EVALUATION OF THE 'MIKADO' TREE TRAINING SYSTEM VERSUS THE SPINDLE FORM IN APPLE TREES

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A B S T R A C T

The experiment was conducted at the Experimental Orchard in Dąbrowice, near Skierniewice, from 1994 to 2000. Apple trees of the cultivar 'Šampion' on semi-dwarfing M.26 rootstock were planted 1.8 x 4 m apart. Trees were trained either according to the four-leadered 'Mikado' method or to the spindle method.

Spindle trees were more vigorous than 'Mikado' trees, probably because they have only one main leader, whereas 'Mikado' trees have four. 'Mikado' trees had higher yields and better colored fruits. 'Mikado' trees had higher total leaf areas, higher leaf area indices, and intercepted more incident light. Trees trained as 'Mikado' had also very good light distribution in the whole volume of the canopy. Light distribution in the 'Mikado' canopies was more uniform than in the spindle canopy. The 'Mikado' system is a superior method to ensure high yields of high-quality apples. Only the high cost of the supporting framework limits its broader application.

Key words: apple tree, training and pruning, growth, yield, fruit quality, light interception and distribution

INTRODUCTION

Extensive studies have been carried out recently in Europe on growing dwarf and semi-dwarf apple trees with spindle, super-spindle or open canopies in orchards with 700 to 10,000 trees per hectare. Light intensity is a critical factor in yield and fruit quality. It is possible to provide trees with adequate water and mineral nutrients even in super-densely planted orchards. In young orchards which are planted moderately densely, light interce-ption is insufficient, which reduces yield. In densely planted orchards, 60-70% of the light reaching the canopies is intercepted within two or three years after establishing the orchard. Light distribution within the canopies is not uniform, which means that part of the crop will not be of the highest quality. The pattern of light intensity in open canopies, such as ‘V’, ‘Mikado’, and ‘Solen’, promotes high fruit quality. Insufficient light intensity in orchards planted in multiple rows results in poor fruit quality.

In Europe, most dwarf and semi-dwarf apple and pear trees are trained as spindles. Most canopy forms produced by lightly pruning and bending the shoots promote early and heavy cropping (Mika, 1973). Many tree-training methods have recently been modified with attention to tree planting density, light intensity patterns in the orchard, and fruit quality (Mika and Antoszewski, 1974).

Densely planted apple trees trained as spindles intercept sufficient light and produce high yields. Mutual shading reduces light intensity inside spindle canopies, which delays and hampers the development of flower buds and fruits (Palmer, 1974).

The spindle canopy works best with for trees with low or moderate vigor. Excessive growth may be a problem in densely planted orchards. Tree training methods that simplify tree shaping, allow optimal use of orchard space, promote light interception, and ensure uniform light distribution need to be developed.

The common feature of spindle, super spindle, espalier and axial canopies is a central leader from which weaker lateral shoots branch out. Trees with central leaders can be planted fairly densely in a row in hedge systems (Liebster and Pesserl, 1982). Trees can also be trained to have open canopies, in which several leaders are directed away from the axis of the row towards the alleyways. In some fruit growing regions, especially in Switzerland, France, Germany, USA, New Zealand and Australia, many orchards with open tree canopies are being established. Each canopy has at least two leaders spread out on ‘V’ or ‘Y’ shaped frames to provide adequate light distribution. Open canopies increase light interception and light penetration to the center of the canopy, improving yields and fruit quality.

Widmer and Krebs (1996) from the Institute in Güttingen in Switzerland have developed the open canopy systems called ‘Mikado’ and ‘Drilling’, which reduce the number of trees planted per unit area and make full use of orchard space. In these systems, three or four main scaffold branches are tied to stakes and wires suspended two meters above the ground. These branches are directed away from the center of the row towards the alleyways at an angle of 25º and form leaders.

Recent Swiss studies have shown that trees planted and trained at an angle have higher yields and better fruit quality than trees trained vertically. Trees trained according to the ‘Mikado’ system already produce abundant, high-quality fruit in the third year after planting (Widmer and Krebs, 1996).

MATERIAL AND METHODS

The experiment was conducted at the Experimental Orchard in Dąbrowice, near Skierniewice, from the spring of 1994 to the autumn of 2000. Apple trees of the cultivar ‘Šampion’ on semi-dwarfing M.26 rootstock were planted 1.8 x 4 m apart. The tree rows were aligned north-south. Trees were trained either according to the four-leadered ‘Mikado’ method or to the spindle method.

The experiment was designed as a randomized block with three replicates. Each plot consisted of a row of six trees. The site was drip irrigated, and in the third year after planting, grass was established in the alleyways.

Tree vigor was estimated by measuring trunk diameter, total annual shoot length, and total annual shoot count. Trunk diameter was measured every year 30 cm above the ground. Total annual shoot length was measured only in 1999. Yield, size and color were recorded from 1995 to 1999. In September 1999, the total area of the leaves of one tree of each canopy type was measured using an Area Measurement System (Delta-T Devices Ltd., Great Britain).

Light interception was measured from May to June in 1999 and 2000 with a Tube Solarimeter type TSL (Delta-T Devices Ltd., Great Britain). Solarimeters were placed at ground level under the tree canopy and in the alleyways. One solarimeter was placed above the tree canopy to measure incident light. Light interception was calculated as the difference between incident and transmitted light.

Light distribution was measured on sunny days from June to September in 1999 and 2000 with a SunScan Probe type SS1 (Delta-T Devices LTD, Great Britain). Light distribution inside the tree canopies was measured at 0.5, 1.2 and 1.8 meters above the ground.

Data were statistically evaluated by R.A. Fisher’s analysis of variance. Significance of differences between means was determined by Duncan’s test at P = 0.05. Most statistical calcu-lations were carried out on the results from direct measurements. Values expressed as percentages, such as fruit size and color, were transformed by Bliss’ method.

RESULTS AND DISCUSSION

From 1994 to 2000 there was little difference in trunk growth between trees trained with the ‘Mikado’ system and trees trained with the spindle system (Tab. 1). ‘Mikado’ trees were slightly less vigorous than spindle trees.

When shoots were counted and measured in 1999, ‘Mikado’ trees had significantly fewer and shorter shoots than spindle trees (Tab. 2).

In the first two fruit-bearing seasons, spindle trees yielded slightly better. In the next three seasons, there was no difference in yield between ‘Mikado’ trees and spindle trees. In subsequent years, ‘Mikado’ trees yielded significantly better than spindle trees (Tab. 3).

The total yield for the first five years of fruit-bearing was slightly higher for the ‘Mikado’ trees than spindle trees. ‘Mikado’ trees produced 14.3 tons more fruit (Tab. 4).

In 1997 and 1998, ‘Mikado’ trees had a significantly higher productivity index than spindle trees (Tab. 4).

T a b l e 1. Trunk cross-sectional area of 'Šampion'/M.26 apple trees

Training system	Trunk cross-sectional area [cm^2]						
	1994	1995	1996	1997	1998	1999	2000
'Mikado'	4.2 a*	8.5 a	13.2 a	18.1 a	22.9 a	31.2 a	43.9 a
Spindle	3.5 a	9.1 a	14.5 a	19.6 a	26.4 a	35.2 a	47.9 a

*Means followed by the same letter do not significantly differ at P = 0.05. Comparisons are valid within the same column

T a b l e 2. Shoot length and shoot count of 'Šampion'/M.26 apple trees

Training system	Total annual shoot length [m/tree]	Total annual shoot count per tree	Mean annual shoot length [cm]
'Mikado'	35.9 a	168.8 a	21.0 a
Spindle	45.6 b	192.4 b	23.6 b

*For explanation, see Table 1

T a b l e 3 .Yielding of 'Šampion'/M.26 apple trees

Training system	Yield [kg/tree]				
	1995	1996	1997	1998	1999
'Mikado'	0.7 a	14.8 a	27.0 a	44.1 b	41.3 b
Spindle	1.6 a	18.5 a	25.6 a	37.8 a	34.1 a

*For explanation, see Table 1

T a b l e 4. Productivity index and total yield of 'Šampion'/M.26 apple trees

Training system	Productivity index [kg/cm^2 TCSA]					Total yield 1995-1999 [kg/tree]	Total yield 1995-1999 [t/ha]
	1995	1996	1997	1998	1999		
'Mikado'	0.1 a	1.1 a	1.5 b	1.9 b	1.3 a	127.8 a	177.5
Spindle	0.2 a	1.3 a	1.3 a	1.4 a	1.0 a	117.5 a	163.2

*For explanation, see Table 1

In 1996, the third year after planting, spindle trees produced the most apples less than 7.5 cm in diameter, and 'Mikado' produced the most apples greater than 7.5 cm in diameter. Only 25% of the apples from 'Mikado' trees were less than 7.5 cm in diameter. Almost 50% of the apples from spindle trees were less than 7.5 cm in diameter. 'Mikado' trees produced significantly more apples greater than 7.5 cm in diameter than spindle trees.

>From 1997 to 1999, the percentages of apples in each size class were similar for both 'Mikado' trees and spindle trees (Tab. 5).

In all years, and especially from 1997 to 1999, 'Mikado' trees produ-

T a b l e 5. Percentage of apples in different size classes of ‘Šampion’/M.26

Training system	6.0-6.5 cm	6.5-7.0 cm	7.0-7.5 cm	7.5-8.0 cm	8.0-8.5 cm	8.5-9.0 cm
1996						
‘Mikado’	0.8 a	4.5 a	19.9 a	33.0 a	29.7 b	12.1 a
Spindle	2.7 a	14.4 a	30.5 a	31.2 a	14.7 a	6.5 a
1997						
‘Mikado’	1.0 a	6.4 a	20.6 a	30.3 a	31.9 a	9.8 a
Spindle	0.7 a	5.8 a	19.9 a	33.6 a	32.2 a	7.8 a
1998						
‘Mikado’	0.4 a	1.8 a	9.7 a	23.2 a	44.8 a	20.1 a
Spindle	0.0 a	0.9 a	9.3 a	25.9 a	41.6 a	22.3 a
1999						
‘Mikado’	0.4 a	5.6 a	21.9 a	32.0 a	25.4 a	14.7 a
Spindle	0.2 a	4.3 a	20.0 a	28.3 a	26.7 a	20.5 a

*For explanation, see Table 1

T a b l e 6. Color development in apples of ‘Šampion’/M.26

Training system	Percentage of apples with more than 75% blush on surface			
	1996	1997	1998	1999
‘Mikado’	69.3 a	88.1 b	87.0 b	82.8 b
Spindle	62.1 a	78.5 a	75.2 a	64.2 a

*For explanation, see Table 1

T a b l e 7. Total leaf area, leaf area index and light interception of ‘Šampion’/M.26 apple tree

Training system	Leaf area [m^2/tree]	Number of leaves per tree	Mean leaf area [cm^2]	Area under canopies [m^2]	Leaf area index	Percentage of light intercepted	
						1999	2000
‘Mikado’	18.8	12990	14.5	4.5	4.2	60	61
Spindle	12.3	7830	15.6	4.5	2.7	46	60

ced better colored apples, with blushing over more than 75% of the fruit surface (Tab. 6).

In 1999, total leaf area was measured for one representative tree of each canopy type. The total leaf area of the ‘Mikado’ tree was 33% greater than the total leaf area of the spindle tree. The ‘Mikado’ tree had 12,990 leaves, while the spindle tree had 7,830 leaves. The leaf area index was 4.2 for the ‘Mikado’ tree, and 2.7 for the spindle tree. The higher leaf area index observed with the ‘Mikado’ tree is typical of super-dense systems (Tab. 7).

Light interception was measured in 1999 and 2000. ‘Mikado’ trees, with a total leaf area of 18.8 m^2, intercepted 60% of the incident sunlight in both years. Spindle trees, with a total leaf area of 12.3 m^2, intercepted 46% of the incident sunlight in 1999, and 60% in 2000. ‘Mikado’ trees, with their larger total leaf areas, intercepted more light and produced higher yields (Tab. 7).

In 1999, light distribution was more uniform in ‘Mikado’ canopies than in spindle canopies. In spindle trees, light intensity was very low in the middle part of the canopy, and very high in the upper part of the canopy. Because most fruits are present in the middle and upper parts of the canopy, uneven light distribution adversely affects the uniformity of fruit maturation, size and quality. In ‘Mikado’ canopies, branches are directed outward, opening up the upper part of canopy and allowing more light to penetrate to the rest of the canopy. This promotes uniform fruit quality and higher yields.

In 2000, light distribution was more uniform in all parts of ‘Mikado’ canopies than in spindle canopies. In ‘Mikado’ trees, light intensity was good at both 1.2 m and 1.8 m. Because ‘Mikado’ trees do not have a central leader, light distribution was as good in the centers of the canopies as at the peripheries. In spindle canopies, light intensity was lower near the leader at all heights (Fig. 1). In the center of ‘Mikado’ canopies, light intensity was over 600 watts/m^2. In the center of spindle canopies, light intensity was a little over 200 watts/m^2. Light intensity in the center of spindle canopies was very low.

In August 2000, trees were pruned to increase the amount of light penetrating to the middle of the canopies and thereby improve fruit quality. Light distribution was again measured towards the end of vegetative growth. Summer pruning had indeed improved light distribution in all parts of both ‘Mikado’ and spindle canopies. In ‘Mikado’ trees, summer pruning permitted more sunlight to reach the middle and upper parts of the canopy than the periphery. This was not the case with spindle trees. Even after summer pruning, the centers of spindle canopies near the leaders were poorly lit at all heights (Fig. 2-3).

Canopy form affected tree vigor as expressed by trunk cross-sectional area and total annual shoot length. The ‘Šampion’ trees grew poorly in the local sandy soil. Trees grafted on rootstock M.26 grew satisfactorily. The canopy volume of ‘Mikado’ trees increased very quickly, with moderate lateral shoot development. In spindle canopies, many strong shoots grew out in the upper and middle parts of the canopy because of the vertical position of the main leader. Heavier pruning was necessary to restore the conical shape of the canopy.

‘Mikado’ trees yielded better, which agrees with the results obtained in Switzerland (Widmer and Krebs, 1996). ‘Mikado’ trees, with their four main branches directed outward towards the alleyways, are well lit from the top, which permits quick and thorough filling of the orchard space. Good light distribution and moderate lateral shoot development promote early bearing.

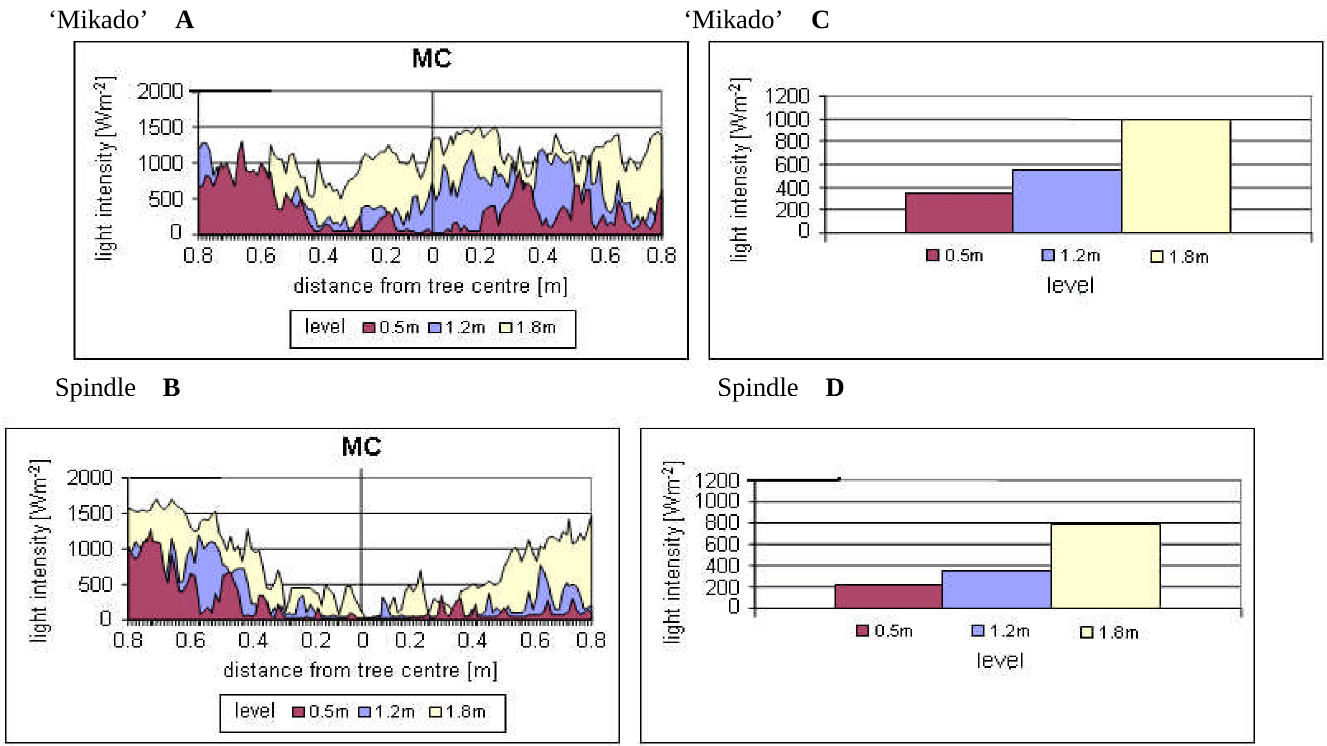
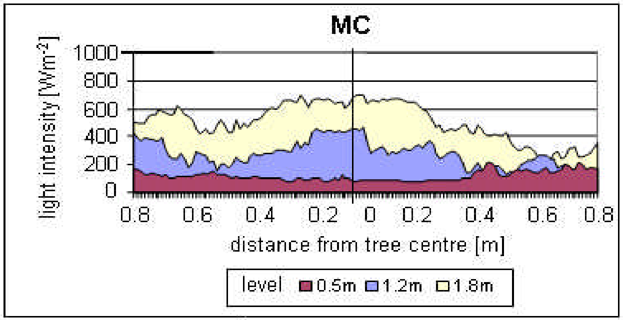
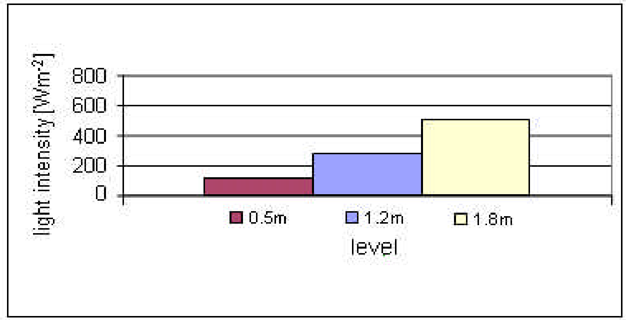


Figure 1. Light distribution from the periphery to the middle of canopy (MC) at 3 levels (0.5, 1.2, 1.8 m) of ‘Šampion’ apple trees trained as Mikado and spindle (A,B) and mean illumination at 3 levels (C,D)

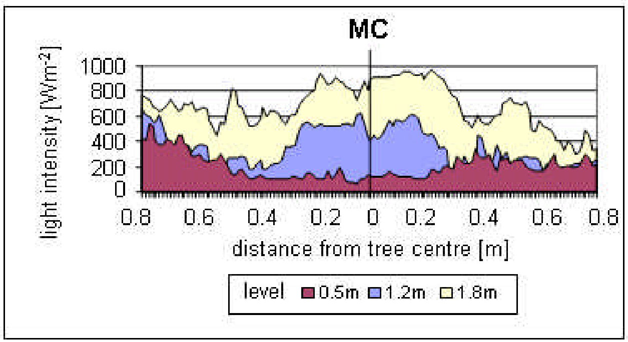
‘Mikado’, before summer pruning **A**



Mikado’, before summer pruning **C**



‘Mikado’, after summer pruning **B**



‘Mikado’, after summer pruning **D**

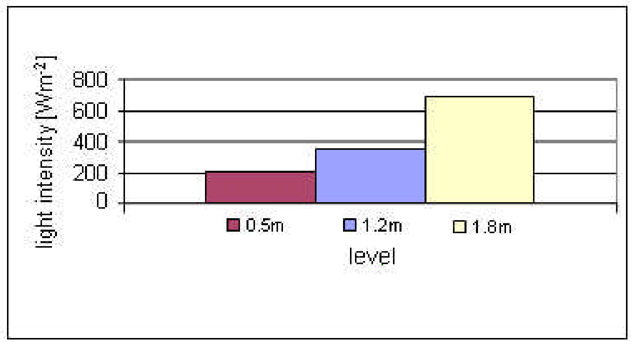


Figure 2. Light distribution from the periphery to the middle of canopy (MC) at 3 levels (0.5, 1.2, 1.8 m) of ‘Šampion apple trees trained as Mikado before and after summer pruning (A,B) and mean illumination at 3 levels (C,D)

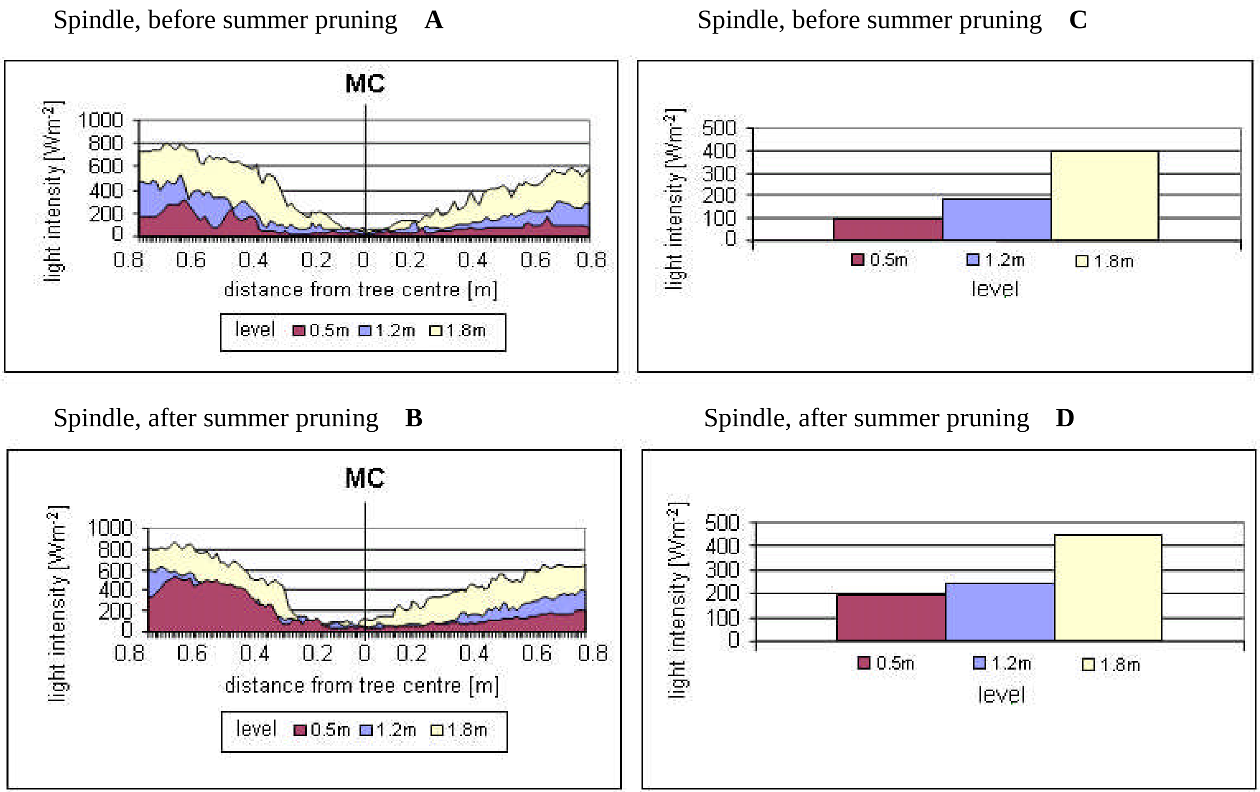


Figure 3. Light distribution from the periphery to the middle of canopy (MC) at 3 levels (0.5, 1.2, 1.8 m) of 'Šampion" apple trees trained as spindle before and after summer pruning (A,B) and mean illumination at 3 levels (C,D)

Training branches at a 25° angle permits full use of the orchard surface and improves yield. 'Mikado' trees also require less pruning to maintain canopy shape, which also improves yield.

In spindle trees, the lowest branches and shoots received less light as the tree got older and consequently bore less fruit. The lower parts of 'Mikado' canopies were better lit and continued to produce well.

There was a direct relationship between light interception and leaf area, and between light interception and yield. Similar results were obtained by Lakso and Robinson (1997), and Palmer and Adams (1997). Light distribution within the canopy affects fruit quality (Jackson et al., 1977; Palmer et al., 1992). In this experiment, light distribution had a large effect on fruit color, and a smaller effect on fruit size. This agrees with the results obtained by Heinicke (1966), Verheij and Verwer (1973), and Jackson et al. (1977).

Poor light penetration reduces blushing in apples (Jackson et al., 1977; Wertheim et al. 1986), as was observed in this experiment. 'Mikado' trees consistently produced better colored apples than spindle trees, which confirms earlier findings by Widmer and Krebs (1996). Heinicke (1963) found that light intensity decreased drastically from the top to the base of the canopies of 'Delicious' trees trained with a vertical leader. In this experiment, it was difficult to ensure proper light distribution in the middle and lower parts of canopies with a vertical leader by pruning trees in early spring. This was not a problem with the more open 'Mikado' canopies.

Robinson et al. (1991) found that V-shaped trees were well lit. The 'Mikado' tree training system can be regarded as a double 'V' system, which improves light penetration throughout the entire canopy.

The 'Mikado' system is a superior method to ensure high yields of high-quality apples. Only the high cost of the supporting framework limits its broader application.

REFERENCES

Heinicke D.R. 1963. The microclimate of fruit trees. II. Foliage and light distribution patterns in apple trees. PROC. AMER. SOC. HORT. SCI. 83: 1-11.

Heinicke D.R. 1966. The effect of natural shade on photosynthesis and light intensity in 'Red Delicious' apple trees. PROC. AMER. SOC. HORT. SCI. 88: 1-8.

Jackson J.E., Palmer J.W., Perring M.A., Sharples R.O. 1977. Effects of shade on growth and cropping of apple trees. III. Effects on fruit growth, chemical composition and quality at harvest and after storage. J. HORT. SCI. 52: 267-282.

Lakso A.N., Robinson T.L. 1997. Principles of orchard systems management optimizing supply, demand and partitioning in apple trees. ACTA HORT. 451: 405-415.

Liebster G., Pesserl G. 1982. Rebe und Wein, Obstbau und Fruchteverwertung. ITTEILUNGEN KLOSTERNEUBURG 32(2): 71-75.

Mika A. 1973. Formowanie koron jabłoni za pomocą cięcia i przyginania pędów. PR. INST. SAD. 17: 63-69.

Mika A., Antoszewski R. 1974. Phytosynthesis efficiency of apple trees trained as hedgerows. FRUIT SCI. REP. 1(1): 10-17.

Palmer J.W. 1974. Crop ecology and orchard systems: crop environment, light interception studies in spacing and systems trials. Rep. E. Malling Res. Sta. Rpt. 1973, pp. 66-67.

Palmer J.W., Adams H.M. 1997. Early results with intensive systems of apples on virus – free M.9 rootstock in New Zealand. ACTA HORT. 451: 487-493.

Palmer J.W., Avery D.J., Wertheim S.J. 1992. Effect of apple tree spacing and summer pruning on leaf area distribution and light interception. SCIENTIA HORT. 52: 303-312.

Robinson T.L., Lakso A.N., Ren Z. 1991. Modyfying apple tree canopies for improved production efficiency. HORT. SCI. 26: 1005-1012.

Verheij E.W.M., Verwer F.L.J.A.W. 1973. Light studies in spacing trial with apple on dwarfing and semi-dwarfing rootstocks. SCIENTIA HORT. 1: 25-42.

Wertheim S.J., de Jager A., Duyzens M.J.J.P. 1986. Comparison of single–row and multi-row planting systems with apple, with regard to productivity, fruit size and colour and light conditions. ACTA HORT. 160: 243-258.

Widmer A., Krebs C. 1996. ‘Mikado’ and ‘Drilling’ (Triplet) – two novel training systems for sustainable high quality apple and pear production. ACTA HORT. 451: 519-528.

OCENA WARTOŚCI KORONY 'MIKADO' W STOSUNKU DO KORONY WRZECIONOWEJ

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STRESZCZENIE

Doświadczenie przeprowadzono w latach 1994-2000 w Sadzie Doświadczalnym w Dąbrowicach, koło Skierniewic. Materiał doświadczalny stanowiły jabłonie odmiany 'Szampion' na półkarłowej podkładce M.26, posadzone w rozstawie 4 x 1,8 m. Zastosowano dwa rodzaje formowania koron:

1. Korona wrzecionowa – kontrola.
2. Korona czteroprzewodnikowa – 'Mikado'.

Drzewa prowadzone w formie korony wrzecionowej rosły silniej niż w formie 'Mikado' prawdopodobnie dlatego, że miały tylko jeden pionowy przewodnik. Drzewa prowadzone w formie 'Mikado' miały po cztery przewodniki prowadzone ukośnie, co mogło osłabić ich wzrost. Drzewa prowadzone w formie 'Mikado' plonowały obficiej. Duże różnice zanotowano przy porównaniu wybarwienia jabłek. Drzewa prowadzone w systemie 'Mikado' miały istotnie większy średni procent jabłek najlepiej wybarwionych w porównaniu do jabłek pochodzących z korony wrzecionowej. Drzewa prowadzone w formie 'Mikado' miały także większą powierzchnię liściową, posiadały wyższą wartość wskaźnika powierzchni liściowej oraz większy procent intercepcji światła. Wykazywały również bardzo dobre nasłonecznienie w całej objętości korony, ze względu na brak pionowego przewodnika i rozłożeniu konarów na boki. Stworzyło to bardzo dobre warunki do przenikania od góry światła słonecznego aż do dolnych partii korony. Jabłonie prowadzone w formie wrzecionowej miały bardzo dobrze nasłonecznioną górną część korony, natomiast środkowa strefa korony była mocno zacieniona. Tam właśnie znajdowała się główna masa owoców.

Doświadczenie wykazało dużą wartość korony 'Mikado'. Przeszkodą w jej upowszechnieniu jest kosztowne rusztowanie i konieczność przyswojenia sobie nowej wiedzy z zakresu formowania koron.

Słowa kluczowe: jabłoń, formowanie i cięcie, wzrost, plon, jakość owoców, inercepcja i dystrybucja światła