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V-shaped Canopies in an Apple Orchard from the Perspective of over a Dozen Years of Research

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ABSTRACT

The purpose of this research was to assess the influence of several orchard systems involving trees trained to different leader numbers on growth, cropping, and fruit quality of two apple cultivars. The study was conducted during 1994-2007 at the Fruit Experimental Station in Samotwór, next to Wrocław (south-western Poland). One-year-old trees of 'Elstar' and 'Jonagold' cultivars on the M.9 rootstock were planted in the spring 1994 using 3.5 m spacing between rows and a variable in-row spacing: 2.4 m (Mikado-four leaders), 1.8 m (Drilling-three leaders), 1.2 m (Tatura-two leaders), and 0.6 m (Güttingen-V-one leader). In this way, the number of leaders per hectare was almost the same, regardless of the system. The most vigorous growth occurred on the most sparsely planted trees under the Mikado system, whereas the Güttingen-V apple trees developed thinnest shoot systems. The bloom abundance registered in the 2004-2007 periods was more related to the year, rather than to the planting system. The 1995-2007 total per-tree yield was decreasing as the planting density increased. When yield per hectare was considered instead, the Güttingen-V system still produced the lowest. As the trees aged, the quality of apples diminished-possibly as a result of increasing tendency toward biennial bearing. In the last years of the study (2003-2007), the trees with the largest numbers of leaders, i.e. Mikado and Drilling, showed the most irregular yielding patterns. The orchard planting system had no significant influence on the fruit mean weight.

Keywords: Biennial bearing, Fruit quality, Training system.

INTRODUCTION

Fruit tree and orchard productivities have been investigated in relation to an array of agronomic factors, such as training system, rootstock, and crop management practices (Costes *et al*., 2003). 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). Choice of orchard system is one of the major factors on which apple crop size and quality depend. Various systems, including those that involve wire trellises, in combination with proper tree training and pruning allow, among others, for an improved light interception by the fruits. Orchard systems are being evaluated all around the world, including Australia (Shafiq *et al*., 2014), North America (Robinson, 2007), North Africa (Hassan *et al*., 2010), Far East (Jung and Choi, 2010), and Europe (Uselis, 2003; Licznar-Małańczuk, 2006).

The most popular V-shaped canopy systems, recommended as an alternative for orchards with high tree densities, are the Güttingen-V system, the Y-system (Tatura), the Drilling system, and the Mikado system (Robinson, 2000). The open forms with slender elements, which characterize these systems, allow for optimal light interception

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and promote good yield of high-quality fruits (Monney and Evéquoz, 1999; Widmer and Krebs, 2001; Hampson *et al.*, 2002; Buler and Mika, 2007; Hassan *et al.*, 2010). V-shaped systems involve dwarfing rootstocks, such as M.9 and M.27. 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 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 from the floor (Gandev and Dzhuvinov, 2014). Owing to fewer trees per hectare that have to be planted, in terms of investment costs, open systems with 2, 3, or 4 leaders (Tatura, Drilling, and Mikado, respectively) have a financial advantage over the current single-row spindle and Güttingen-V plantings (Widmer, 2005). Also the costs of pruning are much lower for systems with multiple leaders per a single tree (Sosna, 2004). In comparison to these savings, the expenses associated with developing trees with extra scaffold supports are minor (Widmer, 2005). In addition, by dividing the total tree vigor among two to four axes, a greater control of the vegetative growth can be achieved (Dorigoni *et al.*, 2011). In the study by Hampson *et al.* (2004), apple trees grown as the Y-trellis system (two leaders) showed weaker growth —expressed by Trunk Cross-Sectional Areas (TCSAs), canopy widths and heights — than single-leader trees planted at the same density and maintained in the V-system. Also, Buler and Mika (2007) noted decreased growth of apple trees with Mikado crowns in relation to the traditional spindle system. The aim of the present study was to compare the growth, tendency towards biennial bearing, as well as fruit yield and quality of apple trees maintained under several orchard planting systems based on V-shaped canopies in the conditions of the Lower Silesia. The published results are based on data obtained during 14 years of research.

MATERIALS AND METHODS

The experiment was established in the spring 1994 at the Fruit Experimental Station in Samotwór, next to Wrocław (51° 06' 12" N; 16° 49' 52" E). The orchard was located on a fawn soil consisting of slightly sandy, light clay over medium clay, and representing the IIIb class of the Polish economical soil classification. 'Elstar' and 'Jonagold' budded on M.9 rootstock were planting in split-plot design with four replications (the main plot was training system; the split-plot was cultivar). Each plot consisted of either: three trees in the form of Mikado (four leaders; 1,190 trees ha^{-1}), four trees with a Drilling canopy (three leaders; 1,587 trees ha^{-1}), six trees with a Tatura canopy (two leaders; 2,381 trees ha^{-1}), or twelve trees under the Güttingen-V system (one leader; 4,762 trees ha^{-1}) (Figures 1, a-d). The in-row tree spacing were: 2.4 m (Mikado), 1.8 m (Drilling), 1.2 m (Tatura), and 0.6 m (Güttingen-V); whereas the distance between rows was 3.5 m. In this way, the number of leaders per hectare was kept almost the same, regardless of the system (Table 1). The trees were planted as non-feathered and headed at 100 cm (Güttingen-V) or 60 cm (the remaining systems) 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 the petal fall, starting from the fourth year following the orchard establishment. No irrigation was applied. The fruitlets were thinned annually using a chemical agent only (biopreparation Pomonit, based on 1-naphthylacetic acid). The orchard floor management system consisted of herbicide fallow 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.

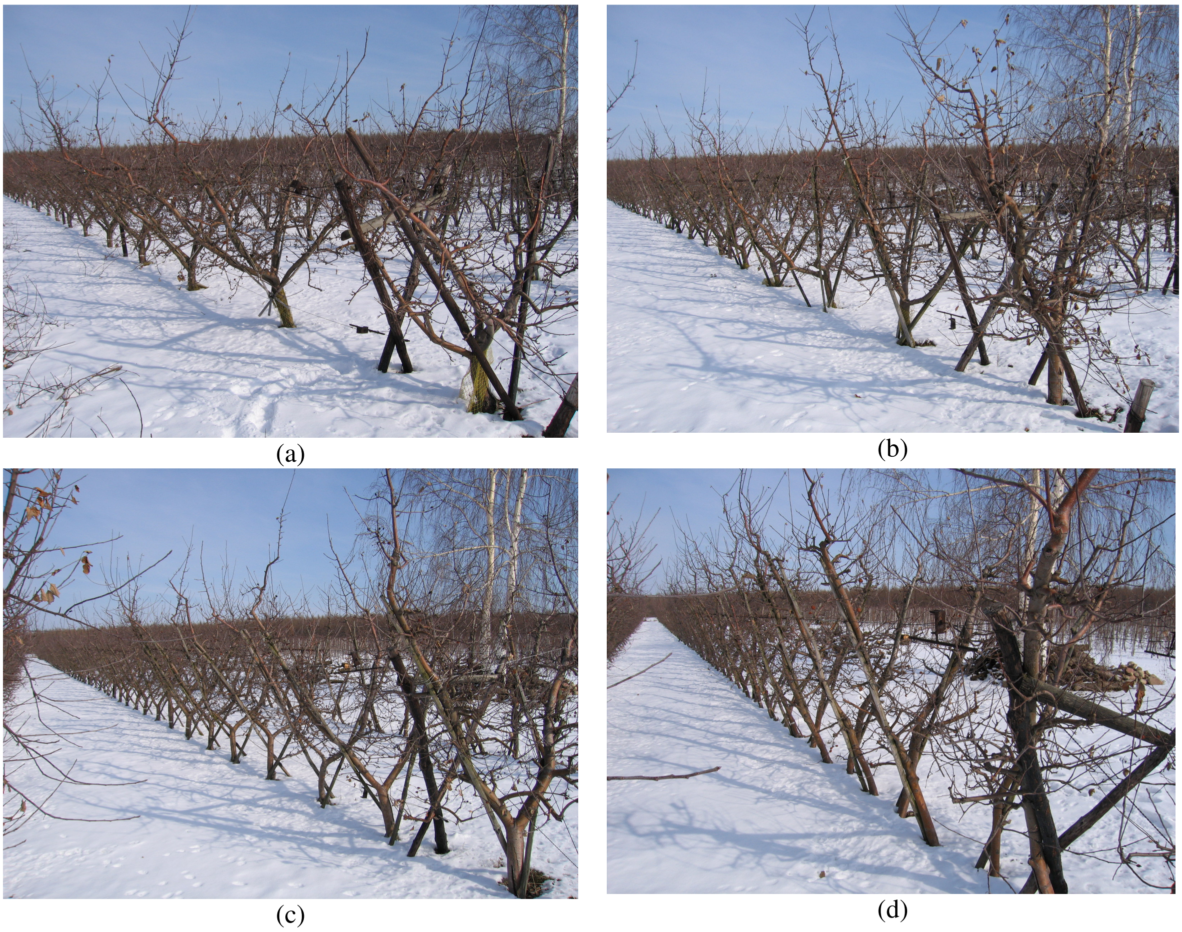

Figure1. The apple canopies Mikado(a), Drilling(b), Tatura(c) and Güttingen-V system (d).

Table 1. Characteristic of multi-leader apple canopies and Güttingen-V system.

Number of trees per hectare	Spacing (m)	Training system	Number of leaders per hectare
1190	3.5×2.4	Mikado - 4 leaders	4760
1587	3.5×1.8	Drilling – 3 leaders	4761
2381	3.5×1.2	Tatura – 2 leaders	4762
4762	3.5×0.6	Güttingen-V – 1 leader	4762

In 1994–2007, tree growth and bloom abundance, fruit yield per tree and per hectare, biennial bearing and yield indexes, as well as mean fruit weight, size, and skin coloration were assessed. For the purpose of data collection, each cultivar was harvested following a single-picking schedule, and the apples from each tree were collected into separate boxes. To determine crop quality, for each experimental plot, two boxes of apples were randomly selected and a sample of 20 fruits per tree was taken from them. This was followed by weighting the fruits, and in 2004–2007 seasons, fruit diameters and coloration were recorded. Annual harvests were used to calculate biennial bearing indexes. During 2004–2007, 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 assessed by measuring trunk circumference 20 cm above bud union and calculating TCSA values as well as their two- and four-year increments. The last set of TCSA together with the 1995–2007 fruit yield sums were used to calculate Crop Efficiency Coefficients (CEC), which were obtained at the end of the study.

Data were subjected to Analysis Of Variance (ANOVA) using a model appropriate for the split-plot design. Means were compared at the α= 0.05 level by Duncan's multiple range test. In case of percentage data pertaining to the fruit quality, an angular transformation according to Bliss function was applied prior to the ANOVA.

RESULTS AND DISCUSSION

Radial growth, expressed using TCSA and its two- and four-year increments, were closely correlated with in-row tree density (Table 2). The apple trees with Mikado canopies were characterized by highest TCSA values, whereas the Güttingen-V trees, growing in a fourfold higher density, developed the thinnest trunks. The results were significant, confirming that the in-row planting distance may have even bigger influence on the tree vegetative growth than the rootstock (Widmer and Krebs, 2001; Uselis, 2003; Robinson, 2007, Uselis *et al.,* 2007). According to an earlier study by Sosna (2004), the number and total length of annual shoots per leader decreased in direct proportion to the number of leaders per tree. The least dense canopies were observed in case of the four-leader Mikado system, while the densest were developed by the single-leader Güttingen-V trees. A similar relationship was noted by Hampson *et al.* (2002), Buler and Mika (2007), and Choi *et al.* (2014). In addition, Inomata *et al.* (2004) reported a bigger number of annual shoots and branches on apple trees with the Tatura canopy in comparison to the traditional spindle. In an experiment involving apple trees planted in the same density, the trees grown under the Tatura system had thinner trunks in relation to Güttingen-V trees (Barritt *et al.,* 2008). Likewise, in the study

Table 2. Trunk growth of 'Elstar' and 'Jonagold' apple trees as influenced by four training systems.

Training system	Trunk cross-sectional area TCSA autumn 2007 (cm^2)	TCSA increment (cm^2)	
		2005-2007	2003-2007
	'Elstar'		
Mikado–quadruple system	134.5 d*	26.8 d	51.8 d
Drilling –triple system	110.5 c	21.1 c	40.8 c
Tatura-Y system	89.2 b	15.4 b	31.0 b
Güttingen-V system	52.3 a	9.2 a	17.6 a
	'Jonagold'		
Mikado–quadruple system	121.2 d	25.8 c	48.3 d
Drilling –triple system	100.0 c	23.2 c	41.4 c
Tatura-Y system	66.7 b	11.8 b	22.3 b
Güttingen-V system	38.7 a	6.4 a	11.4 a
	Mean for cultivar		
'Elstar'	96.6 b	18.1 a	35.3 a
'Jonagold'	81.7 a	16.8 a	30.9 a
	Mean for training system		
Mikado	127.9 d	26.3 d	50.0 d
Drilling	105.2 c	22.1 c	41.1 c
Tatura	78.0 b	13.6 b	26.6 b
Güttingen-V system	45.5 a	7.8 a	14.5 a

* Means within columns, cultivars and main effects followed by common letters do not differ according to Duncan's test ($P < 0.05$).

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.

The bloom abundance in a given growing season was mostly influenced by yield in the preceding year. Of the two studied cultivars, the flowering of 'Elstar' was less regular — the years of abundant and weak bloom were alternating with each other (Table 3). The blooming of 'Jonagold' was on average weaker, but more regular. Regardless of the cultivar, the most irregular flowering was observed in case of trees with Mikado canopies, whereas the adoption of the Güttingen-V system resulted in the most regular flower set, in particular in case of the 'Jonagold' cultivar. That said, significant differences among the bloom abundances in relation to the planting system were noted only in 2005 and 2006. In 2005, the bloom of the Güttingen-V apple trees was the weakest, whereas a year later, the trees maintained in this system developed a significantly higher number of flowers than the Mikado trees. Unfortunately, due to the dearth of relevant information in the available and published literature, the results pertaining to the relationship between the planting system and the bloom of apple trees could not be compared with reports of other authors.

Concerning the yields obtained during the first 14 years after the planting of the two cultivars, regardless of the planting system, 'Jonagold' bore more fruit than 'Elstar'. In case of both cultivars, the trees with Mikado canopy gave the highest yields, whereas the densely-planted Güttingen-V apple trees performed worst in this respect (Table 4). In other words, as the tree planting density increased, the yield per tree diminished. A similar association was observed also by other authors (Widmer and Krebs, 2001; Hampson *et al*., 2004; Ozkan *et al*., 2012). Due to the different tree planting densities involved in each system, the yield calculated in relation to the unit area showed a different pattern. Yet, even when calculated per hectare, the yields obtained from the dense Güttingen-V plots were significantly lower in comparison to the remaining systems. In contrast, in the conditions of Turkey, the highest yields per hectare were obtained from systems based on high planting

Table 3. Flowering intensity of 'Elstar' and 'Jonagold' apple trees as influenced by four training systems (in 0-5 scale).

Training system	2004	2005	2006	2007
		'Elstar'		
Mikado	1.1 a*	3.8 b	1.1 a	3.1 a
Drilling	1.0 a	3.9 b	1.2 a	3.1 a
Tatura	0.7 a	3.5 b	1.4 a	3.2 a
Güttingen-V system	0.3 a	2.4 a	1.6 a	2.7 a
		'Jonagold'		
Mikado	2.8 a	3.5 b	2.0 a	3.0 a
Drilling	3.5 a	2.8 ab	3.1 b	2.7 a
Tatura	3.5 a	2.9 ab	2.9 b	2.7 a
Güttingen-V system	3.5 a	2.1 a	3.4 b	2.3 a
		Mean for cultivar		
'Elstar'	0.8 a	3.4 b	1.3 a	3.0 b
'Jonagold'	3.3 b	2.8 a	2.9 b	2.7 a
		Mean for training system		
Mikado	2.0 a	3.7 b	1.6 a	3.1 a
Drilling	2.3 a	3.4 b	2.2 ab	2.9 a
Tatura	2.1 a	3.2 b	2.2 ab	3.0 a
Güttingen-V system	1.9 a	2.3 a	2.5 b	2.5 a

* Explanations see Table 2.

densities (Ozkan *et al*., 2012). The values of yield indexes provide additional illustration of the high fruit bearing potential of trees with multiple leaders. High productivity of such apple trees was also reported by Monney and Evéquoz (1999), Inomata *et al*. (2004), Buler and Mika (2007), Uselis *et al*. (2007), and Rutkowski *et al*. (2009). When comparing the differences between cumulative yields per hectare in relation to planting distances, Robinson (2007) found out that the densest planted trees performed three times better than the ones growing in most sparsely spacing. At higher tree densities, V-shaped apple trees gave a lower cumulative yield than conic-shaped ones, whereas in a looser setting, the V-shaped canopy occurred to be superior. In an experiment set up next to Kraków (Poland), the number of fruits collected from the trees grown under the Mikado system was significantly smaller than in case of the traditional spindle with a single leader. According to the authors, the difference resulted from more disruptive pruning that is required in order to obtain a Mikado canopy (Porębski *et al*., 2008). In case of many apple tree cultivars, the Güttingen-V planting system occurred to be very suitable for commercial orchards. The onset of production came early and the trees were giving abundant yields (Platon, 2007; Dadashpour *et al*., 2011).

Among the two cultivars, significantly stronger tendency towards biennial fruit bearing was observed in case of 'Elstar' (Table 4). For both cultivars, up to the ninth year following the orchard establishment, the planting system had no influence on the bearing regularity. 'Elstar' cultivar under the Mikado system and 'Jonagold' trees with Güttingen-V canopies showed some tendency towards biennial bearing. In later years, the problem became much more pronounced in case of the systems involving multiple leaders (Mikado and Drilling). The fruit bearing of apple trees with Tatura and Güttingen-V canopies was significantly more regular. The available literature lacks any information regarding this subject.

The mean fruit weight in 1998–2007 periods was related to the cultivar and age

Table 4. Yielding of 'Elstar' and 'Jonagold' apple trees as influenced by four training systems.

Training system	Cumulative yield 1995-2007		CEC $kg\ cm^{-2}$	Biennial bearing index 0-1	
	$kg\ tree^{-1}$	$t\ ha^{-1}$	1994-2007	1998-2002	2003-2007
			'Elstar'		
Mikado	329.2 d*	391.7 c	2.45 c	0.84 b	0.97 c
Drilling	246.0 c	390.4 c	2.23 c	0.58 a	0.95 c
Tatura	142.8 b	340.0 b	1.60 b	0.50 a	0.77 b
Güttingen-V system	62.3 a	296.7 a	1.19 a	0.52 a	0.57 a
			'Jonagold'		
Mikado	465.4 d	553.8 ab	3.84 b	0.49 a	0.77 b
Drilling	368.8 c	585.3 bc	3.69 b	0.46 a	0.61 ab
Tatura	252.6 b	601.4 c	3.79 b	0.52 a	0.50 a
Güttingen-V system	111.2 a	529.5 a	2.87 a	0.72 b	0.54 a
			Mean for cultivar		
'Elstar'	195.1 a	354.7 a	1.87 a	0.61 b	0.82 b
'Jonagold'	299.5 b	567.5 b	3.55 b	0.55 a	0.61 a
			Mean for training system		
Mikado	397.3 d	472.8 b	3.15 c	0.67 a	0.87 b
Drilling	307.4 c	487.9 b	2.96 bc	0.52 a	0.78 b
Tatura	197.7 b	470.7 b	2.70 b	0.51 a	0.64 a
Güttingen-V system	86.8 a	413.1 a	2.03 a	0.62 a	0.56 a

* Explanations see Table 2.

(Table 5). Of the two studied cultivars, 'Elstar' produced significantly smaller apples. The fruits from older 'Elstar' apple trees were a little heavier, while in case of 'Jonagold', an opposite tendency was observed. Trees from the dense Güttingen-V 'Jonagold' plantings developed fruits characterized by the lowest weight, whereas the weight of apples obtained from the 'Elstar' cultivar did not vary significantly across the different orchard planting systems. A negative influence of high tree planting density on fruit size was reported by Ozkan *et al.* (2012). In an earlier study by Sosna (2004), the fruits obtained from younger trees of both cultivars were typically characterized by bigger size and better coloration. The only exception was 'Elstar' grown under the Güttingen-V system. The small size of apples obtained from this cultivar — in particular in case of the Mikado and Drilling systems — can be explained in terms of its strong tendency towards biennial bearing. In the year of fructification, despite chemical thinning, too many apples remained on the trees, and they were not achieving their proper final size.

Regardless of the cultivar, apple trees with three or four leaders developed smaller but better colored fruits (Table 5). In terms of the blush size, apples from the Tatura system had the poorest quality. This observation conflicts with the findings by Dorigoni *et al.* (2011). In comparison to the Güttingen-V system, the trees grown under the Mikado, Drilling, or even Tatura systems had more sparse canopies, favoring improved light transmission. The high quality of fruits originating from such trees — either in terms of mean weight, size, or coloration — was noted by numerous authors (Monney and Evéquoz, 1999; Widmer and Krebs, 2001; Inomata *et al.*, 2004; Buler and Mika, 2007; Porębski *et al.*, 2008; Kwon *et al.*, 2011; Talaie *et al.*, 2011). In the present study, the dense planting trees in Güttingen-V system resulted in fruits whose coloration was not substantially different than in case of the remaining systems. The good quality of apples that can be obtained from a Güttingen-V orchard is mentioned by

Table 5. Quality of 'Elstar' and 'Jonagold' apples as influenced by four training systems.

Training system	Mean fruit weight (g)		% Of apples with diameter>7.5 cm	% Of apples with blush over ½
	2004-2007	1998-2007	2004-2007[a]	2004-2007[a]
'Elstar'				
Mikado	148 a*	146 a	19.1 a	72.6 b
Drilling	150 a	148 a	26.0 ab	71.9 ab
Tatura	156 a	153 a	40.5 bc	60.4 a
Güttingen-V system	159 a	152 a	46.2 c	65.8 ab
'Jonagold'				
Mikado	207 b	216 b	57.0 a	55.2 a
Drilling	205 b	216 b	49.2 a	57.8 a
Tatura	196 ab	209 ab	61.4 a	51.6 a
Güttingen-V system	183 a	201 a	56.0 a	55.1 a
Mean for cultivar				
'Elstar'	153 a	150 a	33.0 a	67.7 b
'Jonagold'	198 b	211 b	55.9 b	54.9 a
Mean for training system				
Mikado	178 a	181 a	38.1 a	63.9 b
Drilling	178 a	182 a	37.6 a	64,9 b
Tatura	176 a	181 a	51.0 b	56.0 a
Güttingen-V system	171 a	177 a	51.1 b	60.5 ab

* Explanations see Table 2. [a] Means transformed according to Bliss function.

Rutkowski *et al.* (2009) and Dadashpour *et al.* (2012). In an experiment by Licznar-Małańczuk (2006), fruits of apple trees grown under this system and planted in high density (5,333 trees ha^{-1}) were also characterized by a very good quality. The yields, however, were bigger in case of the spindle canopy (3,333 trees ha^{-1}), and for this reason the author judged the latter system to be preferable.

CONCLUSIONS

The planting density affected vegetative growth and cropping of apple trees, but had no substantial influence on the quality of the obtained fruits. As the trees became older, the tendency of the studied apple cultivars towards biennial fruit bearing increased. In the final years of the research project (2003–2007), this tendency was particularly pronounced in case of the systems that involved the highest numbers of leaders — Mikado and Drilling. The fruits from all of the studied V-shaped apple tree canopies were characterized by similar mean weight. Significantly bigger apples developed on less productive trees with the Güttingen-V and Tatura canopies. In addition, apples from the latter system developing relatively poor coloration.

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دیدگاه هایی مبتنی بر پژوهش های دراز مدت در باغ های سیب با سایه سارهای V (Canopies) شکل

ی. سوسنا

چکیده

هدف این پژوهش ارزیابی رشد، عملکرد و کیفیت میوه دو کولتیوار سیب در اثر چندین سامانه درختکاری بود که درختانی پیرایش شده با تعداد مختلفی پیش آهنگ (leader) را شامل می شد. پژوهش در طی سال های ۲۰۰۷-۱۹۹۴ در ایستگاه تحقیقات میوه در منطقه Samotwór در نزدیکی Wrocław واقع در جنوب غربی لهستان اجرا شد. در بهار۱۹۹۴، نهال های یکساله سیب شامل کولتیوار های Elstar و Jonagold پیوند شده روی پایه M.9 با فاصله۳/۵ متر بین ردیف ها و فواصل مختلف روی ردیف ها کاشته شد. فواصل روی ردیف ها عبارت بودند از:۲/۴ متر(در سامانه Mikado با ۴ پیش آهنگ)، ۱/۸ متر(سامانه Drilling با سه پیش آهنگ)، ۱/۲ متر (سامانه Tatura با دو پیش آهنگ) و ۰/۶ متر(سامانه Güttingen-V با یک پیش آهنگ). به این ترتیب، تعداد پیش آهنگ ها در هکتار تقریبا یکسان و فارغ از نوع سامانه بود. قوی ترین رشد در درختانی رخ داد که دارای سامانه Mikado و بیشترین فاصله کاشت بودند در حالیکه درختان سیب سامانه Güttingen-V تُنک ترین سیستم شاخسار را داشتند. فراوانی شکوفه ها که در دوره۷-۲۰۰۴ ثبت شد بیشتر مربوط به شرایط سال بود و نه سامانه کاشت. کل عملکرد هر درخت در دوره ۲۰۰۷-۱۹۹۵ با زیاد شدن تراکم کاشت کاهش یافت و زمانی که عملکرد در هکتار درنظر گرفته شد سامانه Güttingen-V کمترین تولید را نشان داد. با افزایش سن درختان، کیفیت سیب ها کاهش یافت که احتمالا ناشی از گرایش به سال آوری بود. در سال های اخر مطالعه (۲۰۰۷-۲۰۰۳) درختانی که بیشترین تعداد پیش آهنگ را داشتند (منظور سامانه های Mikado و Drilling است) نامنظم ترین طرح تولید را نشان دادند. اثر سامانه کاشت درختان باغ روی میانگین وزن میوه معنادار نبود.