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THE INFLUENCE OF BA AND BA+GA_{4+7} ON FORMATION OF SYLLEPTIC SHOOTS ON ONE-YEAR-OLD APPLE NURSERY TREES

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Abstract: This study presents the influence of BA (6-benzyladenine) and BA+GA_{4+7} (6-benzyladenine + gibberellic acids 4 and 7) on feathering of one-year-old apple trees of two cultivars Jonagold and Čadel. Different concentrations of BA (300, 600, 1,200 and 1,800 mg L^{-1}) and BA+GA_{4+7} (500, 1,000, 1,500 and 2,000 mg L^{-1}) were applied, and two treatments for both chemicals were performed. The first treatment was applied at 70-cm height of nursery trees and the second 2 weeks later. Comparison was performed in relation to untreated control. An application of BA and BA+GA_{4+7} did not affect both rootstock and nursery tree diameter at 10 cm above the grafting union. Nursery trees of cultivar Jonagold were not influenced by treatments applied, whereas in cultivar Čadel, the treatment with BA+GA_{4+7} decreased apical growth of nursery trees. The development of sylleptic shoots in both cultivars tested was influenced by the type of growth regulator and concentration applied. Treatment with BA at 300 mg L^{-1} concentration in both cultivars tested did not influence total length and number of sylleptic shoots, as well as the number of sylleptic shoots longer than 20 cm. The most positive influence on all studied parameters was observed on nursery trees treated with the concentration of 1,200 mg L^{-1} BA. The lowest concentration of BA+GA_{4+7} (500 mg L^{-1}) caused the low feathering of both studied cultivars. The higher concentrations (1,000, 1,500 and 2,000 mg L^{-1}) similarly increased the number and total length of sylleptic shoots of nursery trees.

Key words: apple cultivars, nursery trees, cytokinins, gibberellins, lateral branching.

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Introduction

A successful high density orchard should start cropping early and give annually a production of high amounts of high-quality fruit in an economically justified way (Volz et al., 1994; Wertheim et al., 2000). High quality nursery trees should be used for establishment of new apple orchard, from which growers expect fruiting in the second leaf and full production by the fourth leaf (Wilton, 2001). It is very important because early cropping controls vegetative growth (Mika, 1992). High quality apple nursery trees should have enough lateral shoots which are developed at desirable height, achieving appropriate length and crotch angle. 'Feathers' provide sites for the first spur flower buds and also the primary limbs for future structure of the tree (Volzetal., 1994; Yildirim and Kankaya, 2004). Consequently, one of the main objectives in apple nursery production is the induction of sufficiently long sylleptic shoots on nursery trees. In apple trees, lateral buds of growing shoots usually do not leaf out (Tromp, 1996). Lateral bud break can be enhanced at the desired height of a nursery tree by overcoming apical dominance (Volz et al., 1994; Gudarowska and Szewczuk, 2006).Lateral shoot formation depends on cultivar (Gudarowska and Szewczuk, 2006). However, in early summer, lateral buds may grow into 'sylleptic shoots' when the supply of nutrients and water is abundant, a condition that is usually satisfied in nurseries for apple nursery trees in the first year after bud-grafting (Tromp, 1996). Additionally, the development of sylleptic shoots on apple nursery trees can be stimulated by spraying with plant growth regulators.

The aim of this study was to investigate the effect of two chemicals containing the phytohormones cytokinin (BA), or the mix of cytokinin and gibberellins (BA+GA4+7) applied at different concentrations on feathering of one-year-old apple trees of two cultivars Jonagold and Čadel.

Material and Methods

This research was conducted in the nursery of the Fruit Research Institute located in Čačak (Western Serbia). Two apple cultivars Jonagold and Čadel grafted on M9 dwarfing clonal rootstock were investigated. The rootstocks were planted in early spring of 2009 with a spacing of 0.8 x 0.1 m. In August, the rootstocks were budded ('T' budding method) at the height of 10 cm above ground level.In the next year (2010), different concentartions of two plant growth regulators were applied: benzyl adenine (BA) (300, 600, 1200 and 1800 mg L-1) and combination of benzyl adenine and gibberellin (BA+GA4+7) (500, 1000, 1500 and 2000 mg L-1). Two treatments for both chemicals were performed. The first spraying was applied when nursery trees were about 70 cm in height, and the second spraying was done two weeks later. Hand sprayer was used to apply 10

ml of solution to the upper part of each nursery tree (1 l of solution per 100 nursery trees). Before the first treatment, all spontaneously developed sylleptic shoots on apple nursery trees were removed by hand. Control trees were left unsprayed.

The experiment was established as a randomized complete block. Each treatment was represented by 16 trees and replicated four times. Drip irrigation was used. Pests and weed control were managed as required. At the end of 2010 growing season, all nursery trees from each plot were measured in the nursery for: 1) rootstock diameter (measured at the height of 10 centimeters below the bud union), 2) scion diameter (measured at the height of 10 centimeters above the bud union), 3) total length of nursery trees above ground level, 4) total number of sylleptic shoots per tree, 5) number of sylleptic shoots longer than 20 centimeters, 6) total and average sylleptic shoot length, and 7) crotch angle of each sylleptic shoot. The data were analysed by one-way analyses of variance using program Statistica 6 for Windows (StatSoft Inc., Tulsa, OK, USA). Differences between means were evaluated separately for cultivars using Tukey's comparison test at the level of $P<0.05$.

Results and Discussion

An application of BA or BA+GA4+7 in order to promote the development of sylleptic shoots influencedneither rootstock nornursery tree diameter.The height of nursery tree of cultivar Jonagold was not affected by the treatment applied (Table 1), whereas in cultivar Čadel, the treatment with BA+GA4+7 decreased apical growth of nursery trees in relation to the untreated control (Table 2). Significantly lower nursery trees were obtained at spraying rate of 2,000 mg L-1 compared to those from the other treatments. Comparing to our results, Yildirim and Kankaya (2004) reported lower values for nursery tree height and diameter of several apple cultivars grown in Turkey.

Characteristics of sylleptic shoots in both cultivars tested were influenced bythe type of growth regulator and the concentration applied. BA applied at the concentration of 300 mg L-1 in cultivar Jonagold did not affect total length and total number of sylleptic shoots, number of sylleptic shoots longer than 20 cm, as well as the crotch angle of sylleptic shoots. However, higher concentrations of BA significantly increased total number and length of sylleptic shoots, and the number of sylleptic shoots longer than 20 cm. That is in accordance with results of Sazo and Robinson (2011) who concluded that three applications of 500 mg L-1BA affect very good branching of nursery trees of most apple cultivars. In our work, only average height of sylleptic shoots did not increase by treatment applied, whereas crotch angle of sylleptic shoots was decreased in comparison to the control.

Table 1. The influence of BA and BA+GA_{4+7} on nursery tree characteristics of apple cultivar Jonagold.

Treatments	Rootstock diameter (mm)	Scion diameter (mm)	Nursery tree height (cm)	No. of sylleptic shoots	No. of sylleptic shoots>20 cm	Total length of sylleptic shoots (cm)	Average length of sylleptic shoots (cm)	The crotch angle(°)
Control	21.6	13.7	140.3	10.8bc	6.5b	358ab	30.7ab	59.5a
BA 300 mg L^{-1}	18.3	10.9	126.1	5.0c	4.3b	185b	36.2a	55.4a
BA 600 mg L^{-1}	20.4	11.9	129.3	25.0ab	21.3a	793a	31.6ab	44.1b
BA 1200 mg L^{-1}	20.6	12.1	112.3	32.0a	22.8a	833a	26.1ab	45.3b
BA 1800 ml/ L^{-1}	19.5	11.8	126.6	32.0a	20.8a	839a	25.9ab	43.8b
BA+GA_{4+7} 500 mg L^{-1}	23.5	12.0	125.4	25.0ab	15.0ab	603ab	23.3b	42.8b
BA+GA_{4+7} 1000 mg L^{-1}	20.2	11.6	120.0	26.5a	20.3a	737a	27.8ab	41.5b
BA+GA_{4+7} 1500 mg L^{-1}	18.7	11.5	129.3	31.5a	21.3a	806a	27.3ab	44.3b
BA+GA_{4+7} 2000 mg L^{-1}	18.8	11.6	125.3	29.8a	21.3a	814a	27.5ab	41.0b
Significance	ns	ns	ns	*	*	*	*	*

Values within a column followed by the same letter are not significantly different at $P>0.05$. ns, non significant; *, significant at $P < 0.05$.

Table 2. The influence of BA and BA+GA_{4+7} on nursery tree characteristics of apple cultivar Čadel.

Treatments	Rootstock diameter (mm)	Scion diameter (mm)	Nursery tree height (cm)	No. of sylleptic shoots	No. of sylleptic shoots>20 cm	Total length of sylleptic shoots (cm)	Average length of sylleptic shoots (cm)	The crotch angle(°)
Control	20.4	12.6	140.0a	11.0d	4.0d	230d	24.2	68.5a
BA 300 mg L^{-1}	22.1	12.6	137.8a	12.3d	5.8cd	302cd	24.6	56.7b
BA 600 mg L^{-1}	21.1	13.7	136.8a	33.5abc	17.8abc	775ab	23.3	53.8bc
BA 1200 mg L^{-1}	21.9	13.5	140.9a	39.3ab	25.0a	1084a	24.4	52.0bcd
BA 1800 ml/L^{-1}	20.6	12.6	137.2a	43.8a	26.8a	972a	22.2	52.0bcd
BA+GA_{4+7} 500 mg L^{-1}	21.6	12.7	128.4ab	22.8cd	11.3bcd	503bcd	21.6	44.8cde
BA+GA_{4+7} 1000 mg L^{-1}	21.9	12.6	127.8ab	36.3abc	22.8ab	837ab	23.1	43.3de
BA+GA_{4+7}1500 mg L^{-1}	20.5	11.9	125.9ab	29.5bc	20.3ab	695abc	24.0	43.5de
BA+GA_{4+7} 2000 mg L^{-1}	19.6	12.2	117.6b	36.3abc	24.5ab	910ab	25.1	42.8e
Significance	ns	ns	*	*	*	*	ns	*

Values within a column followed by the same letter are not significantly different at $P>0.05$. ns, non significant; *, significant at $P < 0.05$.

Treatment with BA+GA4+7 in lower concentration of 500 mg L-1 caused the lower feathering of nursery trees of cultivar Jonagold compared to the treatments with higher concentrations of the same growth regulator. For instance, significantly higher number of sylleptic shoots per nursery tree, number of sylleptic shoots longer than 20 cm and total length of sylleptic shoots were recorded on nursery trees treated with BA+GA4+7 in concentration of 1000 mg L-1. Increasing of BA+GA4+7 concentration did not showa positive influence on mentioned parameters. In general, all treatments with BA+GA4+7 decreased crotch angle of sylleptic shoots.

A similar tendency was observed in promoting the development of sylleptic shoots on nursery trees treated with both chemicals in the case of cultivar Čadel (Table 2). The lowest concentration ofBA (300 mg L-1) caused the low feathering of nursery trees, while two-fold higher concentration of 600 mg L-1 had a positive influence on the formation of sylleptic shoots on nursery trees of this cultivar. The most positive effect on all studied parameters was observed on nursery trees treated with BA at concentration of 1200 mg L-1. All applied concentrations above 600 mg L-1 were enough to produce a beneficial effect as previously reported by Volz et al. (1994). These authors estimated that a well feathered tree should have at least five branches, each >20 cm in length. On the other hand, Wilton (2001) considered that the nursery tree should have a minimum of seven branches (feathers), all at an adequate height and well distributed, with wide branch angles. Further enhancement of BA concentration did not positively influence the development of sylleptic shoots. Satisfactory development of sylleptic shoots was recorded in BA+GA4+7 treatment at the concentration of 500 mg L-1, whereas the higher concentration of 1000 mg L-1 producedthe most positive effect. In contrast to our results, Rossi et al. (2004) reported that Promalin® application at the concentration of 1500 mg L-1 of the active ingredient promoted the formation of well-branched trees of the cultivar Catarina.

Conclusion

In general, the application of BA or BA+GA_{4+7} did not influence the diameter orheight of nursery tree. Treatment with BA at 300 mg L^{-1} concentration, in both tested cultivars, did not influence total length and number of sylleptic shoots, as well as number of sylleptic shoots longer than 20 cm. Treatment with the lowest concentration of BA+GA_{4+7} producedsimilar effects. The most positive influence on all studied parameters was observed on nursery trees treated with the concentration of 1200 mg L^{-1} BA and 1000 mg L^{-1} BA+GA_{4+7}. Beneficial effects of higher concentrations on the formation of sylleptic shoots were not observed in this investigation.

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UTICAJ BA I BA+GA_{4+7} NA FORMIRANJE PREVREMENIH GRANČICA NA JEDNOGODIŠNJIM SADNICAMA SORTI JABUKE

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R e z i m e

U ovom radu je ispitivan uticaj BA (6-benziladenin) i BA+GA_{4+7} (6-benziladenin + giberelinska kiselina 4 i 7) na bočno grananje jednogodišnjih sadnica dve sorte jabuke Jonagold i Čadel. Primenjene su različite koncentracije BA (300, 600, 1.200 i 1.800 mg L^{-1}) i BA+GA_{4+7} (500, 1.000, 1.500 i 2.000 mg L^{-1}) pri čemu su kod oba hemijska jedinjenja tretmani izvedeni dva puta. Prvi tretman je izveden kada su sadnice bile visine 70 cm, a drugi tretman je izveden dve nedelje kasnije. Kontrola je bila bez tretiranja. Primena BA i BA+GA_{4+7} nije ispoljila uticaj na prečnik podloge i sadnice na visini od 10 cm iznad spojnog mesta. Kod sadnica sorte Jonagold nisu registrovane razlike u vršnom porastu pod uticajem primenjenih tretmana, dok je kod sorte Čadel tretman sa BA+GA_{4+7} uticao na smanjenje vršnog porasta sadnica. Ustanovljeno je da su tip hemijskog regulatora i primenjena koncentracija uticali na razvoj prevremenih grančica kod obe ispitivane sorte. Tretman sa BA u koncentraciji od 300 mg L^{-1} nije ispoljio uticaj na ukupnu dužinu i broj prevremenih grančica, kao i na broj prevremenih grančica dužih od 20 cm. Najpozitivniji uticaj na sve ispitivane parametre je zabeležen kod sadnica tretiranih sa BA u koncentraciji od 1.200 mg L^{-1}. Najniža koncentracija BA+GA_{4+7} (500 mg L^{-1}) je izazvala slabo grananje sadnica kod obe ispitivane sorte. Veće koncentracije (1.000, 1.500 i 2.000 mg L^{-1}) su uslovile slično povećanje broja i ukupne dužine prevremenih grančica na sadnicama.

Ključne reči: sorte jabuke, sadnice, citokinini, giberelini, bočno grananje.

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