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COMPARISON OF TWO TRAINING METHODS APPLIED TO APPLE TREES TRAINED TO SLENDER SPINDLE DURING THE FIRST YEARS AFTER PLANTING

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Abstract

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The research was focused on the comparison of two pruning methods (winter pruning and winter + summer pruning) applied to apple trees trained to a standard and a modified slender spindle. The orchard of 'Topaz' trees, grafted on rootstock M 9, was planted in spring 2011. In the years 2013–2016, trunk cross sectional area (TCSA), crown volume, cumulative yields, yield efficiency, relative proportion of fruit size classes, number of cuts and dry matter of pruned wood were analyzed. The total growth intensity of the trees, measured by TCSA, was similar among the treatments. The trees of modified slender spindle had lower mean crown volume (2.751–2.765 m^3) comparing to slender spindle with additional summer pruning (3.355 m^3) and proved to better control the tree size. The modified slender spindle brought similar or slightly lower cumulative yields, but significantly higher proportion of good sized fruits (in categories above ø 70 mm) comparing to slender spindle. The pruning of modified spindle brings generally higher number of cuts removing a higher amount of woody biomass in comparison to slender spindle, regardless if combined with summer pruning. The additional summer pruning brought no beneficial effect in reduction of growth, fruit production and fruit size of the modified slender spindle.

Keywords: *malus*, summer pruning, tree size, woody biomass, growth vigor, yield, "click"

INTRODUCTION

The training and pruning of fruit trees is a basic agricultural measure which influences the height, stability and quality of the yield. Among others, it has an important impact on light interception, distribution and the use of assimilates by the tree (Wertheim, 2005). Slender spindle is the most common shape of intensively grown apple trees in Europe and in the world nowadays. The shape and its pruning was well described by Wertheim (1968, 1970 and 1978). The proposed rules were in different climatic and socioeconomic conditions consecutively modified. The main attribute influencing, the choice of the training system, was the trees growth vigor induced by a soil, climate, irrigation, rootstock and grafted variety. The ban of some growth regulating products and shortage of qualified workers led to development of new way of pruning, which would be easy to explain to unqualified workers, quick to do and could decrease the regrowth induced by pruning. As the response on this need, the development of the pruning modification used for training slender spindle, in some countries unofficially called "click pruning", was done. Its main characteristics are the heading cut ("click") of the permanent basal frame branches and terminal only in one year old extension shoots and renovation of whole temporary branches by stump cut usually in three or four years cycle

(Dallabetta *et al.*, 2014; de Wit, 2008). The heading cut in one year old wood use the effect described by Koopmann (1896) and confirmed by Jonkers (1982), that the heading of twig in basal area leads to smaller growth reaction. The remaining 2 or 3 basal latent buds on one year old wood then usually develop to less vigorous shoots. The trees take advantage from the growth located at the top of the frame branches and of the terminal, but the reaction is not too strong. Moreover, there is evidence that it can increase flower bud formation (Mohammadii *et al.* 2013). Heading in older wood is avoided because it usually causes strong growth reaction (Stephan *et al.* 2007). Renovation of the temporary branches by stump cut keeps the tree well illuminated and allows to create new twigs and branches. However, little is known about the combination of „click pruning" technique with additional summer pruning. Summer pruning is used mainly to improve fruit quality by better light distribution and to control the tree size (Buler and Mika, 2009; Wertheim, 2005). Moreover, it changes the physiology of fruit trees, e.g. the intensity of the photosynthesis (Ferree *et al.*, 1984). Nevertheless, many works dealing with summer pruning brought different results (Bound and Summers, 2001; Guerra and Casquero, 2010; Platon and Zagrai, 1997; Stover *et al.*, 2003; Tahir *et al.*, 2007; Tahir *et al.*, 2008). It is likely caused by the different time and severity of summer pruning, as well as by different conditions and type of used trees. Abovementioned inconsistent effects of summer pruning could be well explained by the results of Li *et al.* (2003). They suggest a model for estimation of the tree response on summer pruning based on physiological crop load (carbohydrate supply/demand) and reduction of canopy transpiration.

In this paper, we examined two training systems in combination with or without summer pruning and we studied their impact on production characteristics. It picks up the threads of our previous work (Mészáros *et al.*, 2015). The objective was to confirm the hypothesis that modified training system using "click pruning" eventually combined with summer pruning can help to increase yield efficiency, increase the fruit size, control the tree size and make the pruning faster.

MATERIALS AND METHODS

The analysis were performed on the apple trees of cultivar 'Topaz', grafted on rootstock M 9 and planted at Research and Breeding Institute of Pomology Holovousy Ltd., (North-East Bohemia region of the Czech Republic) in spring 2011. The trees were grown on fertile brown soil. Planting distance was 3.9×1.4 m. The orchard was situated in 300 m a.s.l. with annual precipitation of 630, 511, 506 and 478 mm and average temperature of 8.8, 10.3, 10.1 and 9.3°C during the years 2013–2016 respectively. The weed in rows was managed by herbicides and the inter-rows were covered with periodically mowed grass. The fertilization and plant protection followed local recommendations according to standard integrated pest management practices. The trees were managed without irrigation and since 2014 their fruits were thinned by hand. In the years 2013–2016, four different pruning systems (treatments) were applied and analyzed. There were slender spindle (SS) and modified spindle (MS), which were pruned either only in winter (WP) or in winter with additional summer pruning (WP+SP). Summer pruning was done in late July. The winter pruning of the SS followed the rules of Wertheim (1968). The modified spindle was carried out using "click pruning" with following rules: 1) periodical "click" cut of the extension shoots of the frame branches and central leader releasing only 2–3 buds after reaching of the final tree size, 2) removal of competing shoots, 3) maintaining 30–40 cm high space "window" free of branches above the frame (4–6 basic frame branches) fulfilled only with spurs and brindles up to 0.15 m, 4) keeping of branches above the window not older than 3 years, which were after then removed by a stump cut. The summer pruning was slight, removing mainly vertical or competing shoots. For each pruning treatment, trunk cross-section area (TCSA), crown volume, number of cuts, dry weight of pruned wood, cumulative yield, yield efficiency counted from TCSA and crown volume per tree, as well as the total weight of fruits in different size classes (<65 mm, 65–70 mm, 70–75 mm, 75–80 mm, >80 mm) were assessed. The treatments were in four replications with five trees, randomly distributed in a split plot block design. For the data processing, analysis of variance (ANOVA) followed by Tukey's HSD test in statistical program "R" was used. For the analysis of the fruit size proportion, Pearson's χ^2 test was used.

RESULTS

Growth, yield and fruit size

In 2016, the trunk cross-section area per tree was similar among all treatments (Tab. I). The highest average crown volume was found in slender spindle combined with winter and summer pruning, whereas the lowest size of the crown volume was in both modified spindle treatments in 2016 (Tab. I). The mean size of crown volume showed similar results. The trees of slender spindle showed a trend to bring higher cumulative yields and specific yields per trunk cross-section area comparing to modified spindle, but the difference was not significant (Tab. I). Opposite was true for the specific yields per crown volume, where the trees of modified spindle had slightly higher values in both sub-treatments.

During the years 2013–2016, the relative proportion of the fruits within each fruit size category was significantly different among the treatments (Tab. II). The highest relative proportion of fruits with size less than 65 mm was in slender spindle pruned in winter, whereas the lowest proportion was found in modified spindle

I: *Comparison of trunk cross-sectional area, crown volume, cumulative yields, yield efficiency per TCSA and mean yield efficiency per crown volume among training systems of 'Topaz' apple trees in the years 2013–2016*

Treatment	TCSA 2016 (cm^2)	Crown volume 2016 (m^3)	Ø Crown volume 2013–2016 (m^3)	Cumulative yield ($kg.tree^{-1}$)	Yield efficiency per TCSA ($kg.cm^{-2}$)	Ø Yield efficiency per CV 2013–2016 ($kg.m^{-3}$)
SS–WP	26.70 a	3.161 ab	3.116 ab	69.06 a	2.813 a	5.49 a
SS–WP+SP	29.26 a	3.590 a	3.355 a	72.99 a	2.661 a	5.54 a
MS–WP	29.23 a	2.924 b	2.751 b	67.11 a	2.461 a	6.26 a
MS–WP+SP	29.25 a	2.908 b	2.765 b	65.88 a	2.423 a	6.22 a

TCSA = trunk cross sectional area, CV = crown volume, SS = slender spindle, WP = winter pruning, SP = summer pruning, MS = modified slender spindle
Values marked with the same letter do not differ significantly, Tukey HSD test (α = 0.05); results are comparable only within each column.

II: *Relative proportion of the fruit size categories among training systems of 'Topaz' apple trees in the years 2013–2016*

Treatment	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	23.82 a	25.95 a	22.86 c	16.87 c	10.50 c
SS–WP+SP	18.00 b	27.07 a	25.77 b	18.82 b	10.34 c
MS–WP	6.99 d	19.37 b	30.20 a	26.20 a	17.24 a
MS–WP+SP	10.23 c	19.71 b	29.09 a	25.72 a	15.25 b

SS = slender spindle, WP = winter pruning, SP = summer pruning, MS = modified slender spindle
Values marked with the same letter do not differ significantly, Pearson's χ^2 test (α = 0.05); results are comparable only within each column.

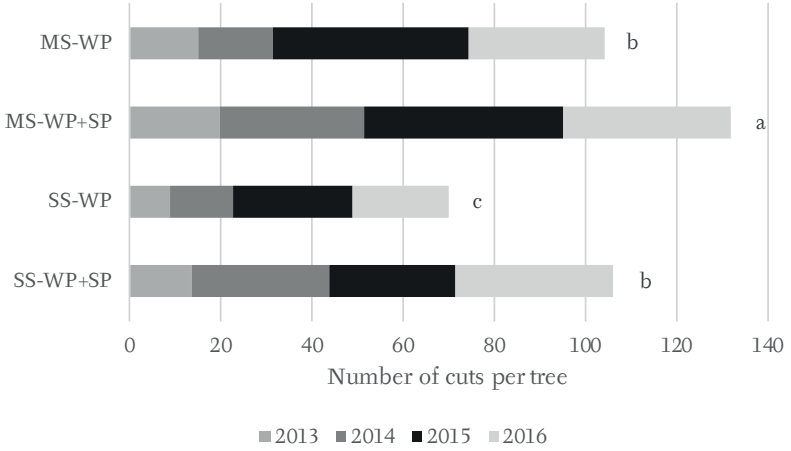
pruned in winter. In the fruit size of 65–70 mm, the highest relative proportion of fruits was in both treatments of slender spindle. In contrast to the first two categories, the highest percentage of fruits within size of 70–75 mm and 75–80 mm was in both modified spindle treatments. The lowest values were found in slender spindle pruned in winter for these two fruit size categories. The highest percentage of fruits with the size above 80 mm was found in winter pruned modified spindle. The lowest relative proportion was found in both treatments pruned as slender spindle.

Pruning demands

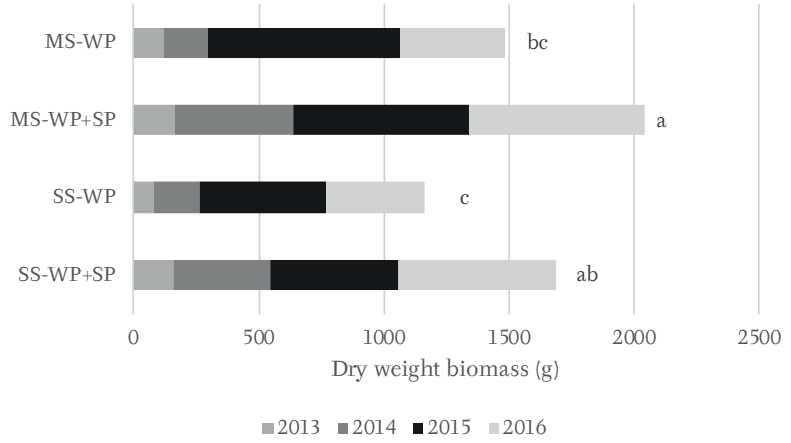
During the first four years of the treatments, the mean number of cuts per tree (Fig. 1) ranged between 70–106 in slender spindle and 104–132 in modified spindle. The modified spindle had significantly higher number of cuts comparing to slender spindle. This was true for each individual pruning date as well. The trees, pruned in winter and summer had the higher number of cuts comparing to those pruned only in winter. The total amount of woody dry weight, removed from the trees, showed similar trend (Fig. 2). The mean amount of removed woody dry weight per tree ranged between 1161–1690 g in slender spindle and 1482–2043 g in modified spindle. However, the total removed woody dry weight in treatments of modified spindle were not significantly higher comparing to slender spindle treatments. The treatments of modified spindle pruned in winter and slender spindle pruned in winter and summer showed similar performance. The total amount of woody dry weight removed in winter period was less comparing to those removed in the trees periodically pruned in winter and summer.

DISCUSSION

The results of TCSA means that the total cumulative growth of the trees was in general not affected by the pruning technique. The additional summer pruning didn't decrease the growth, which is in accordance with Platon and Zagrai (1997) and Sus and Prskavec (1991). Unlike to the TCSA, the difference in the crown volume is connected with diverse growth habits of the shoots within the crown. The smaller crowns of both modified spindle treatments are most likely a consequence of the development of 2–3 extension shoots at the end of the frame branches as the result of the "click" cuts in winter. These shoots, sprouting from normally latent buds at the shoot base, were usually shorter than the freely growing extension shoots in slender spindle, according to Koopmann (1896) rules. This effect was consistent with the mean crown volume for the whole period of the trial. The overall decrease of the total crown volume comparing to those recorded two years ago (Mészáros *et al.*, 2015) was probably the consequence of the drought in the years 2015 and 2016, as well as the heading back cuts to one-year-old shoots or side branches in slender spindle (Wertheim, 1978). The slightly higher cumulative yields and yield efficiency, related to TCSA, were linked with more intensive



1: *The number of cuts per tree in years 2013–2016 from winter pruning: SS – WP, MS – WP and from winter and summer pruning: SS – WP + SP and MS – WP + SP*



2: *Average dry weight of removed wood biomass per tree in years 2013–2016 from winter pruning: SS – WP, MS – WP and from winter and summer pruning: SS – WP + SP and MS – WP + SP*

pruning of modified spindle leading to larger crown volume in slender spindle. Consequently, it allows the development of higher number of flower clusters in slender spindle. The findings are in accordance with the previous results (Mészáros *et al.*, 2015) and confirms, that the modified spindle using "click pruning" technique brings no higher yields. However, the better fruit size of modified spindle treatments indicates to more balanced distribution of the assimilates leading to the higher mean specific yields per crown volume, which is in accordance with Dallabetta *et al.* (2014). The effect of the summer pruning on fruit size seems to be different in the two training systems. While the response of slender spindle to additional summer pruning was positive, rather opposite effect was true for the modified spindle. The explanation can be found in the different pruning severity of both training systems (Li *et al.*, 2003; Tahir *et al.*, 2008). The pruning of modified spindle brings generally higher number of cuts removing a higher amount of woody dry weight in both pruning dates comparing to slender spindle. This could be limiting for the modified spindle system, but not for slender spindle in order to keep enough assimilates to the fruit growth (Ferree *et al.*, 1984). The trees of modified spindle using "click pruning" treatment are more compact and prove to bring more balanced yields of better sized fruits.

CONCLUSION

In the first four years the "click pruning" do not influence the total cumulative growth, but can effectively improve the control of the crown size. However, the accomplishment of this technique requires higher intensity of pruning connected with the renewal stump cut of the bearing branches and "click" management of extension shoots. This training system brings similar yields as standard slender spindle, with more balanced yield of fruits with better size. The combination of "click

pruning" in winter with additional late summer pruning treatment brought no beneficial effects and can't be so far recommended.

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