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EFFECT OF SHOOT HEADING DATE ON SYLLEPSIS AND SYLLEPTIC SHOOT TRAITS IN PLUM ČAČANSKA LEPOTICA

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Abstract

Apart from frequent spontaneous syllepsis, sylleptic shoot development in plums can be induced by diverse practices, most notably plant hormone application and shoot tip removal. Research was conducted in 2008 and 2009 to evaluate the effect of summer pruning heading date on the degree of sylleptic branching and major morphological and anatomical properties of sylleptic shoots in plum 'Čačanska Lepotica' grafted on Myrobalan (*Prunus cerasifera* Ehrh.) seedling rootstock. Shoots were cut back to 4-5 buds above the base at 5 dates (T_1 – 20 May, T_2 – 5 June, T_3 – 20 June, T_4 – 5 July and T_5 – 20 July). At the end of dormancy, sylleptic shoots were subjected to morphological measurement: sylleptic shoot length and diameter (cm), number of nodes, internode length (cm), number of vegetative buds, number of flower buds, and anatomical analysis: primary xylem length (μm), number of tracheae per mm^2 and trachea width (μm). Results showed that at the late heading dates (T_4 and T_5) sylleptic branching was absent in a large percentage of shoots (81.59% at T_4 and 94.10% at T_5). In contrast, the highest positive response was observed for dates T_2 and T_3 which led to sylleptic shoots reaching moderate length (T_2 = 52.79 cm, T_3 = 22.09 cm), with a very good vegetative to flower buds ratio (at T_2 - 1:0.43, and at T_3 1:0.98). The sylleptic shoots emerging at dates T_2 and T_3 had the following anatomical properties: primary xylem width 94.79 μm and 70.43 μm; number of tracheae per mm^2 141.18 and 134.88, and trachea width 3.09 μm and 3.07 μm, respectively. Data suggest that 5-20 June, or T_2 and T_3 as used in this study, is the most suitable date to cut back shoots in plum'Čačanska Lepotica' for sylleptic branching.

Keywords: plum, sylleptic shoots, morphological and anatomical properties, shoot heading.

Introduction

Sylleptic shoot formation in fruit trees is affected by a variety of factors, primarily fruit species and cultivar (Wertheim 1978; Marini 2010). Some fruit crops, such as peaches [*Prunus persica* (L.) Batsch], exhibit an increased genetic tendency for the development of sylleptic shoots compared with other fruit trees (Hipps et al., 1995). The use of some agricultural practices such as an intensified supply of mineral fertilisers, particularly nitrogen, can promote not only proleptic but also sylleptic shoot formation (Jordan et al. 2009). In general, any practice or technique that contributes to fruit tree vigour and growth – irrigation, more severe pruning and nitrogen supply – enhances sylleptic branching (Chalmers et al., 1981; Jordan et al., 2009). Nonetheless, key stimulators of sylleptic shoot formation include plant hormones (cytokinins and auxins) (Cook et al., 1998; Cline and Dong-Il, 2002), and mechanical injury or pruning during the growing season (Oullette and Young, 1994).
Sylleptic branching in different fruit crops can have both positive and negative aspects. The occurrence of sylleptic i.e. feather shoots in nursery trees is positive and advantageous (De

Wit et al., 2002). On the other hand, in young fruit trees during the second or third year after planting, extensive sylleptic shoot development can cause tree training problems, thus revealing its negative aspects. In some cases, sylleptic branching may significantly increase leaf area and the general growth of the tree (Cline and Dong-Il, 2002). Also, in some fruit trees that have a thin crown and a tendency to produce blind wood, such as plums, sylleptic shoot development is highly desirable.
In modern plum orchards under High Density Planting system (HDP), summer pruning is a mandatory practice (Milosevic et al., 2008) which, inter alia, promotes sylleptic branching and prevents blind wood and the movement of the bearing potential and fruiting zone towards the top and periphery of the crown (Milosevic et al., 2009). Serbian plum cultivar ‘Čačanska Lepotica’ has the aforementioned negative tree properties (Nenadovic-Mratinic et al., 2007), particulary under HDP system.
The main objective of this study was to determine an optimal timing for summer pruning heading cuts in cv. ‘Čačanska Lepotica’ trees during the first part of the growing season to stimulate the development of sylleptic shoots that would exhibit normal morphological traits. In addition, the anatomy of sylleptic shoots was studied. This allowed a broad analysis of both morphological and anatomical characteristics, thus contributing towards a good understanding of sylleptic shoot formation in plum trees.

Materials and methods

Plant material and field trial
Research was conducted from 2008 to 2009 to evaluate Serbian plum cultivar ‘Čačanska Lepotica’ budded onto Myrobalan seedling rootstock at 25 cm above ground level. The orchard was established in 2003. The choice of cultivar was due to the potential interest in this cultivar in the Čačak region, because of its maturity time and good fruit quality.
The experimental orchard was established at Gornja Gorevnica near Čačak (43°53’N latitude; 20°21’E longitude; 390 m a.s.l.), Western Serbia, five and six years after planting. Trees were planted under HDP system at a spacing of 4 m $\times$ 2 m (1,250 trees ha^{-1}) and trained to the Spindle Bush system. Orchard management was consistent with standard practices for HDP, except irrigation. Summer pruning was used. In addition, climatic conditions were similar in both years.

Experimental procedure and analysis of the morphology and anatomy of sylleptic shoots
Heading shoots to four buds during the growing season was conducted at 5 dates (T). The first heading date (T_1) was 30 days after the onset of shoot growth (20 May), the remaining four at 15-day intervals: T_2 = 5 June, T_3 = 20 June, T_4 = 5 July and T_5 = 20 July. Each heading treatment involved the cutting back of 20 shoots in four replications (totalling 80 shoots) and subsequent monitoring of sylleptic shoot development.

Sylleptic shoots were collected for morphological and anatomical analyses in the first ten days of February in the following year. The morphological traits analysed included: sylleptic shoot length and diameter (cm), number of nodes, internode length (cm), number of vegetative buds and number of flower buds per shoot. A ruler and a digital caliper (Starrett, 727 Series, Athol, New England, USA) were used. The shoots were subjected to the following anatomical measurement: primary xylem width (μm), number of tracheae per mm^2 and trachea width (μm). The specimens collected for anatomical analysis were sectioned using a Reichert, Biocut 2030 sliding microtome (Germany). Permanent histological mounts were prepared by standard procedure. Thereafter, a microscope (Reichert, Germany) was used to measure tissue parameters. Primary xylem width and trachea width were measured under 50x and 400x magnification, respectively, and tracheae number per mm^2 were counted under 100× magnification. Images of the cross-sections of sylleptic shoots were taken with a Leica DC 300 camera, and processed and analysed by the Leica IM 1000 software. The terminology of wood anatomical aspects followed Wheeler et al. (1989).

Data analysis

The data obtained were analysed according to a factorial design arranged in a randomised complete block design with four replicates, with heading dates and years as factors, each with three and/or two levels (dates: T_1, T_2, T_3, T_4, T_5; years: 2008 and 2009). Analysis of variance (ANOVA) was performed at $P \leq 0.05$ and $P \leq 0.01$ significance levels, followed by an LSD test at $P \leq 0.05$ and $P \leq 0.01$ using the MSTAT-C statistical package (Michigan State University, East Lansing, MI, USA).

Results and discussion

Results on the response of 'Čačanska Lepotica' shoots to heading treatments during the growing season are presented in Table 1.

Tab. 1. Sylleptic shoot development in 'Čačanska Lepotica' depending on heading date

Response		No sylleptic branching (%)	Vegetative sylleptic shoots (%)	Generative sylleptic shoots (%)
Heading date (A)				
T_1		3.56±0.18 d	74.02±6.47 a	22.41±1.29 c
T_2		5.56±0.39 d	64.85±4.11 b	29.59±2.02 b
T_3		17.56±0.95 c	44.60±3.15 c	37.84±2.32 a
T_4		81.59±6.15 b	13.00±0.84 d	5.41±0.36 d
T_5		94.10±7.35 a	2.02±0.11 e	3.37±0.30 d
Year (B)				
2008		39.93±3.07	39.61±2.83	20.45±1.21
2009		41.01±2.94	39.79±3.01	19.20±1.31
A × B				
T_1	2008	3.20±0.15	72.15±5.60	24.65±1.18
	2009	3.92±0.20	75.90±7.34	20.18±1.40
T_2	2008	5.52±0.38	65.30±4.33	29.18±2.20
	2009	5.60±0.40	64.40±3.90	30.00±1.85
T_3	2008	17.22±0.80	45.30±3.20	37.48±2.10
	2009	17.90±1.11	43.90±2.90	38.20±2.55
T_4	2008	80.85±5.90	13.20±0.90	5.95±0.33
	2009	82.33±6.40	12.80±0.78	4.87±0.40
T_5	2008	92.90±8.11	2.10±0.12	5.00±0.24
	2009	95.30±6.60	1.95±0.11	2.75±0.35
ANOVA				
A		**	**	**
B		ns	ns	ns
A × B		ns	ns	ns

Differences between the years were not significant, but those across heading dates were highly significant. At heading dates T_4 and $T_{5,}$ the absence of sylleptic branching was observed in a large percentage of shoots (81.59% at T_4 and 94.10% at T_5). In contrast, the

percent of positive response was very high at heading dates T_1, T_2 and T_3, with sylleptic shoots developing in 82.44% to 96.44% of shoots headed at T_3 and T_1, respectively.
Sylleptic shoots were mostly vegetative, and their percent decreased from T_1 to T_3.
The vegetative activity of plum trees significantly declines in July, with shoot elongation ceasing (Bulatovic and Mratinic, 1996). Given that heading treatments at T_4 and T_5 occurred in July, the lack of response to these treatments can, in our opinion, be attributed to the above observation.

Results on the effect of shoot heading date on the morphological characteristics of sylleptic shoots in plum 'Čačanska Lepotica' are given in Tab. 2.

Tab. 2. Morphological characteristics of sylleptic shoots in plum 'Čačanska Lepotica' depending on shoot heading date

Parameter		Sylleptic shoot length (cm)	Sylleptic shoot diameter (mm)	Number of nodes	Internode length (cm)	Number of vegetative buds	Number of flower buds
Heading date (A) *							
T_1		64.84±4.86 a	4.40±0.21 a	16.41±1.15 a	4.04±0.20	16.05±0.95 a	4.85±0.38 c
T_2		52.79±4.56 b	4.07±0.25 a	15.56±1.20 a	3.84±0.20	15.37±1.00 a	6.72±0.46 a
T_3		22.09±2.02 c	2.98±0.12 b	6.08±0.37 b	3.92±0.20	5.40±0.41 b	5.31±0.34bc
Year (B)							
2008		47.33±3.93	3.84±0.22	12.57±0.86	3.90±0.21	12.16±0.84	5.47±0.42
2009		45.49±3.69	3.79±0.17	12.79±0.94	3.96±0.19	12.39±0.72	5.79±0.37
A × B							
T_1	2008	65.39±4.43	4.41±0.22	16.51±1.20 a	3.98±0.18	15.80±1.01	4.80±0.43
	2009	64.30±5.29	4.39±0.20	16.32±1.10 a	4.10±0.22	16.30±0.89	4.90±0.34
T_2	2008	55.41±5.22	4.10±0.31	15.32±1.09 b	3.79±0.19	15.30±1.10	6.30±0.51
	2009	50.18±3.90	4.04±0.20	15.80±1.30 b	3.89±0.21	15.45±0.90	7.15±0.41
T_3	2008	22.20±2.15	3.02±0.13	5.90±0.31 c	3.94±0.25	5.40±0.43	5.30±0.33
	2009	21.99±1.90	2.95±0.11	6.25±0.44 c	3.90±0.14	5.41±0.39	5.32±0.35
ANOVA							
A		**	*	*	ns	*	*
B		ns	ns	ns	ns	ns	ns
A × B		ns	ns	**	ns	ns	ns

* At heading dates T_4 and T_5, the percent positive response i.e. percentage of shoots positively responding to heading during the growing season and exhibiting vegetative or generative growth was extremely low (Tab.1.); accordingly, these dates were considered unfavourable and, therefore, not included in Tabs. 2 and 3.

As regards the morphological characteristics of the sylleptic shoots, the effect of heading dates was significant or very significant, except for node length which was not significantly affected by either heading date or year as variance factors. The effect of year as a variance factor was random for the other morphological parameters as well.
The T_1 date resulted in the highest values for sylleptic shoot length (64.84±4.86 cm) and diameter (4.40±0.21mm). The lowest values were obtained at T_3 (22.09±2.02cm and 2.98±0.12mm, respectively). The differences were very significant. No significant differences were observed in the number of nodes between T_1 and T_2 (16.41±1.15 at T_1; 15.56±1.20 at

T_2), whereas T_3 led to significantly fewer nodes on sylleptic shoots – 6.08±0.37. Internode length showed no statistically significant differences. The flower to vegetative buds ratio on sylleptic shoots was most favourable at T_3 (close to 1:1), followed in a decreasing order by T_2 (1:2.5), and T_3 (approximately 1:4). The observed differences were significant. Heading at T_3 gave the shortest sylleptic shoots that were predominantly generative. At T_2, sylleptic shoots showed moderate vigour and were either vegetative or generative, as opposed to vigorous vegetative sylleptic shoots developing at T_3.

Our results regarding sylleptic shoot vigour are in agreement with the findings of Morgas et al. (1998), who reported that early summer pruning can induce vigorous growth of sylleptic shoots. Sylleptic shoots that emerge as a result of early summer pruning, i.e. early heading cuts are usually more vigorous, while those that develop later in the growing season are generally less vigorous (De Wit et al., 2002). In the present study, later heading cuts as part of summer pruning induced shorter sylleptic shoots that had fewer nodes and shorter internodes, but a higher number of flower buds, which is in agreement with a previous study on plum (Mika and Piatkowski, 1989).Results on the effect of heading date on the anatomical characteristics of sylleptic shoots in plum ’Čačanska Lepotica’ are given in Tab. 3.

Tab. 3. Anatomical characteristics of sylleptic shoots in plum ’Čačanska Lepotica’ depending on heading date

Parameter		Xylem width (µm)	Tracheae number per mm^2	Trachea width (µm)
Heading date (A)				
T_1		103.45±4.46 a	147.32±6.36	3.13±0.06
T_2		94.79±4.45 b	141.18±5.51	3.09±0.05
T_3		70.43±3.38 c	134.88±6.83	3.07±0.05
Year (B)				
2008		90.03±4.26	140.88±6.56	3.11±0.05
2009		88.97±3.94	141.37±5.90	3.08±0.06
A × B				
T_1	2008	103.70 ± 5.04	147.78 ± 6.06	3.21 ± 0.07 a
	2009	103.21 ± 3.89	146.86 ± 6.63	3.09 ± 0.05 c
T_2	2008	94.63 ± 4.36	141.00 ± 5.90	3.08 ± 0.05 cd
	2009	94.61 ± 4.55	140.36 ± 5.11	3.14 ± 0.05 b
T_3	2008	71.77 ± 3.40	135.35 ± 7.54	3.05 ± 0.04 d
	2009	69.10 ± 3.37	134.40 ± 6.16	3.05 ± 0.04 d
ANOVA				
A		*	ns	ns
B		ns	ns	ns
A × B		ns	ns	*

The above results showed that summer pruning heading date and year had no significant effect on the number of tracheae and trachea width in sylleptic shoots. Significant differences were observed only in xylem width. Xylem width was highest at T_1 (103.45±4.46 µm), and lowest at T_3 (70.43±3.38µm), which was positively correlated with sylleptic shoot diameter presented in Tab. 2.

Conclusion

Shoot heading in plum cv. ’Čačanska Lepotica’ in the July treatment (dates T_4 and T_5) gave no response in the majority of cases i.e. led to no sylleptic shoot development until the end of the growing season in question. Therefore, these dates cannot be considered suitable for summer pruning in promoting sylleptic branching.

Heading date T_1 is also considered unsuitable as it gave too vigorous vegetative sylleptic shoots.

At T_2 and T_3 heading treatments conducted as part of summer pruning, moderately vigorous sylleptic shoots exhibiting a favourable flower to vegetative buds ratio developed until the end of the growing season. Therefore, dates T_2 and T_3 lasting from 5 to 20 June provide an optimal timing for the summer pruning of shoots for enhanced crown vigour and sylleptic branching.

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