JOURNAL OF FRUIT AND ORNAMENTAL PLANT RESEARCH

VOL. X
2002

SKIERNIEWICE, POLAND

Maria Licznar-Małańczuk
Agricultural University, Department of Horticulture
Rozbrat 7, 50-334 Wrocław, POLAND

INFLUENCE OF PLANTING, TRAINING SYSTEM AND DRIP IRRIGATION OF APPLE TREES ON THEIR GROWTH AND YIELD

ABSTRACT. Apple tree growth was estimated together with its effect on inflorescence number and yield in seven training systems (from 3333 to 13223 trees per hectare) on drip-irrigated and unirrigated plots. Trees were planted as a single-, multi-row or V-system with a spindle at low densities and a slender- or superspindle at high densities.

Planting density was the major factor determining tree growth which was the lowest in those trained as a superspindle with 13223 trees per hectare. The drip irrigation increased the growth rate but it caused alternate bearing. In consequence trees did increase their yield in comparison to those unirrigated.

Key words: apple, training system, spacing, irrigation, growth, inflorescence, yield

INTRODUCTION. Training systems determine tree form, sunlight distribution within canopy and directly affect the balance between the fruiting and vegetative growth (Barrit, 1992). Proper light conditions

affect the formation of flower buds and this ensures a high yield (Taylor and Lenz, 1991). Strong growth of trees limits the formation of flower buds and can result in the reduction of the crop (Quinlan and Preston, 1971 cit. from Mika 1984), and fruit quality (Mantinger, 1993). Also, over-vigorous growth affected by irrigation can lead to alternate bearing (Guzewski, 1996).

The aim of the present study was the estimation of apple tree growth in seven training systems (from 3333 to 13223 trees per hectare) in drip-irrigated and unirrigated conditions, and its influence on the number of flower buds and yield.

MATERIAL AND METHODS: Experiment was established at the Fruit Experimental Station in Samotwór near Wrocław (Lower Silesia) on pseudopodsolic soil, IIIb class. One-year-old apple trees of cvs 'Jonagold', 'Golden Delicious,' and also 'Elastar' as a pollinator, grafted on M.9 rootstock, were planted in the spring of 1992. Seven orchard management systems were compared under drip irrigation conditions and without water supply (Tab 1). Irrigation was started when the soil water tension exceeded 0.03 Mpa and was conducted during the four successive vegetation periods from early May 1993 until mid August 1996.

Minimum pruning and horizontal bending of limbs were performed during the first two years after planting. Since 1994 trees were pruned annually after blooming. Herbicide fallow was kept in tree rows and sward in alleyways. Plant protection was carried out according to the current recommendations of the Orchard Protection Programme.

Quality of maiden trees depended on planting and training systems (Tab. 1). One-year-old 'Jonagold' and 'Golden Delicious' trees were planted in two separate trials and each consisted of two parts. The experiment was carried out by the split-cross method with rows of planted trees as the first factor and irrigation as the second. Each treatment was established on eight plots used as replications. Depending on the planting density the number of trees per plot varied from 4 to 10.

T a b l e 1 . Quality characteristic of maiden trees in estimated training systems

No	Trees /ha	Spacing	Planting system	Training system	'Jonagold'		'Golden Delicious'	
					trunk cross section area [cm^2]*	number of shoots	trunk cross section area [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	spindle	1.01	> 4	0.88	> 4
3.	6667	3.00 + 2 x (0.75) x 1.00	three-row	spindle	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	system V	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	superspindle	0.74	0-2	0.67	0-2

*LSD(5%)=0.24 * *LSD(5%)=0.13

Growth of trees was estimated during the first five years after planting. Trunk cross-sectional area (TCSA) was evaluated upon the trunk diameter and also the length of annual shoots over 5 cm was measured. During the first four years of cropping the yield in kg per plot was estimated. In 1994 and 1995 the number of inflorescence was recorded. The experiment results were statistically elaborated and verified by the Student`s t - test at P=0.05.

RESULTS AND DISCUSION. Along with the increase of tree number per hectare there was a reduction of annual increments of both TCSA and total length of shoots (Tab. 2 and 3, Fig. 1 and 2). The plant growth depended on the quality of maiden trees but it was considerably stronger in the system of 3333 trees/ha and much more limited at the highest density of 13223 trees/ha (Tab. 1). The results

T a b l e 2 . Total length of annual shoots of ‘Jonagold’ trees in relation to training system and irrigation

Tree density/ training system	Length [cm/tree]											
	1992	1993			1994			1995			1996		
		1	2	d	1	2	d	1	2	d	1	2	d
3333 trees/ha Single-row	**384.3**	1091.6	1100.3	**8.7**	856.2	947.9	**91.7**	1310.3	1439.8	**129.5**	2474.5	1895.3	**579.2**
5333 trees/ha Double-row	**334.4**	691.4	1001.5	**310.1***	610.3	757.1	**146.8**	1086.8	1018.0	**68.8**	1769.8	2102.0	**332.2**
6667 trees/ha Three-row	**261.8**	729.8	1022.0	**292.2***	567.6	932.4	**364.8**	1120.4	1419.0	**298.6**	1721.6	1773.3	**51.7**
5333 trees/ha Single-row (V system)	**172.6**	587.7	839.4	**251.7***	393.6	637.7	**244.1**	865.8	1256.1	**390.3**	1290.8	1880.6	**589.8***
5333 trees/ha Double-row (V system)	**154.0**	626.2	767.2	**141.0**	525.2	701.7	**176.5**	806.0	1000.9	**194.9**	1400.3	1693.2	**292.9**
7407 trees/ha Single-row	**168.5**	606.0	620.6	**14.6**	481.8	546.4	**64.6**	695.4	824.1	**128.7**	1198.0	1327.9	**129.9**
13223 trees/ha Double-row	**149.7**	530.8	553.0	**22.2**	351.1	387.8	**36.7**	579.6	561.3	**18.3**	807.3	1235.5	**428.2**
$\overline{X}$	**231.8**	**687.5**	**857.7**	**170.0***	**540.8**	**701.6**	**160.8***	**923.5**	**1074.2**	**150.7**	**1523.2**	**1672.5**	**149.3**
$LSD_{\alpha=0.05}$ (system)	96.1		-			-			-			-	
$LSD_{\alpha=0.05}$ (system x irrigation)	-		162.3			n s			n s			442.8	

1 – unirrigated trees; 2 – irrigated trees; d – difference * – significant n s – not significant

T a b l e 3 . Total length of annual shoots of ‘Golden Delicious’ trees in relation to training system and irrigation

Tree density/ training system	Length [cm/tree]											
	1992	1993			1994			1995			1996		
		1	2	d	1	2	d	1	2	d	1	2	d
3333 trees/ha Single-row	**383.5**	904.1	1003.7	**99.6**	1190.3	1040.3	**150.0**	1768.6	1601.8	**166.8**	2436.6	2170.9	**265.7**
5333 trees/ha Double-row	**358.5**	831.6	889.3	**57.7**	846.2	1359.1	**512.0**	1097.9	1331.7	**233.8**	1813.9	2216.6	**402.7**
6667 trees/ha Three-row	**375.2**	825.0	968.1	**143.1**	986.6	978.1	**8.5**	1117.3	1417.4	**300.1**	1840.1	2468.2	**628.1**
5333 trees/ha Single-row (V system)	**263.1**	680.5	730.5	**50.0**	762.7	776.3	**13.6**	1010.6	1213.8	**203.2**	1695.0	1638.9	**56.1**
5333 trees/ha Double-row (V system)	**231.8**	692.1	859.4	**167.3**	627.2	874.8	**247.6**	1046.2	1293.8	**247.6**	1757.3	1768.5	**11.2**
7407 trees/ha Single-row	**197.6**	601.9	632.3	**30.4**	827.0	818.4	**8.6**	1096.1	1098.6	**2.5**	1408.6	1355.3	**53.3**
13223 trees/ha Double-row	**175.9**	530.2	533.8	**3.6**	453.6	507.9	**54.3**	705.6	662.3	**43.3**	753.5	877.3	**123.8**
$\overline{X}$	**290.6**	**730.8**	**816.1**	**85.3***	**813.4**	**907.8**	**94.4**	**1120.3**	**1231.3**	**111.0**	**1672.1**	**1785.1**	**113.0**
$LSD_{\alpha=0.05}$ (system)	75.6		-			-			-			-	
$LSD_{\alpha=0.05}$ (system x irrigation)	-		n s			301.4			n s			n s	

1 – unirrigated trees; 2 – irrigated trees; d – difference ***** – significant n s – not significant

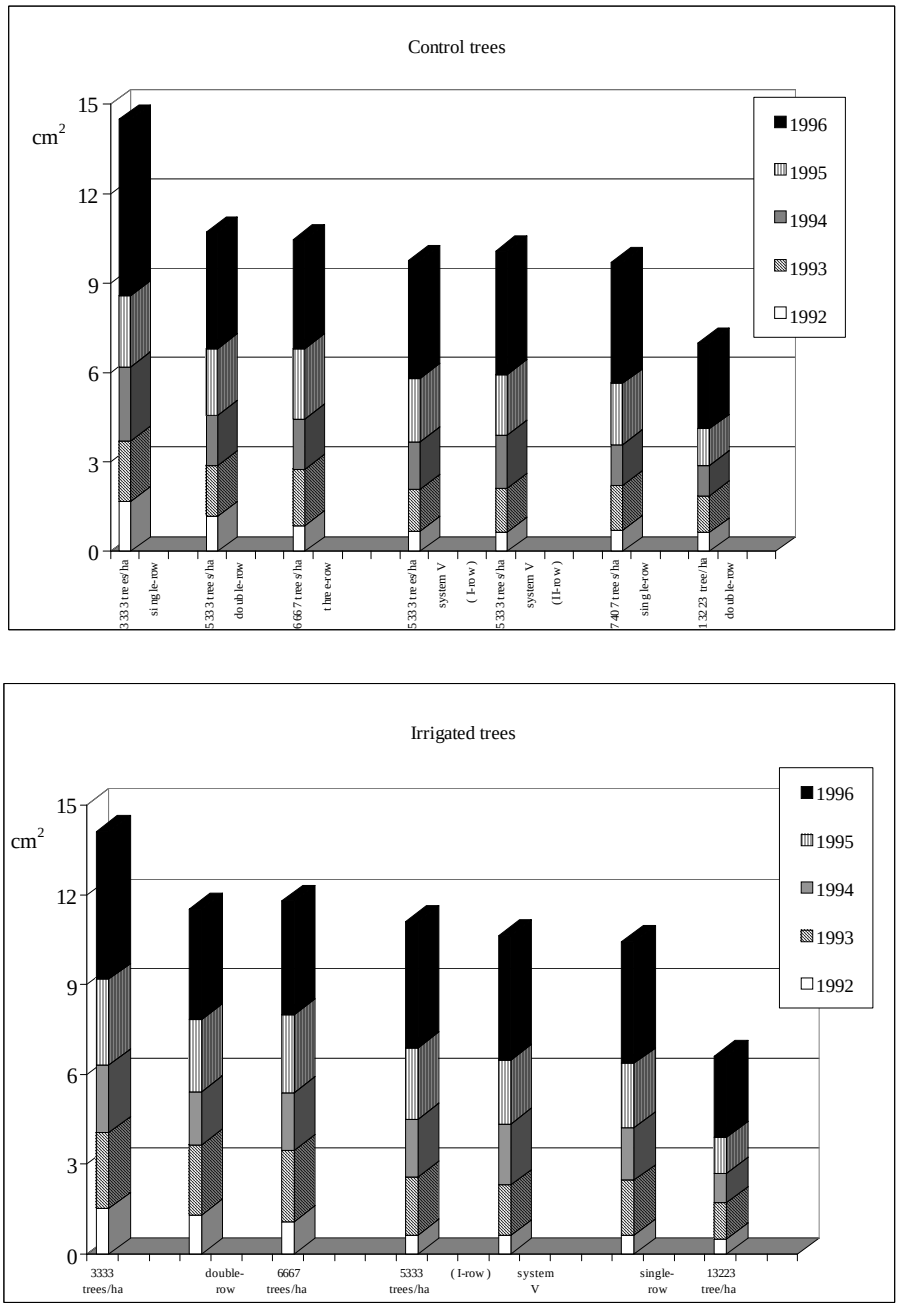

Figure 1. Annual increments of trunk cross-sectional area of 'Jonagold' trees in relation to training system and irrigation

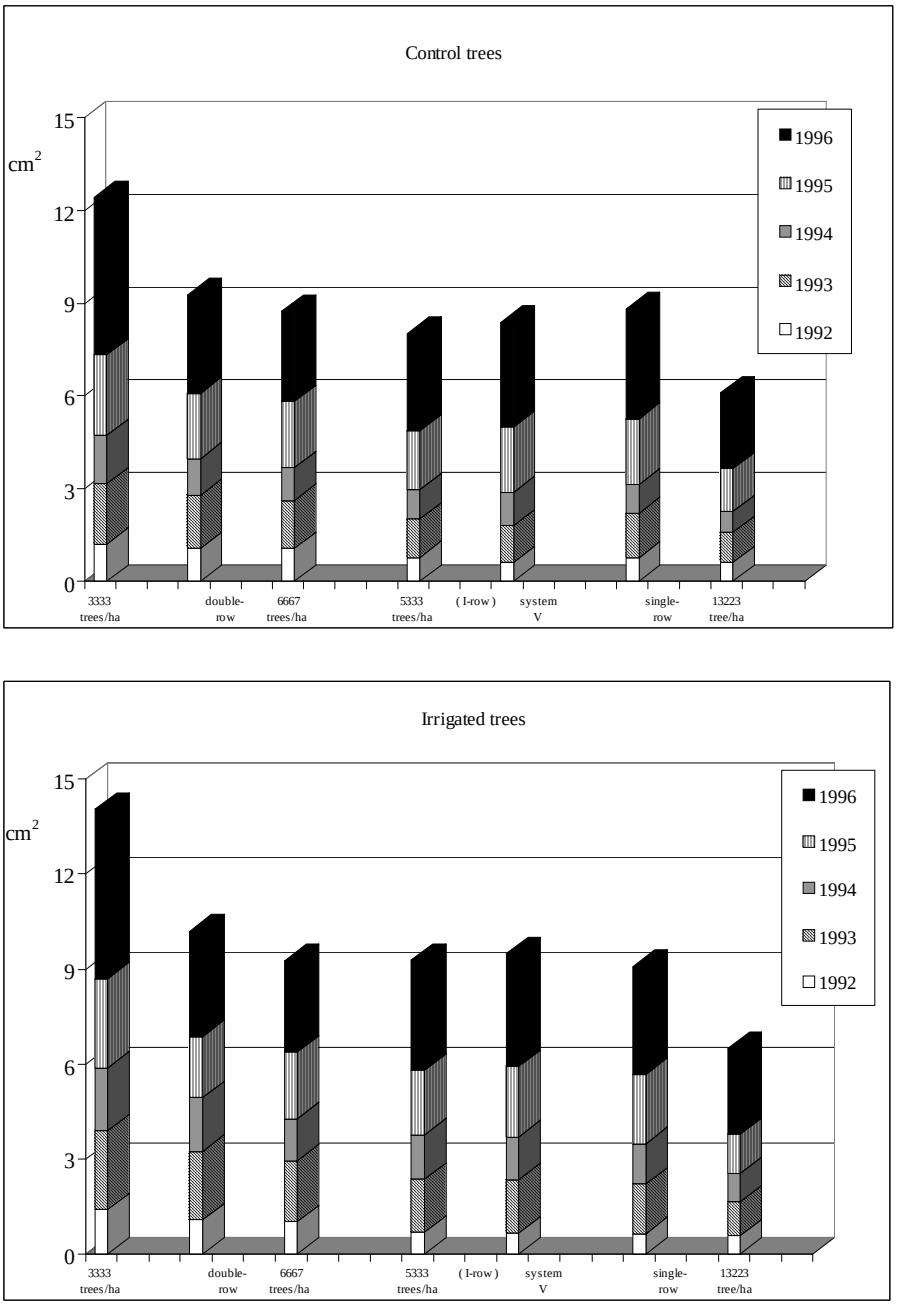

Figure 2. Annual increments of trunk cross-sectional area of 'Golden Delicious' trees in relation to training system and irrigation

proved that the planting and training system had a clear influence on apple tree growth. In the 5th year after planting the TCSA of 'Jonagold' cv. was 15.31 cm^2 in the system of 3333 trees/ha and only 7.51 cm^2 in that of 13223 trees/ha. Sansavini et al. (1986) found that up to the 4th year after planting within a density of 1196-3571 trees/ha the TCSA was significantly lower (17.9 cm^2) in comparison to planting at a density between 892 and 1190 trees/ha (23.2 cm^2). Similar relation was described by Wertheim (1985) for the systems of 2000-8333 trees/ha. Considerable reduction of growth, observed in the present study for the most intensive system (13223 trees/ha) was also confirmed for other apple cultivar – 'Jonica' on M.9 rootstock (Mika,1995). In the 4th year of that experiment at a density of 8000-10000 trees/ha a mean trunk diameter was only 1.8 cm whereas for 2000-4000 trees/ha it increased to about 3 cm.

At the end of the 1st year of irrigation (1993) both investigated cultivars had significantly greater annual increments of TCSA and total length of shoots. Similar but not always statistically significant reaction was observed in the following sesons. In the 5th year after planting the mean TCSA of irrigated 'Jonagold' and 'Golden Delicious' trees was respectively by 0.56 and 0.87 cm^2 higher in relation to those from unirrigated plots. Similar results were obtained by Rakićević (1989) and Sosna (1995). Mika (1995) found that at the end of the 4th year after planting the total length of annual shoots of irrigated 'Gloster' tree on M.9 rootstock was 18-23 m, while for those unirrigated it was only 10-15 m. In the present experiment in the similar single-row spindle system that length in unirrigated 'Jonagold' trees amounted to 36.3 m, and in 'Golden Delicious' to 42.4 m while on irrigated plots it was 38.7 and 40.4 m, respectively.

During the first four years of cropping, planting density was the major factor determining the total yield per tree, which was the highest in the system of 3333 trees/ha (Tab. 4). Along with an increase of tree density there was no proportional rise of the estimated total yield per unit area. This was the highest at a density of 6 667 trees/ha and amounted to about 102 and 104 tons of apples for 'Jonagold' and 'Golden Delicious', respectively. Similar some results were obtained by Mantinger (1993).

T a b l e 4 . Inflorescence number and total yield of two apple cultivars in relation to training system and irrigation

Tree density/ raining system	Number of inflorescences per tree												Total yield [kg tree^{-1}]					
	'Jonagold'						'Golden Delicious'						'Jonagold'			'Golden Delicious'		
	1994			1995			1994			1995			1993-1996			1993-1996		
	1	2	d	1	2	d	1	2	d	1	2	d	1	2	d	1	2	d
3333 trees/ha Single-row	121.1	140.8	**19.7**	73.1	47.1	**26.0**	131.9	108.6	**23.3**	23.3	24.8	**1.5**	24.46	27.57	**3.11***	20.85	24.76	**3.91**
5333 trees/ha Double-row	74.8	116.0	**41.2**	30.9	21.8	**9.1**	103.4	125.5	**22.1**	15.4	29.9	**14.5**	18.14	18.80	**0.66**	16.56	18.10	**1.54**
6667 trees/ha Three-row	83.0	90.3	**7.3**	30.1	9.9	**20.2**	114.3	102.6	**11.7**	18.3	28.5	**10.2**	14.85	15.91	**1.06**	15.59	15.61	**0.02**
5333 trees/ha single-row V system)	43.0	69.9	**26.9**	25.3	10.8	**14.5**	99.1	83.0	**16.1**	11.4	9.0	**2.4**	10.75	12.08	**1.33**	14.50	13.56	**0.94**
5333 trees/ha double-row (V system)	49.1	64.3	**15.2**	30.4	36.6	**6.2**	67.6	77.5	**9.9**	11.6	13.4	**1.8**	11.05	10.94	**0.11**	14.13	12.95	**1.18**
7407 trees/ha Single-row	64.4	44.5	**19.9**	26.1	23.0	**3.1**	83.4	62.9	**20.5**	2.9	0.6	**2.3**	10.85	8.43	**2.42***	11.61	10.73	**0.88**
13223 trees/ha Double-row	39.8	36.8	**3.0**	6.9	7.4	**0.5**	38.9	45.1	**6.2**	4.0	1.5	**2.5**	5.78	5.40	**0.38**	7.26	5.49	**1.77**
$\overline{X}$	**67.9**	**80.3**	**12.4**	**31.8**	**22.4**	**9.4**	**91.2**	**86.5**	**4.7**	**12.4**	**15.4**	**3.0**	**13.70**	**14.16**	**0.46**	**14.36**	**14.46**	**0.10**
LSD $_{\alpha=0.05}$ (system x irrigation)	n s			n s			n s			n s			2.23			1.81		

1 – unirrigated trees; 2 – irrigated trees; d – difference ***** – significant n s – not significant

Beneficial effect of irrigation on the yield reported by many authors, mainly in young intensive orchards (Sosna, 1995; Treder and Mika, 1996, cit. from Treder, 1996; Treder and Czynczyk, 1997) was not confirmed by the present research. Number of inflorescences per tree on both irrigated and control plots showed no significant differences, and as a result there was a similar total yield per tree in many treatments in 1993-1996. The same trend was also observed by Treder and Czynczyk (1997) who found that after a high yield in the 3rd year of cropping (in the present experiment in the 2nd) the yield of irrigated trees was very low in the following season. This phenomenon may be explained by the fact that in the spring of 1995, after good cropping in 1994, both irrigated and unirrigated trees had less inflorescences (Tab. 4). This trend was clearer in several irrigated planting systems plots, where stronger growth of trees was observed. It is generally in agreement with results showing that over-vigorous growth can limit a number of formed flower buds per tree and reduce the yield (Quinlan and Preston, 1971, cit. from Mika, 1984) or can lead to alternate bearing (Guzewski, 1996).

In good environmental conditions of the present experiment the irrigation of trees resulted in their stronger growth, limited the of number of flower buds and caused alternate bearing. Irrigated trees did not increase fruit yield in comparison to the control durring the first four years of cropping.

REFERENCES

Barrit B.H. 1992. Intensive orchard management. Good Fruit Grower. Yakima. Washington.

Guzewski W. 1996. Przyczyny przemiennego owocowania drzew. SAD KARŁOWY. 2: 91-93.

Mantinger H. 1993. Dotychczasowe i nowe systemy sadzenia jabłoni w rejonie Południowego Tyrolu. SAD KARŁOWY. 2: 8-16.

Mika A. 1984. Związek między intensywnością wzrostu a kwitnieniem i owocowaniem. In: L. Jankiewicz (ed.), Fizjologia roślin sadowniczych. PWN. Warszawa, pp. 409-419.

Mika A. 1995. Drzewka holenderskie i polskie po czterech latach. SAD KARŁOWY 6:45-50.

Rakićević M. 1989. Uticaj navodnjavanja na početnu rodnost, masu ploda i vegetativni porast jabuke Zlatni Delišes. JUG. VOC. 23: 571-574.

Sansavini S., Marangoni B., Buscaroli C., Corelli L., Tazzari G. 1986. The relationship between spacing and rootstock effects in an intensive planting trial of two apple cultivars. ACTA HORT. 160: 23-37.

Sosna I. 1995. Ocena kilku parchodpornych odmian jabłoni wysadzonych w dużym zagęszczeniu z uwzględnieniem nawadniania kroplowego. I Ogólnopol. Sem. Prac. Kat. Sad. Postęp w Intensyfikacji Upraw Sadowniczych, Poznań 27-28 września, pp. 139-143.

Taylor B.H., Lenz F. 1991. Kronenform, Licht und Fruchtbehang beeinflussen den Blattmineralstoffgehalt, Blutenansatz und Fruchtertrag bei Apfelbaumen. ERWERBSOBSTBAU 31:143-146.

Treder W. 1996. Badania nad efektywnością nawadniania roślin sadowniczych w Polsce. Mat. XXXIV Ogólnopol. Nauk. Konf. Sad., Skierniewice 28-30 sierpnia, pp. 53-70.

Treder W., Czynczyk A. 1997. Wpływ nawadniania na wielkość i jakość plonowania intensywnego sadu jabłoniowego. II Ogólnopol. Sem. Prac. Kat. Sad. i ISK. Współczesne trendy w agrotechnice sadów. Lublin 25-26 września, pp.30-33.

Wertheim S.J. 1985. Productivity and fruit quality of apple in single and full-field planting systems. SCI. HORT. 26:191-208.