EVALUATION OF SLENDER SPINDLE FORM IN YOUNG 'TOPAZ' APPLE ORCHARD*

M. Mészáros[2], J. Sus[1], L. Laňar[2], J. Náměstek[2]

[1]Czech University of Life Sciences Prague, Prague, Czech Republic
[2]Research and Breeding Institute of Pomology Ltd., Holovousy, Czech Republic

Two growing systems were compared – slender spindle and modified slender spindle, supplemented with or without additional summer pruning. The trial was carried out in orchard of the apple variety 'Topaz' in years 2012–2014. The assessed parameters were: trunk cross sectional area (TCSA), crown volume, number of cuts, dry matter weight of pruned wood, cumulative yield, yield efficiency, and relative occurrence of size classes of fruits. The objective was to confirm the hypothesized advantages of modified slender spindle in the period of increasing yields. Based on statistical analysis there was no significant difference among systems in growth measured by TCSA. Increase in crown cubage was the highest on slender spindle with additional summer pruning. The lowest increase of crown cubage was on modified spindle without summer pruning. Number of winter cuts and similarly dry weight was significantly higher on the modified spindle only in 2013. Additional summer pruning influenced both the above-mentioned parameters. There were no significant differences in cumulative yield and yield efficiency between systems. Similarly, the difference in the occurrence of various fruit size classes was not significant. We conclude that study needs to be extended in order to confirm the suggested trends.

Malus; pruning; woody biomass; growth; yield

DE GRUYTER OPEN

doi: 10.1515/sab-2015-0032
Received for publication on January 19, 2015
Accepted for publication on July 29, 2015

INTRODUCTION

The slender spindle training system was first described by Wertheim (1968). Its main attributes are a high central axis with the frame of permanent branches at the base and short horizontal side branches around the vertical leader which are appropriately headed or renewed to keep conical well illuminated crowns. The higher grows the branch, the lighter it should be. This system is well known nowadays and is widely used worldwide (Wertheim, 2005; Robinson, 2007, 2011). Formerly, the growth control of this system was easily attained by plant growth regulators with e.g. daminozide or chlormequat-chloride. However, these compounds were progressively banned for fruit production in the EU. Root pruning and the prohexadione–Ca utilization offered a partial solution to growth control but a new approach to training and pruning of slender spindle was still needed. The new system called 'klik' pruning has recently become commonly used throughout Europe. The main rules of this system are to keep the elongation growth of terminal and of basic permanent frame branches by pruning only in one-year-old wood (heading of extension twig by 'kliking') and renewal of no frame branches made by stump cut in a 3-year cycle. However, variety growth type must be considered (de Wit, 2008; Dallabetta, 2014). Ca. a 0.3–0.4 m wide space (called a 'window') is sometimes kept above the frame branches, where crowned twigs no longer than 0.15 m are accepted. This ensures enough light for frame branches. The aim of this system is to regulate the growth and keep the canopy light (de Wit, 2008). Together with the heading ('kliking') of extension twig of terminal and frame branches it should enhance flower bud formation (Mohammadi et al., 2013) and thus keep the yield per volume of the canopy high. The balance between vegetative and reproductive growth should ensure stable yields of good quality fruits, moreover, it is an easy system to be learned by less skilled labour. No

* Supported by the Ministry of Agriculture of the Czech Republic, Project No. QJ1210104, and by the infrastructure of the Project No. CZ.1.05/2.1.00/03.0116.

information on combining this system with summer pruning has been found.

Summer pruning is a common technique in fruit production, which increases light penetration and distribution in canopy (Buller, Mika, 2009). It can have positive effects on size and inner and outer quality of the fruits (Van der Boon, 1980; Barden, Marini, 1984; Guerra, Casquero, 2010), however the opposite was also recorded (Bound, Summers, 2001). Inner quality is influenced by higher soluble solids (Barden, Marini, 1984; Guerra, Casquero, 2010) or a higher content of Ca (Sus, Prskavec, 1991). These can have positive effect on the incidence of a bitter pit (Perring, Preston, 1974; Guerra, Casquero, 2010), which along with better colour (Stover et al., 2003; Tahir et al., 2007) improves outer quality and storability. Another reason for the utilization of summer pruning is growth regulation (Barden, Marini, 1984; Sus et al., 1997; Platon, Zagrai, 1997). When considering the effect of summer pruning and its impact on growth, yield, and quality, it is necessary to keep in mind the time and severity of pruning, actual crop load, and overall conditions (Li et al., 2003; Wertheim, 2005). Sus, Prskavec (1991) describe how summer pruning influences the number of cuts and the amount of removed biomass. Based on their study, a combination of winter and additional summer pruning removes the highest amount of biomass, but also increases the labour requirement.

Modification of the slender spindle system by 'klik'pruning and its effect on growth, yield, and pruning demand is insufficiently described in literature. To bridge this gap we decided to conduct an experiment which would compare the standard and the modified system. The aim of this study was to test the hypothesis that the modified 'klik' pruning increases yield, decreases growth, and thus increases yield efficiency which is assessed by the trunk cross sectional area TCSA (kg/cm^2) and crown volume (kg/m^3). Different systems could also lead to the increase in the amount of fruits with a higher marketable price (> 65 mm). A possible influence of summer pruning on both systems and the accompanying effect of different pruning methods on the number of cuts and woody biomass production are assessed.

MATERIAL AND METHODS

The experiment has been conducted in an orchard of apple variety 'Topaz' on M9 planted in the spring of 2011. The orchard is situated at Holovousy (north-east region of the Czech Republic), 300 m a.s.l. The soil is fertile brown earth without irrigation. Average annual precipitation during the last 30 years is 666 mm (371 mm from April to September) and average temperature is 8.9°C, giving moderate climate conditions. Planting distance is 3.9 × 1.4 m. Herbicides were used for regulating weed in the rows. Grass in the inter-rows was cut periodically. Plant protection followed the scheme of integrated production.

During the experiment, four variants with different pruning system and pruning time were analyzed from 2012 to 2014. In the first two variants the trees are grown in slender spindle (SS) planting system. They are pruned either only in winter (SS-WP), or in winter and supplemented with additional summer pruning done in late July (SS-WP+SP). Winter pruning was carried out following the rules of Wertheim (1968). If the branches are too long or thick, they are cut out or shortened (headed) where the suitable branch or twig of lower order is joined. Erect, competing or inward growing twigs are removed. Lateral branches are simplified if necessary. There is not any heading in one-year-old wood.

In the next two variants a modified slender spindle (MS) was used, with the same pruning time combinations as in the first two variants (MS-WP and MS-WP+SP). For the modification of the slender spindle system the rules of 'klik' pruning were used. The extension twig of the leader and of the basic scaffold branches which reached final allotted length is headed to only 2 or 3 remaining buds every year. If there is still space for elongation, these extension twigs are just tipped. Competing twigs are removed. Above the frame of 4–6 basic scaffold branches, a 30–40 cm long space free of any branches is kept. Only crowned twigs no longer than 0.15 m are accepted there. Above this "window" branches no older than 3 years are accepted and they are removed by stump cut allowing renovation. Shortening (heading) of branches in wood older than one year is strictly avoided.

Additional summer pruning of both the systems was slight and consists of removing only vertical or competing shoots. Hand fruit thinning in June was made on all variants in 2014. The assessment in 2012 served just for initial information and to design the pruning management for the following years. The main change in pruning management was done in the spring of 2013. The assessed parameters were: TCSA measured 0.1 m below the first branch, crown volume, increment of crown volume, number of cuts, dry weight of pruned wood, cumulative yield, yield efficiency counted from TCSA or crown volume, and relative occurrence of size classes of fruits (< 65 mm, 65–70 mm, 70–75 mm, 75–80 mm, >80 mm).

The trees were distributed in a randomized complete block split plot design. For each variant four replications of 5 trees were used, the replication was equal to a block. Data were evaluated by the analysis of variance (ANOVA) with following Tukey's HSD test, using the R statistical software package (Ihaka, Gentleman, 1996). The statistical significance was tested at $P = 0.05$, the 95% confidence intervals were computed.

Table 1. Tree growth vigour and fruit yield of 'Topaz' apple trees on 'M9' (planted in 2011) in the years 2012–2014

Variant	Trunk cross sectional area in 2014 (cm^2)	Crown volume in 2014 (m^3)	Crown volume increment 2013–2014 (m^3)	Cumulative yield (2012–2014) (kg per tree)	Yield efficiency per TCSA (kg cm^{-2})	Yield efficiency per crown volume (kg m^{-3})
SS-WP	19.37[a]	3.510[a]	2.957[ab]	27.95[a]	1.443[a]	5.306[a]
SS-WP+SP	20.28[a]	3.807[a]	3.182[a]	29.81[a]	1.470[a]	5.104[a]
MS-WP	20.43[a]	3.268[a]	2.605[b]	28.46[a]	1.393[a]	5.541[a]
MS-WP+SP	20.10[a]	3.538[a]	2.948[ab]	29.54[a]	1.470[a]	5.638[a]

TCSA = trunk cross sectional area, SS = slender spindle, WP = winter pruning, SP = summer pruning, MS = modified slender spindle

[a,b]means marked with the same letter do not differ significantly, Tukey HSD test (α = 0.05); results are comparable only within each column

Table 2. Relative proportion of fruit diameter of 'Topaz' apple trees on 'M9' (planted in 2011) in the years 2013–2014

Variant	Fruits ø < 65 mm (%)	Fruits ø 65–70 mm (%)	Fruits ø 70–75 mm (%)	Fruits ø 75–80 mm (%)	Fruits ø > 80 mm (%)
SS-WP	0.59[a]	11.15[a]	25.58[a]	33.69[a]	29.00[a]
SS-WP+SP	1.25[a]	11.21[a]	25.76[a]	32.81[a]	28.97[a]
MS-WP	0.33[a]	7.84[a]	22.84[a]	32.77[a]	36.22[a]
MS-WP+SP	0.60[a]	8.34[a]	24.42[a]	34.37[a]	32.27[a]

SS = slender spindle, WP = winter pruning, SP = summer pruning, MS = modified slender spindle

[a]means marked with the same letter do not differ significantly, Tukey HSD test (α = 0.05)

results are comparable only within each column

RESULTS

Intensity of growth expressed by TCSA was similar among the variants (Table 1). The highest average crown volume reached the slender spindle system supplemented with summer pruning, however, there were no significant differences detected between the systems. A slightly higher volume was detected in both variants supplemented with summer pruning. Significant differences were found when the volume increments in the years 2013–2014 were compared. The highest increment was registered on the slender spindle with supplemented summer pruning and the lowest was registered on the modified spindle without supplemented summer pruning. There were no significant differences in cumulative yield and yield efficiency expressed in yield related to TCSA. Similarly, if the yield efficiency was expressed as yield related to crown volume, no significant difference was recorded, though higher efficiency was detected on both modified variants. A higher amount of fruits sizing 65–70 mm at the expense of size 80+ mm was recorded on slender spindle compared to modified slender spindle (Table 2). However, the differences were not statistically significant.

Fig. 1 shows the average amount of cuts per tree during the studied years. Significant differences from winter pruning were detected between the slender spindle and the modified spindle both with and without summer pruning in the year 2013. In the following year there was a significant difference from winter pruning only between the slender spindle combined with summer pruning and the modified spindle without summer pruning. Supplementary summer pruning has a substantial influence on the total amount of cuts. Both variants with summer pruning have a higher number of cuts per tree than the variants with only winter pruning. Significant differences in the total number of cuts between the variants with summer pruning were detected only in the year 2013.

Average dry weight of removed wood biomass is shown in Fig. 2. There was a significant difference in the amount of biomass removed by winter pruning

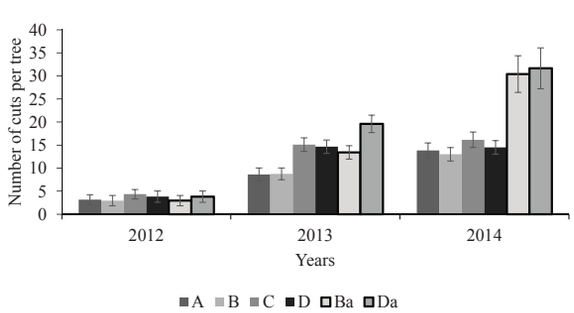

Fig. 1. The number of cuts per tree in years 2012 - 2014 from winter pruning: A) SS-WP, B) SS-WP+SP, C) MS-WP, D) MS-WP+SP and the number of cuts per tree in years 2012 - 2014 from winter and summer pruning: Ba) SS-WP+SP and Da) MS-WP+SP

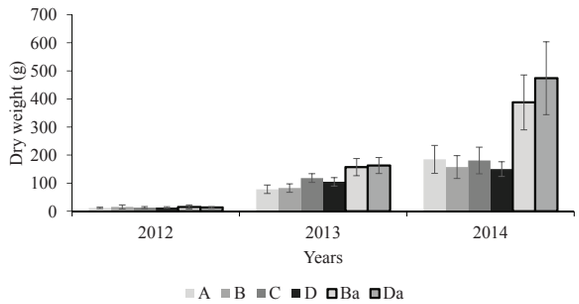

Fig. 2. Average dry weight of removed wood biomass per tree in years 2012 - 2014 from winter pruning: A) SS-WP, B) SS-WP+SP, C) MS-WP, D) MS-WP+SP and average dry weight of removed wood biomass per tree in years 2012 - 2014 from winter and summer pruning: Ba) SS-WP+SP and Da) MS-WP+SP

between the modified spindle with only winter pruning and both the slender spindle variants, which had lower averages in the year 2013. In the following year there was no significant difference in the amount of removed biomass during winter pruning but it was obvious that the variants without summer pruning had a higher amount of wood biomass removed in winter. The total amount of removed wood biomass was higher in the variants with summer pruning in the years 2013 and 2014.

DISCUSSION

Based on the two-year-long assessment, we may conclude that pruning of the modified spindle does not substantially influence the trunk cross sectional area if compared with slender spindle, though some difference exists in the volume of crowns. That can be explained by more demanding pruning mainly in the year 2013 and it may indicate that 'klik' pruning can really regulate the growth. Summer pruning did not influence the measured TCSA substantially, which is in accord with previous studies (Platon, Zagrai, 1997; Sus, Prskavec, 1991). However, the influence of summer pruning on TCSA may increase in the coming years (Sus et al., 1997). A slightly higher crown volume of the summer-pruned variants can be explained by the low intensity of this operation (Saure, 1985), which does not cause reduction of extension growth, but makes the crown just lighter and possibly influences the elongation of remained extension shoots. The modified variants in the year 2013 had lower yields (data not shown) but this was compensated the following year so there were no differences in the cumulative yield between the variants. This could be connected with the beginning of reconstruction on 'klik' system in 2013 and can affect future yield fluctuations. Though not significant, a similar trend was detected in the results of yield efficiency expressed in yield related to TCSA. If the yield efficiency expressed by yield related to crown volume was used, no significant difference was recorded, but a higher efficiency was detected on both the modified variants. Our hypothesis assuming a higher yield efficiency of the modified pruning has not been confirmed till now, however, results indicate the trend of growth control with comparable or higher yields of 'klik' pruned trees. We did not confirm the hypothesis of a higher amount of fruits with diameter above 65 mm. There were hardly any fruits with the diameter below 65 mm, being probably a consequence of the tree age and of fruit thinning.

The influence of summer pruning on the lower yield of the variety 'Topaz' was not registered, which is in a certain disagreement with former experiences (Sus, Prskavec, 1991) and corresponds with the results of Platon, Zagrai (1997) and Tahir et al. (2007). Since the trees are young, the weight of removed biomass is relatively low and differences are also low, but it is obvious from the results that 'klik' pruning was either equally or more demanding (in number of cuts), which is in contrast with the assumption of quicker pruning (de Wit, 2008). Despite some differences in crown volume and yield of the studied systems, in the first years the changes did not negatively influence the size of the fruits described by Bound, Summers (2001). The reason can be ascribed to balanced crop load, light, and a relatively late summer pruning, which did not decrease the physiological crop load below the critical threshold described by Li et al. (2003).

CONCLUSION

Based on the two-year experiment with four different treatments we cannot confirm that 'klik' pruning leads to a higher amount of marketable fruits and higher yield efficiency. Nevertheless, certain trends and differences among the studied systems were observed, indicating a trend of growth control with comparable or higher yields of 'klik' pruned trees and a shift in size classes of fruits. Further assessment will confirm or refute these trends and will be the subject of future studies.

REFERENCES

Barden JA, Marini RP (1984): Summer and dormant pruning of apple – a four year summary. Acta Horticulturae, 146, 263–268.

Bound SA, Summers CR (2001): The effect of pruning level and timing on fruit quality in red 'Fuji' apple. Acta Horticulturae, 557, 295–302.

Buler Z, Mika A (2009): The influence of canopy architecture on light interception and distribution in 'Sampion' apple trees. Journal of Fruit and Ornamental Plant Research, 17, 45–52.

Dallabetta N (2014): The implication of different pruning methods on apple training systems. Agriculture and Forestry, 60, 173–179.

De Wit J (2008): 'Klik' pruning. Sad Nowoczesny, 34, 10–12. (in Polish)

Guerra M, Casquero PA (2010): Summer pruning: an ecological alternative to postharvest calcium treatment to improve storability of high quality apple cv. 'Reinette du Canada'. Food Science and Technology International, 16, 343–350. doi: 10.1177/1082013210366977.

Ihaka R, Gentleman R (1996): R: A language for data analysis and graphics. Journal of Computational and Graphical Statistics, 5, 299–314. doi: 10.2307/1390807.

Li KT, Lakso AN, Piccioni R, Robinson T (2003): Summer pruning effects on fruit size, fruit quality, return bloom and fine root survival in apple trees. Journal of Horticultural Science and Biotechnology, 78, 755–761.

Mohammadi A, Mahmoudi MJ, Rezaee R (2013): Vegetative and reproductive responses of some apple cultivars (*Malus domestica* Borkh.) to heading back pruning. International Journal of AgriScience, 3, 628–635.

Peering AM, Preston AP (1974): The effect of orchard factors on chemical composition of apple. III. Some effects of pruning and nitrogen application on 'Cox's Orange Pippin' fruit. Journal of Horticultural Science, 49, 85–93.

Platon I, Zagrai L (1997): The influence of training system and pruning time on growth and apple fruiting. Acta Horticulturae, 451, 513–518.

Robinson T, Hoying SA, DeMaree A, Iungerman K, Fargion M. (2007): The evolution towards more competitive apple orchard systems in New York. New York Fruit Quarterly, 15, 3–9.

Robinson T (2011): Advances in apple culture worldwide. Revista Brasileira de Fruticultura, 33, 37–47. doi: 10.1590/S0100-29452011000500006.

Saure M (1985): The influence of cutting time and average intensity on growth and growth performance of young apple trees. Erwerbsobstbau, 27, 169–173. (in German)

Stover E, Fargione MJ, Watkins CB, Iungerman KA (2003): Harvest management of Marshall 'McIntosh' apples: effects of AVG, NAA, ethephon, and summer pruning on preharvest drop and fruit quality. HortScience, 38, 1093–1099.

Sus J, Prskavec K (1991): Effect of pruning on productivity of slender spindle in the period of increasing yields. Zahradnictví, 18, 161–178. (in Czech)

Sus J, Susová V, Hudský M (1997): Effect of prune on growth of trees and on amount and quality of fruits in apple slim spindle in the period of full bearing. Vědecké práce ovocnářské, 15, 79–88.

Tahir II, Johansson E, Olsson ME (2007): Improvement of quality and storability of apple cv. Aroma by adjustment of some pre-harvest conditions. Scientia Horticulturae, 112,164–171. doi: 10.1016/j.scienta.2006.12.018.

Van der Boon J (1980): Prediction and control of bitter pit in apples. II. Control by summer pruning, fruit thinning, delayed harvesting and soil calcium dressing. Journal of Horticultural Science, 55, 313–321.

Wertheim SJ (1968): The training of the slender spindle. Proefstation voor de Fruitteelt, Wilhelminadorp.

Wertheim SJ (2005): Pruning. In: Tromp J, Webster AD, Wertheim SJ (eds): Fundamentals of temperate zone tree fruit production. Backhuys Publishers, Leiden, 176–185.

Corresponding Author:

doc. Ing. Josef S u s , CSc,.Czech University of Life Sciences Prague, Faculty of Agrobiology, Food and Natural Resources, Department of Horticulture, Kamýcká 129, 165 21 Prague 6-Suchdol, Czech Republic, phone: +420 224 382 551, e-mail: sus@af.czu.cz