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INFLUENCE OF PLANTING AND TRAINING SYSTEMS ON FRUIT YIELD IN APPLE ORCHARD

Maria Licznar-Małańczuk

Agricultural University, Department of Horticulture
Rozbrat 7, 50-334 Wrocław, POLAND
e-mail: liczmal@hotmail.com

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A B S T R A C T

Several orchard management systems with 3 333 to 13 223 trees per ha were compared over the first ten years of cropping (1993-2002) for their effect on fruit yield. Apple trees were planted as a single- or multi-row or V-system with a spindle at low densities and a slender spindle or superspindle at high densities.

The results showed that planting density and training system were the critical factors determining the total apple yield per tree, which was the highest at the density of 3 333 trees per ha and the lowest at 13 223 trees per ha. The densities over 5 333 trees per ha did not significantly increase the mean yield per unit area during the first ten years of cropping. For 'Jonagold' trees the cumulative fruit yield for 1993-2002 was the highest at the densities of 3 333 and 5 333 trees per ha, varying from 380 to 400 t per ha. In the case of 'Golden Delicious' the highest cumulative fruit yield (about 440 t per ha) was obtained at the densities of 3 333 and 7 404. Planting density and training system had also an effect on tree vigour, which was the weakest for the trees trained as a superspindle with 13 223 trees per ha.

Key words: apple, planting, training, spacing, yield, growth

INTRODUCTION

Since the late 1980`s there has been a rapid increase in planting density of apple trees in different regions of Europe (Mantinger and Vigl 1999ab). About ten years later, Widmer and Lemmenmeier (1999) showed that in orchards with 10 000 trees per ha, an increase of yields was insufficient to obtain a profitable production. Doubling the density from 3 000 to 6 000 spindle trees per ha generated higher yields, up to the seventh year of cropping, but it was still insufficient for offsetting additional investment costs

(Mantinger and Vigl, 1999ab; Widmer and Krebs, 2000; 2001). Taking into account the profitability and risk of production under the climate condition of northen Europe, as an upper limit, densities from 3 000 to 4 000 trees per ha seem to be recomendable (Mantinger and Vigl, 1999a).

The aim of the present study was to estimate an influence of planting density from 3 333 to 13 223 trees per hectare and training systems on the yield and growth of apple trees during the first ten years of cropping (1993-2002) under the climatic conditions of Lower Silesia (SW Poland).

MATERIAL AND METHODS

Experiment was carried out at the Fruit Experimental Station in Samotwór near Wrocław, on a medium silty loam soil classified as III b class. One-year-old apple trees of 'Jonagold' and 'Golden Delicious'/M.9 were planted in the spring of 1992. The research focused on several tree training systems at the densities from 3 333 to 13 223 trees per ha, planted as a single-/multi-row design or as V-system with a typical spindle, slender spindle or superspindle canopy shape (Tab. 1). Quality of maiden trees depended on the planting and training systems. Minimum pruning and horizontal bending of limbs were performed during the first two years after planting. Since 1994 trees were pruned annually after blooming, except for 1999, and since 1996 summer pruning was also conducted. Herbicide fallow was introduced in the tree row and sward in the alleyways. Plant protection was carried out according to the current recommendations of the Orchard Protection Programme.

Table 1. Quality characteristics of maiden trees in estimated planting and training systems

No	Trees /ha	Spacing	Planting system	Training system	'Jonagold'		'Golden Delicious'	
					TCSA [cm^2]*	number of shoots	TCSA [cm^2]**	number of shoots
1.	3333	3.00 x 1.00	single-row	spindle	1.01	> 4	0.90	> 4
2.	5333	3.00+0.75 x 1.00	double-row		1.01	> 4	0.88	> 4
3.	6667	3.00+2 x (0.75) x 1.00	three-row		1.04	> 4	0.90	> 4
4.	5333	3.75 x 0.50	single-row	system V	0.87	2-3	0.72	2-3
5.	5333	3.50+0.25 x 1.00	double-row		0.84	2-3	0.73	2-3
6.	7407	2.25 x 0.60	single-row	superspindle	0.75	0-2	0.70	0-2
7.	13223	2.25+0.50 x 0.55	double-row		0.74	0-2	0.67	0-2

* $LSD_{0.05} = 0.24$ * * $LSD_{0.05} = 0.13$

The experiment was carried out in a randomised block design with 8 replications. Depending on planting density the number of trees per plot varied from 4 to 10. During the first ten years of cropping (1993-2002) the effects of planting and training systems on apple yield were examined. The increment of trunk cross section area (TCSA) was evaluated upon trunk diameter. Experimental data were statistically elaborated and verified by Student`s multiple range t-test at $P = 0.05$.

RESULTS

During the first ten years of cropping, planting density was the major factor determinig annual yield per tree, which was the highest at 3 333 trees per ha (Tab. 2 and 3). The level of cropping and alternate bearing depended on cultivar in the following vegetation season, however each density over 5 333 trees per ha significantly decreased the mean yield per tree; this was the lowest (below 3 kg per tree) for the most intensive system with 13 223 trees per ha.

Densities over 5 333 trees per ha did not significantly increase the mean yield per unit area during the first ten years of cropping. For 'Jonagold', cumulative fruit yield for 1993-2002 was the highest at 3 333 and 5 333 trees per ha, varying from 380 to 400 t per ha. In the case of 'Golden Delicious' the highest cumulative yield (about 440 t per ha) was obtained at 3 333 and 7 404 trees per ha.

The quality of maiden trees (Tab. 1) influenced tree growth which was also affected by the system (Tab. 4) and was the strongest at 3 333 trees per ha. This system was also characterised by the highest crop coefficient index. Along with an increase of tree number per hectare there was a reduction of TCSA increment. This value at 3 333 trees per ha during the first eleven years of training was for 'Jonagold' and 'Golden Delicious' 38.98 and 29.98 cm^2 respectively, and only 14.99 and 12.28 cm^2 when planting density enhanced to 13 223 trees per ha.

DISCUSSION

Meland and Hovland (1997) observed that irrespective of training system, yield per ha was positively correlated with tree density from 1250 to 2500 per ha, up to the sixth year after planting. Similar results during the first fifteen years of cropping were obtained by Lepsis and Blanke (2001) in an apple orchard with planting density from 1 587 to 3 175 trees per ha. However, as shown by Widmer and Krebs (2000, 2001) and Mantinger and Vigl (1999ab) and also confirmed by the present study, yield per ha did not proportionally

Table 2. Mean annual yield of 'Jonagold' trees in relation to planting and training systems (1993-2002)

Planting/ training system	Yield [kg tree^{-1}]										$\overline{X}$ [kg tree^{-1}]	$\overline{X}$ [t ha^{-1}]
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002		
3 333 trees/ha												
Single-row	2.47	3.91	9.10	8.98	14.54	14.31	21.89	16.03	9.40	15.47	**11.61**	38.70
5 333 trees/ha												
Double-row	0.99	4.23	5.26	7.66	8.79	8.19	15.82	6.79	9.98	8.53	**7.62**	40.65
6 667 trees/ha												
Three-row	0.87	3.78	4.94	5.26	5.55	3.98	8.68	7.53	4.57	7.21	**5.24**	34.91
5 333 trees/ha												
Single-row (V system)	1.05	2.15	3.54	4.01	6.96	3.70	12.29	4.27	7.44	4.11	**4.95**	26.41
5 333 trees/ha												
Double-row (V system)	1.08	2.07	3.97	3.94	6.52	4.04	11.98	4.39	9.10	3.48	**5.06**	26.96
7 407 trees/ha												
Single-row	0.85	3.18	2.93	3.90	5.09	2.23	9.68	4.55	4.17	4.43	**4.10**	30.37
13 223 trees/ha												
Double-row	0.30	1.94	1.27	2.28	3.08	1.20	3.92	3.71	2.75	2.29	**2.39**	31.57
$\overline{X}$	**1.09**	**3.04**	**4.43**	**5.15**	**7.22**	**5.38**	**12.04**	**6.75**	**6.77**	**6.50**	-	-
$LSD_{0.05}$	-	-	-	-	-	-	-	-	-	-	**1.40**	7.19

T a b l e 3. Mean annual yield of 'Golden Delicious' trees in relation to planting and training system (1993-2002)

Planting/ training system	Yield [kg tree^{-1}]										$\overline{X}$ [kg tree^{-1}]	$\overline{X}$ [t ha^{-1}]
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002		
3 333 trees/ha Single-row	2.21	5.77	3.18	9.69	19.04	18.60	23.03	19.49	9.15	22.48	**13.26**	44.21
5 333 trees/ha Double-row	2.04	5.25	1.82	7.44	10.71	5.00	14.10	4.45	7.88	8.61	**6.73**	35.90
6 667 trees/ha Three-row	1.96	5.71	1.77	6.16	7.91	3.21	7.90	6.51	4.84	6.09	**5.21**	34.69
5 333 trees/ha Single-row (V system)	1.63	5.02	2.29	5.56	9.89	7.42	12.36	6.59	5.47	6.50	**6.27**	33.44
5 333 trees/ha Double-row (V system)	1.41	4.58	2.31	5.83	8.62	7.31	11.64	10.44	6.16	9.41	**6.77**	36.10
7 407 trees/ha Single-row	1.04	4.73	1.30	4.55	7.14	6.16	9.63	11.90	2.25	10.25	**5.89**	43.66
13 223 trees/ha Double-row	0.96	2.70	0.62	2.99	3.32	2.93	3.10	5.90	1.66	4.34	**2.90**	38.24
$\overline{X}$	**1.61**	**4.82**	**1.90**	**6.03**	**9.52**	**7.23**	**11.68**	**9.33**	**5.34**	**9.67**	**-**	-
$LSD_{0.05}$	-	-	-	-	-	-	-	-	-	-	**1.30**	7.15

T a b l e 4. Increment of trunk cross section area (TCSA) and crop coefficient index in relation to planting and training systems

Planting/ training system	'Jonagold'		'Golden Delicious'	
	TCSA increment 1992-2002 [cm^2]	crop coefficient index 2002 [kg cm^{-2}]	TCSA increment 1992-2002 [cm^2]	crop coefficient index 2002 [kg cm^{-2}]
3 333 trees/ha Single-row	38.98	3.01	29.98	4.32
5 333 trees/ha Double-row	28.97	2.58	22.12	2.96
6 667 trees/ha Three-row	25.98	1.95	19.96	2.52
5 333 trees/ha Single-row (V system)	27.52	1.77	21.73	2.84
5 333 trees/ha Double-row (V system)	26.69	1.88	20.76	3.25
7 407 trees/ha Single-row	25.86	1.54	19.71	2.91
13 223 trees/ha Double-row	14.99	1.52	12.28	2.25
$LSD_{0.05}$	6.57	0.73	3.60	0.93

increase with a growing tree density from 3 000 to 6 000 or more trees per ha, because high density planting evidently resulted in a decrease of both growth and yield per tree. In the case of 'Golden Delicious' the highest and similar cumulative yield (ca. 440 t per ha) was obtained for both densities: 3 333 and 7 404 trees pr ha. Tree response to high density planting also depended on cultivar and similar data were obtained by Mantinger and Vigl (1999a). Cumulative yield was decreased in the case of alternate bearing as it was also noted in superspindle orchards of the South Tyrol (Mantinger and Vigl, 1999b).

Early cropping and an annual production of high and good quality yields should characterize a succesful high-density orchard (Wertheim et al., 2001). Taking into account the profitability and risk of production in the climatic conditions of northen Europe, as an upper limit, densities from 3 000 to 4 000 trees per ha seem to be recomendable (Mantinger and Vigl, 1999a). This is generally in agreement with results of the present research showing that only a single-row system with 3 333 trees per ha was found the best in comparison to higher planting densities of apple trees.

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WPŁYW SYSTEMU SADZENIA I PROWADZENIA DRZEW NA PLONOWANIE W SADZIE JABŁONIOWYM

Maria Licznar-Małańczuk

STRESZCZENIE

W kilku systemach prowadzenia jabłoni z liczbą od 3 333 do 13 223 drzew na hektarze porównywano plonowanie drzew w okresie pierwszych dziesięciu lat owocowania (1993-2002). Jabłonie posadzone w systemach wrzecionowych jedno-, wielorzędowych i systemie V charakteryzowały się mniejszym zagęszczeniem drzew na jednostce powierzchni, natomiast wysokim w systemach superwrzecinowych.

Uzyskane wyniki wykazały, że zagęszczenie drzew i system ich prowadzenia wpłynęły na wysokość sumy plonu z drzewa. Najwyższą uzyskano przy 3 333 jabłoniach na hektarze, a najniższą przy 13 223. Przy zagęszczeniu powyżej 5 333 drzew na hektarze nie zanotowano istotnego wzrostu średniego plonu z jednostki powierzchni w okresie pierwszych dziesięciu lat owocowania. Dla odmiany 'Jonagold' suma plonu z lat 1993-2002 była najwyższa przy zagęszczeniu 3 333 i 5 333 jabłoni na hektarze i kształtowała się w zakresie od 380 do 400 ton z hektara. W przypadku odmiany 'Golden Delicius' około 440 ton z hektara uzyskano zarówno przy zagęszczeniu 3 333, jak i 7 407 jabłoni na hektarze. System sadzenia i prowadzenia drzew wpłynął również na wzrost drzew – najsłab-szy zanotowano w systemie superwrzecionowym z liczbą 13 223 jabłoni na hektarze.

Słowa kluczowe: jabłoń, sadzenie, prowadzenie, rozstawa, plon, wzrost