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Full Length Research Paper

The effects of heading and benzyladenine applications on branching of apple (cvs. 'Red Delicious' and 'Golden Delicious') trees in nursery

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This study was carried out in two independent experiments on one year old apple (*Malus domestica* cvs. 'Red Delicious' and 'Golden Delicious') nursery trees with the main purposes of improving lateral shoot formation and increasing the quality of trees. In the first experiment, the effect of different heading treatments (0, 40, 60 and 80 cm above ground) and in the second experiment, benzyladenine (BA) treatments (0, 200, 400, 600 mgL^{-1}) was investigated. Trees were treated with foliar sprays of BA thrice at 7-day intervals in mid-June at the end of the growing season. The tree quality was measured on the basis of their diameter and height of trees, number and length of lateral shoots. A factorial experiment was laid out in a completely randomized block design with 3 replications where each replication was comprised of 10 trees. The results showed that the heading treatments had significant effects on the branching of apple trees. Heading in 60 cm was the best treatment for improving the total number of lateral shoots. The results of second experiment showed that there were significant differences between cultivars and BA treatments. In both experiments, 'Red Delicious' had better response to treatments than 'Golden Delicious' cultivar. BA treatments had more significant effect on the number and length of lateral shoots than heading treatments. Repeated BA treatments induced lateral shoots more than a single treatment.

Key words: 'Golden Delicious', height, lateral shoot, 'Red Delicious', tree quality.

INTRODUCTION

Most apple cultivars produced in nurseries do not have any lateral shoot after one year of growth, so, more number of lateral shoot is one of the most important factors for apple tree producers. One of the main purposes of fruit tree nurserymen is improving lateral shoot formation and increasing the quality (diameter and height of trees, number and length of lateral shoots) of apple trees. If not properly managed, leaders of young trees produce hardly lateral shoots (Jacyna and Puchala, 2004). The lateral shoot formation of young trees is an important factor inducing early fruit production. One-year-old trees without branches need at least one year to produce crown (Bielicki and Czyczyk, 2004b). Several studies have shown that larger trunk circumference trees grow more and produce higher yield in 4 to 5 years (Robinson, 2003; Wertheim and Webster, 2003). Robinson (2003) recommended that the trunk circumference of trees used in high density planting be a minimum of 15 mm and that they have five to ten well-positioned branches on the tree. Formation of lateral shoots differs among apple cultivars. Many economically important cultivars produce few lateral shoots in nursery by nature, because of strong apical dominance (Jaumien et al., 1993; Cline, 2000). According to Elfing (1984), a balance between auxin and cytokinin levels controls formation of lateral branches, and the diffusible auxin at a

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Abbreviation: BA, Benzyladenine.

high concentration produced mainly in the apical bud, inhibits growth of lateral shoots. Rootstock, environmental conditions and growing method are other important factors in lateral shoot formation (Bielicki and Czynczyk, 2004).

Traditional techniques to promote branching not always give satisfactory results, so, application of bioregulators may be necessary (Csiszar and Buban, 2004). Pinching leaders can overcome strong apical dominance (Wertheim, 1978). Pruning (tipping) can interrupt the apical dominance mechanism and encourage buds that otherwise might remain quiescent (Elfving and Visser, 2007). In semi-dwarf orchard systems at wider spacing, a heading cut is very effective at creating branches; however, they may have an invigorating effect that is not necessarily desirable in high-density orchards (Clements et al., 2010). Using traditional techniques to promote branching (pruning, tying down shoots, etc.) do not always carry satisfactory results, so, applying bioregulators that promote feathering may be necessary. Synthetic compounds of cytokinin activity, like benzyladenine (BA), can be effectively used for this purpose. Benzyladenine is applied most often for training canopies of nursery trees (Hrotko et al., 2000; Theron et al., 2000) and young trees in newly planted orchards (Buban, 2000). Several products containing BA alone or in combinations with other plant hormones (mostly GA4+7) are available on the world market (Buban, 2000). Hrotko et al. (1996) reported a positive effect of repeated BA treatments on stimulating branching in one-year-old 'Idared' / M.26 nursery trees.

A combination of notching and BA application, or BA application alone (single or possibly multiple applications), may be the best options for improving branching in poorly branched trees (Clements et al., 2010). Cytokinins such as BA, alone or in combination with gibberellins, have been used to overcome apical dominance and to stimulate the development of lateral shoots, with positive results in many countries (Hrotko et al., 1996; Jaumien et al., 2002). It was reported by Caglar and Ilgin (2009) that the exogenous application of BA might have influenced the internal BA contents of the buds, and there by caused the different branching pattern. In Iran, there is little information about mechanical heading and chemical treatments to stimulate branch development in the nursery. So, the main purpose of this study was to investigate the effects of heading and BA treatments on increasing lateral shoot formation of nursery apple trees.

MATERIALS AND METHODS

This study was conducted in two independent experiments in a commercial apple nursery. The nursery was located at Golmakan Horticultural Research Station (59° 17' N; 36° 32' E), North east of Iran/Mashhad, with an average altitude of about 1176 m. In 2011, the mean temperature for growing season was 13.4°C and total seasonal precipitation was 239.7 mm. The nursery soil was sandy loam with low organic matter. Drip irrigation was applied in the nursery.

Plant material

Trials were conducted on apple trees (*Malus domestica* cvs. 'Red Delicious' and 'Golden Delicious'). The trees were planted at a spacing of 100 ×10 cm (100.000 trees ha^{-1}) and budded (T-budding technique) 10 cm above the ground level. Measurements were carried out at the end of the growing season and they included tree height (from the graft union), tree diameter (10 cm above the graft union) and also number and length of lateral shoots.

Experiment 1: Heading treatments

In late spring of the 1st year of planting, trees of 'Red Delicious' and 'Golden Delicious' cultivars were pruned at the height of 40, 60 and 80 cm above the soil level. Trees did not have any lateral branch when treatments applied.

The experimental design was 2 factors factorial adopted completely randomized design with 3 replicates (10 trees per replication). Factor A was cultivar ('Red Delicious' and 'Golden Delicious') and factor B, was heading (0, 40, 60 and 80 cm). All data were subjected to analysis of variance using MSTATC and Duncans multiple range test which were used to compare the treatment means. Differences at $p < 0.05$ were considered to be significant.

Experiment 2: BA treatments

The BA concentrations used were 0, 200, 400 and 600 mgL^{-1}. They were first applied on 15 June 2011, when the growing scion shoots were 60 to 65 cm above the bud union. The treatments were repeated thrice at 7 days interval (15, 22 and 29 June). Untreated (control) trees were sprayed with only water at each spraying. Trees did not have any lateral branch when treatments were applied.

The experimental design was 3 factors factorial adopted completely randomized design with 3 replicates (10 trees per replication). Factor A was cultivar ('Red Delicious' and 'Golden Delicious'), factor B was BA concentration (0, 200, 400 and 600 mgL^{-1}) and factor C, was application times (1, 2 and 3 times).

BA was applied to the nursery trees in distilled water with the addition of Tween 20 as a non-ionic surfactant (Hrotko et al., 1996). The upper 20 cm of actively growing scion shoots with leaves were sprayed with atomizer-type hand sprayers (Cody et al., 1985) and each tree received 25 ml solution. All data were subjected to analysis of variance using MSTATC and Duncans multiple range test which were used to compare the treatment means. Differences at $p < 0.05$ were considered to be significant.

RESULTS

Experiment 1: Heading treatments

The data presented in Table 1 indicated that cultivar and heading treatment and interaction had significant effect at levels 1 and 5%, respectively for lateral shoot formation. All of the variables were significant at 1% level for the tree height and stem diameter (Table 1). The heading treatments had significant effects on the branching of

Table 1. Analysis variance of heading on the lateral shoot formation, height and diameter of tree.

S.O.V	df	MS				
		Total	>10 cm	<10 cm	Height (cm)	Diameter (mm)
Replication	2	0.146	0.148	0.065	98.997	0.004
Cultivar	1	1.976**	0.687*	1.206**	51.628^{ns}	0.416**
Heading	3	6.760**	2.426**	0.793**	969.685**	1.259**
Cultivar× heading	3	0.264*	0.093^{ns}	0.045^{ns}	166.196*	0.227**
Error	14	0.06	0.12	0.033	36.97	0.003
C.V.%		9.92	20.47	21.63	5.65	0.53

**Significantly different at 1% level; *significantly different at 5% level; ^{ns} not significant.

Table 2. Effect of heading treatments on the number of lateral shoots.

Heading (cm)	Total	Number of shoots per tree	
		>10 cm	<10 cm
'Red Delicious'			
Control**	0.9^{e}*	0.6^{c}	0.3^{d}
40	3.5^{a}	2.1^{ab}	1.4^{a}
60	3.4^{ab}	2.3^{a}	1.1^{b}
80	3.0^{bc}	1.9^{ab}	1.1 ^{b}
'Golden Delicious'			
Control	0.6^{e}	0.5^{c}	0.1^{d}
40	2.4^{d}	1.6^{b}	0.8^{bc}
60	2.6^{cd}	1.9^{ab}	0.7^{cd}
80	2.6^{cd}	1.9^{ab}	0.7^{cd}

*Means with similar letter in each column aren't significantly different at 5% level; **without heading.

apple trees. There were significant difference between cultivars and heading treatments. 'Red Delicious' had better response to heading treatments than 'Golden Delicious' cultivar (Table 2). In all the heading treatments, the number of lateral shoot increased in comparison with control. Heading in 60 cm was the best treatment for improving the total number of lateral shoots (Table 2). In all of the heading treatments, the number of long laterals (>10 cm) and short laterals (<10 cm) increased in comparison with control. In both cultivars, heading at 60 and 40 cm were the best treatments for long laterals (>10 cm) and short laterals (<10 cm) formation, respectively (Table 2). There were no significant differences between 40 to 60 cm and 60 to 80 cm in 'Red Delicious' and 'Golden Delicious' cultivars, respectively. Height and stem diameter of treated trees were slightly lower than control trees. There was no significant difference between 60 and 80 cm for stem diameter with control in 'Red Delicious' cultivar. In both cultivars, heading at 80 cm improved the tree height and stem diameter (Table 3).

Experiment 2: BA treatments

All of the BA treatments significantly affected lateral shoot formation (P<0.01). The data presented in Table 4 indicated that application time, concentration and interaction between them were not significant for both height and stem diameter of trees but some of the variables were significant at 1 and 5% levels.

There was significant difference between cultivars and BA treatments. BA treatments significantly increased the total number of lateral shoots compared with the untreated trees (control). The total number of lateral shoots improved with the application of higher concentrations of BA but there was no difference between 400 and 600 mgL^{-1} (Figure 1). 'Red Delicious' had better response to BA treatments than 'Golden Delicious' cultivar. Repeated BA treatments induced more laterals compared with single treatment (Figure 2).

The number of long laterals (>10 cm) and short laterals (<10 cm) were also affected with BA treatments. In all the BA treated trees, the number of long laterals (>10 cm) were significantly greater than control. The most number of long laterals (>10 cm) were observed in BA600×3 and BA400×2 in 'Red Delicious' cultivar. The best treatment for inducing long laterals (>10 cm) in 'Golden Delicious' cultivar was BA200×3 spray (Table 5). The number of short laterals (<10 cm) increased with the application of BA treatments but BA200×1 spray did not have any

Table 3. Effect of heading treatments on the height and diameter of trees.

Treatments	Height (cm)	Diameter (mm)
'Red Delicious'		
Control**	114.7 b*	10.9a
40	102.4cd	10.0c
60	95.5 d	10.8a
80	113.7bc	10.9a
'**Golden Delicious'**		
Control	132.8 a	10.9a
40	102.7cd	10.0 c
60	95.5d	9.7 d
80	107.2bc	10.6b

*Means with similar letter in each column aren't significantly different at 5% level; **without heading

Table 4. Analysis variance of BA on the lateral shoot formation, height and diameter of tree.

S.O.V	df	MS				
		Total	>10 (cm)	<10 (cm)	Height (cm)	Diameter (mm)
Replication	2	0.035	0.031	0.001	30.493	0.195
Cultivar	1	17.898**	4.199**	5.044**	654.956**	0.456
Application time	2	8.350**	1.826**	0.500**	208.616ns	0.622
Cultivar× application time	2	0.239**	0.068*	0.045**	244.122*	3.744**
Concentration	3	35.664**	3.586**	2.883**	83.469ns	1.138ns
Cultivar × concentration	3	7.667**	1.087**	0.618**	487.794**	1.486ns
Application time× concentration	6	4.149**	0.382**	0.161**	135.356ns	0.491ns
Cultivar ×Application time× concentration	6	5.760**	0.950**	0.105**	171.162*	1.582ns
Error	46	0.425	0.02	0.005	73.555	0.841
C.V.%		6.17	13.93	13.52	6.69	8.68

**Significantly different at 1% level; *significantly different at 5% level; ns not significant.

significant differences with control in 'Golden Delicious'cultivar. For both cultivars, the best treatments for inducing short laterals (<10 cm) were observed in BA400×3 and 600×3 sprays (Table 5). BA400×3 sprays induced the strongest influence in height and stem diameter of trees in 'Golden Delicious' cultivar but other treatments were slightly lower than control trees. Height in 'Golden Delicious' was more than 'Red Delicious' genetically, and with BA treatments, same result was obtained (Table 6).

DISCUSSION

'Red Delicious' with easy branching habit had better response to treatments than 'Golden Delicious' and it is confirmed by Kviklys (2006) who said that for apple cultivar with easy branching habit, every treatment was sufficient to increase the percentage of branched trees but cultivars that normally do not produce lateral branches during the first year in the nursery had different response to treatments. Magyar and Hrotko (2005) reported that for such cultivars, more application of plant growth regulators might be needed to increase the percentage of branched trees.

The present research has proven that the heading treatments had significant effects on the branching of apple trees. Heading at 60 cm was the best treatment for improving the total number of lateral shoots. It is confirmed with Bielicki and Czynczyk (2004) who reported that for high quality of planting material, trees should be pruned at the height of 65 cm. Gudarowska et al. (2006) reported that pruning at 40 and 60 cm positively affected the lateral shoot of planting material in cv.'Ligol' apple tree. Heights and stem diameter of treated trees were slightly lower than control trees and heading at 80 cm improved the height and stem diameter of trees. Similar data were presented by Foreshy (1986) who reported that plenty of regrowth is in relation with intensity of pruning and the most effect of heading on

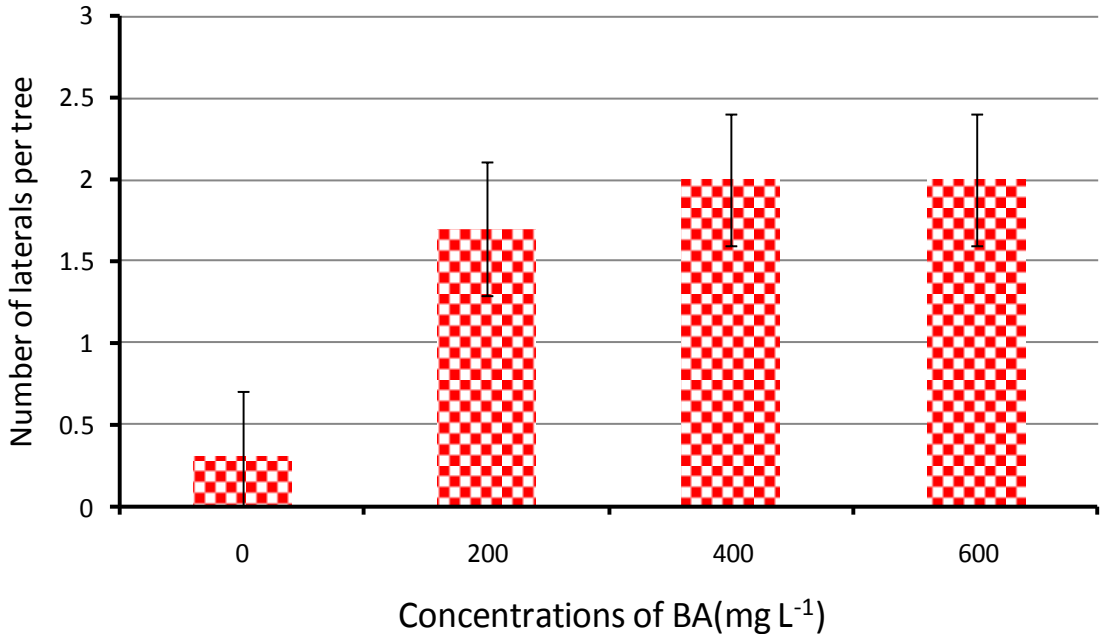

Figure 1. Effect of BA concentrations on the total number of lateral shoots.

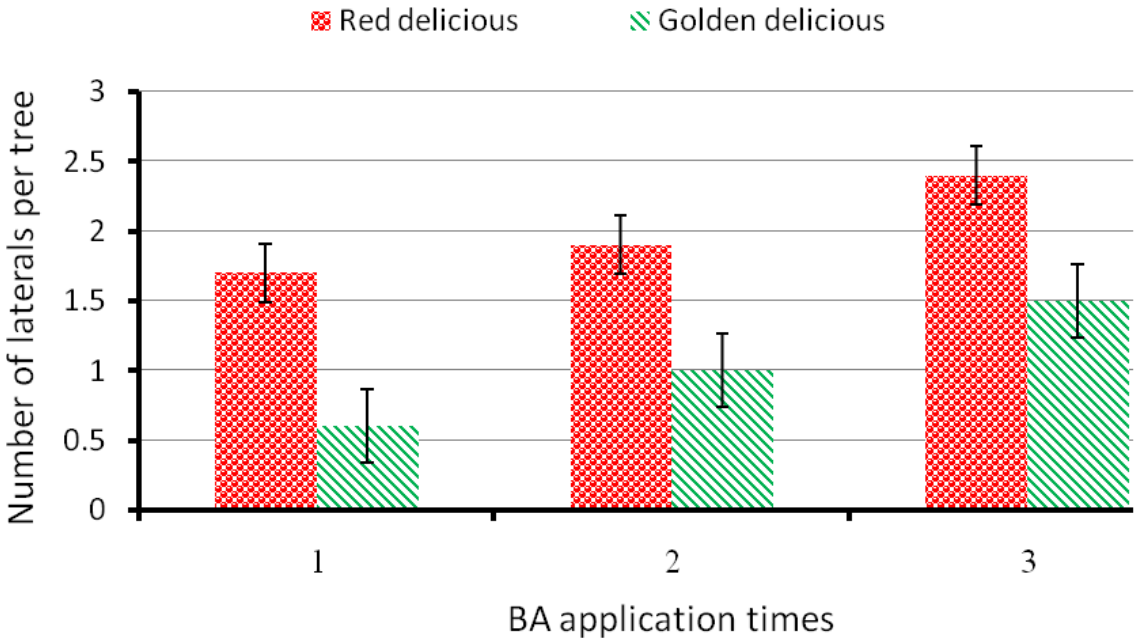

Figure 2. Effect of cultivar and BA application times on the total number of lateral shoots.

trees is the reduction of total vegetative growth. Gudarowska et al. (2006) found that pruning at the height of 80 cm improved the height of 'Ligol' apple trees.

BA treatments significantly increased the total number of lateral shoots compared with the untreated trees (control). Our result is in agreement with Kaplan (2010) who reported that in all of the cultivars under study, the apple control maiden trees formed lower lateral shoot counts than those with growth regulators applied. It is also in agreement with Taemyung et al. (2001) who reported that BA treatments was more effective on lateral shoot formation in 'Tsugaru' apple trees in nursery. Furthermore, not only the rate, but also, the type of active ingredients of any chemical could be important in the

Table 5. Effect of BA treatments on the number of lateral shoots.

Treatments	Total	Shoot number	
		>10 cm	<10 cm
'Red Delicious'			
Control	0.5^{m}**	0.5^{h}	0.0^{g}
BA200×1*	2.0^{f}	1.5^{c}	0.5^{e}
BA200×2	2.0^{f}	1.0^{ef}	1.0^{c}
BA200×3	2.2^{e}	1.4^{cd}	0.8^{d}
BA400×1	2.8^{c}	1.4^{cd}	1.4^{b}
BA400×2	3.1^{b}	2.1^{a}	1.0^{c}
BA400×3	3.7^{a}	2.0^{b}	1.7^{a}
BA600×1	1.9 ^{gh}	0.9^{g}	1.0 ^{c}
BA600×2	2.0^{f}	1.2^{de}	0.8^{d}
BA600×3	3.8^{a}	2.2^{a}	1.6^{a}
'Golden Delicious'			
Control	0.2^{n}	0.2^{i}	0.0^{g}
BA200×1	0.2^{n}	0.2^{i}	0.0^{g}
BA200×2	1.4 ^{j}	1.2^{de}	0.2^{f}
BA200×3	2.5^{d}	2.3^{a}	0.2^{f}
BA400×1	0.8^{i}	0.7^{gh}	0.1^{fg}
BA400×2	0.7^{i}	0.2^{i}	0.5^{e}
BA400×3	1.5^{ij}	0.8^{fg}	0.7^{d}
BA600×1	1.1^{k}	0.7^{gh}	0.4^{e}
BA600×2	1.6^{hi}	1.1^{e}	0.5^{e}
BA600×3	1.8^{g}	1.1^{e}	0.7^{d}

*Repeated sprays (1, 2 and 3) were applied at 7- days interval, starting 15 June 2011; **Means with similar letter in each column aren't significantly different at 5% level.

branching process (Gastol and Poniedzialek, 2003).

Repeated BA treatments induced more laterals compared with single treatment and it is in agreement with Buban (2000) who found that regular application of plant growth hormones could increase the number of lateral shoots in apples. Wertheim and Estabrooks (1994) and Hrotko et al. (1996) also found that repeated BA sprays improve the BA absorption in apple trees. It is reported by Cook et al. (2001) that the possible relationship of branching habit to cytokinin content of apple shoots and suggested that the differential distribution of cytokinin reflects the pattern of budburst and may be correlated with growth habit and it is in agreement with our result.

The best treatment for inducing long laterals (>10 cm) in 'Golden Delicious' cultivar was BA200×3 spray and it is in agreement with Caglar and Ilgin (2009) who reported that two or three sprays of 200 mgL^{-1} BA seemed sufficient to form at least four vigorous laterals (30 to 50 cm) and two medium growth laterals (10 to 30 cm) with wider crotch angles in cv. 'Gala' apple tree. For both cultivars, the best treatments for inducing short laterals (<10 cm) were observed in BA400×3 and 600×3 sprays.

Application of higher concentrations of BA benefits short laterals formation (Magyar and Hrotko, 2002) and it is in agreement with our result. Heights and stem diameter of BA treated trees were slightly lower than control trees and it is confirmed by Caglar and Ilgin (2009).

These results support the need for branch inducement research with different scion cultivars, rootstocks and chemicals to obtain well lateral shoot trees (Caglar and Ilgin, 2009). The chemical treatments produced greater branch number than mechanical heading. Reduction in the tree size from chemical treatments was usually no greater, and sometimes less than from mechanical heading (Cody et al., 1985; Gudarowska and Szewczuk, 2004), and it is in agreement with our results.

Conclusion

In both experiments, 'Red Delicious' had better response to treatments than 'Golden Delicious' cultivar; however, heading and BA application improved branching on young apple trees, but BA treatments had more significant effect on the number and length of lateral shoots than heading treatments. The total number of

Table 6. Effect of BA treatments on the height and stem diameter of trees.

Treatments	Height (cm)	Diameter (mm)
'Red Delicious'		
Control	129.1^{abcdefg**}	10.9^{ab}
BA200×1*	123.5^{bcdefg}	11.2^{ab}
BA200×2	138.7^{ab}	11.2^{ab}
BA200×3	123.9^{abcdefg}	10.1^{b}
BA400×1	129.3^{abcdefg}	11.2^{ab}
BA400×2	117.8^{fgh}	9.7^{b}
BA400×3	119.1^{efgh}	10.1^{b}
BA600×1	133.8^{abcdef}	11.0^{ab}
BA600×2	121.9^{cdefgh}	9.6^{b}
BA600×3	127.1^{abcdefg}	10.3^{b}
'Golden Delicious'		
Control	138.9^{abc}	10.9^{ab}
BA200×1	107.5^{h}	9.7^{b}
BA200×2	121.0^{defgh}	10.4^{ab}
BA200×3	134.5^{abcde}	11.3^{ab}
BA400×1	124.8^{abcdefg}	10.2^{b}
BA400×2	138.9^{abc}	11.1^{ab}
BA400×3	139.9^{a}	12.2^{a}
BA600×1	130.9^{abcdefg}	9.9^{b}
BA600×2	130.8^{def}	10.4^{ab}
BA600×3	133.0^{abcdef}	9.8^{b}

*Repeated sprays (1, 2 and 3) were applied at 7-days interval, starting 15 June 2011; **Means with similar letter in each column aren't significantly different at 5% level.

lateral shoots improved with application of higher concentrations of BA and repeated BA treatments induced lateral shoots more than a single treatment.

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