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Effects of Summer Pruning on Vegetative Growth, Fruit Quality and Carbohydrates of 'Regina' and 'Kordia' Sweet Cherry Trees on 'Gisela 5'

V. Usenik, A. Solar, D. Meolic and F. Štampar
(University of Ljubljana, Biotechnical Faculty, Agronomy Department, Ljubljana, Slovenia)

Summary

Five-year-old sweet cherry trees of 'Kordia' and 'Regina' were summer pruned in 2003, 2004 and 2005. Pruning in 2003 consisted of three treatments of heading new shoots (0, 33.3 and 66.6 % of the length of annual shoots was removed), in 2004 of pruning like in 2003 and by thinning vigorous branches, and in 2005 of thinning of vigorous branches only. Summer pruning positively influenced vegetative growth and fruit quality of 'Kordia' and 'Regina' on 'Gisela 5' and had no negative effect on the content of soluble carbohydrates in the dormant shoots. Pruning to remove some major branches promoted better fruit quality than did heading of annual shoots. Control trees had a similar yield and yield efficiency as pruned trees but lower fruit weight and quality. Trees of 'Kordia' and 'Regina' on 'Gisela 5' should be pruned annually to avoid the development of blind wood and to balance canopy F:LA for high sweet cherry fruit quality. Trees of 'Regina' should be pruned more strongly than those of 'Kordia'.

Key words. sweet cherry – pruning – summer – fruit – quality – yield efficiency – growth

Introduction

Fruit weight is the most important character of sweet cherry (*Prunus avium* L.) fruit quality (Usenik et al. 2005). Introducing precocious, vigour-controlling rootstocks, as 'Gisela 5' (Stehr 2005; Usenik et al. 2006) in sweet cherry production often results in high yields of small fruits. The reduction of fruit quality may be a consequence of higher ratios of fruit number to leaf area (F:LA) (Whiting and Lang 2004). Poor management of a high density orchard system can provide disastrous results for yields, fruit quality and tree longevity (Lang 2005). A relationship exists between fruit quality, yield, and LA in sweet cherry canopies, particularly on dwarfing rootstocks. Balancing canopy F:LA is critical for improving sweet cherry fruit quality on dwarfing rootstocks. Pruning strategies are being investigated from that point of view (Whiting and Lang 2004). Precise shoot pruning is important for optimising relationships between shoot growth, source leaf area, current photosynthesis, annual building of storage reserve and the ultimate realisation of good yields of high quality fruit (Lang 2001).

Both young and mature trees on Gisela stocks must be pruned more aggressively than those on Mazzard (Lang 2001), but in many parts of the world where sweet cherries are grown, trees may be severely damaged by bacterial canker (*Pseudomonas mors prunorum* and *P. syringae*). Because of this risk, many sweet cherry growers in Europe perform pruning in summer (Flore et al. 1996) because trees are less likely to become infected (Müller and Storck 1991). Shading can have a profound effect on the vegetative and reproductive growth of sweet cherry, especially in high density orchards (Flore et al. 1996). Summer pruning reduces shading within the canopy and stimulates new shoot growth of apricots (Küden and Son 2000). Cherries are unique among deciduous tree fruits because of their short period between flowering and harvest (Roper and Kennedy 1986). Spur leaves alone do not have the capacity to support maximum fruit growth in sweet cherry and must be supplemented by photosynthates from other sources. During stage III of fruit development, much of the additional carbohydrate for fruit growth on 2-year-old spurs must come from leaves on 1-year-old wood and from current season growth (Roper et al. 1987). Since vegetative vigour can slow as cropping begins, especially on precocious rootstocks such as 'Gisela 5' (Lang 2001), the stimulation of new vegetative growth with precise shoot pruning is needed.

Summer pruning caused very little to no regrowth of 'Sweetheart' sweet cherry trees on Mazzard rootstock and fruit size was unaffected (Kappel et al. 1997). Young sweet cherry trees ('Bing' on 'Damil' rootstock) can be pruned about 45 days after full bloom (DAFB) by heading the shoots to 15 to 20 cm to maximize the benefits of summer pruning on initiating new flowers (Guimond et al. 1998). In a trial with the cherry rootstocks '*Prunus avium*', 'CAB 11E', 'Maxma 14', 'Gisela 5' and 'Edabriz' pruning severities were applied (0, 30, 60 and 90 % of the new vegetative growth was removed). Pruning significantly affected root length and weight of the rootstocks (Gonçalves et al. 2003). Delaying pruning until after harvest can reduce the subsequent accumulation of storage

reserves, thereby reducing the resources available for subsequent season vigour (LANG 2005).

There are few data about the effect of pruning on vegetative growth and the relationship between crop load and fruit quality in sweet cherry production when using standard non-precocious, and especially when using precocious (e.g., 'Gisela 5') rootstocks. Also, there are no exact data about the vegetative characteristics and fruiting habit of the most important sweet cherry cultivars for middle Europe, 'Kordia' and 'Regina'. The objective of this research was to study the effects of severity of summer pruning on accumulation of carbohydrates in shoots, vegetative and reproductive growth, fruit quality and yield efficiency of the two light-bearing sweet cherry cultivars 'Kordia' and 'Regina' on 'Gisela' 5 rootstock.

Materials and Methods

'Kordia' and 'Regina' sweet cherries on the rootstock 'Gisela 5', planted in spring 1999 and spaced 2.5 x 4 m, were trained to a Vogel spindle (VOGEL 1994) at Fruit Growing Centre Gacnik (Slovenia). Trees were irrigated with under-tree drippers. Thirty experimental trees were selected per cultivar on the basis of uniform vigour (according to trunk diameter). Trees were assigned to a randomised complete block design of two blocks (orchard location) per cultivar and tree treatments per block. Five trees were selected per treatment. Treatments were applied to whole trees. Two comparable branches on two different parts of every tree, 1 to 2 m above ground level, were selected per tree for measurements. Standard orchard management practices (irrigation, fertilization, pest control) were followed in all years.

Pruning treatments

Pruning treatments imposed 3 June 2003 (38 DAFB) consisted of a control (no pruning, T1), removal of $^1/_3$ of the length of all new shoots, longer than 20 cm (T2) and removal of $^2/_3$ of the length of all annual shoots (T3). Pruning in 2004: **pruning treatments in block 1** were imposed in the middle of July 2004 as noted for 2003, **pruning in block 2** was imposed by thinning pruning: i.e., 2 to 3 vigorous branches per tree were thinned out (basal diameter greater than half of the diameter of the leader). Pruning in 2005 was imposed in the middle of July, in all trees by thinning pruning as described for 2004.

Vegetative characteristics

Trunk diameter at 40 cm above the ground level was measured at the end of dormancy in spring 2003, and in 2004 and 2005 during the dormant period. From trunk diameter data trunk cross-sectional areas (TCA) were calculated. Basal diameters of two randomly selected branches per tree were measured on 27 April 2004 and 24 April 2005. On two selected branches per tree, the result of 2003 pruning was observed on 5 July 2004: the number of dead shoots, the number of new shoots and the length of new shoots in July 2004. 'Dead shoots' are ones that grew in 2003, from which $^1/_3$ or $^2/_3$ of the length were removed and died between pruning and season 2004.

Reproductive characteristics per branch

The number of flowers was counted on selected branches in 2004 and 2005. Fruit set was calculated from the number of flowers and mature fruits on individual branches. Flowers and mature fruits were counted on two branches per tree. Flowers were counted at the beginning of flowering (27 April 2004 and 24 April 2005) and mature fruits at harvest ('Kordia': 5 July 2004, 23 June 2005 and 5 July 2006; 'Regina': 5 July 2004, 5 July 2005 and 10 July 2006). Fruit number per branch and yield per tree were recorded at harvest ('Kordia': 69 DAFB in 2004 and 60 DAFB in 2005; 'Regina' 69 DAFB in 2004 and 72 DAFB in 2005**).** Fruit weight per branch was calculated from the total fruit mass per branch and the number of fruits per branch.

Yield and fruit quality per tree

Yields per tree were recorded in years 2004, 2005 and 2006. From each tree, mean fruit weight was calculated from a representative sampling of 50 fruits per tree. Yield efficiency (kg cm^{-2}) was calculated using the ratio of each year's yield to TCA or using the ratio of cumulative yield of two or three years to TCA.

Carbohydrates in the bark of dormant shoots

After summer pruning in 2003 annual shoots were collected at the beginning of dormancy (29 October 2003). Three shoots per tree were sampled. Shoots were analysed for the content of individual sugars (glucose, fructose, sucrose) and sorbitol. Phloem with cambium was used and prepared for analyses. The content of sugars was measured with High Performance Liquid Chromatography method (HPLC - Thermo separation products, Riviera beach, USA), using an isocratic method according to ŠTURM et al. (1999) on a Rezex RCM-monosacharide (300 x 7.8 mm) column.

Statistic analyses

Analyses were conducted with the program Statgraphics Plus 4.0. One-way ANOVA was used to analyse the effect of pruning on vegetative growth and reproductive parameters (yield, fruit quality) measured per tree. Two-way ANOVA was used to analyse the effect of the factors cultivar, pruning and block on vegetative growth and reproductive parameters measured per branch. Differences between treatments were estimated with LSD test and Duncan's multiple range test (α<0.05).

Results and Discussion

Carbohydrates in dormant shoots

In 'Kordia' and 'Regina' sweet cherry, both on 'Gisela 5', the content of glucose, fructose, sucrose and sorbitol was analysed in the bark of dormant shoots from the preceding growing season (Fig. 1). Sucrose and sorbitol had the highest values compared to other soluble carbohydrates. KELLER and LOESCHER (1989) showed that sucrose was the predominant soluble carbohydrate during dormancy, but sorbitol dominated during active growth of 'Bing'/Maz-

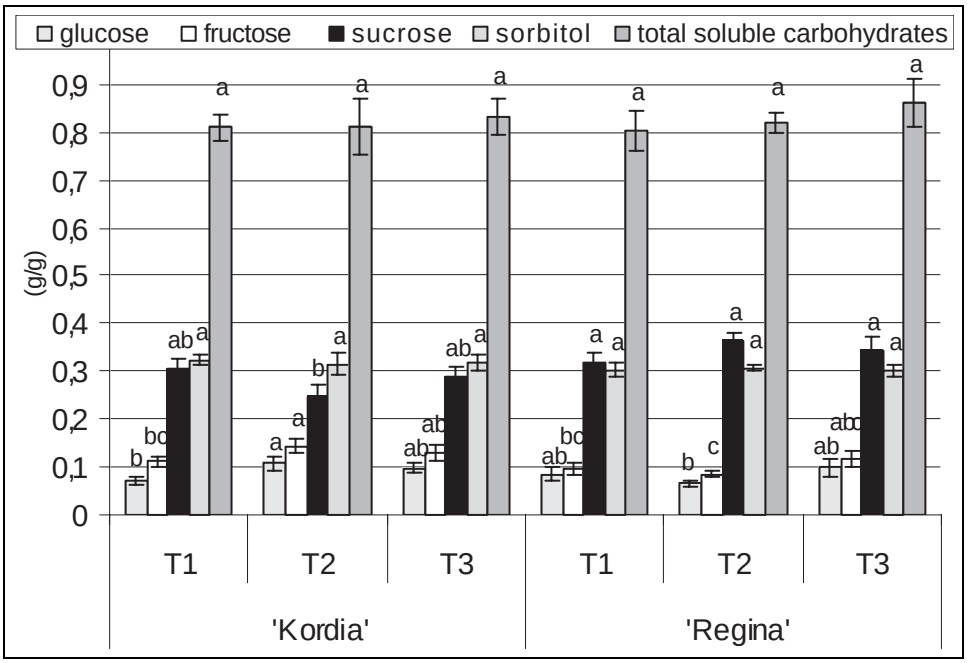


Fig. 1. Effects of summer pruning in 2003 (treatments (1–3) on the content of soluble carbohydrates in dormant shoots of 'Kordia' and 'Regina' sweet cherry on 'Gisela 5' rootstock. Mean separation by Duncan's New Multiple Range Test (P=0.05).

zard sweet cherry. VEBERIC et al. (2003) showed that sorbitol reached the highest bark concentration at the end of the season in apple, while the contents of sucrose, glucose and fructose were lower. Generally, in the present experiment there were no significant differences between 'Kordia' and 'Regina' in the content of glucose, sorbitol and the sum of carbohydrates. 'Kordia' had a higher content of fructose and lower content of sucrose than 'Regina'. According to pruning treatments glucose and fructose contents were higher in pruned 'Kordia' shoots ($^1/_3$ = T2, $^2/_3$ = T3) compared to control trees (T1). CLAIR-MACZULAJTYS et al. (1994) showed that after summer pruning the middle and upper parts of the trunk of sweet cherry contained the highest concentrations of starch and soluble sugars. None of the dormant pruning treatments in apple trees affected combined concentrations of sorbitol and glucose analysed together by REICH (1985). Pruning had no effect on the content of sorbitol, sucrose, or total carbohydrates in either cultivars as shown in the present experiment (Fig. 1). Pruning did not affect the content of glucose and fructose in 'Regina' shoots. In 'Kordia' T2 resulted in more glucose and fructose and less sucrose than in control trees; differences between T3 and the control were not significant. Our results are not in agreement with the statement of LANG (2005) that pruning until after harvest can reduce the subsequent accumulation of storage reserves. Starch was shown to be the most common storage material by KELLER and LOESCHER (1989) but was not measured in our analyses. Starch and soluble sugar concentrations were quite similar in the lower and upper parts of the trunk of sweet cherry, the concentrations of soluble sugars were

Table 1. Branch circumference, branch growth increment 2004–2005 and the number of headed shoots per branch of 'Kordia' and 'Regina' sweet cherry on 'Gisela 5' rootstock. Values in a vertical row followed by a different letter are significantly different at α<0.05 by Duncan multiple range test.

Cultivar	T*	Branch circumference 2004 (mm)		Branch growth increment (mm)	Headed shoots branch^{-1} (no.)	
		Branch 1	Branch 2	2004–2005	Branch 1	Branch 2
'Kordia'	1	39.3±2.5	42.0±2.0	2.6±0.6 b	0.0±0.0 c	0.0±0.0 c
	2	43.8±1.5	42.1±2.0	6.4±1.1 a	7.9±1.5 a	9.2±1.3 a
	3	42.9±3.0	40.7±1.3	4.6±1.1 ab	8.2±0.6 a	6.6±0.7 ab
'Regina'	1	43.7±2.4	43.4±1.7	5.6±1.0 ab	0.0±0.0 c	0.0±0.0 c
	2	43.7±2.3	43.9±2.7	5.8±1.1 ab	3.1±0.8 b	4.4±0.9 b
	3	41.5±2.2	43.9±1.8	6.9±1.4 a	5.5±0.8 ab	7.5±1.5 ab

*Pruning treatments were imposed 3 June 2003 (38 DAFB) as follows: T1 = control (no pruning), T2 = removal of $^1/_3$ of the length of all current shoots longer than 20 cm, and T3 = removal of $^2/_3$ of the length of all current shoots. In mid-July 2004, these were repeated in block I, and in block 2, pruning was by thinning of branches. In mid-July 2005, all pruning (both blocks) was by thinning as in block 2 in 2004.

generally higher than those of starch (Clair-Maczulajtys et al. 1994).

Vegetative characteristics per branch

There were no differences in basal diameters of selected branches between cultivars and treatments. On average, more annual shoots were headed per branch on 'Kordia' than on 'Regina' (Table 1). There were no significant differences in the number of headed shoots per tree between T2 (214) and T3 (250) in 'Kordia' and between T2 (94) and T3 (105) in 'Regina'. Generally, 'Kordia' responded to pruning with more vigorous regrowth the following season than did 'Regina'. Similarly, significant differences were recorded between 'Merton Glory' and 'Van' in their response to summer pruning (Webster and Shepherd 1984).

In 'Kordia', T2 resulted in a higher number of new shoots (regrowth in 2004). New shoots also were longer compared to the control (Table 2). T3 had no influence on the number of new shoots, but new shoots were longer compared to the control. In 'Regina', T2 resulted in similar number of new shoots to the control, but these were longer. T3 had no influence on the number and length of new shoots in 'Regina', compared to the control. Results with 'Bing'/*'Prunus avium*' showed that, independently from the season and pruning severity, regrowth was observed (Wilckens et al. 1998).

Pruning influenced the number of dead shoots (Table 2). Treatments 2 and 3 resulted in higher number of died shoots in both cultivars compared to control. Generally, the number of died shoots increases with the length of shoot removal although differences were not significant.

Our results indicate that, in sweet cherry trees on precocious rootstock new regrowth must be managed to promote vigour. This can be obtained with summer pruning (shoot heading). Leaves on 1-year-old wood and from current season growth are essential for fruit growth on 2-year-old spurs (Roper et al. 1987). Leaf area (LA) on the typical spur is only sufficient to support the full growth potential of a single fruit; more heavily-set spurs require supplemental LA from non-fruiting shoots (Whiting and Lang 2004). Increased vigour through pruning can be accomplished by imposing primary heading cuts, rather than thinning cuts (Lang 2005).

The results of this trial do not confirm the finding of Wilckens et al. (1998) that, as the amount of removed wood increased, the number of regrowth shoots also increased. With both cultivars, T2 (removal of $^1/_3$ of the length of each shoot) in 2003 resulted in a higher number of new shoots, which were longer, and a lower number of dead shoots compared to T3. As an architectural rule, the response to pruning varies greatly depending on the site of the cut (Lauri 2005).

Vegetative characteristics per tree

Pruning had no influence on the trunk growth of 'Kordia' (Table 3). In 'Regina' summer pruning in 2003 resulted in about 30 % less trunk growth in 2003–2004. Kappel et al. (1997) also reported that summer-pruned trees had smaller increments and their final TCA was smaller than that of the control trees.

Generative characteristics per branch

Fruit set and yield efficiency in 2004 (after summer pruning in 2003) were higher in 'Regina' than 'Kordia' but fruit weight was higher in 'Kordia' (Table 4). Our results for flower number per branch were in contrast to those of Guimond et al. (1998), who found that all summer pruning lengths significantly increase the number of flower buds formed at the base of the pruned shoots. Number of flowers in 2004 was similar in all treatments for 'Kordia' and 'Regina' with no significant difference between cultivars (data not shown). Pruning in 2003 had no significant effect in either cultivar on 2004 fruit set, yield efficiency or fruit weight, measured per branch. Though not significant, with cv. 'Kordia', T2 resulted in higher fruit set, lower yield efficiency and the highest average fruit weight compared to the other two treatments. Fruit weight in T2 and T3 was 12 % and 3.6 % higher, respectively With 'Regina', T2 resulted in lower fruit set and yield efficiency compared to control. The average fruit weight of 'Regina' was higher but not significant in pruned trees compared to control trees (19.6 % higher in T2 and 16.1 % in T3).

Table 2. Effects of summer pruning treatments in 2003 (T1–T3) on the number of new shoots, length of new shoots and number of dead shoots per branch of 'Kordia' and 'Regina' sweet cherry on 'Gisela 5' rootstock, determined on 5 July 2004. Values in a vertical row followed by a different letter are significantly different at α<0.05 by Duncan multiple range test.

Cultivar	T*	New shoots (no.)		Length of new shoots (cm)		Dead shoots (no.)	
		Branch 1	Branch 2	Branch 1	Branch 2	Branch 1	Branch 2
'Kordia'	1	3.2±0.3 bc	3.1±0.3 c	10.1±1.0 c	11.5±1.5 d	0.0±0.0 c	0.0±0.0 c
	2	4.5±0.4 a	6.9±0.6 a	21.1±1.1 a	18.6±0.9 b	4.0±1.6 ab	2.9±0.9 a
	3	2.3±0.3 c	2.5±0.3 c	24.9±1.9 a	26.6±2.4 a	5.9±0.6 a	4.5±0.6 a
'Regina'	1	2.5±0.3 ab	3.6±0.5 bc	11.2±1.2 c	12.3±1.3 cd	0.0±0.0 c	0.0±0.0 c
	2	3.5±0.4 b	4.9±0.6 b	16.2±1.4 b	15.7±1.4 bc	1.0±0.0 b	1.7±0.3 a
	3	3.0±0.3 ab	2.7±0.3 c	13.4±1.6 bc	13.0±1.6 cd	3.0±0.4 b	3.5±0.8 a

*Pruning treatments were imposed 3 June 2003 (38 DAFB) as follows: T1 = control (no pruning), T2 = removal of $^1/_3$ of the length of all current shoots longer than 20 cm, and T3 = removal of $^2/_3$ of the length of all current shoots.

The highest 2005 yield and yield efficiency, and the lowest fruit weight, in 2005 measured per branch, were obtained with 'Regina' compared to 'Kordia' (Table 4). Pruning had no influence on those parameters, except on fruit set of 'Regina'. Fruit set per branch in T2 trees was significantly lower compared to T1 and T3. Lower 2005 fruit set in block 2 can be the consequence of the strong thinning pruning in 2004 which have resulted in the reduction of storage reserves available for the next season (LANG 2005). Although different types of pruning were imposed in 2004, similar fruit weights measured per branch indicate that the F/LA in the branch had not been changed. Our results indicate that every branch acts as an autonomous unit within the crown.

Yield and fruit quality per tree

Yields in 2004, 2005 and 2006 were sub-optimal, especially with 'Kordia'. This may have been the consequence of local climatic conditions and the sensitivity of 'Kordia' to low temperatures during flowering. Fruit weight is one of the most important parameters of fruit quality, which in our trial depended on the genotype as discussed by GONÇALVES et al. (2006), crop load, picking time and also pruning treatments.

Yield efficiency in 2004 of control trees of 'Regina' (0.31 kg cm^{-2} TCA) was twice that of 'Kordia' (0.15 kg cm^{-2} TCA) (Table 3). Pruning in 2003 had no significant influence on yield, fruit weight and yield efficiency of 'Kordia' in 2004. In spite of this insignificance, we can not overlook that average yield and fruit weight of pruned 'Kordia' was higher than trees without pruning. Pruning of 'Regina' in 2003 resulted in higher 2004 yields in T2 and lower, but not significant, yields in T3. Pruning had no influence on 'Regina' fruit weight in 2004. Average fruit weight in T2 trees was similar to control trees, but was lower in T3. With T3, a larger amount of shoots, including vigorous branches, were removed, which could have reduced the resources available for subsequent season vigour as discussed by LANG (2005).

Table 3. Effects of summer pruning treatments (T1–T3) on trunk growth 2003–2004, yield, fruit weight and yield efficiency in 2004, measured per tree, of 'Kordia' and 'Regina' sweet cherry on 'Gisela 5' rootstock. Values in a vertical row followed by a different letter are significantly different at α<0.05 by Duncan multiple range test.

Cultivar	T*	Trunk growth (mm)	Yield (kg tree^{-1})	Fruit weight (g)	Yield efficiency tree^{-1} (kg cm^{-2} TCA)
		2003–2004		2004	
'Kordia'	1	27.8±2.7 b	5.9±1.1 b	8.14±0.3 a	0.15±0.02 b
	2	29.3±3.9 b	7.3±0.5 b	8.40±0.3 a	0.11±0.01 b
	3	27.4±3.2 b	7.3±0.5 b	8.24±0.2 a	0.15±0.02 b
'Regina'	1	44.5±5.0 a	6.5±1.1 b	7.42±0.5 ab	0.31±0.04 a
	2	30.4±4.9 b	11.2±1.3 a	7.64±0.3 ab	0.36±0.06 a
	3	31.0±4.4 b	5.9±0.8 b	6.76±0.4 b	0.28±0.04 a

*Pruning treatments were imposed 3 June 2003 (38 DAFB) as follows: T1 = control (no pruning), T2 = removal of $^1/_3$ of the length of all current shoots longer than 20 cm, and T3 = removal of $^2/_3$ of the length of all current shoots.

Table 4. Effects of summer pruning treatments (T1–T3) on yield efficiency, fruit set and fruit weight (g) in 2004 and 2005, measured per branch, of 'Kordia' and 'Regina' sweet cherry on 'Gisela 5' rootstock. Values in a vertical row followed by a different letter are significantly different at α<0.05 by Duncan multiple range test.

Cultivar	T*	Yield efficiency branch^{-1} (kg cm^{-2} TCA)	Fruit set (%)	Fruit weight (g)	Yield efficiency branch^{-1} (kg cm^{-2} TCA)	Fruit set (%)	Fruit weight (g)
		2004			2005		
'Kordia'	1	0.74±0.19 b	4.1±0.9 c	8.3±0.4 a	0.85±0.14 b	9.8±1.5 c	8.2±0.3 a
	2	0.64±0.09 b	5.2±0.7 c	9.3±0.7 a	0.67±0.07 b	9.7±1.8 c	8.1±0.3 a
	3	0.78±0.18 b	5.1±0.7 c	8.6±0.6 a	0.83±0.13 b	10.2±0.8 c	8.4±0.5 a
'Regina'	1	2.09±0.15 a	16.5±1.2 ab	5.6±0.2 b	1.95±0.21 a	36.0±4.1 a	6.3±0.3 b
	2	1.92±0.13 a	13.8±1.5 b	6.7±0.3 b	1.93±0.21 a	26.5±2.9 b	6.3±0.4 b
	3	2.04±0.19 a	18.3±1.8 a	6.5±0.5 b	1.85±0.20 a	33.6±3.5 ab	5.9±0.4 b

*Pruning treatments were imposed 3 June 2003 (38 DAFB) as follows: T1 = control (no pruning), T2 = removal of $^1/_3$ of the length of all current shoots longer than 20 cm, and T3 = removal of $^2/_3$ of the length of all current shoots. In mid-July 2004, these were repeated in block I, and in block 2, pruning was by thinning of branches.

Table 5. Effects of summer pruning treatments (T1–T3) on yield, fruit weight and yield efficiency of 'Kordia' and 'Regina' sweet cherry on 'Gisela 5' rootstock, measured per tree in different years. Values in a vertical row followed by a different letter are significantly different at $\alpha<0.05$ by Duncan multiple range test.

Cultivar	T*	Yield (kg tree^{-1})		Fruit weight (g)		Yield efficiency/tree (kg cm^{-2} TCA)	
		Block 1	Block 2	Block 1	Block 2	Block 1	Block 2
		2005		2005		2004–2005	
'Kordia'	1	10.4±0.9 cd	5.6±0.4 g	8.4±0.2 a	8.7±0.1ef	0.31±0.03 cd	0.13±0.01 f
	2	7.5±0.3 d	7.3±0.9 fg	7.7±0.6 abc	9.8±0.7 e	0.17±0.01 d	0.17±0.02 f
	3	8.0±1.2 d	9.8±1.0 fg	7.9±0.3 ab	8.6±0.2 ef	0.16±0.02 d	0.29±0.02 ef
'Regina'	1	17.8±3.1 b	16.8±2.7 e	6.8±0.4 bc	8.0±0.7 f	0.55±0.13 ab	0.45±0.06 e
	2	27.6±2.7 a	12.6±3.2 ef	6.3±0.1 cd	8.7±0.6 ef	0.73±0.09 a	0.38±0.10 e
	3	15.7±3.2 bc	16.7±1.8 e	5.3±0.4 d	8.4±0.3 f	0.49±0.09 bc	0.44±0.07 e
		2006		2006		2004–2006	
'Kordia'	1	8.1±1.7 b	4.5±0.7 b	8.6±0.1 c	9.6±0.4 fg	0.43±0.02 bc	0.19±0.02 b
	2	4.1±0.2 cd	7.1±1.6 ab	8.2±0.5 c	9.3±0.7 g	0.22±0.01 c	0.24±0.02 b
	3	2.4±0.5 d	10.3±1.1 a	8.7±0.4 bc	9.1±0.2 g	0.19±0.03 c	0.45±0.03 a
'Regina'	1	7.0±1.2 bc	7.6±0.8 ab	9.7±0.4 ab	9.8±0.5 fg	0.67±0.16 ab	0.55±0.05 a
	2	11.9±0.7 a	8.4±1.9 ab	9.3±0.3 abc	10.6±0.3 ef	0.89±0.09 a	0.51±0.12 a
	3	5.4±1.0 bc	6.2±1.3 b	9.8±0.4 a	11.2±0.1 e	0.58±0.11 b	0.52±0.08 a

*Pruning treatments were imposed 3 June 2003 (38 DAFB) as follows: T1 = control (no pruning), T2 = removal of $^1/_3$ of the length of all current shoots longer than 20 cm, and T3 = removal of $^2/_3$ of the length of all current shoots. In mid-July 2004, these were repeated in block I, and in block 2, pruning was by thinning of branches. In mid-July 2005, all pruning (both blocks) was by thinning as in block 2 in 2004.

Pruning in 2004 resulted in different yields between blocks of 'Kordia' and 'Regina' in 2005 (Table 5). Pruning treatments in block 1 were the same in 2004 as in 2003. Trees in block 2 were pruned in 2004 strongly with thinning cuts. Generally, different pruning in blocks affected yield and fruit weight of both cultivars. Strong thinning pruning in block 2 promoted higher fruit weight of both cultivars, especially with 'Regina', and in some treatments also lower yields.

Pruning influenced yield and fruit weight of 'Kordia' also in 2006 (Table 5), being higher in block 2 than block 1, except for the control trees (T1). Yield in 2006 of 'Regina' was similar in both blocks, but pruning influenced higher 'Regina' fruit weight in block 2. Comparison of 2004–2006 yield efficiencies for 'Kordia' and 'Regina' revealed: no significant differences between blocks 1 and 2. Pruning in block 2 resulted in lower yield efficiency in T1 and higher yield efficiency in T3 of 'Kordia' compared to block 1 and with 'Regina', lower yield efficiency in block 2.

Our results partly confirm the statement of WOLFRAM (1999) that non-pruned trees showed higher yield but lower fruit weight compared to pruned trees. Non-pruned trees in our research showed similar yield and yield efficiency as pruned trees but lower fruit weight/lower fruit quality. In non-pruned trees of 'Kordia' and 'Regina' the proportion of blind wood (non-productive wood) increased every year due to shading of the interior part of the tree crown. Pruning strategies are being investigated that focus on annual balancing of crop load with leaf area (WHITING and LANG 2004).

Conclusions

Our data suggest that there are differences between 'Kordia' and 'Regina' in tree vigour and fruiting habit even though both are generally strong-growing and light-bearing cultivars. 'Kordia' is more vigorous and less productive with higher fruit weight than 'Regina' under the conditions of this study. These differences influenced the response of these two cultivars to pruning treatments. Pruning had no influence on soluble carbohydrates in dormant shoots. There were no differences between 'Kordia' and 'Regina' in the contents of soluble carbohydrates. Our data suggest that summer pruning positively influences vegetative growth and generative development of sweet cherries on precocious rootstocks. Pruning to remove some major branches after harvest had a greater influence on fruit weight than summer heading of current season- shoots to increase light penetration into the canopy. Pruned trees have a larger proportion of new shoots, which are necessary for high quality fruits, and a smaller shaded proportion of the crown, which improves photosynthesis and reduces blind, unproductive wood. Because of the influence of shading and also cultivar characteristics the blind wood effect, common on sour cherry varieties, also is a concern in high density sweet cherry orchards.

Under conditions of high pressure of *Pseudomonas* infection, pruning sweet cherry trees after harvest (summer pruning) is convenient for managing vigour, crop load and fruit quality. Annual pruning of sweet cherry trees on

dwarfing, precocious rootstocks is essential for balancing the vegetative growth with current and future productive parts in the tree. The importance of promoting this balance increase when very productive cultivars are included. Further studies of pruning of sweet cherry trees are needed to refine cultural strategies to achieve this balance across cultivars and production regions.

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Addresses of authors: Valentina Usenik (corresponding author), Anita Solar, Damjan Meolic and Franci Štampar, University of Ljubljana, Biotechnical Faculty, Agronomy Department, Ljubljana, Slovenia, e-mail: valentina.usenik@bf.uni-lj.si.