ISSN 1644-0692
www.acta.media.pl

ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol. Hortorum Cultus, 14(3) 2015, 13-24*

MODIFYING APPLE SPINDLE TREES TO IMPROVE FRUIT QUALITY

Augustyn Mika, Zbigniew Buler
Research Institute of Horticulture in Skierniewice

Abstract. Dwarf and semidwarf apple trees planted at high density orchard are poorly illuminated when they come into full bearing. Insufficient illumination has adverse effect on apple red blush. Studies were carried out in years 2009–2013 in the Institute of Horticulture at Skierniewice. The object of the study were 12-year-old apple trees of 'Jonagold' and 'Gala'. Trees were grafted on semi-dwarf M.26 rootstock, planted at 4 × 2 m, trained to the spindle system, had been pruned until the spring of 2009 by the renewal method. Prior to the trial the trees were 3 m of height and 2.5 m in spread. To improve fruit quality, additional four pruning treatments were applied in 2009–2013. They were: 1. Removing the lowest branches up to 1 m above the ground; 2. Heading annual shoots at the tree top and the base of the canopy; 3. Cutting out a slim waist in the middle part of the canopy; 4. Slimming the tree top; 5. Trees in the standard spindle form treated with renewal pruning served as the control. All the pruning systems ensured high yields. Only the pruning to a slim waist and slimming the tree top improved light penetration to the interior part of the tree canopy, fruit size and color. Pruning treatments slimming tree silhouette can solve the problem of poor quality apples in densely planted orchards.

Key words: pruning systems, canopy improvement, light penetration

INTRODUCTION

In Europe, most apple trees are grafted on dwarf and semi-dwarf rootstocks, planted at a spacing of 3.5–4.0 × 1.0–2.0 m, and trained in the spindle form described by Wertheim [1981]. The spindle canopy has a shape of a cone with a broad base and a slender top. In a young orchard, spindle canopies ensure high yields and good quality fruit. After a few years, insufficient amount of sunlight can be observed at the base and in the centre of the canopy as a result of numerous shoots vigorously growing out at the top of the tree, which shade the lower parts of the canopy [Buler and Mika 2009].

Corresponding author: Zbigniew Buler, Research Institute of Horticulture, Konstytucji 3 Maja 1/3, 96-100 Skierniewice, Poland, e-mail: zbigniew.buler@inhort.pl

Uniform exposure to sunlight throughout the volume of the canopy is necessary for abundant formation of flower buds, growth of fruit to the required size, and color development on apples [Jackson 1980, Robinson et al. 1993]. Measurements of light distribution within the apple tree canopy at the peak of fruiting show that the level of illumination in the top part of the canopy is about 70% relative to that above the canopy. At half the height of the canopy it is about 40%, whereas at the base of the canopy it is only 15–20% [Verheij and Verwer 1973]. With such low levels of light exposure, apples do not grow to the required size and have no blush [Mika and Piątkowski 1986, Robinson et al. 1991]. To ensure uniform light distribution and regular fruiting of trees, every year in the spring tree canopies are subjected to what is called renewal pruning. In this system of pruning, the only permanent part of the tree is the central vertical limb, called the leader. Branches are replaceable. After reaching the age of three years, they are cut off and replaced by young shoots. The branches are removed in such a way that a short stub is left at the leader, from which new shoots will sprout. Despite this method of pruning, older apple trees, especially those grafted on semi-dwarf rootstocks, have in their yield too large percentage of fruit with a poorly developed blush. Dense planting of trees in a row is also an important reason for the lack of color on apples. It is therefore helpful to cut away the new summer growth to expose apples to the sun [Mika 1986].

The uniformity of light distribution within the tree canopy can be improved by breaking up the canopy into a few limbs some distance away from each other. This is achieved in the spread-open forms such as the V, Y and Tatura trellis systems, and in the axial form [Chalmers and van den Ende 1975, Lespinasse and Delort 1986]. Unfortunately, these forms require additional outlays to establish the orchard and a lot of skill in the training of trees [Robinson et al. 1991].

Recently there have been a few ideas to improve the renewal pruning method. Dutch advisers suggested that in addition to the standard renewal pruning one should cut back in the spring strong annual growth at the top of the canopy and leave the weaker growth without pruning. The purpose of this method is to reduce the growth at the top and improve light penetration in the outer mantle of the canopy below the tree top. The same author also recommends cutting back the shoots on the branches at the base of the canopy in order to stiffen them. Stiff branches do not droop towards the ground and are thus better exposed to the sun. One can suppose that the similar results may be achieved by complete removal of the lower branches to a height of 1 m as the tree becomes older. As a result, the branches situated higher up can dangle down freely without the fear that they will come close to the ground. Lespinasse [1987] suggested a few ways of training apple trees, which should ensure uniform exposure of canopies to sunlight. One of them consists in cutting out the waist, i.e. a narrowing, halfway up the canopy. The cut-out waist is to serve as a window letting sunlight through to the base of the canopy. The same author promotes very slender axial canopies of low density, and thus well-exposed to the sun at the center.

The aim of the study was to modify spindle canopies in such a way as to obtain in the yield the highest percentage of apples of a marketable size (7–8 cm in diameter), with a blush covering at least 50% of the fruit surface.

MATERIALS

The study was conducted in 2009–2013 in the Experimental Orchard of the Institute of Horticulture in Dąbrowice (longitude 51º57' N, latitude 20º08' E, altitude 120 m). The objects of the study were 12-year-old (in the first year of the experiment) apple trees of the cultivars 'Jonagold' and 'Gala', grafted on M.26 rootstock, planted at 4 × 2 m, and trained in the spindle system with renewal pruning. Throughout the experimental period, the height of the trees was kept constant at 2.5 m. The spread of the canopies of the cultivar 'Jonagold' was 2.6 m at their base, and those of the cultivar 'Gala' 2.3 m in 2009. Flower pollination was assured by neighboring rows with 'Topaz', 'Rubinola', 'Sampion' apple trees. At flowering time two bee hives were supplied per a hectare.

Trees of the cultivar 'Jonagold' grow vigorously, produce long shoots, form large spreading canopies of medium density, with branches hanging down. Pruning this cultivar is difficult because the long shoots over 50 cm in length do not set flower buds. The cutting must be done skillfully so that sufficiently many spur shoots grow and remain within the canopy. Strong new growth and drooping branches prevent sunlight from penetrating to the base of the canopy. The semi-dwarf rootstock M.26 does not provide trees with a favorable growth vigor. In practice, however, it is often used because of frost resistance and tolerance to poor soils. The cultivar 'Jonagold' used to be planted widely when it was first introduced into cultivation. It has now been replaced by mutants bearing fruit with an extensive blush, such as 'Jonagored' or 'Jonaprince'. The mutants also require adequate sunlight for the development of color on the skin of the fruit.

Trees of the cultivar 'Gala' grow moderately, form compact, shapely canopies with a lot of small new growth. They set flower buds abundantly on spur and long shoots, and bear fruit abundantly every year, with a tendency towards excessive fruiting. They are easy to shape and prune. In orchards, the cultivar 'Gala' is being gradually replaced by red mutants ('Gala Must', 'Gala Royal'), but the problem of a very poor blush still remains.

METHODS

Pruning of the trees was performed every year before flowering, during the swelling of the flower buds. The following methods of pruning were used:

1. Renewal pruning with the removal of the lowest branches in the canopy and shaping of the canopy base at a height of 100 cm.
2. Renewal pruning and cutting back of the annual growth at the top of the leader and on the branches at the base of the canopy, which in the Netherlands is called 'klik' pruning.
3. Renewal pruning and cutting out the waist (a 70 cm high narrowing) in the canopy at a height of 1.5 m above the ground in order to ensure better light penetration to the base of the canopy.

4. Renewal pruning with a thorough slimming down of the upper part of the tree. This was achieved by cutting off on the leader all the long one-, two- and three-year-old growth, leaving shoots up to 30 cm in length.

5. Control. Renewal pruning performed by the method widely used in the orchards in the Grójec region of Poland (longitude 51º51' N, latitude 20º52' E, altitude 120 m).

The renewal pruning, as the primary method of pruning used in all the combinations, required the removal of about 30% of branches and almost 70% of one-year shoots from the canopy. Depending on the degree of compaction of the canopy, 3–5 branches extending from the leader were cut away, leaving 2–3 cm long stubs. Small 2- to 3-year-old shoots and very long (over 50 cm) one-year shoots were thinned out. After pruning, there remained in the canopy mostly 2-year-old shoots, short one-year shoots and small 3-year-old shoots. The canopy was given a conical shape by leaving at the base of the canopy long branches overlapping those of adjacent trees, gradually changing into very short shoots at the top of the canopy. This basic renewal pruning was modified as described in the combinations 1–4. The silhouettes of the trees after pruning are shown in Figure 1.

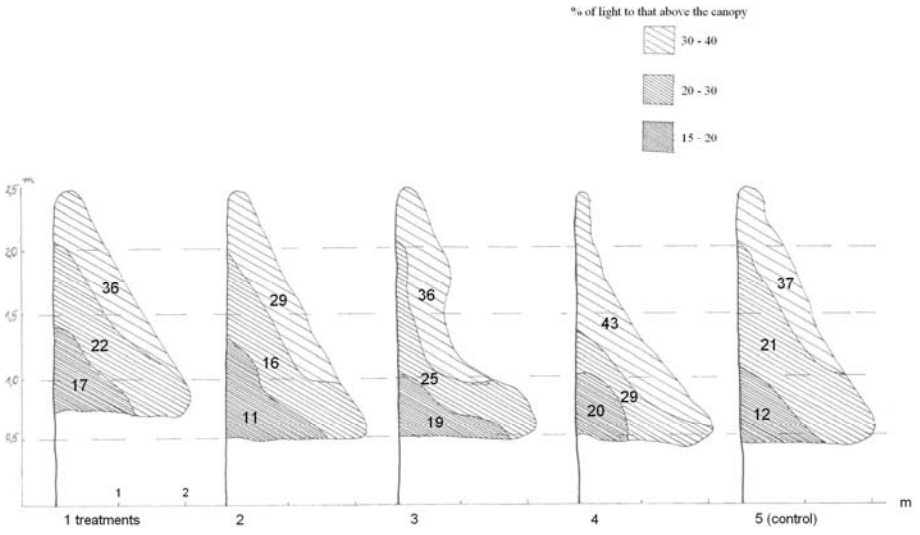

Fig. 1. Longitudinal cross-section of apple tree canopies subjected to 5 pruning treatments with marked illumination levels

The trees were cultivated in a standard way. A 2-m-wide strip of grass was maintained between the rows and black herbicide fallow in the rows using foliar herbicides. The orchard was drip irrigated at a dose of about 150 mm of water a year. Mineral fertilization was applied according to the results of soil analyses, with a nitrogen dose of about 70 kg of pure ingredient per hectare. Fruitlets were not thinned. Towards the end of August, the strongest new growth (suckers) at the top of the canopies were cut away,

in the same way on all the trees. Chemical protection against diseases and pests effectively protected the trees and fruit against damage.

All the pruning combinations were arranged in one row consisting of evenly-sized trees of one cultivar. Each combination consisted of five trees growing next to each other, all treated in the same way. Five trees were regarded as five replications. Each year, the circumference of the trunk and the span of the canopy at its base were measured, new shoots longer than 20 cm were counted, fruit crop was weighed, mean fruit mass was calculated, and the percentage distribution of fruit according to the size of the diameter and extent of the blush was determined. For this purpose, random samples of 100 fruit were collected from each tree. In August of 2010 and 2012, illumination of the canopies was measured at three levels using a Sun Scan Probe type SS1 tube solarimeter (Delta-T Devices Ltd, Great Britain). The levels of sunlight irradiation were measured on sunny days only, at midday hours. The measurements were done in three levels (1.0, 1.5, 2.0 m) across the tree row. There were 64 readings obtained from each measurement. The results of the measurements in $W \cdot m^{-2}$ were converted to the percentage of light reaching inside the canopy in relation to the irradiation above the canopy.

The consumption of labor in pruning was recorded for each combination. Most of the collected data were subjected to analysis of variance using statistical software. Significance of the differences between means was assessed with Duncan's test at the significance level of $P = 0.05$.

RESULTS

Tree growth and fruiting

Over the period of the experiment there was no damage to the trees caused by winter sub-zero temperatures, spring frosts, or hail. The 2012 growing season was particularly favorable to the trees, which resulted in very high yields. Air temperatures and total precipitation were higher than the long-term averages. Trees were in good health condition during the trial. The 2013 growing season was less favorable due to a very cold and wet spring. The yields were lower.

Trunk cross-sectional area after five years under the various pruning regimes was in both cultivars slightly larger than in the control trees, but significant differences were found only in three cases out of ten (tab. 1). Only 'Gala' trees pruned to slim waist had the largest TCA, because it was also the largest at the beginning of the trial. Canopy span decreased slightly over the years as a result of the pruning modifying the canopy. Canopies of the 'Gala' trees lost about 0.4 m in their span, while those of the cultivar 'Jonagold' about 0.2 m. In most years, there were no significant differences in canopy span between the pruning combinations, nor in relation to the control combination. The modifications of the shape of the canopy and the cutting associated with it exerted a significant influence on the growth of shoots. The largest increase in the number of shoots was recorded in the combination with the pruning back of one-year shoots and cutting out of the slim waist. The smallest increase was associated with the removal of the lowest branches and the slimming down of the leader (tab. 1).

Table 1. Effects of modifying spindle trees on TCA (trunk cross area), yield, cropping efficiency and number of terminal shoots

Coltivar	Treatments	TCA (cm^2)		Total yield 2009–2013 ($kg \cdot tree^{-1}$)	Mean number of terminal shoots >30 cm	Cropping efficiency index 2009–2013 ($kg \cdot cm^{-2}$ TCA)
		2009	2013			
'Jonagold'	Removal of the lowest branches	132.0 a*	198.7 b	175.5 a	52 a	0.9 a
	Heading laterals	123.2 a	190.9 b	192.5 a	88 c	1.0 a
	Cutting out slim waist	124.3 a	175.5 ab	148.8 a	75 b	0.8 a
	Sliming tree top	120.9 a	183.0 ab	154.9 a	44 a	0.8 a
	Control	117.1 a	171.7 a	165.6 a	65 ab	1.0 a
'Gala'	Removal of the lowest branches	99.5 ab	126.8 ab	186.2 a	45 ab	1.5 ab
	Heading laterals	96.7 ab	120.9 ab	223.6 a	76 d	1.8 b
	Cutting out slim waist	128.1 b	136.5 b	196.5 a	64 c	1.4 a
	Sliming tree top	93.1 ab	114.9 ab	173.9 a	36 a	1.5 ab
	Control	83.1 a	103.0 a	181.1 a	54 b	1.8 b

*In all the tables, means with the same letter are not significantly different at P = 0.05

The pruning methods did not have a significant effect on tree productivity (cropping efficiency index, tab. 1). Trees of all the pruning combinations delivered high yields, which, however, varied considerably from year to year. There were no significant differences in tree productivity between the combinations of canopy modifications. The average annual yield for the cultivar 'Jonagold' was 34 kg of marketable apples per tree, and 38 kg for the cultivar 'Gala'. With the spacing of 4 × 2 m and planting density of 1250 trees per hectare, the average annual yield per hectare was 42.5 and 47.5 tonnes, respectively. The cultivar 'Gala' had a higher cropping efficiency index than the cultivar 'Jonagold' (tab. 1). The treatments modifying the shape of the canopy did not have a significant effect on the efficiency index of 'Jonagold' trees. Cutting out a slim waist significantly reduced the efficiency index of the cultivar 'Gala'.

Fruit quality

Size distribution. The 'Jonagold' is classified as large-fruited cultivar. The market demands that apples of this cultivar should have a diameter of at least 7.5 cm. The 'Gala' belongs to the class of small-fruited cultivars. The market accepts apples of this cultivar with a diameter of at least 7.0 cm. The percentage distribution of apples in these size classes is presented in table 2. In the majority of cases, 'Jonagold' apples met the commercial size requirements. In three consecutive years, the cutting out of a slim waist and slimming the tree top were found to have a positive effect on the size of those apples in relation to the control. In two experimental years there was no significant effect in that respect. Raising the trunk height and cutting back new growth did not increase the percentage of large apples compared with the control. In the cultivar 'Gala', a signi-

ficantly higher percentage of proper-sized apples was recorded following the cutting out of a slim waist and slimming of the tree top.

Table 2. Effects of modifying spindle trees on % of apples of 'Jonagold' with minimum diameter of 7.5 cm and 'Gala' minimum diameter 7.0 cm

Cultivar	Treatments	2009	2010	2011	2012	2013
'Jonagold'	Removal of the lowest branches	92 b*	64 a	97 a	87 a	93 a
	Heading laterals	92 b	59 a	97 a	88 a	87 a
	Cutting out slim waist	90 b	76 b	97 a	93 b	92 a
	Sliming tree top	91 b	74 b	98 a	94 b	89 a
	Control	83 a	66 a	96 a	86 a	89 a
'Gala'	Removal of the lowest branches	48 a	67 a	92 b	65 b	23 b
	Heading laterals	52 a	61 a	86 ab	64 b	12 a
	Cutting out slim waist	54 ab	84 b	90 b	78 c	30 c
	Sliming tree top	63 b	82 b	90 b	72 bc	30 c
	Control	50 a	58 a	82 a	26 a	14 a

* For explanations see Table 1

Light distribution within the tree canopy. The results of measurements in $W \cdot m^{-2}$ were converted to the percentage (%) light reaching the inside of canopy in relation to amount of light above the canopy assumed to be 100%. The results showed much of variation between cultivars and years, thus they were averaged and presented here in form of drawings. The drawings show illumination levels in top, middle and bottom tree. Trees treated with slimming pruning had the largest part of tree canopy well illuminated (fig. 1).

Extent of the blush. 'Jonagold' and 'Gala' apples, unlike their red mutants, develop only a partial blush on the surface of the skin. In trade, apples with a blush on at least half of the fruit surface are valued by the market because they can be displayed in an attractive way in flat cartons with the blush facing up. The percentage of apples with an extensive blush (1/2 or more of fruit surface area) varied considerably from year to year (tab. 3). In most years, in both cultivars, cutting out a slim waist and slimming the tree top significantly increased the percentage of apples with an extensive blush relative to the control. On the other hand, raising the trunk height and pruning back new growth did not have any positive effect on the coloration of apples. Both of these treatments can be regarded as ancillary in the maintenance of the orchard as they prevent branches from drooping to the ground. Pruning back annual growth stimulates the sprouting of new growth, and that is not conducive to ensuring high exposure to sunlight.

In the first year of the experiment (2009), the pruning modifying the shape of the canopies had no significant effect on the average mass of apples. From the second year onwards (2010–2013), a significant increase in mean fruit mass of 'Jonagold' was recorded in the combination involving the cutting out of a slim waist and slimming the

Table 3. Effects of modifying spindle trees on % of 'Jonagold' and 'Gala' apples with red blush covering >50% of fruit surface

Cultivar	Treatments	2009	2010	2011	2012	2013
'Jonagold'	Removal of the lowest branches	31 a*	18 a	66 b	86 a	100 b
	Heading laterals	28 a	15 a	46 a	87 a	90 a
	Cutting out slim waist	55 b	52 c	78 bc	91 b	100 b
	Sliming tree top	51 b	54 c	88 c	91 b	100 b
	Control	34 a	28 b	69 b	85 a	90 a
'Gala'	Removal of the lowest branches	10 a	20 a	43 b	64 b	88 b
	Heading laterals	8 a	19 a	23 a	56 a	77 a
	Cutting out slim waist	9 a	44 c	50 c	70 b	97 c
	Sliming tree top	12 a	32 b	45 b	69 b	97 c
	Control	11 a	29 b	26 a	69 b	79 a

* For explanations see Table 1

tree top compared with the control. In case of 'Gala' three treatments: removal of the lowest branches, cutting out of a slim waist and slimming the tree top increased mean fruit mass (tab. 4).

Table 4. Effects of modifying spindle trees on fruit quality

Cultivar	Treatments	Mean fruit mass 2009–2013 (g)	Mean firmness 2011–2013 (lb)	Brix 2011–2013 (%)
'Jonagold'	Removal of the lowest branches	214 a*	16.2 b	13.7 b
	Heading laterals	210 a	16.0 a	13.3 a
	Cutting out slim waist	229 b	16.5 b	14.0 b
	Sliming tree top	230 b	16.4 b	13.9 b
	Control	211 a	16.5 b	13.7 b
'Gala'	Removal of the lowest branches	143 b	16.9 a	12.3 b
	Heading laterals	135 ab	17.3 b	11.2 a
	Cutting out slim waist	140 b	17.4 b	12.2 b
	Sliming tree top	147 b	16.9 a	12.7 b
	Control	130 a	17.7 b	12.1 b

* For explanations see Table 1

Fruit firmness and refraction were assessed in 2011–2013. Both these indicators of fruit quality were high (tab. 4). Apples with such quality characteristics were suitable for long storage. In both cultivars, significantly lower refraction was recorded following the pruning back of annual growth. With this pruning method, apples of the cultivar

'Jonagold' also had the lowest firmness. There were, however, no differences between the other combinations of canopy modification.

Labour consumption in pruning

Each year the amount of work involved in pruning was recorded and the values were converted per hectare of orchard. Pruning of the cultivar 'Jonagold' consumed on average from 115 to 127 hours per year, and of the cultivar 'Gala' from 77 to 123 hours. Values of this order are often associated with densely planted commercial orchards. Trees with a slimmed top required less pruning time than the control trees.

DISCUSSION

The attempt to modify spindle canopies revealed that apple trees grafted on a semi-dwarf rootstock had a high yield-forming ability. The pruning treatments applied in the experiment, such as the cutting-out of a slim waist halfway up the canopy, or slimming the tree top, which reduced the volume of the canopy, did not cause any decrease in tree productivity. This result differs from quite a number of reports stating that pruning to restrict the volume of the canopy can reduce fruit yield and increase the growth of shoots [Mika 1986, Robinson et al. 1993]. The result obtained in this work provides a basis for recommending the pruning treatments described above, which improved the quality of apples. Slimming the tree top and cutting out a slim waist increased the percentage of apples in the class of best-sized fruit, although the increase was not spectacular. It is likely that a better result could be obtained by chemical or hand-thinning of fruitlets. Despite these possibilities, spring pruning is always the first treatment that regulates fruiting and fruit size, without which it is not possible to produce apples of a commercial value [Mika 1986].

Pruning back annual growth on the periphery of the canopy, in order to prevent branches from drooping and overlapping, has proved to be effective and has a rejuvenating effect on the canopy, but unfortunately it stimulates the tree to produce more shoots that obstruct the sunlight from reaching the fruit. It has been repeatedly demonstrated in experiments that pruning intensifies the sprouting of new growth, in particular when small shoots are cut off or cut back [Mika 1986]. Under very low growth vigor, pruning back annual growth may lead to an increase in yield [Mohammadi et al. 2013], but in this work there was no such effect observed.

Results of experiments on the pruning of trees have provided many data indicating that pruned trees, despite stronger growth, remain smaller than unpruned trees because they are not able to rebuild the removed parts in time [Mika 1986]. Trees that are regularly pruned have thinner trunks, smaller canopy span, and less bulk. Such an outcome could have been expected in this experiment. There were no such results, however, because the control trees were also pruned, and the additional modifications involved only a small portion of the canopy, so they did not cause any significant changes in tree growth.

The main purpose of the modifications to spindle canopies was to improve light penetration and fruit quality, above all, the extent of the blush on apples. The measurements of light exposure taken within the canopies at three levels revealed the desired

value of illumination in the upper part of the canopy between the heights of 1.5 and 2.5 m. Below and deeper within the canopy, the intensity of light was low, ranging from 10 to 20% of the illumination above the canopy. The measurements were made in the second half of August, because that is when apples begin to develop color. Comparison of the results of light exposure measurements for a modified canopy and the canopy of a control tree reveals that the additional pruning did not produce sensational results. The spindle canopy and other canopies currently used in orchards, such as axial canopy, the 'V' and 'Y' systems, have numerous clearances in the foliage, which facilitate penetration by sunlight [Robinson et al. 1991]. Such canopies are difficult to improve on. The treatments carried out in the spring are gradually neutralized during the growing season by new growth and branches sagging under the mass of the fruit. As a result of these processes, the desired level of light exposure (50–70%) is only at the periphery of the canopy, while at the base it reaches only 15% [Verheij and Verwer 1973]. According to Looney [1968], the level of illumination at the base of the canopy can be in the range 6–30%. The limited exposure to sunlight reduces not only the quality of the fruit but also the quality of fruit-bearing shoots, and thus the productivity of the lower branches [Robinson et al. 1983, Barritt et al. 1991, Mika et al. 2001]. The best way to improve light penetration is to maintain trees at a reasonable height in a densely-planted orchard (2.0–2.5 m), and with very slim tree tops [Buler et al. 2000]. Cutting out, in the spring, a slim waist or a window at mid-height of the canopy gives variable results. If the apple cultivar produces short and rigid shoots, the cutting-away serves its purpose. But if the cultivar produces long, flexible shoots, like 'Jonagold', then the cut-out space soon becomes filled with drooping branches.

By observing pruned and unpruned trees, it is easy to notice that after the treatment the pruned trees produce considerably more new growth than the unpruned trees. This has been confirmed by numerous experiments [Mika 1986]. The number of shoots growing out is the higher, the more particular and severe the pruning is. Cutting back shoots causes much more abundant growth than removing shoots or branches [Mika 1986]. In this experiment, all the trees were pruned by the renewal method, which was modified in four combinations by removing the lowest branches, cutting back some shoots, cutting out a slim waist, and slimming the tree top. These additional treatments had an insignificant effect on the number of long shoots, with the exception of shoot heading. Shoot heading increased the number of long shoots by more than 20%. This result was not favorable because the trees grew vigorously, and the additional shoots caused excessive shading of the fruit.

Measurements of light exposure made by Buler and Mika [2009] in an intensive apple orchard, with similar parameters to the one in the experiment described here, had shown that apples developed an extensive blush if a few weeks before the harvest the amount of sunlight that reached inside the canopy was at least 50% of the amount of sunlight above the canopy. Such favorable illumination is usually recorded between the tree top and halfway down the canopy, i.e. about 1.5 m above the ground. Below that, light penetration rapidly decreases to 20% at the circumference of the canopy, and to 10% in the centre of the canopy. To improve the distribution of light in conical canopies, Willaume et al. [2004] propose a method of pruning called a centrifugal training system. As is known, in a centrifuge the centrifugal force moves the heavier matter

outward. These authors propose cutting away all fruit-bearing shoots from the centre of the canopy and leaving the shoots at the circumference of the canopy. In this way, the fruits that set around the circumference of the canopy receive favorable exposure to sunlight. This method of pruning can be laborious, but worth being investigated further.

CONCLUSIONS

1. 'Jonagold' and 'Gala' apple trees grafted on a semi-dwarf rootstock, trained in the spindle form, give satisfactory yields of apples, but the percentage of proper-sized fruit covered with an extensive blush is too small in some years.

2. Light penetration of tree canopies and fruit quality can be improved effectively by slimming the top of the canopy, which means cutting away in the spring the long shoots at the top of the tree, leaving only short fruit-bearing shoots.

3. Cutting out a slim waist at mid-height of the canopy helps the fruit grow to the desired size. It also improves light exposure at the base of the canopy if the upper branches do not droop and fill up the window cut in this way.

4. Pruning back in the spring the annual shoots at the periphery of the canopy is effective in stiffening it, but may reduce light penetration and the quality of apples.

5. Cutting away the lowest branches in the canopy has an insignificant effect on the quality of apples.

REFERENCES

Buler, Z., Mika, A. (2009). The influence of canopy architecture on light interception and distribution in 'Sampion' apple trees. J. Fruit Ornam. Plant Res., 17(2), 45–52.

Buler, Z., Mika, A., Treder, W., Chlebowska, D. (2000). Influence of new training systems of dwarf and semidwarf apple trees on yield, its quality and canopy illumination. Acta Hort., 557, 253–259.

Barritt, B.H., Rom, C.R., Konishi, B., Dilley, M.A. (1991). Light level influences spur quality and canopy development and light interception influence fruit production in apple. HortSci., 26(8), 993–999.

Chalmers, D.J., van den Ende, B. (1975). The tatura trellis: A new design for high yielding orchards. J. Agr. Victoria, 73, 473–476.

Jackson, J.E. (1980). Light interception and utilization by orchard systems. Hort. Rev., 2, 208–267.

Lespinasse, L.M. (1987). Reflexions sur le conduite du pommier: une nouvelle forme, le 'Solen'. L'arboricult. Fruit., 34(399), 45–48.

Lespinasse, J.M., Delort, J.F. (1986). Apple tree management in vertical axis: appraisal after ten years of experiments. Acta Hort., 160, 139–155.

Looney, N.E. (1968). Light regimes within standard size apple trees as determined spectrophotometrically. Proc. Amer. Soc. Hort. Sci., 93, 1–6.

Mika, A. (1986). Physiological responses of fruit trees to pruning. Horticultural Review 8. Avi Publishing, 337–378.

Mika, A., Piątkowski, M. (1986). Results of 10 year trial of high density planting of Macspur apple trees. Acta Hort., 160, 293–304.

Mika, A., Treder, W., Buler, Z. (2001). Wpływ struktury korony jabłoni na jej nasłonecznienie, plenność i jakość owoców. Zesz. Nauk. ISK, 9, 49–56.
Mohammadi, A., Mahmoudi, M.J., Rezaee, R. (2013). Vegetative and reproductive responses of some apple cultivars (*Malus domestica* Borkh.) to heading back pruning. Int. J. AgriSci., 3(8), 628–635.
Robinson, T.L., Lakso, A., Ren, Z. (1991). Modifying apple tree canopies for improved production efficiency. HortSci., 26(8), 1005–1012.
Robinson, T.L., Seeley, E.J., Barritt, B.H. (1983). Effect of light environment and spur age on 'Delicious' apple fruit size and quality. J. Amer. Soc. Hort. Sci., 108, 855–861.
Robinson, T.L., Wünsche, J., Lakso, A. (1993). The influence of orchard system and pruning severity on yield, light interception, conversion efficiency, partitioning index and leaf area index. Acta Hort., 349, 123–127.
Verheij, E.W.M., Verwer, F.L.J.A.W. (1973). Light studies in a spacing trial with apple on a dwarfing and a semi-dwarfing rootstock. Sci. Hort., 1, 25–42.
Wertheim, S.J. (1981). High-density planting: development and current achievements in the Netherland, Belgium and West Germany. Acta Hort., 114, 318–323.
Willaume, M., Lauri, P.E., Sinoquet, H. (2004). Light interception in apple trees influenced by canopy architecture manipulation. Trees, 18, 705–713.

MODYFIKACJA KORONY WRZECIONOWEJ JABŁONI W CELU POPRAWIENIA JAKOŚCI OWOCÓW

Streszczenie. Karłowe i półkarłowe jabłonie posadzone w dużym zagęszczeniu są słabo nasłonecznione po wejściu w okres pełnego owocowania, co ma ujemny wpływ na wybarwianie się jabłek. W celu rozwiązania tego problemu w Instytucie Ogrodnictwa w Skierniewicach w latach 2009–2013 podjęto badania. 12-letnie jabłonie 'Jonagold' i 'Gala" szczepione na półkarłowej podkładce M.26, posadzone w rozstawie 4 × 2 m i prowadzone w formie wrzecionowej cięto do roku 2009 standardowo, metodą odnawiającą. Przed rozpoczęciem doświadczenia drzewa miały 3 m wysokości i 2,5 m rozpiętości. W celu poprawy jakości jabłek w latach 2009–2013 zastosowano 4 sposoby dodatkowego cięcia: 1. Wycięcie dolnych gałęzi do wysokości 1 m; 2. Skracanie rocznych przyrostów u podstawy korony i u wierzchołka; 3. Wycinanie talii w połowie wysokości korony; 4. Wyszczuplanie wierzchołka drzewa; 5. Kontrola, drzewa cięte standardowo. Wszystkie sposoby cięcia zapewniły wysoki plon. Wycinanie talii i wyszczuplanie wierzchołka drzewa istotnie poprawiło nasłonecznienie w koronach, rumieniec i wielkość owoców. Cięcie wyszczuplające koronę i wycinanie talii może poprawić jakość jabłek w sadach gęsto sadzonych.

Słowa kluczowe: systemy cięcia, usprawnienie korony, nasłonecznienie korony

Accepted for print: 4.03.2015

For citation: Mika, A., Buler, Z. (2015). Modifying apple spindle trees to improve fruit quality. Acta Sci. Pol. Hortorum Cultus, 14(3), 13–24.