha^{-1}), whereas the distance between rows was equal to 3.5 m. In this way, the number of leaders per hectare in Drilling system (5043) was more than twice higher in comparison with V-system (2381). The trees were planted as non-feathered and headed at 100 cm (V-system) or 60 cm (Drilling system) above the budding height, which delayed the onset of production by one growing season. The emerging leaders were trained to 60-degree angles toward the alleyways. The trees were annually pruned soon after flowering, starting from the fourth year following the orchard establishment. No irrigation was applied and fruitlets were not thinned. The orchard floor management system consisted of herbicide fallow (Glifosate + MCPA) in the tree rows and sward in the alleyways — both introduced in the year of the tree planting. The chemical protection was carried out according to up-to-date recommendations of the Orchard Protection Program.

In 2001–2012, tree growth, bloom abundance, fruit yield per tree and per hectare, yield index, as well as mean fruit weight, size and skin coloration ('Dicolor' – 2010 and 2012) were assessed. For the purpose of data collection, each cultivar was harvested following a single-picking schedule, and the fruit from each tree were collected into separate boxes. To determine external crop quality, for each experimental plot two boxes of pears were randomly selected and a sample of 20 fruits per tree was taken from them. This was followed by weighting the fruits, and in 2010 and 2012 fruit diameters and coloration (only 'Dicolor' – the other cultivars do not create a blush) were recorded. In 2008–2012, bloom abundance was rated for each tree on a scale of 0 to 5, where 0 = no bloom, and 5 = very abundant bloom. Each year, in mid-October, the extent of vegetative growth was evaluated by measuring trunk circumference 20 cm above bud union and calculating trunk cross sectional area (TCSA) values as well as their two-year increments. In autumn 2012, all annual shoots from 1 tree for each experimental plot were measured. The last set of TCSA together with the 2002–2012 fruit yield sums were used to calculate cumulative yield efficiency coefficients (CYEC), which were obtained at the end of the study. In this study, the published results are based on data obtained during 12 years of research.

The collected experimental data were subjected to statistical analysis based on the analysis of variance (ANOVA) approach involving a model appropriate for the split-plot design. Significant differences at the α = 0.05 level were obtained using the Duncan's multiple range test.

RESULTS AND DISCUSSION

In the course of twelve years of the study, three of the pear cultivars trained to the Drilling form with 3 leaders exhibited stronger vegetative growth than the trees from the V system (Tab. 1). The trees with three leaders developed significantly thicker trunks and had more annual shoots. According to training systems, no statistical differences with regard to the tree growth were noted only for mean shoot length. The obtained results corroborate the well-known fact that within-row planting density is the biggest determinant of tree vegetative growth intensity – the denser planting, the weaker growth [Uselis et al. 2007, Choi et al. 2014, Sosna 2017]. Oftentimes, a modification of the planting system has no significant influence on tree growth as long as the resulting within-row spacing remain similar [Kappel and Brownlee 2001, Widmer 2005, Sosna 2006]. However, there have been reports of weaker growth of apple trees with several leaders [Hampson et al. 2002, Barritt et al. 2008]. Likewise, in the study by Porębski et al. [2008], in comparison to the classical spindle, apple trees with the Mikado canopy had lower TCSA values, however the differences were not significant. According to an earlier study by Sosna and Czaplicka [2008], the number and total length of annual shoots per leader decreased in proportion to the number of leaders per tree. Less dense canopies were observed in case of the three-leader Drilling form. A similar relationship was noted by Maas and Steeg [2001], Buler and Mika [2006], Yoshida et al. [2006] and Dorigoni et al. [2011]. The investigated cultivars differed with respect to their growth patterns (Tab. 1). Significantly thinnest trunks with smaller two-year diameter increments were noted for 'Carola' cv., whereas 'Dicolor' pear trees developed the highest numbers of long annual shoots. The 'Erika' cultivar was characterized by the sparsest crowns. Zygmuntowska and Jadczuk-Tobjasz [2008] also report the weakest growth of 'Carola'. On the other hand, pre-

Table 1. Biometric measurements of some pear cultivars on Quince S_1 rootstock as influenced by two training systems

Training system	Cultivar	Annual shoots			Trunk cross-sectional area TCSA (cm^2)	
		(number tree^{-1}) autumn 2012	(cm tree^{-1}) autumn 2012	mean length (cm)	autumn 2012	increment 2010–2012
Drilling	'Carola'	117.0 a*	2415.0 ab	20.2 ab	68.9 a	16.3 a
	'Dicolor'	99.0 a	2825.8 b	29.3 b	90.8 b	20.4 b
	'Erika'	100.8 a	1440.9 a	14.6 a	87.5 b	20.0 b
V system	'Carola'	66.8 a	1426.9 a	21.9 ab	58.2 a	12.4 a
	'Dicolor'	55.0 a	1507.5 a	27.0 b	74.0 b	16.6 b
	'Erika'	58.8 a	704.5 a	12.1 a	69.7 b	14.5 ab
Mean for training system						
Drilling – triple system		105.6 b	2227.2 b	21.1 a	82.4 b	18.9 b
Güttingen – V system		60.2 a	1213.0 a	20.1 a	67.3 a	14.5 a
Mean for cultivar						
'Carola'		91.9 b	1920.9 b	20.9 b	63.6 a	14.4 a
'Dicolor'		77.0 a	2166.7 b	28.1 c	82.4 b	18.5 b
'Erika'		79.8 ab	1072.7 a	13.4 a	78.6 b	17.3 b

* Means indicate by the same letter within the columns, training systems and main effects do not significantly differ at P ≤ 0.05 according to Duncan's t-test

Table 2. Blooming intensity of some pear cultivars as influenced by two training systems (in 0–5 scale)

Training system	Cultivar	2008	2009	2010	2011	2012
Drilling	'Carola'	2.1 a*	3.8 b	2.6 a	2.6 b	2.7 b
	'Dicolor'	3.5 b	2.3 a	3.7 b	0.6 a	1.8 a
	'Erika'	2.7 a	3.6 b	2.5 a	2.6 b	2.4 ab
V system	'Carola'	1.9 a	3.6 b	2.1 a	2.1 b	2.6 b
	'Dicolor'	2.8 b	2.8 a	2.6 a	1.0 a	1.9 a
	'Erika'	2.1 a	3.6 b	2.3 a	2.3 b	2.4 ab
Mean for training system						
Drilling – triple system		2.8 b	3.2 a	2.9 b	1.9 a	2.3 a
Güttingen – V system		2.3 a	3.3 a	2.3 a	1.8 a	2.3 a
Mean for cultivar						
'Carola'		2.0 a	3.7 b	2.4 a	2.4 b	2.7 b
'Dicolor'		3.2 b	2.6 a	3.2 b	0.8 a	1.9 a
'Erika'		2.4 a	3.6 b	2.4 a	2.5 b	2.4 b

* See Table 1

Table 3. Yielding and cumulative yield efficiency (CYE) of some pear cultivars as influenced by two training systems (year of tree planting – the spring 2001)

Training system	Cultivar	Yield (kg tree^{-1})					Cumulative yield 2002–2012		CYE (kg cm^{-2}) 2001–2012
		2008	2009	2010	2011**	2012	(kg tree^{-1})	(t ha^{-1})	
Drilling	'Carola'	6.0 a*	43.3 b	23.1 a	16.0 c	22.6 b	143.4 a	241.1 a	2.08 b
	'Dicolor'	20.2 b	23.2 a	37.8 c	0.8 a	13.9 a	145.1 a	243.9 a	1.60 a
	'Erika'	25.9 c	60.8 c	29.9 b	7.6 b	33.7 c	221.3 b	372.0 b	2.53 c
V system	'Carola'	3.7 a	31.4 b	12.6 a	6.0 a	10.9 a	100.7 a	239.8 a	1.73 a
	'Dicolor'	12.3 b	21.8 a	21.5 b	1.7 a	10.6 a	103.6 a	246.7 a	1.40 a
	'Erika'	13.1 b	40.8 c	18.5 b	5.2 a	20.8 b	156.3 b	372.2 b	2.24 b
Mean for training system									
Drilling – triple system		17.4 b	42.4 b	30.3 b	8.1 b	23.4 b	169.9 b	285.6 a	2.07 b
Güttingen – V system		9.7 a	31.3 a	17.5 a	4.3 a	14.1 a	120.2 a	286.2 a	1.79 a
Mean for cultivar									
'Carola'		4.9 a	37.4 b	17.9 a	11.0 b	16.8 a	122.1 a	240.5 a	1.91 b
'Dicolor'		16.3 b	22.5 a	29.7 c	1.3 a	12.3 a	124.4 a	245.3 a	1.50 a
'Erika'		19.5 c	50.8 c	24.2 b	6.4 b	27.3 b	188.8 b	372.1 b	2.39 c

* See Table 1 **Strong spring frost

In the present study, the yield per hectare of both investigated systems were almost identical and exhibited no statistical difference. This is in contrast to the previous study by Sosna and Czaplicka [2008], who obtained similar per-tree yields of young pear trees trained to the Drilling and V-Güttingen systems, whereas the latter performed significantly better in terms of yields per hectare. Also Barritt et al. [2008], Choi et al. [2014], and Lordan et al. [2018] noted superior yield per hectare in systems with higher planting densities. According to Sosna [2006] and Buler et al. [2008], similar yields can be obtained from pear trees trained to the V and the traditional vertical spindle systems, as long as the planting density remains the same. Kappel and Brownlee [2001] and Inomata et al. [2004] presented different conclusion. In their studies, the yields of pear and apple trees were significantly higher under the two-leader Y-trellis (Tatura) system compared to the slender spindle. Similarly, Rabcewicz et al. [2017] obtained higher yields from stone fruit trees trained to the Y system than from the system V.

Modification of the training system affected the 12-year CYE (Tab. 3). The three-leader Drilling canopy was associated with significantly higher productivity of the trees. This is in contrast to the inverse tendency observed in the earlier years of the experiment, when the V system performed better [Sosna and Czaplicka 2008]. In the study by Yoshida et al. [2006], an increased number of leaders resulted in higher CYE of Japanese pear trees. Similar patterns were reported by other authors [Kappel and Brownlee 2001, Buler and Mika 2006, Barritt et al. 2008, Rutkowski et al. 2009, Sosna 2017]. ‘Erika’ occurred to give the highest yields from among the investigated pear tree cultivars, as corroborated by Blažek et al. [2003] and Sosna and Czaplicka-Pędzich [2013]. Also Lewko and Modrak [2009] noted high ‘Erika’ productivity, when grafted on various quince clones. In the study by Błaszczyk [2005], in turn, ‘Erika’, ‘Carola’, and ‘Dicolor’ were comparable in terms of both yields and CYE.

The harvested fruit quality differed among the investigated canopy training systems (Tab. 4). The Drilling trees developed heavier pears up to the seventh year after planting, but the effect could not be statistically confirmed. Difference between the mean fruit weight harvested from older trees (in the 2008–2012 period) was smaller for both evaluated training systems, and also statistically non-significant. However, the Drilling system exhibited a positive effect on mean ten-year pear weight. The fruits harvested from the trees trained to this system were not only heavier, but also larger, and in case of the ‘Dicolor’ cultivar – they had slightly weaker coloration. These results are in agreement with Inomata et al. [2004] and D’Abrosca et al. [2017], who reported bigger weights of apples obtained from the Tatura and Drilling systems compared to the V-Güttingen. In other studies, in turn, pear and apple tree canopy modifications had no effect on the quality of harvested fruits [Hampson et al. 2002, Buler et al. 2008, Sosna and Czaplicka 2008, Rutkowski et al. 2009, Choi et al. 2014]. According to some authors, yielding intensity of trees has a stronger influence on mean fruit weight than their crown shape [Kappel and Brownlee 2001, Uselis et al. 2007]. In the experiment by Sosna [2017], densely planted apple trees trained to the V-Güttingen and Tatura systems developed significantly larger apples than trees with Drilling and Mikado crowns. Compared to the traditional spindle, apples from the Mikado system had a similar weight, but an improved coloration under the same tree planting density [Porębski et al. 2008]. In the present study, the fruits from ‘Dicolor’ cultivar were the smallest, which is in agreement with reports by other authors [Błaszczyk 2005, Paprštein et al. 2007, Zygmuntowska and Jadczuk-Tobjasz 2008]. The biggest advantage of this cultivar is the red blush, which extends over more than half of the fruit skin surface. The remainder of the investigated cultivars do not develop a distinct blush. The ‘Carola’ and ‘Erika’ trees bore fruits of similar weight, but pears from the former were clearly larger. Similar results were obtained by Sosna and Czaplicka-Pędzich [2013]. As reported by Paprštein et al. [2007] and Lewko and Modrak [2009], ‘Erika’ tends to develop fruits of attractive size and excellent storage properties.

V-shape systems present a good approach for obtaining abundant yields of very good quality fruits in pear and apple orchards [Monney and Evéquoz 1999, Bianco et al. 2007, Kwon et al. 2011, Dadashpour et al. 2012, Vercammen 2014]. However, given the high establishment costs of orchards with multiple-leader crowns, planting of two-year-old feathered trees and training them to the traditional spindle shape seems to be a preferable management option [Lordan et al. 2017].

Table 4. Fruit quality of some pear cultivars as influenced by two training systems

Training system	Cultivar	Mean fruit weight (g)			% of pears with diameter >7 cm 2010 and 2012	% of pears with blush over ½ 2010 and 2012
		2003–2007	2008–2012	2003–2012		
Drilling	'Carola'	273 c*	226 b	249 c	97.8	–
	'Dicolor'	195 a	167 a	181 a	81.7	66.5
	'Erika'	252 b	224 b	238 b	95.9	–
V system	'Carola'	234 b	212 b	223 b	88.9	–
	'Dicolor'	184 a	172 a	178 a	58.9	71.4
	'Erika'	238 b	221 b	230 b	72.9	–
Mean for training system						
Drilling – triple system		240 a	206 a	223 b	91.8	66.5
Güttingen – V system		219 a	202 a	210 a	73.6	71.4
Mean for cultivar						
'Carola'		254 b	219 b	236 b	93.4	–
'Dicolor'		190 a	170 a	180 a	70.3	69.0
'Erika'		245 b	223 b	234 b	84.4	–

* See Table 1

CONCLUSIONS

1. Less densely planted trees trained to the Drilling system exhibited more vigorous growth. Their trunks were thicker and they developed more annual shoots in the final year of the study. Yet, the individual leaders obtained under this system were sparser.

2. Training of pear trees to the Drilling system had a positive effect on their yield per tree and CYE up to the twelfth year after planting. The yield per hectare was similar between both systems, exhibiting no statistical difference.

3. The quality of harvested fruits differed between the investigated training systems. The Drilling system trees developed significantly heavier and larger fruit than those trained to the V-Güttingen system.

4. Presented long-term study confirmed the suitability of both of the investigated V-shape systems for pear orchards. The Drilling form occurred to be superior from among the two, owing to the high yields and fruit quality. Among the investigated cultivars, 'Erika' can be the most recommended for both training systems.

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