GROWTH, YIELD AND FRUIT QUALITY IN 'ŠAMPION' APPLE TREES TRAINED USING FOUR DIFFERENT TRAINING SYSTEMS: HYTEC, SOLEN, MIKADO AND SPINDLE

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A B S T R A C T

In the spring of 1994, 'Šampion' apple trees grafted on semi-dwarfing M.26 rootstock were planted 1.8 x 4 meters apart at the Experimental Orchard of the Research Institute of Pomology and Floriculture in Skierniewice. Immediately after planting the trees were trained using four different training systems: HYTEC, Solen, Mikado and spindle. Growth was significantly less vigorous with the HYTEC and Solen systems than with the traditional spindle system. Five-year cumulative yield was 40% higher with the Mikado and spindle systems than with the HYTEC and Solen systems. The five-year cumulative productivity index was significantly higher with the Mikado system than with the spindle, HYTEC and Solen systems. Fruit color was best with the Mikado system, and worst with the Solen system. Fruit size was about the same with all of the training systems evaluated.

Key words: apple tree, training, HYTEC, Solen, Mikado, spindle systems

INTRODUCTION

Apple trees grafted on dwarf and semi dwarf rootstocks start to bear earlier and produce better when light pruning and shoot bending are performed (Mika, 1973). These procedures are routinely carried out when training apple trees in accordance with the spindle system, which is very popular in Europe.

Excessive growth is a problem when trees are planted very densely, or on rich soil. For example, in the Wenatchee fruit growing region in the United States, the soil is very rich volcanic ash, all orchards are irrigated, sunshine is abundant and temperatures are ideal for growing apple trees. The HYTEC training system was developed to slow down growth in apple trees growing in the region.

The HYTEC system is a modification of the traditional spindle system in which the leader is cut back every year and replaced with a side shoot, which is bent upright and tied to a pole. The treatment gives the leader a zig-zag shape, which chokes the flow of nutrients, thereby restricting shoot growth. The trees are shorter and have fewer branches than traditional spindle-formed trees (Barritt, 1992).

Another training system, the Solen system, has been developed to limit tree growth in orchards in southern France. Dwarf apple trees are planted along wires suspended horizontally 120 cm above ground level. After planting, the lowest side shoots are removed. The upper side shoots are tied to the wires and trained to grow in both directions along the wires. After two years, they hang down, forming a sort of umbrella about 80 cm in diameter. In subsequent years, the canopy is regularly thinned by pruning (Lespinasse, 1987).

In most training systems for dwarf and semi dwarf apple trees, one vertical leader supports the fruiting branches arranged around it. However, in some new training systems, two leaders are stretched toward the the alleyways on either side in a V-shape or Y shape. These systems are called Tatura trellis, V systems or Y systems, and are popular in Australia and New Zealand. These systems require strong and expensive supports for the trees, but provide excellent light penetration to the inner part of the canopy (Chalmers et al., 1978; McKenzie et al., 1978).

Two similar systems have been developed in Switzerland. In the Mikado system, four leaders are stretched on a diagonal and tied to wires suspended horizontally two meters above ground level. The wires are supported by concrete poles. The Drilling system is essentially a modification of the Mikado system with three leaders per tree instead of four. In dwarf apple trees trained with these systems, yields are higher and fruit quality is better (Widmer and Krebs, 1996).

The aim of this study was to evaluate growth, yield and fruit quality in 'Šampion' apple trees trained using four different training systems: HYTEC, Solen, Mikado and the traditional spindle system.

MATERIAL AND METHODS

In the spring of 1994, 'Šampion' apple trees grafted on semi-dwarfing M.26 rootstock were planted 1.8 x 4 meters apart on light sandy soil of medium quality at the Experimental Orchard of the Research Institute of Pomology and Floriculture in Skierniewice. Immediately after planting, the trees were trained using four different training systems. Concrete posts were placed along the tree rows. Two wires were suspended horizontally from the posts 120 and 180 cm above ground level. Leaders and shoots were tied to the wires.

The following training systems were evaluated:

HYTEC: After planting, the leader was cut back to 80 cm above ground level. The uppermost side shoot was bent upright to serve as a new leader. The other side shoots were headed back by one third. Side

shoots less than 50 cm above ground level were removed completely. In the spring of the following three years, the leader was again cut back and replaced with the uppermost side shoot just as in the first year. Shoots were thinned in accordance with recommended standard apple growing practices.

Solen: After planting, all side shoots were completely removed. The new shoots that developed were stretched and tied to two horizontal wires 120 cm above ground level. New shoots were tied over the first three years, after which they were thinned to prevent overcrowding.

Mikado: The initial leader on each tree was cut off about 60 cm above ground level. Four side shoots were selected to serve as leaders. These shoots were trained along bamboo canes inserted into the ground at the foot of the tree and tied to the horizontal wires.

Spindle: The leader was trained vertically to a height of 2.5 m. Side shoots were bent horizontally. Pruning was carried out to maintain a cone shape.

Each training system was evaluated in three replicates of six trees growing together in the same row. All trees were treated in accordance with the same agricultural practices.

Starting in the third year after planting, all trees were regularly pruned in the spring to ensure that canopy diameter, height and density remained within the specifications for the given training system.

Every year, trunk circumference was measured, and the trunk cross-sectional area was calculated. Growth vigor was estimated on the basis of the increase in the trunk cross-sectional area.

Shoot growth parameters were recorded in 1999, when the trees were bearing at full capacity. The parameters recorded included total annual shoot length, the number of annual shoots, and the mean length of annual shoots.

Every year, data were also recorded on yield per tree, on the basis of which the yield per hectare was calculated. Based on the data collected from 1995 to 1999, the cumulative productivity index, the cumulative yield per tree, and the cumulative yield per hectare were also calculated.

Every year, the proportion of apples with more than 75% surface blushing, mean fruit diameter and mean fruit weight were recorded for each training system.

All results were statistically elaborated using analysis of variance, followed by means separation using Duncan's multiple-range t-test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Growth was significantly less vigorous with the HYTEC and Solen systems than with the traditional spindle system. With the Mikado system, growth was not significantly different than with the traditional spindle system (Tab. 1).

Total annual shoot length was significantly lower with the HYTEC, Solen and Mikado systems than with the spindle system (Tab. 2).

Table 1. Trunk cross-sectional area in 'Šampion'/M.26 apple trees trained using four different training systems

Training system	Trunk cross-sectional area TCSA [cm^2]						
	1994	1995	1996	1997	1998	1999	2000
HYTEC	3.1 a*	7.1 a	11.3 a	15.2 a	21.2 a	28.3 a	41.5 a
Solen	3.5 a	7.1 a	11.3 a	15.2 a	19.6 a	28.3 a	42.9 a
Mikado	4.2 a	8.5 ab	13.2 ab	18.1 ab	22.9 a	31.2 ab	43.9 a
Spindle	3.5 a	9.1 b	14.5 b	19.6 b	26.4 b	35.2 b	47.9 b

*Means in columns followed by the same letter do not differ significantly according to Duncan's multiple-range t-test at $P \leq 0.05$

Table 2. Annual shoot growth data for 1999 in 'Šampion'/M.26 apple trees trained using four different training systems

Training system	Total annual shoot length [m]	Number of annual shoots per tree	Mean annual shoot length [cm]
HYTEC	35.3 a*	141.7 a	24.9 b
Solen	31.6 a	141.9 a	22.3 ab
Mikado	35.4 a	168.8 ab	21.0 a
Spindle	45.4 b	192.4 b	23.6 ab

*For explanation, see Table 1

The number of annual shoots was highest with the spindle system, and lowest with the HYTEC and Solen systems.

Mean annual shoot length was highest with the HYTEC system, and lowest with the Mikado system.

The HYTEC and Solen systems were both effective in reducing growth vigor, which agrees well with previous studies (Barritt, 1992; Lespinasse, 1987). In the present study, growth suppression was especially high because 'Šampion' is a weakly growing cultivar.

From the second year of bearing (1996) trees trained to 'Mikado' and spindle system produced higher yields than trees trained to HYTEC and 'Solen' (Tab. 3).

Five year cumulative yield was about 120 kilograms per tree with the Mikado and spindle systems, and about 80 kilograms per tree with the HYTEC and Solen systems. With the Mikado system, cumulative yield per hectare was 15 tons higher than with the spindle system, 59 tons higher than with HYTEC system, and 70 tons higher than with the Solen system. The cumulative productivity index was significantly higher with the Mikado system than with the spindle, HYTEC and Solen systems (Tab. 4).

Table 3. Annual yield from 1995 to 1999 in 'Šampion'/M.26 apple trees trained using four different training systems

Training system	Yield per tree [kg]					Yield per hectare [tons]				
	1995	1996	1997	1998	1999	1995	1996	1997	1998	1999
HYTEC	1.2 ab*	12.1 b	19.5 a	30.2 a	22.9 a	1.7	16.8	27.1	42.0	31.8
Solen	0.8 a	6.7 a	16.7 a	30.0 a	23.9 a	1.1	9.3	23.2	41.7	33.2
Mikado	0.7 a	14.8 bc	27.0 b	44.1 c	41.3 c	1.0	20.5	37.5	61.3	57.4
Spindle	1.6 b	18.5 c	25.6 b	37.8 b	34.1 b	2.2	25.7	35.5	52.5	47.4

*For explanation, see Table 1

Table 4. Cumulative yield and productivity indices for 1995-1999 in 'Šampion'/M.26 apple trees trained using four different training systems

Training system	Cumulative yield per tree 1995-1999 [kg]	Cumulative yield per hectare 1995-1999 [tons]	Cumulative productivity index 1995-1999 [kg/cm^2 TCSA]
HYTEC	87 a*	119	3.0 a
Solen	78 a	108	2.8 a
Mikado	128 b	178	4.1 b
Spindle	118 b	163	3.3 a

*For explanation, see Table 1

Yield in apple trees greatly depends on light interception (Heinicke, 1964; Jackson et al., 1971; Jackson, 1997). Light interception in turn depends on geographical latitude, time of the year, tree height, the width of the tree rows, and the orientation of the tree rows (Palmer, 1989). Light interception is better in taller trees. For each additional meter of tree height, light interception increases by about ten percent (Wagenmakers, 1995). Light interception is also higher when tree canopies are spread out, as they are in the V and Y systems (Wagenmakers, 1991).

The higher yields obtained with the Mikado and spindle systems were due to the fact that not as many shoots were cut off as with the HYTEC and Solen systems. In the Mikado and spindle systems, shaping was carried out mainly by tying the shoots. In the HYTEC and Solen systems, on the other hand, shaping was carried out by greatly reducing the number of shoots. Therefore, light interception was higher with the Mikado and spindle systems than with the HYTEC and Solen systems from the first year after the trees were planted. This in turn increased yield (Buler and Mika, 2004). The higher cumulative productivity indices obtained with Mikado and spindle systems were therefore simply due to high yields. The high yields controlled excessive growth in the trees.

Table 5. Percentage of fruit with more than 75% surface blushing in 'Šampion'/M.26 apple trees trained using four different training systems

Training system	1996	1997	1998	1999
HYTEC	74.5 b*	69.8 ab	75.9 a	66.7 ab
Solen	43.1 a	57.4 a	76.7 a	45.6 a
Mikado	69.3 ab	88.1 c	86.8 a	82.8 b
Spindle	62.1 ab	78.5 bc	75.0 a	64.2 ab

*For explanation, see Table 1

From 1997 to 1999, when the trees were were bearing at full capacity, the proportion of fruits with more than 75% surface blushing was highest with the Mikado system and lowest with the Solen system. With the HYTEC system, the proportion of fruits with more than 75% surface blushing was about the same as with the spindle system (Tab. 5).

The Solen system has been reported to improve light penetration and fruit color in apple trees (Lespinasse, 1987). However, in the present study, this was true only for the upper part of the tree canopy. Canopies trained with the Solen system have a horizontal structure consisting of a few layers of branches. The branches in the middle and lower parts of the canopy are poorly illuminated, which has a negative impact on fruit color.

Mean fruit diameter and mean fruit weight were essentially the same with all of the training systems evaluated (data not presented).

CONCLUSIONS

1. Growth was significantly less vigorous with the HYTEC and Solen systems than with the traditional spindle system.
2. Five-year cumulative yield was about 40% higher with the Mikado and spindle systems than with the Hytec and Solen systems.
3. The five-year cumulative productivity index was significantly higher with the Mikado system than with the spindle, HYTEC and Solen systems.
4. Fruit color was best with the Mikado system, and worst with the Solen system.
5. Fruit size was about the same with all of the training systems evaluated.

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WPŁYW CZTERECH FORM KORON JABŁONI ODMIANY ‘SZAMPION’ (HYTEC, SOLEN, MIKADO I WRZECIONOWEJ) NA WZROST, PLONOWANIE I JAKOŚĆ OWOCÓW

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

Wiosną 1994 roku w Sadzie Doświadczalnym w Dąbrowicach posadzono jabłonie odmiany ‘Szampion’ na podkładce M.26 w rozstawie 1,8 x 4,0 m. Zastosowano cztery rodzaje formowania koron: HYTEC, Solen, Mikado i wrzecionową.

W ciągu siedmiu lat prowadzenia doświadczenia drzewa formowane w kształcie korony wrzecionowej odznaczały się największą siłą wzrostu. Słabszą siłę wzrostu stwierdzono na drzewach formowanych w kształcie korony Mikado, a zdecydowanie najsłabszą u drzew z koroną Solen i HYTEC. Z drzew prowadzonych w formie Mikado zebrano najwyższe plony i były one najbardziej produktywne. Były one najlepiej nasłonecznione i zebrano z nich najlepiej wybarwione jabłka.

Słowa kluczowe: jabłoń, formowanie, systemy prowadzenia drzew – HYTEC, Solen, Mikado, wrzeciono