BIOLOGY OF FLOWERING AND FRUITING OF SOUR CHERRY TREES GROWN AT HIGH DENSITY

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(Received April 20, 2011/Accepted May 18, 2011)

A B S T R A C T

A study was carried out of shoot growth and branching, fruit bud setting and fruiting in four sour cherry cultivars: 'Debreceni Bőtermo', 'Nefris', 'Schattenmorelle' and 'Serocka'. Trees were planted at a high density (4 x 1.5 m), trained with a leader and pruned with the renewal method. A relationship was shown to exist between shoot length and fruit bud setting density. Trees of 'Debreceni Bőtermo' were found to be the most vigorous, setting fruit buds on weak shoots and two-year-old spurs. 'Nefris' and 'Serocka' were medium in vigour, setting fruit buds mostly on one-year-old shoots irrespective of shoot length. They were characterized by heavy branching. 'Schattenmorelle' trees were small, slowly growing, setting fruit buds on one-year-old shoots with only one terminal leaf bud. This type of fruiting led to bare wood. Pruning appropriate to tree morphology is suggested.

Key words: sour cherry, tree morphology, tree pruning

INTRODUCTION

The cultivation of sour cherry trees in Poland is of considerable economic importance. They are grown on about 35 thousand ha, and the amount of fruit collected annually varies between 180 and 200 thousand tonnes, except for the years when spring frosts damage flowers or fruitlets. About 65% of the harvested fruit is exported to Western Europe after initial processing (Nosecka, 2005). In traditional sour cherry orchards, trees were planted at a spacing of 5 x 3 m and were al-

lowed to develop their crowns cultivar 'Schattenmorelle', constituting 70% of sour cherry trees, formed dome-shaped crowns with trailing branches, which over the years became bare wood, devoid of small shoots and leaves. Short fruit-bearing shoots kept growing higher and higher up within the crown, and so it was necessary to cut back the tops of the branches every 2-3 years to bring the fruit-bearing zone closer to the ground (Mika, 1992).

In Western Europe and the USA, sour cherry trees grafted on Mazzard seedlings are planted at a low density, most often 6 x 6 m, cut back heavily after planting, with the trunk made to reach the height of 80 cm and the crown so formed that it consists of 3-4 branches without a leader. The fruits are harvested by shaking them off onto collecting screens with a trunk gripping device (Childers, 1985; Callesen, 1997). The cultivars grown there, such as 'Montmorency' in the USA, 'Stevensberry' in Danmark, 'Pandy' ('Kerezer') in Hungary, grow vigorously by nature and have a tendency to form a strong leader, which helps in forming the trunk to a height required for harvesting by shaking. 'Schattenmorelle' grown in Poland comes late into bearing fruit if the formation of a tall trunk is undertaken, because then it is necessary to cut off many lateral shoots in order to form the trunk (Mika et al., 1982). In the 1980s, a concept was born in Poland to plant sour cherry trees at a high density and to collect fruit with a continuously moving harvester, in freely. Under these conditions, the the same way currants are harvested. The new technology of cultivating sour cherry had been developing with some difficulty until Mika (2006) proposed a new way of pruning the trees after planting, the formation of crowns with a leader, and renewal pruning after they had formed. For this method, sour cherry trees are now planted in Poland at a spacing of 4 x 1.5 m and 4 x 2 m. After planting, all lateral branches are cut back to 1-2 buds. The leader is not cut back and so it gets to dominate over the lateral shoots and forms the vertical axis of the tree. After three years, renewal pruning is introduced, which consists in cutting off the oldest branches while leaving one- and two-year-old shoots within the crown. The vertical leader, up to a height of 3 m, and young pliable shoots make it possible to collect the fruits with a continuously travelling harvester (Mika et al., 2005).

In Poland, the leading cultivar in the cultivation of sour cherry is the very productive 'Schattenmorelle', which sets fruit abundantly after self-pollination (Szpadzik et al., 2009). The fruits are dark red in colour, highly valued by the processing industry. Unfortunately, 'Schattenmorelle' trees are difficult to shape and cut back, because along the shoots they form almost exclusively flower buds with usually one leaf bud at the tip of the shoot. After fruiting, the shoots are left as bare wood, without any leaves, terminated with one new extension growth. Because of abundant fruiting, the leader

has a tendency to lose its shape and become indistinguishable. These features become more pronounced when the trees grow on a poor soil. In extensive cultivation (at a density of 700 trees/ha), it is necessary to cut back the ends of the branches so that a suitable number of annual shoots can grow out (Mika, 1992).

The Hungarian cultivar 'Debreceni Bőtermo', originating from the old cultivar 'Kerezer', is valued in Poland for its early ripening, large and tasty fruits, which have both dessert and processing value. The trees grow vigorously, produce new long shoots and form long and stiff branches. This cultivar is allogamous and, as was shown by Szpadzik et al. (2009), it sets a negligible number of fruits after self-pollination. It requires the presence of pollinating cultivars, favourable weather conditions during flowering, and sufficient numbers of pollinating insects. 'Schattenmorelle' cannot be a pollinator for the cultivar 'Debreceni Bőtermo' because it flowers 7-10 days later. A good pollinator for 'Schattenmorelle' is the cultivar 'Nefris', which makes it necessary to plant it in orchards. 'Debreceni Bőtermo' grows well and produces abundant fruit, even on a poor soil, thanks to its innate vigour. The strong growth of this cultivar does not favour abundant fruiting.

The cultivar 'Nefris' is often planted as a pollinator for the cultivar 'Debreceni Bőtermo' because of a similar flowering time. It is self-pollinating. It grows fairly vigorously, but not as strongly as 'Debreceni Bőtermo'; it produces a lot of new growth, and bears fruit abundantly. Its fruits are also valued by the processing industry. However, its high susceptibility to fungal and bacterial diseases of stone fruit trees is a serious disadvantage.

The most sought after by the processing industry nowadays are small, very dark sour cherries of the local Polish cultivars commonly known as 'Sokówki' or 'Wiślanki'. The most frequently grown is 'Serocka 27' (Rozpara et al., 1996). The trees are full of vigour, produce a lot of new growth, form conical, dense crowns, didn`t become affected by the diseases of stone fruit trees, and bear fruit early and abundantly.

Studies of the structure of tree crowns were first begun by Halle et al. (1978). He found a high level of organization in the special arrangement of the shoots and buds, which, when shown in the form of a diagram, helps to understand the relationship between the individual organs of the tree. These studies were developed further in France (Lespinasse, 1977; Lauri et al., 1996, 1997) in an attempt to describe tree morphology in the form of mathematical formulae, which could be used to regulate the fruiting of trees. At present, these authors are trying to computerize the morphology of the most important cultivars of apple. Costes et al. (1997) are of the opinion that the knowledge of the architecture of trees is the key to the understanding of their growth and fruiting strategy.

MATERIAL AND METHODS

The aim of the study was to determine the crown structure of a few most frequently grown sour cherry cultivars planted at a high density and pruned using the renewal method, and to find out if the growth and fruiting biology of these trees is significantly different from that of freely growing cherry trees. The crown structure can be described in terms of the percentage share of shoots of different age and length, their tendency to branching, and especially their ability to set flower buds. The knowledge of the growth and fruiting character of the most common sour cherry cultivars makes it possible to carry out rational pruning in a densely planted orchard.

The experiment and observations were carried out in the Experimental Orchard in Dąbrowice in the years 2005-2010, in the sector occupied by densely planted sour cherry trees, whose fruits were to be collected with a combine harvester. The experimental plantation consisted of four sour cherry cultivars grafted on *Prunus mahaleb*: 'Debreceni Bőtermo', 'Nefris', 'Schattenmorelle' and 'Serocka'. The plantation was situated on a podsolic, sandy-loam soil of Quality Class IV B. The study made use of experimental plots with a tree spacing of 4 x 1.5 m (1666 trees/ha), on which the fruits were picked by hand so that their quality could be compared with the quality of those collected with a combine harvester. A single experimental plot consisted of three trees and was replicated 4 times. On these plots, over a period of 6 years, tree growth vigour was assessed by taking annual measurements of the trunk's diameter, converted later into the trunk's cross-sectional area. The measurements also included the height and span of the crowns, the number of new shoots in specific length classes, and the percentage of flower buds on annual and older shoots. From the third year of tree vegetation, the structure of the crowns was studied. In the autumn, the new shoots were counted and measured, and described in terms of the way in which they branched. In the spring, inflorescences were counted on the shoots, classified at 20 cm intervals in order to determine the relationship between shoot length and flower bud density. Two three-year-old branches coming off the leader were chosen for that purpose. The results were evaluated statistically and presented in the form of tables and graphs.

The significance of differences between means was evaluated by Duncan's multiple range t-test at $p = 0.05$.

RESULTS

The planted trees had been growing vigorously, so in the third year they had already formed wide, shapely crowns with a leader of about 2 m in height. The most heavily branched trees were those of the cultivars 'Serocka' and 'Nefris', which in the third year had about 40 branches coming off the leader, while the trees of 'Schattenmorelle' were the least branched

(15 branches). The number of new annual shoots in the third year ranged from 250 in 'Schattenmorelle' to 800 on the trees of 'Serocka'. The trees in the third year blossomed profusely. The cultivars 'Nefris' and 'Serocka' each developed about 4000 flowers per tree, and the other cultivars from 1200 to 2000. During the 6-year study period, the cultivars 'Debreceni Bőtermo' and 'Nefris' came into flower on average between April 28 and 31, while the 'Schattenmorelle' and 'Serocka' between May 7 and 10. Because of the difference in the time of flowering, only the cultivar 'Nefris' could perform the role of a pollinator for the allogamous cultivar 'Debreceni Bőtermo'. The trees of all the cultivars blossomed abundantly every year, but in the third year after planting (2007) the fruitlets were completely destroyed by a May frost. In the fifth year (2009), the fruitlets of the cultivar 'Schattenmorelle' got frostbitten. Measurements of the trunk's diameter and crown span revealed the strongest growth of the trees of the cultivars 'Serocka' and 'Debreceni Bőtermo', significantly weaker growth of the cultivar 'Nefris', and very weak growth of the cultivar 'Schattenmorelle'. The trees of 'Schattenmorelle' were significantly the shortest in relation to the other cultivars and their crowns had the smallest span (Tab. 1).

Detailed measurements of the length and number of shoots on selected branches showed that most shoots (about 60%) in the cultivars 'Schattenmorelle', 'Nefris' and 'Serocka' fell in the length range of > 20-30 cm. About 15% of shoots was in the range of up to 30 cm and in the range of > 30-40 cm (Tab. 2). The cultivar 'Debreceni Bőtermo' produced much longer shoots, even up to 1 m long, and so in the length ranges of > 30-50 cm there were recorded twice as many shoots as for the other cultivars. The propensity of the trees for producing new growth manifested itself in the number of bifurcations recorded on 3-year-old branches (Tab. 3). The trees of the cultivars 'Nefris' and 'Serocka' formed twice as many bifurcations as the cultivar 'Debreceni Bőtermo', and four times as many as the 'Schattenmorelle'.

Table 1. Trunk cross-sectional area, tree height, and crown span in the sixth year after planting (2010)

Cultivar	TCSA [cm²]	Tree height [m]	Crown span [m]
Debreceni Bőtermo	38.36 bc*	3.15 c	2.03 ab
Nefris	33.21 b	2.77 bc	2.08 ab
Schattenmorelle	24.58 a	2.36 a	1.94 a
Serocka	41.53 c	3.08 bc	2.25 b

*Means were evaluated within the columns. Duncan's multiple range t-test at p = 0.05

Table 2. Percentage of one-year-old shoots in length classes from 10cm to 100 cm

Shoot length [cm]	Debreceni Bőtermo	Nefris	Schattenmorelle	Serocka
< 10	8.5	16.8	11.8	17.0
11-20	22.0	30.3	29.9	37.2
21-30	31.5	31.8	34.7	30.6
31-40	24.7	16.8	15.9	11.5
41-50	7.5	3.7	4.8	3.1
51-60	2.7	0.6	3.0	0.7
61-70	2.0	-	-	-
71-80	0.7	-	-	-
81-100	0.3	-	-	-

Table 3. Average number of bifurcations on a three-year-old branch (2008-2010)

	Debreceni Bőtermo	Nefris	Schattenmorelle	Serocka
Number of bifurcations	21.7 b*	48.1 c	12.5 a	48.1 c

*Means were evaluated within the line. Duncan's multiple range t-test at p = 0.05

Table 4. Percentage of inflorescence buds on annual, two-, and three-year-old shoots in the sixth year after planting (2010)

Cultivar	Annual shoots	Two-year-old shoots	Three-year-old shoots
Debreceni Bőtermo	74.4 a*	13.0 c	12.6 c
Nefris	98.4 c	0.1 a	1.5 a
Schattenmorelle	99.5 c	0.2 a	0.3 a
Serocka	88.6 b	5.1 b	6.3 b

*Explanation, see Table 1

In the cultivar 'Schattenmorelloe', all lateral buds on the shoots were flower buds, and only at the tip of the shoot was there a leaf bud. In the other cultivars, the leaf buds were situated at the base of the shoots and at their tip, with the flower buds occupying mainly the middle section of the shoots. In all the cultivars, the overwhelming majority of the flower buds could be found on one-year-old shoots, and only a slight percentage on older growth. The cultivar 'Debreceni Bőtermo' was the only one to set about 30% of buds on dwarf shoots (spurs) seated on two- and three-year-old shoots (Tab. 4). With the exception of the cultivar 'Serocka', all the other cultivars were found to set fruit abundantly (20-40%) in relation to the number of inflorescences. 'Sokówka Serocka'

Table 5. Fruit setting in 2008-2010

Cultivar	Percentage of fruitlets in relation to the number of flowers		
	2008	2009	2010
Debreceni Bőtermo	26.0 b	27.1 b	23.0 b
Nefris	22.5 b	31.3 b	42.7 cd
Schattenmorelle	34.2 bc	37.4 bc	36.2 c
Serocka	4.3 a	2.4 a	7.5 a

*Explanation, see Table 1

Table 6. Yielding of sour cherry trees in 2008-2010

Cultivar	Yield [kg/tree]			Total yield 2008-2010 [kg/tree]
	2008	2009	2010	
Debreceni Bőtermo	6.0 b*	6.3 b	6.1 c	18.4 c
Nefris	5.8 b	2.2 a**	5.1 bc	13.1 bc
Schattenmorelle	5.1 b	**	4.2 b	9.3 ab
Serocka	1.6 a	2.8 a	2.5 a	6.9 a

*Explanation, see Table 1
**Zero yield or drop in yield caused by frost damage

was poor at setting fruit, only 3-7% in relation to the number of inflorescences (Tab. 5). Fruit yields until the sixth year after planting (2010) were not sufficiently high, ranging from 4 to 6.3 kg per tree, except for the cultivar 'Serocka', which produced yields half as big. With 1666 trees per hectare, the maximum annual yield was 10 tonnes/ha, which is in contrast with the expected 15 tonnes. The most abundantly fruiting cultivar was 'Debreceni Bőtermo' (Tab. 6).

The relationship between the length of one-year-old shoots and their ability to set flower buds is an important indicator as to the way in which trees should be cut back. This relationship was studied for three years in the cultivars 'Nefris', 'Schattenmorelle' and 'Debreceni Bőtermo', which differed most in the character of their growth and fruiting (Fig. 1, 2, 3). A linear regression analysis revealed a highly significant, positive correlation between the length of shoots of the cultivar 'Nefris' and the number of flower buds growing on them (Fig. 1). This means that in this cultivar there is a fixed distance between the flower buds on the shoot regardless of the length of the shoot. In the cultivars 'Schattenmorelle' and 'Debreceni Bőtermo', the number of flower buds increased with the length of the shoot, but only if its length was in the range of 20-60 cm. Longer shoots were found to have fewer flower buds. This means that longer shoots have a lower potential ability to produce a high yield in comparison with shorter shoots. This relationship manifested itself particularly clearly in the 'Debreceni Bőtermo'.

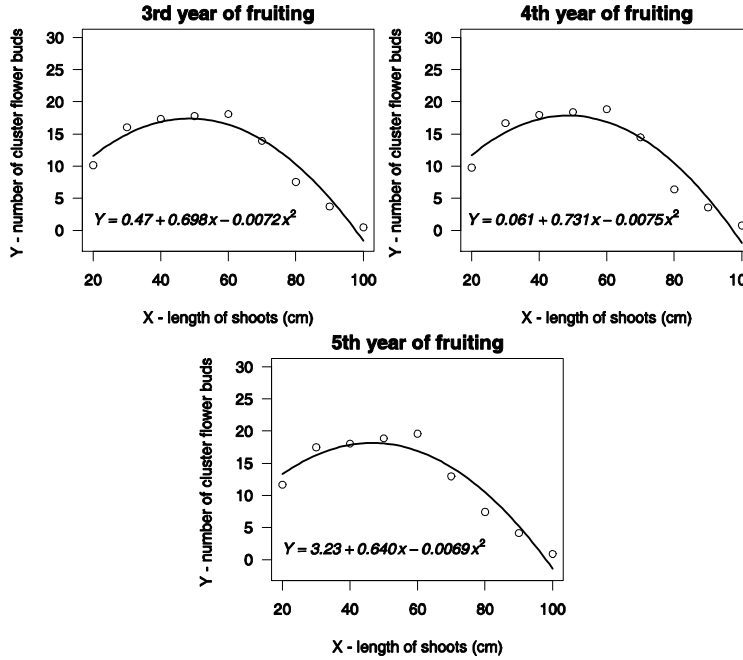

Figure 1. Relationship between shoot length and flower bud setting density in 'Debreceni Bőtermo' (linear regression)

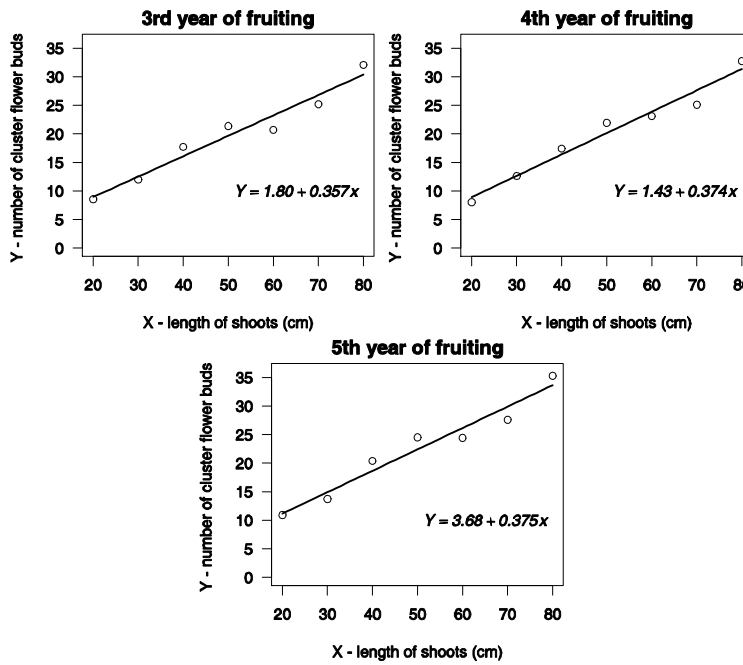

Figure 2. Relationship between shoot length and flower bud setting density in 'Nefris', R = 0.95 (linear regression)

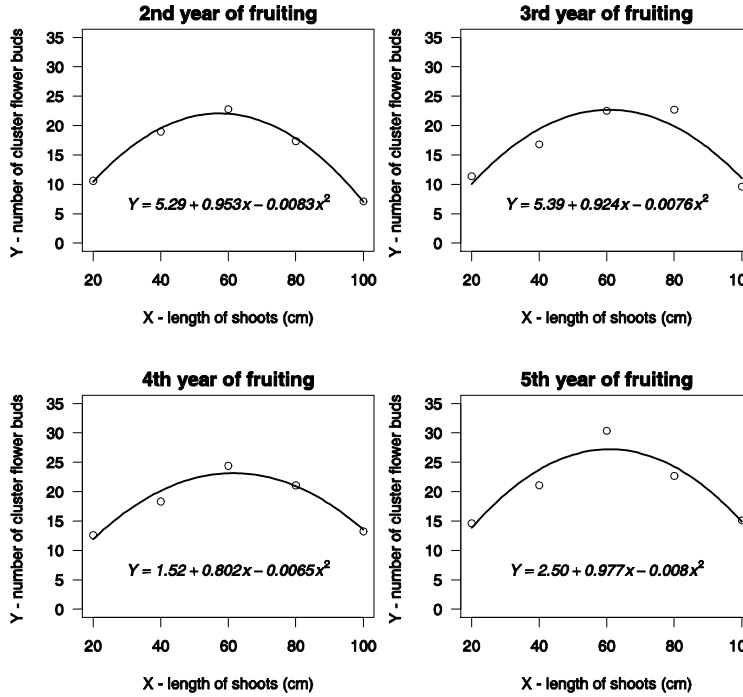

Figure 3. Relationship between shoot length and flower bud setting density in 'Schattenmorelle' (linear regression)

The number and location of leaf buds had a significant effect on the branching of the trees (Tab. 3-4). The 'Nefris' and 'Serocka' produced twice as many new shoots as 'Debreceni Bőtermo' and four times as many as 'Schattenmorelle'. The growth and fruiting character of 'Schattenmorelle' trees was the reason why, with hardly any new growth, two- and three-year-old, as well as older, shoots remained as bare wood after fruiting. The renewal type of pruning used in the experiment from the third year of tree life stimulated the shoots to grow more vigorously to an extent greater than the traditional thinning of the crowns observed among the trees planted at a low density. With renewal pruning, there appeared in the crown sylleptic shoots, i.e. shoots that branch out as they grow. The main shoot was then seen to set flower buds, and the sylleptic shoots – leaf buds. As a result, the structure of the crown was more favourable to fruiting, full of numerous new shoots, which do not usually appear after the traditional thinning of the crowns. In spite of that, it was not possible to completely prevent the shoots from becoming bare wood.

The way in which cultivars bear fruit is a result of how the flower and leaf buds are arranged on the shoots (Fig. 4, 5, 6). In the cultivar

Figure 4. Arrangement of the leaves and fruits on the shoots of ‘Debreceni Bőtermo’

Figure 5. Arrangement of the leaves and fruits on the shoots of ‘Nefris’

Figure 6. Arrangement of the leaves and fruits on the shoots of 'Schattenmorelle'

'Debreceni Bőtermo', most of the fruits are on the leaved annual and two-year-old shoots (Fig. 4). The 'Nefris' has fruits also on the leaved annual and two-year-old shoots, which are heavily branched (Fig. 5). In the cultivar 'Schattenmorelle', almost all of the fruits can be found on last year's, leafless shoots (Fig. 6). The annual growth extension at the tip of the shoot is rather short, with very few leaves, so the ratio of the number of leaves to fruits is three times lower than in the other cultivars described in this experiment.

DISCUSSION

The results of the experiment confirmed the opinion presented by Halle et al. (1978) and Costes et al. (1997) that the knowledge of the architecture of a tree is very helpful in training it. The most important result of this work was the determination of the relationship between the length of annual shoots and the location and density of the flower bud setting. Among the four cultivars used in the experiment large differences were found in the character in which they grow, set flower buds and bear fruit. The cultivar 'Debreceni Bőtermo', planted in Polish orchards in increasingly larger numbers, is very tolerant of light, sandy soils. On a light soil, the trees grow moderately, produce new shoots up to 50 cm long, on which flower buds set in abundance. However, when growth is vigorous, flower buds do not set on the annual shoots, (but?) on spurs that grew out on two- and three-year-old shoots. Fruiting of young trees is delayed. The growth character of 'Debreceni Bőtermo' trees makes it easier to shape the trees with a taller trunk designed for harvesting by means of shaking devices. Renewal pruning of the trees of this cultivar should be moderate so as not to encourage them to grow vigorously. After pruning there should be one-, two- and three-year-

old shoots left in the crown. This is possible because the trees form loose crowns. The experiment confirmed the observations (Szpadzik et al., 2009) that this cultivar, being allogamous and flowering early, requires a pollinating cultivar with a similar time of flowering.

The 'Nefris' and 'Serocka' normally produce a lot of shoots, develop numerous sylleptic shoots, and branch heavily. They set flower buds mainly on annual shoots regardless of the length of those shoots. The length of shoots in these cultivars has no significant effect on the density of flower bud setting. The trees of these cultivars, when planted at a high density and pruned with the renewal method, do not change their growth or fruiting character in relation to their natural growth in the conditions of low planting density and the traditional way of thinning. The highest number of new shoots is produced by 'Serocka', and that is why the trees planted at a high density and pruned with the renewal method require rotation of shoots every two years. After pruning, only the annual and two-year-old shoots should remain, and those shoots need to be thinned out as well. The crown structure in these cultivars is favourable to the abundant setting of flower buds and to flowering; however, the ability to set fruit in relation to the number of flowers is low, ranging from 6 to 8%, while in the cultivar 'Schattenmorelle' it is around 30% (Szpadzik et al., 2009). The length of shoots in these cultivars had no effect on flower bud setting density.

In the cultivation of 'Schattenmorelle', the main problem is the weak and slow growth of the trees, the shoots becoming bare wood, and the weeping habit of the crown, which makes it difficult to harvest fruit mechanically. The necessity to form the trunk to a height of about 80 cm, as required by fruit shaking harvesters, causes a considerable delay in the bearing of fruit (Mika et al., 1982). To be able to grow and bear fruit properly, this cultivar requires rich soils and an ample supply of water. In the experiment described here the soil of Quality Class IV B and irrigation were not enough to ensure vigorous tree growth. 'Schattenmorelle', like 'Debreceni Bőtermo', has the highest density of flower buds on short, annual shoots (up to 30-40 cm). The number of long shoots in the crown, which have a lower density of flower buds, is in this cultivar so low that the density of flower buds on the shoots is of no economic importance. Long shoots with flower and leaf buds are highly desirable in this cultivar because this prevents the branches from becoming bare wood and is favourable to the development of the crown. In spite of abundant flowering and equally abundant setting of fruits, yields can be low because of the small dimensions of the crowns. The use of renewal pruning clearly stimulated the growth of sylleptic shoots, which set not only flower buds but also leaf buds. The shoots growing out of those buds made it possible to avoid cutting back the tops of the branches, which is necessary in the traditional

cultivation of sour cherry. However, there were too few new shoots to suitably fill up the crown.

CONCLUSIONS

1. The four cultivars of sour cherry commonly grown in Poland, 'Debreceni Bőtermo', 'Nefris', 'Schattenmorelle' and 'Serocka', differ considerably in their growth intensity, crown structure, flower bud arrangement on the shoots, and in their ability to set fruit and produce abundant crops.
2. The 'Debreceni Bőtermo' blossoms and bears fruit abundantly on short shoots (spurs). Any factors that contribute to vigorous growth of the trees of this cultivar may delay or inhibit the bearing of fruit.
3. The 'Schattenmorelle' grows poorly and sets only flower buds (except for the terminal bud) on short shoots (spurs). This growth and fruiting character prevents the shoots from branching out and makes the crown develop slowly. Any factors that favour vigorous growth of the trees of this cultivar become significant yield-enhancing factors.
4. The 'Nefris' grows moderately, branches heavily, sets flower buds regardless of the length of the shoots, is tolerant of average growth conditions, and produces fruit in abundance.
5. The 'Serocka' grows vigorously, branches out heavily, sets flower buds irrespective of the length of the shoots, is tolerant of poor soils, but does not set many fruits and is not very productive.

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BIOLOGIA KWITNIENIA I OWOCOWANIA WIŚNI UPRAWIANYCH W ZWARTEJ ROZSTAWIE

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

Badano strukturę koron, intensywność wzrostu pędów i ich rozgałęzianie się, gęstość osadzenia pąków kwiatowych, obfitość kwitnienia i owocowania czterech odmian wiśni: ‘Debreceni Bőtermo’, ‘Nefris’, ‘Łutówka’ i ‘Serocka’ w gęsto posadzonym sadzie w rozstawie 4 x 1,5 m, ciętym metodą odnawiającą. Stwierdzono intensywny wzrost drzew odmiany ‘Debreceni Bőtermo’, umiarkowany ‘Nefris’ i ‘Serocka’ oraz bardzo słaby ‘Łutówka’. Wykazano związek między długością przyrostów rocznych, a gęstością osadzenia pąków kwiatowych u odmian ‘Debreceni Bőtermo’ i ‘Łutówka’. Słaba zdolność ‘Debreceni Bőtermo’ do zawiązywania pąków kwiatowych na długich przyrostach może opóźniać owocowanie tej odmiany, jeśli drzewa rosną silnie. Bardzo słaby z natury wzrost drzew odmiany ‘Łutówka’ i brak pąków liściowych na przyrostach rocznych utrudnia formowanie koron, powoduje ogałacanie się gałęzi i nie dorastanie drzew do wymaganych parametrów. Zalecane jest intensywne cięcia odnawiające drzew badanych odmian.

Słowa kluczowe: wiśnia, morfologia drzew, cięcie drzew