THE INFLUENCE OF CANOPY ARCHITECTURE ON LIGHT INTERCEPTION AND DISTRIBUTION IN 'SAMPION' APPLE TREES

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A B S T R A C T

The relationship between leaf area index, light interception and light distribution within apple tree canopies trained to the spindle system, HYTEC, "Solen" and "Mikado" was studied. The type of trees studied were 7-year-old 'Sampion' semi-dwarf apple trees which were grown at a distance of 4 x 1.8 m apart. The highest leaf area index (LAI) and the highest light interception was observed in trees trained on the "Mikado" system. The lowest light interception was in the HYTEC and "Solen" systems. Positive relationships were found between total leaf area per tree, LAI and light interception. Light distribution within a tree canopy was the most beneficial in the "Mikado" system. In the other systems, light penetration to the inner and basal parts of the tree canopy was obstructed. Summer pruning significantly improved light distribution within the tree canopy.

Key words: apple tree, training and pruning, HYTEC, "Solen", "Mikado", spindle, leaf area index, light

INTRODUCTION

In Europe most apple and pear trees which have been grafted on dwarfing rootstocks are presently trained as spindle and slender spindle trees. In both systems, the tree has a central, vertical leader. There are a few horizontal branches which are much shorter at the tree top than at the bottom. This system was described in details by Wertheim (1981). In Wenatchee (USA) the spindle form was adopted by Barritt (1992) to more favourable growing conditions. In the hybrid tree cone system (HYTEC) disseminated by Barritt, the leader is cut back each

spring during tree training and replaced by a side shoot. Such treatment slows down tree growth and makes the tree shape more conical. In Southern France, Lespinasse (1989) promoted a tree training system without any leader called "Solen" (later "Solaxe"). In this system, the tree canopy is supported on two parallel wires. These wires are stretched along the row at a height of 1.2 m. The branches naturally bend and hang freely to the ground from supporting wires. In Switzerland, Widmer and Krebs (1996) introduced the "Mikado" system. In this system, four strong leaders stretched at two opposite sides train each apple tree. The leaders are in the shape of the letter V and supported on a horizontal wire trellis. This system is classified under V-shaped canopies.

Each training system plays an important role in light interception and its distribution within the tree canopy. Light interception is an important factor in fruit tree productivity. It influences the flower initiation process and has an impact on fruit quality especially fruit which have a red blush. Maximum potential assimilation is realized by a canopy that absorbs all incoming light (Wagenmakers, 1995). Fruit yield per ground unit area is positively correlated with light interception (Palmer, 1989). Insufficient light interception and exposition may reduce fruit size, colour and TSS (Robinson et al., 1991; Palmer et al., 1992). Light interception can be increased by high density planting, suitable size and shape of tree canopies and high leaf area index (relation of leaf area to ground area under the tree canopy). A smaller, more compact fruit tree is more efficient at intercepting the sun's energy, yet it may require more irrigation water per hectare to sustain productivity (Green et al., 2003). When comparing canopies of various shapes, a positive correlation is expected between the distribution of sunlight in the canopy, volume, and fruit quality. However, this relationship is very complex. In vertical leader-forms, the bulk of the crop grows in the outer fruiting mantle, so illumination in that mantle plays the most important role in fruit quality. In the absence of a vertical leader (the "Solen" and "Mikado" systems), the main bulk of the crop is located on the top of the canopy (the "Solen" system) or on the upper part of four aslant leaders (the "Mikado" system).

The aim of this study was to determine the relationship between different apple tree training systems, leaf area index, and light interception and distribution within a tree canopy.

MATERIAL AND METHODS

The studies were done at the Experimental Orchard of the Research Institute of Pomology and Floriculture in Skierniewice, Poland. They were done on an experimental plot composed of fully grown 7-year-old 'Sampion' apple trees grafted on M.26 rootstock, planted 4 x 1.8 m apart. The apple trees were trained on 4 different systems:

1. Spindle according to Wertheim (1981)
2. HYTEC (hybrid tree cone) according to Barritt (1992)
3. "Solen" according to Lespinasse (1989)
4. "Mikado" according to Widmer and Krebs (1996)

Regular pruning began the first year after being planted. Pruning was done in the spring time for all training systems to keep the tree canopies at the required size, height and density. This was done to assure good productivity of the trees.

A single plot was made up of 8 trees in a uniformly trained row. This was replicated 3 times for each system.

The total leaf area was measured on one representative tree in each training system. All the leaves were removed from the one representative tree in September. The leaves were then measured on Area Measurement System (Delta-T Devices Ltd, Burwell, Cambridge, England).

Light interception was calculated as the difference between the recorded incoming light above tree canopies and that at ground level. This difference was measured with a Delta-T Tube Solarimeter type TSL. Measurements were done continuously from the end of May to September across tree rows and were displayed on an analogue voltometer. Light distribution within tree canopies was measured at noon on sunny days. A Sun Scan Probe type SS1 (Delta-T Devices Ltd,) was used to do the measuring. All measurements were done on 3 horizontal levels (0.5, 1.2, 1.8 m) above the ground, from the alleyway towards the tree centre (TC).

In order to evaluate the effects of new shoot growth on light levels within the tree canopy, summer pruning was done in the middle of August. Strong shoots (above 40 cm of length) classified as water shoots, were cut away.

Data were statistically evaluated by R.A. Fisher's analysis of variance. Significance of differences between means was determined by Duncan's test at $p = 0.05$.

RESULTS AND DISCUSSION

Big differences appeared in the total leaf area within the different training systems. The greatest leaf area was found in the "Mikado" training system. Much less leaf area was found in the spindle system. The lowest leaf area was found in the "Solen" and HYTEC (Tab. 1). The leaf area index (LAI) closely reflected the total leaf area. The LAI value of HYTEC, "Solen" and spindle appeared to be typical for an intensive dwarf orchard that usually reaches a LAI level of 2 – 3 (Wagenmakers, 1995). The LAI of the "Mikado" system was very high. It was comparable to super density orchards planted in a multi-row or bed system. When the LAI exceeds optimum values (2 – 3) one can expect negative shading effects on fruit yield and quality (Wagenmakers, 1995). This is true in vertically trained trees like those trained on the spindle system. In the "Mikado"

Table 1. Total leaf area, leaf area index and light interception of 'Sampion' apple trees on M.26 rootstock

Training system	Leaf area [m^2 $tree^{-1}$]	Number of leaves per tree	Ground area under canopy [m^2]	Leaf area index [LAI]	Light interception [%]
HYTEC	10.6	7500	3.2	3.3	35.5
"Solen"	9.4	6405	3.6	2.6	43.5
"Mikado"	18.8	12990	4.5	4.2	60.5
Spindle	12.3	7830	3.8	3.2	53.0

System, the tree canopy is centrally opened allowing free light penetration to the inner parts. Light interception was generally lower than expected for an intensive apple orchard (Tab. 1) and was closely related with leaf area, and LAI. Most hedgerow type orchards have a LAI of 2 – 3. Hedgerow type orchards are able to intercept 60-70% of incoming light (Wagenmaker, 1995). In this trial, such a value was achieved only in the "Mikado" training system. A higher light interception of V-shaped canopies compared to vertical leader systems has been observed by Robinson et al. (1991).

The intensity of sunlight within tree canopies, measured across the row at three levels (0.5, 1.2 and 1.8 m), decreased from the top of the canopy towards its base (Fig. 1,2). Abundant illumination (1000-1200 W m^{-2}) was found at a height of 1.8 m in all the training systems, but it was the lowest in the spindle system (Fig. 1B). At a height of 1.2 m great differences were recorded in tree illumination. This part of tree canopy was best illuminated in the "Mikado" and HYTEC system (Fig. 1A, 2A), worse in the "Solen" system and the worst in the spindle system (Fig. 1B, 2B). Insufficient illumination in the central part of the spindle canopy at a level of 1.5 m above ground was already reported by Mika et al. (2002). At a level of 0.5 m above the ground, illumination was very poor (below 20% of that above the tree) that means it was at a critical point for sufficient fruit bud setting and fruit development (Jackson, 1970). Lately Willaume et al. (2004) proposed centrifugal training, which is the removal of small side branches around a tree leader, to increase light interception to fruiting shoots in the outer mantle of the tree canopy. The mean illumination calculated for three horizontal levels (Fig. 1CD, 2CD) confirmed the results presented above. The best illuminated were trees trained on the "Mikado" system. HYTEC and "Solen" trained trees were illuminated worse. Trees trained on the spindle system were very poorly illuminated. Illumination recorded from the canopy periphery to its centre decreased at all three measuring levels in training systems: HYTEC, "Solen" and spindle. In the "Mikado" system, the central part of the tree canopy has an illumination

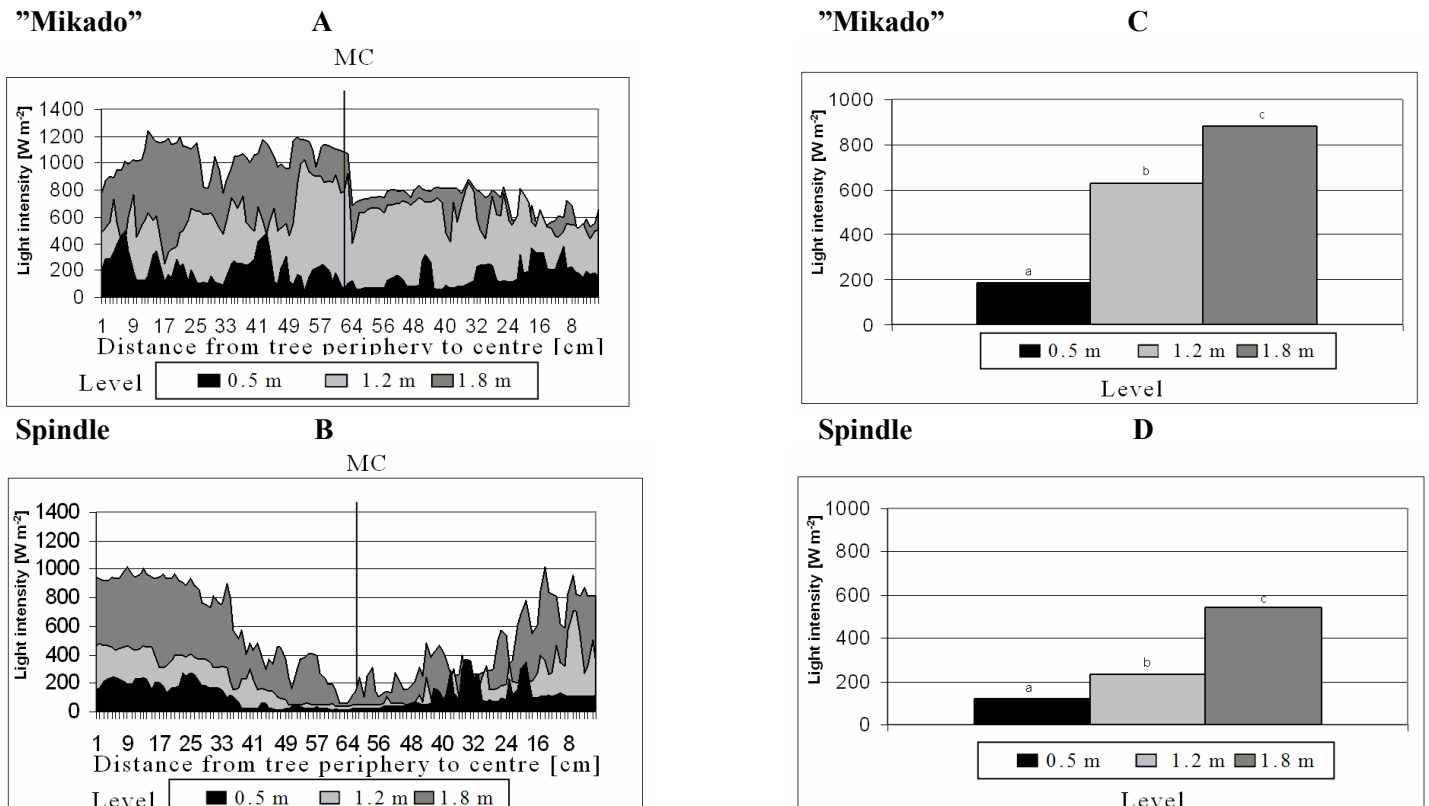

Figure 1. Light distribution from the periphery to the middle of canopy (MC) at 3 levels (0.5, 1.2, 1.8 m) of 'Sampion' apple trees trained as "Mikado" and spindle (A, B), and mean illumination at 3 levels (C, D)

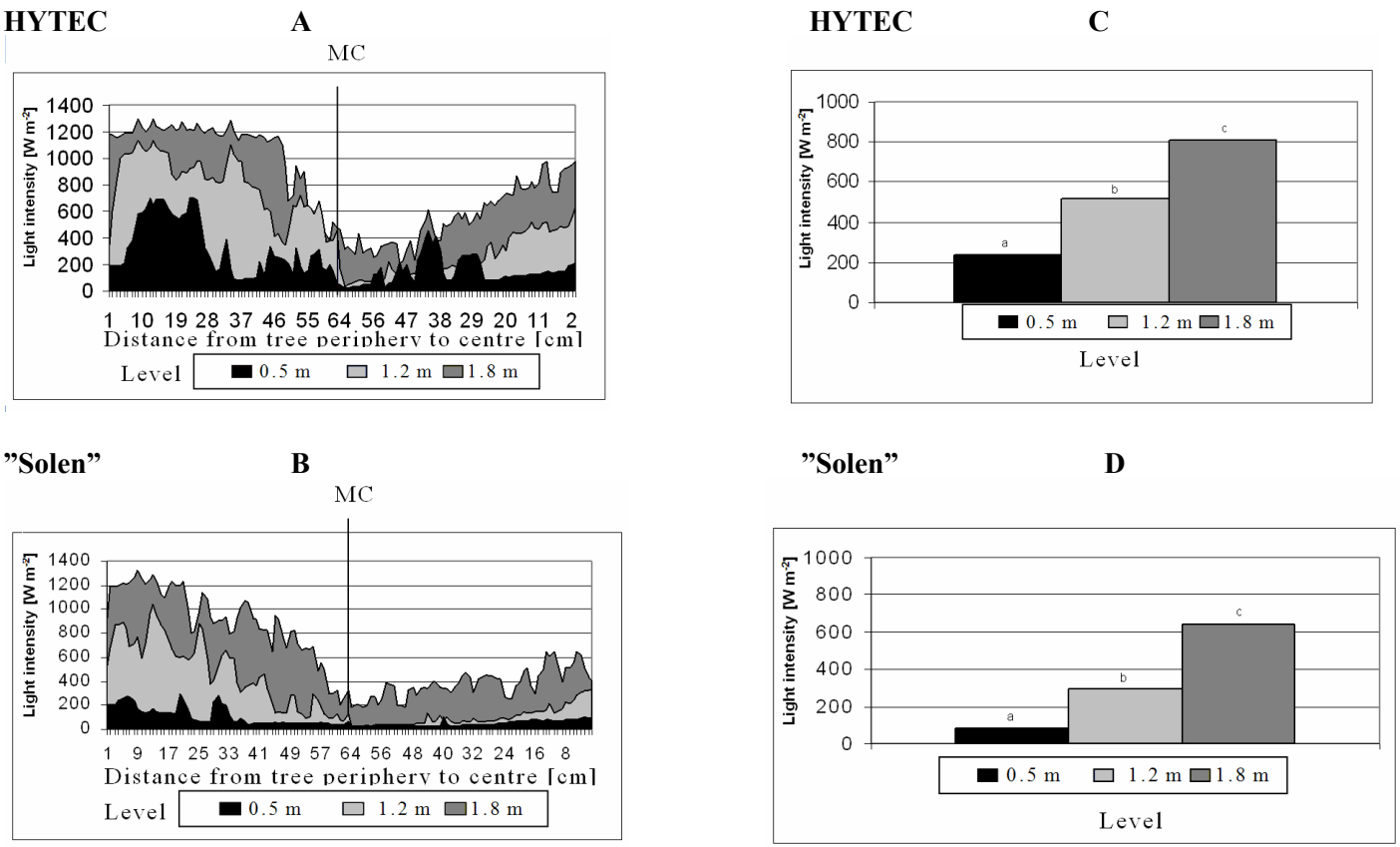

Figure 2. Light distribution from the periphery to the middle of canopy (MC) at 3 levels (0.5, 1.2, 1.8 m) of 'Sampion' apple trees trained as HYTEC and "Solen" (A, B), and mean illumination at 3 levels (C, D)

Table 2. Mean illumination at 3 canopy levels before (A) and after (B) summer pruning

Training system	Mean illumination [W m^{-2}]		
	canopy levels		
	0.5 m	1.2 m	1.8 m
HYTEC A	234 a*	305 ab	720 c
HYTEC B	399 ab	513 b	825 c
”Solen” A	175 a	297 ab	670 c
“Solen” B	191 ab	331 b	711 c
“Mikado” A	153 a	360 b	654 c
“Mikado” B	263 ab	533 c	890 d
Spindle A	126 a	246 a	519 b
Spindle B	246 a	309 a	579 b

*Means followed by the same letter do not significantly differ at p = 0.05. Analysis was performed separately for each training system

which is comparable to that at its peripheral part. The obtained results confirm the findings of Robinson et al. (1991) that V-shaped canopies show higher light interception and better light distribution.

Summer pruning improved light penetration and distribution within the tree canopy at all three measuring levels (Tab. 2). The best significant results were noted in the “Mikado” training system, and negligible results were noted in the ”Solen” system. These results confirm the opinion of Robinson et al. (1991) that V-systems require regular summer pruning to keep the system open. The ”Solen” system with its shape like that of a hanging carpet on two parallel wires, has most of its summer growth on its periphery. Less of a shadow is cast on the canopy centre than in the other systems.

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WPŁYW ARCHITEKTURY KORONY NA INTERCEPCJĘ I DYSTRYBUCJĘ ŚWIATŁA SŁONECZNEGO U JABŁONI ODMIANY 'SZAMPION'

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S T R E S Z C Z E N I E

Na kwaterze siedmioletnich jabłoni 'Szampion' szczepionych na podkładce M.26 rosnących w rozstawie 4 x 1,8 m uformowanych według czterech systemów: korona wrzecionowa, HYTEC, "Solen" i "Mikado" (V-system), badano związki między ogólną powierzchnią liści na drzewie, wskaźnikiem powierzchni liściowej, intercepcją i dystrybucją światła słonecznego w obrębie koron. Stwierdzono pozytywny związek między sumaryczną powierzchnią liści, wskaźnikiem powierzchni liściowej i intercepcją światła. Korona "Mikado" wyróżniła się najwyższą intercepcją światła. Penetracja światła w obrębie koron zmniejszała się raptownie od zewnątrz do środka korony i od góry do podstawy korony. Najmniej korzystne parametry nasłonecznienia stwierdzono w koronie wrzecionowej. Korona „Mikado" korzystała z najbardziej równomiernego nasłonecznienia. Cięcie letnie najskuteczniej poprawiło nasłonecznienie w koronie "Mikado", najmniej w koronie "Solen".

Słowa kluczowe: jabłoń, formowanie i cięcie, HYTEC, "Solen", "Mikado", wrzeciono, wskaźnik powierzchni liściowej, światło