

INDUCTION OF FEATHERS ON ONE-YEAR-OLD APPLE TREES CULTIVAR GOLDEN DELICIOUS USING BENZYLADENINE AND GIBBERELINS 4+7

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SUMMARY: In the production of one-year apple trees some cultivars exhibit poor feathering. The Golden Delicious cultivar has a relatively good tendency to grow feathers but under standard technologies in the production of unbranched trees it forms very few feathers at 62-64 cm above ground. Phytohormones BA and BA+GA₄₊₇ significantly affected the formation of feathers on apple trees. In this research the solutions of BA and BA+GA₄₊₇ in the concentrations from 200 to 450 µl/l of active ingredient BA were applied three times at 7-day intervals during vegetation. At the end of vegetation, the following parameters were measured: the total number of feathers, the total feather length, the mean feather length and tree height. Increasing concentrations of BA and BA+ GA₄₊₇ to a certain limit leads to an increase in the number and total length of feathers. The Golden Delicious cultivar tends to form feathers of different lengths in a nursery. A significant variation was found in the mean feather length with different treatments. The application of BA phytohormone in higher concentrations can negatively affect the tree height.

Key words: feathers, benzyladenine, gibberellins, one-year-old trees, nursery, Golden Delicious.

INTRODUCTION

For a high-quality tree, the presence of a good number of feathers is desirable because they form flower buds in the second year of nursery production and enable the tree to bear fruit in the first year (Sadowski et al., 2007). Also, feathered trees enable an earlier formation of a canopy structure. Apple cultivars vary greatly in their tendency

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to form feathers in the nursery (Wertheim and Webster, 2003). In the production of one-year-old apple trees, some cultivars exhibit poor feathering (Volz et al. 1994; Hrotko et al. 2000; Elfving and Visser, 2006; Sazo and Robinson, 2011). Important factors in feathering are apical dominance (Cline 1991; Volz et al. 1994; Sazo and Robinson, 2011), nutrient availability (Tromp 1996) and ecological conditions (Tromp 1996; Tromp and Boertjes, 1996). Apical dominance is a term referring to the control that the terminal bud exerts over the development of lateral buds (Cline, 1997). This dominance establishes certain branching patterns characteristic of each woody plant species (Wilson, 2000). There are several hypotheses which try to explain the mechanism of apical dominance: the hormonal hypothesis, the photosynthetic hypothesis, and the hypothesis of water and mineral nutrient transport (Wilson, 2000). The hormonal hypothesis stresses the importance of auxins in the apical growth dominance and the importance of cytokinins in overcoming apical dominance (Cline, 1991; Wang et al., 1994; Cook et al., 2001). With apples, benzyladenine (BA) and the combination of BA and gibberellins 4+7 (GA₄₊₇) play an important role in overcoming apical dominance and in the production of well-feathered apple nursery trees (Volz et al., 1994; Hrotko et al., 2000; Rossi et al., 2004; Elfving and Visser 2006; Sazo and Robinson, 2011; Dorić et al., 2013b).

The Golden Delicious and its mutants are still one of the most important apple cultivars in Europe (WAPA, 2012). The objective of this paper is to determine the effects of BA and BA + GA₄₊₇ on feather formation on one-year-old Golden Delicious apple trees in a nursery with standard production methods of one-year-old unbranched trees.

MATERIAL AND METHODS

The experiment was carried out in 2011 and 2012 in a commercial nursery with one-year-old Golden Delicious apple trees on M9 T337 rootstock. The nursery used in the experiment is situated in Kanjiža.

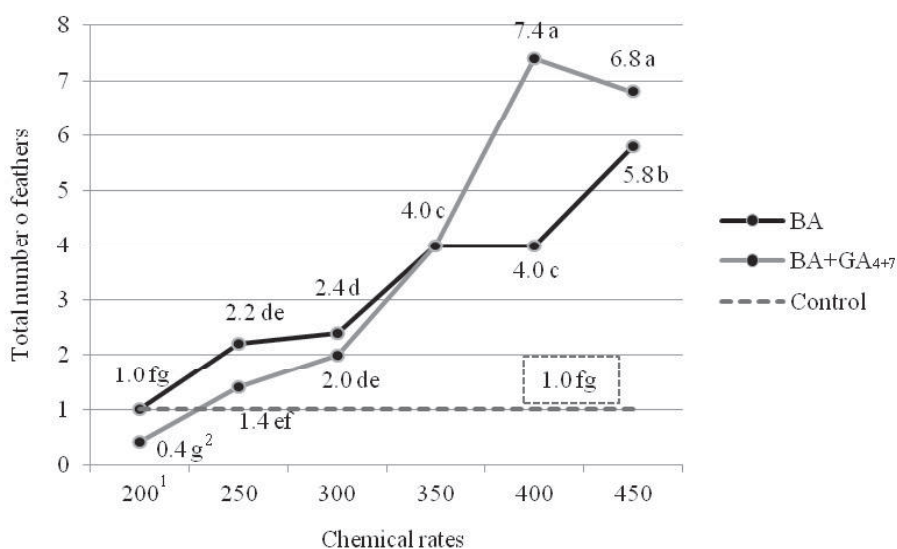
The experiment was set up using a randomized block trial with five replications, where each replication is represented with two plants (total of 10 per treatment). The rootstocks were planted in March, at a 1.1 x 0.1 m distance. In August, during the first vegetation, the plants were grafted by chip budding at 20 cm above the ground. At the time of the second vegetation, during the growth of the main shoot, all feathers below 62-64 cm were removed. During the second vegetation, the apical section of the main shoot was sprayed. Spraying was done with a hand sprayer. Three spray treatments were performed at 7-day intervals. The first treatment was applied in mid-June, when the growth of the main shoot was around 78-80 cm. Irrigation was carried out as needed by utilizing a sprinkler system.

The following treatments were used: Gerba 4 LG, containing 4% BA and Progerbalin LG, containing 1.8% BA and 1.8% GA₄₊₇ ("L-Gobbi", Italy). The applied concentrations were 450, 400, 350, 300, 250 and 200 µl/l of active ingredient (a.i.) BA. To each treatment a surfactant, Trend® 90 ("Du-Pont", USA), was added at the rate of 500 µl/l.

At the end of vegetation, the following parameters were measured: the total number of feathers, the total feather length, the mean feather length and tree height. The data were statistically processed by the analysis of variance (ANOVA) and mean values were compared with Duncan's multiple range test ($P < 0.05$) with Statistica 12 (StatSoft Inc., Tulsa, USA).

RESULTS AND DISCUSSION

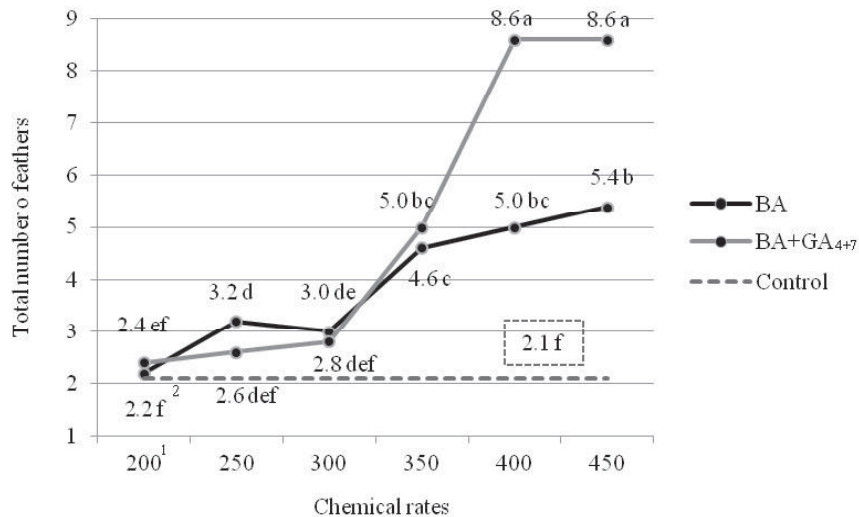
Graphs 1 and 2 present the effects of BA and BA+GA₄₊₇ on the total number of feathers. On the basis of these results, it is evident that in both experimental years the control had very few feathers. In 2011 the control had 1 feather per tree on average, and in 2012 it had 2.1. These trees have practically no feathers because such a small number of feathers (fewer than three) have to be removed at planting in order to avoid the formation of an unbalanced tree in the orchard (Palmer et al., 2011). The treatments with BA and BA+GA₄₊₇ significantly affected the formation of feathers. The total number of feathers increased with an increase in the concentration of BA and BA+GA₄₊₇. In 2011, the highest number of feathers was obtained with BA+GA₄₊₇ 400 (7.4) treatment while in 2012 it was obtained with BA+GA₄₊₇ 450 and 400 (8.6) treatment. Other studies show that increasing concentrations of BA and BA+ GA₄₊₇ to a certain limit leads to an increase in the number of feathers (Rossi et al., 2004; Jacyna and Barnard, 2008).



Graph 1. Effects of BA and BA+GA₄₊₇ applications on total number of feathers in Golden Delicious one-year-old apple trees (year 2011)

¹Number indicates concentration of active ingredient BA µl/l

²Means with different letters are significantly different (P<0.05)



Graph 2. Effects of BA and BA+GA₄₊₇ applications on total number of feathery branches in Golden Delicious one-year-old apple trees (year 2012)

¹Number indicates concentration of active ingredient BA µl/l

²Means with different letters are significantly different (P<0.05)

The results show that in both years the BA+GA₄₊₇ treatments, at higher concentrations, were more effective than BA treatments when the total feathery branch numbers are compared. Benzyladenine is responsible for overcoming apical dominance and enhancing feathering (Müller and Layser, 2011), while the main role of GA is to elongate feathery branches (Volz et al., 1994; Hrotko et al., 2000). Also, when applied on its own, GA is capable of enhancing feathering in pear trees (Palmer et al., 2011). The results show positive effects of GA₄₊₇ in combination with BA on the total number of feathery branches in treatments BA+GA₄₊₇ 400 and 450.

The Golden Delicious has a good branching potential but it is characterized by feathery branches of varying lengths (Cvetković et al., 2010). In standard technologies in the production of unbranched trees, which is still widespread in Serbian nurseries, this cultivar forms a small number of feathery branches if untreated with phytohormones. An important factor which affects feathery branch formation is agroecological conditions (Tromp, 1996; Tromp and Boertjes, 1996). Of great importance in the production of feathery branches is also the production method, primarily nutrition and irrigation. In tree production in Serbia irrigation is performed only when absolutely necessary, in order to avoid drought effects. In the production of feathery branches, however, it is necessary to irrigate the plants more frequently than in the production of unfeathered trees because feathery branches have a higher number of shoots and more leaf area and consequently higher demands for water if an adequate growth rate is to be maintained. Maintaining an adequate growth rate of the main shoot is essential since feathering in apples mainly occurs when the growth rate of the main shoot is the highest (Tromp, 1996).

In 2012, the research results were significantly better than in 2011. A possible reason for this may lie in more favourable environmental conditions in 2012. Soil tempera-

ture, air humidity and air temperature are important factors affecting feather formation and growth on an apple tree (Tromp 1996; Tromp and Boertjes, 1996). The second year, 2012, was warmer than 2011, which possibly facilitated a better growth and development of the trees. Average air temperatures in June, July and August 2011 were 21.4, 22.2 and 23.3 °C, respectively, and in 2012 they were 22.3, 25.0 and 23.9 °C (RHSS 2012). Another important factor in the variable quality of plants is the soil. In order to avoid apple tree diseases, nurserymen often rent new land so different soil types may have an effect too (Palmer et al., 2011).

Tables 1 and 2 contain the following parameters: feather length, tree height and trunk diameter. A parameter that is also important in determining the quality of the trees is the feather length. Sadowski et al. (2007) noted that there is a relationship between the length of laterals and productivity of trees in the orchard. The highest values for the total feather length were recorded in 2011 with BA+GA₄₊₇ 450 (172.6 cm) and 400 (164.3 cm) treatments and in 2012 with BA+GA₄₊₇ 450 (199.6 cm) treatment. Based on the results of the research, it is safe to conclude that increasing BA and BA+GA₄₊₇ concentrations leads to an increase in the total feather length.

Table 1. Effects of BA and BA+GA₄₊₇ applications on feather length and tree height in Golden Delicious one-year-old trees (year 2011)

Treatment	Total feather length (cm)	Average feather length (cm)	Tree height (cm)
BA+GA ₄₊₇ 450 ¹	172.6a ²	25.8bcd	143.2d
BA+GA ₄₊₇ 400	164.3a	22.2cd	151.0cd
BA+GA ₄₊₇ 350	99.0c	25.8bcd	158.5abc
BA+GA ₄₊₇ 300	40.8e	20.4cd	155.0abc
BA+GA ₄₊₇ 250	23.4e	17.9de	159.6ab
BA+GA ₄₊₇ 200	32.5e	32.5ab	155.8abc
BA 450	137.3b	23.6cd	159.4ab
BA 400	105.8c	26.0bcd	157.0abc
BA 350	99.2c	27.1bc	153.3bc
BA 300	41.2e	18.8cde	159.0ab
BA 250	71.5d	35.0a	153.8abc
BA 200	18.0e	11.2e	154.7abc
Control	25.0e	19.9cd	161.4a
F test	*	*	*

¹Number indicates concentration of active ingredient BA µl/l

²Means with different letters are significantly different (P<0.05)

Table 2. Effects of BA and BA+GA₄₊₇ applications on feather length and tree height in Golden Delicious one-year-old trees (year 2012)

Treatment	Total feather length (cm)	Average feather length (cm)	Tree height (cm)
BA+GA ₄₊₇ 450 ¹	199.6a ²	23.1ab	145.7e
BA+GA ₄₊₇ 400	167.7b	19.4b	151.3d
BA+GA ₄₊₇ 350	129.5cd	19.1b	159.2b
BA+GA ₄₊₇ 300	73.0e	25.7a	155.0bcd
BA+GA ₄₊₇ 250	62.1e	24.0ab	157.1bc
BA+GA ₄₊₇ 200	50.6ef	22.1ab	155.8bc
BA 450	132.4c	24.5a	144.9e
BA 400	126.8cd	25.4a	145.9e
BA 350	109.0d	23.4ab	154.3cd
BA 300	73.0e	24.5a	158.0bc
BA 250	70.2e	22.8ab	157.2bc
BA 200	32.2fg	12.8c	159.0b
Control	23.9g	12.3c	169.6a
F-test	*	*	*

¹Number indicates concentration of active ingredient BA µl/l

²Means with different letters are significantly different (P<0.05)

Mean feather lengths varied significantly in both years. In 2011 they ranged from 11.2 to 35.0 cm and in 2012 from 12.3 to 25.7 cm. The highest values of the mean feather length parameter were obtained in 2011 with BA 250 (35.0 cm) and in 2012 with BA+GA₄₊₇ 300 (25.7 cm), BA 400 (25.4 cm), BA 450 (24.5 cm) and BA 300 (24.5 cm). In the course of the 2011 research it was observed that some trees treated with BA+GA₄₊₇ 200 and BA 250, which had a relatively small number of feathers (fewer than 4), formed feathers of greater lengths, even longer than 50 cm. The trees treated with BA+GA₄₊₇ 200 and BA 250 in 2011 formed longer feathers probably because the nutrients were used for the growth of a smaller number of shoots. As the main shoot and feathers are in competition for water and nutrients (Cline, 1991), an increase in the number of feathers enables variation in mean feather length (Dorić et al., 2013a).

The highest values of the tree height parameter in both research years were obtained with the control (161.4; 169.6 cm). A negative effect of phytohormones was observed in 2011 with BA+GA₄₊₇ 450 (143.2 cm) treatment and in 2012 with BA+GA₄₊₇ 450 (145.7 cm) and BA 450 (144.9 cm) and 400 (145.9 cm) treatment. With the other treatments the trees were of satisfactory height. The application of BA affects the flow of auxins (Müller and Layser, 2011) and impedes the growth of the main shoot for a short time (Sazo and Robinson, 2011), which in some cases can lead to a significant decrease of tree height (Hrotko et al., 2000; Sazo and Robinson, 2011). When planting apple orchards it is necessary for the trees to be of an adequate height (150 cm at least) in order to achieve a good position of the lowest tier of branches in the nursery and to enable the

formation of the second tier of branches in the orchard. In the present research we found that the treated trees were lower than the control.

CONCLUSION

One-year-old Golden Delicious apple trees untreated with phytohormones formed a small number of feathery branches at 62-64 cm above ground in a standard nursery production method for one-year-old unbranched trees. Phytohormones BA and BA+GA₄₊₇ significantly affected the formation of feathery branches. Increasing concentrations of BA and BA+GA₄₊₇ to a certain limit leads to an increase in the number and total length of feathery branches. In agroecological conditions prevalent in Serbia, and with standard planting technologies, it is necessary to use BA and BA+GA₄₊₇ in concentrations of 400 µl/l a.m. BA so that a sufficient number of feathery branches is formed. If used in higher concentrations, the result may be trees shorter than 150 cm due to a negative effect of BA. A possible method of obtaining an adequate number of feathery branches with the application of BA and BA+GA₄₊₇ while neutralizing their negative effect on tree height is intensive irrigation accompanied with the provision of nutrients during the period of intensive growth of the main shoot, which should maintain an adequate growth rate.

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**FORMIRANJE PREVREMENIH GRANČICA
KOD JEDNOGODIŠNJI SADNICA JABUKE SORTE ZLATNI DELIŠES
PRIMENOM BENZILADENINA I GIBERELINA 4+7**

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Izvod

U proizvodnji jednogodišnjih sadnica jabuke kod nekih sorti je otežano formiranje prevremenih grančica. Sorta Zlatni Delišeš ima relativno dobru sklonost ka formiranju prevremenih grančica, ali pri standardnoj tehnologiji gajenja koja se primenjuje kod proizvodnje sadnica bez prevremenih grančica veoma slabo obrazuje bočne poraste na 62-64 cm visine od zemlje. Fitohormoni BA i BA+GA₄₊₇ značajno utiču na formiranje prevremenih grančica kod sadnica jabuke. U ovom istraživanju korišćeni su preparati na bazi BA i BA+GA₄₊₇ u koncentracijama od 200 do 450 µl l⁻¹ aktivne materija BA tri puta tokom vegetacije u razmaku od 7 dana. Na kraju vegetacije mereni su parametri: ukupan broj prevremenih grančica, ukupna dužina prevremenih grančica, prosečna dužina prevremenih grančica i visina sadnice. Povećavanjem koncentracije BA i BA+GA₄₊₇ do određene granice povećava se i broj i ukupna dužina prevremenih grančica. Sorta Zlatni Delišeš ima sklonost ka formiranju prevremenih grančica različite dužine u rasadniku. U tretmanima je zabeleženo značajno variranje parametra prosečna dužina prevremenih grančica. Primena fitohormona BA može negativno da utiče na visinu sadnice pri primeni viših koncentracija.

Ključne reči: prevremene grančice, benziladenin, giberelini, jednogodišnje sadnice, rasadnik, Zlatni Delišeš.

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