ISSN 1644-0692
www.acta.media.pl
Acta Sci. Pol. Hortorum Cultus, 15(1) 2016, 113-121

MECHANICAL PRUNING OF APPLE TREES AS AN ALTERNATIVE TO MANUAL PRUNING

Augustyn Mika, Zbigniew Buler, Waldemar Treder
Research Institute of Horticulture in Skierniewice, Poland

Abstract. High costs of manual pruning and lack of skilled workers incline fruit growers to mechanical pruning. Mechanical pruning gives good results in the case of trees that do not require selective pruning, like citrus trees. This pruning method is also acceptable if the fruit is produced for industrial purposes. Twelve-year-old 'Pinova' apple trees grafted on dwarf M.9 rootstocks, spaced at 4 × 1.5 m, trained to the spindle system were mechanically pruned at the pink flower stage (first week of May) and at the fruit setting stage (first week of June). The pruning was done with a STIHL cutting bar as 'topping' (trimming the tops of trees) and 'hedging' – pruning of trees from two sides at an angle of 70°. Before the pruning, the trees had a height of 3.5 m and over 2.0 m spread at the bottom part of tree canopy. Control trees were pruned manually using standard methods. The height of the trees was reduced with mechanical and manual pruning to 2.5 m, and the spread to 2 m at the base of tree canopy. During the three years of the trial, mechanical pruning significantly altered the canopy structure. It developed into a continuous, compact wall without any openings along the row. In the same time, hand pruned trees had free openings in the upper part of tree canopies. Mechanically pruned trees had lower solar irradiation levels than manually pruned trees. In the third year, the trees pruned mechanically gave higher yields than the trees pruned manually, but fruit size, mean fruit weight and the area of the red blush were significantly decreased. The trial indicated that mechanical pruning of apple trees must be supplemented by hand pruning. More attention is also needed to fruit thinning when trees are pruned mechanically.

Key words: growth regulation, canopy structure and illumination

INTRODUCTION

Several fruit species are pruned mechanically: black and red currants, grapes, citrus trees and olives. Most of the species of the temperate climate are pruned manually. Manual pruning of apple, pear and peach trees requires 80–120 working hours of skilled

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

workers per ha. Since the 1960s, efforts have been made to introduce mechanical pruning on most fruit plantations. Nearly fifty years ago, the first pruning machines were implemented in the USA for pruning citrus trees. Trees were trimmed from the top (topping) and from the side (hedging) with cutting bars or rotational saws [Childers 1983]. Evergreen trees (lemon, orange, grapefruit, also olive) are suitable for such treatment because they do not require selective pruning within tree canopy. Mechanical trimming of citrus trees [Bordas et al. 2012] provides the best results in densely planted fruit groves, trained to the hedgerow system. New olive plantations have been lately planted at high density and trained to continuous 'fruit walls' in order to implement mechanical pruning and mechanical fruit harvesting [Dias et al. 2012]. Fruit growers in the USA were very enthusiastic about the results obtained with citrus trees and tried to apply mechanical pruning to apple, pear and peach trees. The results were disappointing. In practice, only topping of peach trees, before or after fruit harvesting, remains as permanent treatment in the USA [Childers 1983].

In Italy, after the 1960s, a new system of growing fruit trees began to be widely used that created groves suitable for mechanical pruning. Most apple, pear and peach trees were trained as flat fruiting walls called 'palmeta', ideal for topping and hedging. A series of trials with mechanical pruning was done in the Bologna fruit-growing region by Scaramuzzi [1968], Baldini [1970], Loreti [1971], Baldini [1974]. The results revealed that mechanical topping and hedging had no negative influence on tree growth and their productivity, but reduced fruit quality. A high percentage of fruit was under the required size; they developed poor red blush, and their appearance was also poor. To maintain satisfactory fruit quality, adequate hand pruning must be done inside the tree canopy. Because of those results, hand pruning is still performed in all Italian orchards, whereas topping is regarded as an additional treatment.

Among the different fruit species, peach trees adapt well to mechanical pruning, but with such treatment they set too many fruits on the tree and induce a reduction in fruit size when compared to hand pruning [Loreti 1971]. Similar results are observed on apple and pear trees. In such cases, adequate, more extensive, fruit thinning is necessary. In all the trials, satisfactory results were obtained only when mechanical pruning was combined with hand pruning inside the canopy. Total pruning time was drastically reduced only where mechanical pruning alone was applied. Supplementing mechanical pruning with selective hand pruning cancelled out the previous time saving benefit [Baldini 1974]. In practice, tree topping is more popular than tree hedging. The latter one requires perfectly vertical trees aligned exactly in a straight line in the row.

In California, trials have started recently with high density planting of plum and olive trees trained as hedgerows, pruned mechanically and harvested also mechanically. Ferguson et al. [2012] demonstrated a high density grove (HDP) of plum trees trained in a hedgerow and pruned mechanically. The trees pruned mechanically yielded better than the trees pruned manually. Such a result is easy to understand because without selective pruning there is more fruiting wood in the canopy. The author concludes that manually treated trees were probably over-pruned. Abundant fruiting of plum trees results in smaller fruits that have lower market value. After mechanical pruning, more attention and time are necessary for fruit thinning. Similar results were obtained by Kruger et al. [2013]. Mechanical topping and shaping of plum trees increased fruit yield. Bordas et al. [2012] suggest that continuous hedgerows of fruit trees create the best conditions for mechanical pruning and mechanical harvesting.

MATERIALS AND METHODS

Twelve-year-old 'Pinova' apple trees grafted on M.9 dwarf rootstock, spaced at 4 × 1.5 m, trained to the spindle system, were the object of the experiment. Trees were planted in the spring of 2000 at the Research Institute of Horticulture ('INHORT'), Skierniewice, Poland (longitude 51°57'N, latitude 20°08', altitude 120 m), on sandy-loam, dip soil with pH 5.5. Skierniewice area is characterized by a Central European climate with 507 mm of rainfall annually and 489 mm of evapotranspiration during the growing season. The mean temperature of the coldest month of January is -3.1°C, and the mean temperature of the warmest month of July is 18.1°C.

The area of the experimental grove was 400 m^2 selected as one row of uniform trees out of a large experimental block of 0.5 ha of trees. There were pollinator cultivars on both sides of the selected tree row. Tree management was as in standard Polish orchards. In the second year after planting, the inter-rows were grassed down, with frequent grass mowing in conjunction with the maintenance of 1.5-m-wide herbicide strips along the rows. The experimental orchard was irrigated with Raam (Netafim – Israel) pressure compensation drip-lines at a discharge rate of 2.3 $l \cdot h^{-1}$. The distance between the drippers was 0.7 m. Trees were fertilized according to soil analyzes. The mean annual dose of nitrogen was 50 $kg \cdot ha^{-1}$ yearly. The minerals P and Mg were applied only before tree planting, and K according to soil analyzes. One or two spray treatments with microelements were performed annually. About fifteen spray treatments were necessary to control fungal diseases and six to control insects.

'Pinova' apple trees are slow growing, forming a regular canopy with many annual shoots. When trees are grafted on M.9 rootstock, they start to yield in the second year from planting. Fruiting is regular, abundant, with a tendency to over-cropping. Fruit thinning is very important in this cultivar in order to obtain marketable fruit size. The trial with mechanical pruning started in the spring of 2012. Prior to the experiment, the trees were 3.5 m high with numerous water shoots on the tree top. Canopy spread measured at 1.5 m above the ground was 2.5 m. The shape of the canopy should be conical, but before pruning it was like a pillar due to more intensive shoot growth at the top of the canopy than at the bottom. The aim of the spring pruning was to shorten the trees to 2.5 m, and to correct the shape towards conical. Before pruning, the trees had 10–15 branches coming from the leader. Fruiting wood developed numerous flower clusters: 400–500 per tree.

The pruning treatments were as follows:

1. Mechanical pruning in the first week of May, at the pink bloom stage, with a STIHL cutting bar propelled with a 10 HP internal combustion engine. The positioning of the cutting bar was adjustable to the desired angle, so it was easy to cut the tree tops ('topping') and to prune the sides of the tree row ('hedging'). Topping was done to a height of 2.5 m. Side pruning (hedging) was done at an angle of 70° to obtain an aslant wall, with the trees trained towards a 'conical' shape.

2. Mechanical pruning in the first week of June, after blooming, when apple trees had already developed annual growth, about 10 cm long, and had set fruits. Pruning in this stage should result in less annual growth, because the first wave of shoot growth is rejected with pruning.

3. Control. Manual pruning. Manual pruning was done in the last week of April according to the standard pruning procedure in Poland. All the water shoots in the tree-top were cut back. Trees were shortened to 2.5 m. Annual growth was stronger in the upper

part of the tree than in the lower part, thus the upper part of the trees had to be pruned harder. When the strong annul growth was removed, the tree returned to the conical shape. Selective shoot thinning was done in the interior part of tree canopy. Old wood was cut back and young 1, 2, 3-old shoots were left as they were. Opened, free spaces, were left between trees to ensure the penetration of sunlight to the base of the canopy. Each pruning method was performed on 6 adjacent trees in the row and was repeated twice. Twelve trees were pruned in the same way. All the data were collected from individual trees. Due to very abundant setting of fruit, hand thinning was carried out every year, leaving the fruits spaced at a distance of about 20 cm apart.

Every year, measurements of the diameter of the tree trunk were taken and used to calculate the trunk cross-section area (TCSA). In the third year of the trial, the density of tree canopy was estimated. To measure the density, a vertical section of the canopy (80 × 60 cm) was selected on 6 trees in each treatment, parallel to the row, against a white board, and a photograph was taken. The photograph was then converted by a computer program ImageJ 1.48v (National Institutes of Health, USA) to the total length of shoots in the selected sections. In the third year of the trial, the levels of sunlight irradiation were measured at midday on a sunny day in August, in three horizontal zones with a 'Sun Scan Probe' portable solarimeter (Delta T-Devices Ltd. Burwell, England). Twelve readings were obtained from each experimental combination. Fruits were harvested at the end of October. The data recorded included the size of the fruit crop from each tree, mean fruit weight, fruit colour, firmness, and TSS content. The results were statistically elaborated using analysis of variance, followed by the separation of means using Duncan's multiple-range t-test at $P < 0.05$.

RESULTS

The growth of trees in 2012–2014, as expressed by the trunk cross-sectional area (TCSA) (tab. 1), showed a significant decrease in TCSA in the treatment involving mechanical pruning, probably due to restricted leaf area on the trees pruned in May and June. During the three years (2012–2014), fruiting was very abundant, and this probably resulted in the moderate tree growth. After three years of the trial, mechanical pruning had altered the canopy structure and its density in comparison with manually pruned trees (fig. 1). The density, calculated as the total length of shoots in a vertical area of the canopy (0.48 m^2), was 50% higher in mechanically pruned trees compared to hand pruned ones (phot. 1). With time, the mechanically pruned trees formed a continuous, compact wall without any intervals between the canopies. Thick branches are present in the mechanically pruned trees in contrast to the hand pruned trees. The latter ones have only thin wood due to renewal pruning. The canopy structure had an influence on the intensity of solar irradiation measured at three levels (tab. 2). In the upper and middle parts of the canopy, the trees pruned manually facilitated significantly higher insolation than in the trees pruned mechanically. This result was due to the openings between the manually pruned trees subjected to the standard treatment. Tree flowering and fruit setting were very abundant. Every year, hand thinning of fruitlets was carried out in July, with the remaining fruitlets left at a distance of about 20 cm apart. During the first two years of the trial there was no significant influence of mechanical pruning on fruit yield when compared to hand pruning. In the third year, the trees pruned mechanically produced higher yields because they had developed more fruiting wood in the interior part of the fruit canopy (tab. 3).

Fruit yield calculated per hectare was, in the last year, very high (60–78 $t \cdot ha^{-1}$). The mean index of fruit productivity revealed only slight differences, not proven statistically. Due to extensive fruit thinning, most of the fruit reached marketable size. However, in two years, the trees pruned manually produced significantly more fruits with a weight above 150 g, which have the highest market value. The percentage of small fruits in the crop increased over time (tab. 4). From the first year, mechanical pruning suppressed red blush development. This effect was increasing up to the third year, when the trees pruned mechanically yielded only 5–15% of fruits with a full red blush, against 47% in manually pruned trees (tab. 5). Pruning treatments had no influence on fruit firmness and TSS in the first two years. In the third year, mechanical pruning significantly increased fruit firmness, but also significantly decreased TSS in comparison with hand pruning (tab. 3).

Table 1. Effect of mechanical and hand pruning on tree growth, cumulative yield and productivity index

Treatments	TCSA** 012 (cm^2)	TCSA 2013 (cm^2)	TCSA 2014 (cm^2)	Cumulative yield 2012–2014 ($kg \cdot tree^{-1}$)	Productivity index ($kg \cdot cm^{-2}$ TCSA)
Mechanical pruning in May	66.5 a*	71.4 a	76.2 a	91.3 a	1.2 a
Mechanical pruning in June	54.6 a	68.9 a	81.1 ab	106.8 a	1.3 a
Hand pruning	84.4 b	90.7 b	97.0 b	95.8 a	1.0 a

* – in all the tables, means with the same letter do not differ significantly at $p < 0.05$ according to Duncan's multiple range t-test
** – trunk cross sectional area

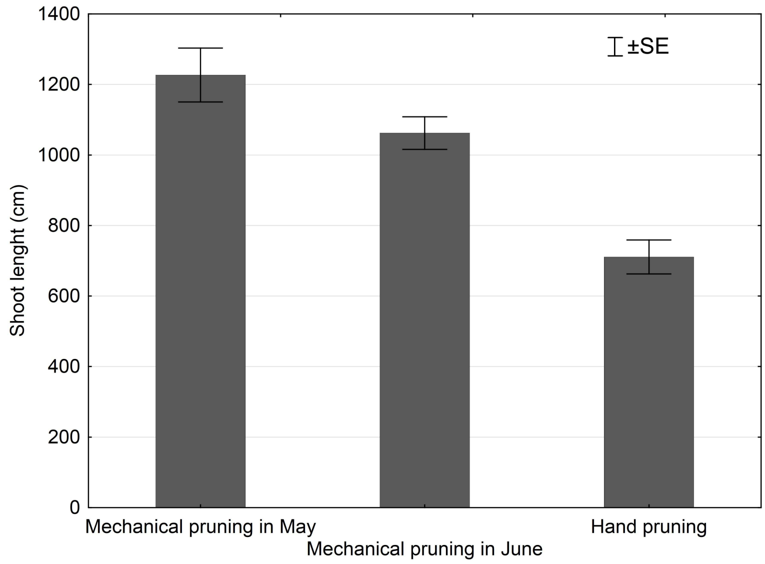
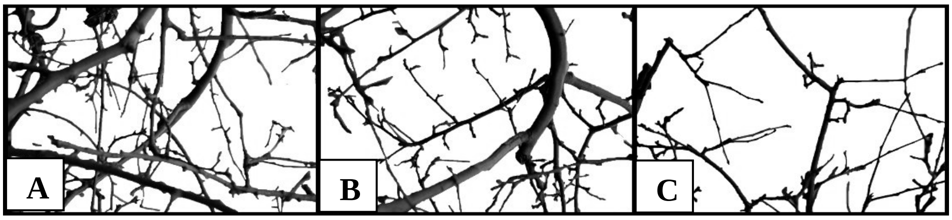


Fig. 1. Canopy density in three pruning treatments expressed as the length of shoots in a 80 × 60 cm canopy section



Fot. 1. Example photos of perpendicular canopy sections (80 × 60 cm) made in 2014, A – mechanical pruning in May, B – mechanical pruning in June, C – hand pruning

Table 2. Effect of mechanical and hand pruning in 2014 on solar irradiation levels within tree canopy compared to % of irradiation above trees

Treatments	Top tree	Middle part	Bottom
Mechanical pruning in May	48 a*	24 a	16 a
Mechanical pruning in June	38 a	21 a	18 a
Hand pruning	61 b	36 b	26 a

* –for explanations see Table 1

Table 3. Effect of mechanical and hand pruning on quality traits

	Treatments	Yield ($kg \cdot tree^{-1}$)	Mean fruit weight (g)	Firmness (pounds)	Brix (%)
2012	mechanical pruning in May	22.8 a*	162 a	15.2 a	15.6 b
	mechanical pruning in June	29.1 b	162 a	15.3 a	14.5 a
	hand pruning	32.7 b	174 a	15.2 a	15.6 b
2013	mechanical pruning in May	25.0 a	132 a	18.8 b	16.4 a
	mechanical pruning in June	30.4 a	130 a	18.5 b	16.4 a
	hand pruning	27.2 a	151 b	17.7 a	16.7 a
2014	mechanical pruning in May	43.5 ab	125 a	14.5 b	14.1 b
	mechanical pruning in June	47.3 b	123 a	14.7 b	13.4 a
	hand pruning	35.9 a	177 b	13.6 a	14.4 b

* – for explanations see Table 1

Table 4. Effect of mechanical and hand pruning on fruit size

	Treatments	Fruit size (%)		
		5.5–6 cm	6.5–7 cm	7.5–8.5 cm
2012	mechanical pruning in May	10.2 b*	55.6 a	34.2 a
	mechanical pruning in June	3.4 a	62.0 a	34.6 a
	hand pruning	3.4 a	48.1 a	48.5 b
		5.5–6 cm	6.5–7 cm	>7 cm
2013	mechanical pruning in May	14.9 b	69.6 a	15.5 a
	mechanical pruning in June	14.2 b	77.3 a	8.5 a
	hand pruning	4.2 a	54.2 a	41.6 b
		5–6.5 cm	7–7.5 cm	8–9 cm
2014	mechanical pruning in May	22.0 b	70.5 b	7.5 a
	mechanical pruning in June	21.1 b	69.4 b	9.5 a
	hand pruning	0.1 a	27.9 a	72.0 b

* – for explanations see Table 1

Table 5. Effect of mechanical and hand pruning on the percentage of fruit in four grades of red blush

	Treatments	Grades of blush (%)			
		<25	26–50	51–75	>75–100
2012	mechanical pruning in May	1.3 a*	10.2 a	39.0 a	49.5 b
	mechanical pruning in June	1.4 a	10.2 a	33.9 a	54.5 b
	hand pruning	5.5 b	19.0 b	37.5 a	38.0 a
2013	mechanical pruning in May	5.6 ab	27.8 b	34.2 a	32.4 a
	mechanical pruning in June	9.8 b	30.7 b	29.4 a	30.1 a
	hand pruning	3.7 a	20.0 a	33.7 a	42.6 b
2014	mechanical pruning in May	9.8 b	45.4 b	29.6 a	15.2 a
	mechanical pruning in June	17.0 b	52.2 b	25.2 a	5.6 a
	hand pruning	1.9 a	21.0 a	29.9 a	47.2 b

* – for explanations see Table 1

DISCUSSION

Fruit growers in Poland have been lately encouraged by foreign enterprises to buy numerous implements for mechanical pruning of fruit trees. These implements are not essential because most of fruit growers are well-equipped with modern platforms to prune the tops of trees, such as long, handy secateurs (loppers), which make the pruning work easy and fast. Due to the overwhelming advertisements of pruning machinery, many fruit growers have become interested in this new technology.

According to the current knowledge, mechanical pruning gives satisfactory results in plantations where selective pruning is not essential, like those of evergreen trees, e.g. citrus species and olives [Bordas et al. 2012, Ferguson et al. 2012]. The role of selective pruning in apple production is very important [Loreti 1971]. Selective pruning prevents over-fruiting, ensures easy penetration of sunlight into the interior part of tree canopy, guarantees acceptable fruit quality, and prevents trees from biennial bearing [Mika 1986]. Apple cultivars with a tendency to biennial bearing (eg. ‘Jonagold’) may become biennial for many years after producing excessive yields in one year. Selective pruning is most important in growing dessert fruits: apples, pears, peaches, apricots and sweet cherries. Manual, selective pruning of these species allows to regulate fruit density and to improve fruit size. Selective pruning improves light penetration into the interior of the fruit canopy and has an important influence on fruit red blush [Jackson et al. 1971, Mika et al. 2002]. Fruits smaller than the marketable size attract a very low price or must be sold as industrial fruits. Trees used for production destined partly as dessert fruit and partly as industrial fruit (plums, prunes, tart cherries, olives) are more suitable for mechanical pruning. In such cases, some percentage of small-sized fruit may be acceptable, and utilized for processing. Several trials published lately [Bordas et al. 2012, Dias et al. 2012] indicate that olive fruits and plums produced by mechanically pruned trees were of acceptable quality. In some trials, fruits were of a smaller size because of a higher yield due to mechanical pruning [Krueger et al. 2013]. Fruit thinning was inevitable after mechanical pruning. In olive plantations, mechanical pruning by topping and hedging is recommended to be carried out once every 5 to 8 years [Dias et al. 2012]. In such cases, trees are trimmed to the required height and spread without much effect on fruit quality. Mechanical pruning of apple trees creates more difficulties, as revealed a long time ago by Loreti [1971], Scaramuzzi [1968], Baldini [1974].

Trees pruned mechanically are able to produce as many fruits as trees pruned manually, or even more [Krueger et al. 2013]. However, lack of selective pruning has a negative effect on fruit size and colour. Mechanical pruning increases the tendency of trees to biennial bearing, which also creates additional work in fruit thinning. The only solution is to carry out topping and hedging, and then supplement this with selective thinning of shoots by hand. Both treatments altogether may take as much time as hand pruning alone [Baldini 1974]. Another solution is to implement mechanical pruning once every 3–4 years to regulate tree height and spread. Not all orchards are suitable for mechanical pruning. They should form continuous wall-like hedges. Trees planted at large distances, with large canopies, are not suitable for such treatments. Among the numerous reports concerning results of trials with mechanical pruning, the leading opinion is that mechanical pruning is only an additional treatment to hand pruning.

In the trial presented here, apple trees of the cultivar 'Pinova' had formed a compact, dense, tight wall after three years of mechanical pruning of the tree tops and sides. At the same time, the trees pruned manually retained their loose, transparent canopies. The results were evident in the measurements of canopy density by means of photographic images converted with a computer program to the total shoot length in a known canopy volume. Mechanical pruning also reduced illumination of the canopy, mainly in the upper and middle parts, where most of apples developed. For this reason the percentage of fruits with red blush was reduced. The lack of selective pruning increased fruit density, which was difficult to regulate with fruit thinning by hand. This resulted in lower mean fruit weight and smaller fruit size.

CONCLUSIONS

1. Mechanical pruning of apple trees with slotting saw changes unfavorably canopy structure and reduces illumination.
2. Mechanical pruning decreases fruit quality.

REFERENCES

Baldini, E. (1970). Meccanizzare la potatura e la raccolta. L'Italia agricola, 5, 411–416.

Baldini, E. (1974). Trends in training systems for deciduous fruit trees. XIX-th International Horticultural Congress, Warszawa 11–18 September, 3, 117–136.

Bordas, M., Torrents, J., Arenas, F.J., Hervalejo, A. (2012). High density plantation system of the Spanish citrus industry. Acta Hort., 965, 123–130.

Childers, N.F. (1983). Modern fruit science. Horticultural Publication. Gainesville. Florida 32606, 583 p.

Dias, A.B., Peca, J.O., Pinheiro, A. (2012). Long-term evaluation of the influence of mechanical pruning on olive growing. Agron. J., 104 (1), 22–25.

Ferguson, L., Glozer, K., Crisosto, C., Rosa, U.A., Castro-Garcia, S., Fichtner, E.J., Guinard, J.X., Lee, S.M., Krueger, W.H., Miles, J.A., Burns, J.K. (2012). Improving canopy contact olive harvester efficiency with mechanical pruning. Acta Hort., 965, 83–87.

Jackson, J.E., Sharples, R.O., Palmer, J.W. (1971). The influence of shade within tree position on apple fruit size, color and storage quality. J. Hort. Sci., 46, 277–287.

Krueger, W.H., Niederholzer, F.J.A., Fichtner, E. (2013). Investigation of pruning strategies for dried plums including hand, mechanical and combinations. Acta Hort., 985, 201–207.
Loreti, F. (1971). Prospettive della potatura meccanizzata negli alberi da frutto. Riv. Ortoflorofrutt. It., 3, 213–229.
Mika, A. (1986). Physiological responses of fruit trees to pruning. Hort. Rev., 8, 337–378.
Mika, A., Buler, Z., Treder, W., Sopyła, C. (2002). Relationship between fruit distribution within 'Jonagold' apple canopy, fruit quality and illumination. J. Fruit Ornam. Plant Res., 10, 75–84.
Scaramuzzi, F. (1968). Evoluzione nella potatura degli alberi da frutto. L'Italia Agric., 1, 71–85.

CIĘCIE MECHANICZNE JABŁONI JAKO ALTERNATYWA DLA RĘCZNEGO CIĘCIA

Streszczenie. Wysoki koszt ręcznego cięcia drzew owocowych i konieczność zatrudnienia do tej pracy pracowników z odpowiednimi kwalifikacjami skłania sadowników do podejmowania prób mechanicznego cięcia drzew. Wieloletnie wyniki doświadczeń i praktyka wskazuje, że cięcie mechaniczne jest możliwe u niektórych gatunków zimozielonych, jak rośliny cytrusowe lub oliwki, które nie wymagają ciecia selektywnego wewnątrz koron. W opisanym doświadczeniu 12-letnie jabłonie odmiany 'Pinova', szczepione na podkładce M.9, posadzone w rozstawie 4 × 1,5 m, prowadzone w formie wrzecionowej, były cięte mechanicznie w pierwszym tygodniu maja i w pierwszym tygodniu czerwca listwą tnącą marki STIHL. W obu terminach cięto drzewa z góry (topping) i z boków (hedging), starając się nadać im kształt stożkowy. Drzewa kontrolne cięto w kwietniu według standardowej metody stosowanej w Polsce, która polega na rozrzedzaniu korony i wycinaniu pędów starych z pozostawianiem pędów młodych. W okresie 3 lat cięcie mechaniczne zmieniło stopniowo strukturę koron. Korona stała się zwarta jak żywopłot wypełniona szczelnie pędami. Te zmiany udokumentowano za pomocą zdjęć poddanych obróbce komputerowej. Korony cięte mechanicznie były gorzej nasłonecznione w części środkowej i wierzchołkowej niż korony cięte ręcznie. Korony cięte mechanicznie zawiązywały więcej owoców niż korony cięte ręcznie i wymagały bardziej intensywnego przerzedzania zawiązków owocowych. Mimo przerzedzania miały skłonność do zbyt obfitego owocowania i wydawania drobnych owoców. Owoce miały mniej rozległy rumieniec. Jakość owoców odgrywa obecnie decydującą rolę w produkcji i dlatego cięcie ręczne jest koniecznym zabiegiem. Może być uzupełniane przez cięcie mechaniczne, głównie przez mechaniczne cięcie pędów wierzchołkowych.

Słowa kluczowe: regulacja wzrostu, struktura korony i nasłonecznienie

Accepted for print: 24.11.2015

For citation: Mika, A., Buler, Z., Treder W. (2016). Mechanical pruning of apple trees as an alternative to manual pruning. Acta Sci. Pol. Hortorum Cultus, 15(1), 113–121.