

CYCLANILIDE TREATMENTS INCREASE LATERAL BRANCHING OF APPLE AND PEAR NURSERY TREES

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Abstract. This study was carried out to investigate the effects of different cyclanilide (Cyc) and Perlan (Pr) doses on formation of lateral branches on apple [Golden Delicious (GD) and Starking Delicious (SD)] and pear (Deveci and Williams) nursery trees grafted on seedling rootstocks. Except for 5 mg L⁻¹ Cyc in Deveci pears, all Cyc concentrations applied in this study increased significantly the number of lateral branches on both apple and pear trees in nursery. In GD apple, while control trees had 2.5 lateral branches, the trees treated 100 mg L⁻¹ Cyc had 12.7 lateral branches per trees. Except for 250 mg L⁻¹ in GD apple, all other Pr treatments did not cause a significant increase in the number of lateral branches on apple and pear trees. Crotch angles of SD apples decreased significantly with 750 mg L⁻¹ Pr treatments. The 250 and 500 mg L⁻¹ Pr treatments significantly reduced number of lateral branches of Williams pears. It was concluded based on present findings that entire Cyc doses could be used as an efficient tool to increase the number of lateral branches in apples and pears; high Cyc doses could also be used to reduce the first branch height in both apple cultivars and Deveci pears.

Keywords: *auxin, benzyladenine, bio-regulator, feather, perlan*

Introduction

For a profitable fruit growing, there are many factors to consider when establishing an orchard. These factors include rootstock, cultivar, tree density, training system, pruning methods and support systems. The primary target of the systems developed for the orchards is to maintain high yield levels through early and late yields and to get exceptional fruit quality (Robinson, 2003). The basic factor for early production is to get fruits from the initial years. Therefore, branched trees are used while establishing orchards (Coşkun, 2011). Number of lateral branches, crotch angle and the first branch height are significant factors in having early and high yields (Barritt, 1992; Hrotko et al., 1996; Kviklyš, 2006; Koyuncu and Yıldırım, 2008; Magyar et al., 2008).

The formation of lateral branches can be controlled through external applications of growth regulators effective in apical dormancy. Cytokinins are known to inhibit apical. Previous researches indicated that benzyladenine (BA), a synthetic cytokinin, stimulated lateral branch formation (Faust, 1989; Atay and Koyuncu, 2016; Ipek et al., 2017). Perlan (Pr) or Promolin (BA+GA₄₊₇) have an active ingredient of cytokinins and gibberellin and these commercial products were also reported to stimulate lateral branch formation in different fruit species (Cody et al., 1985; Elfving, 1985; Yıldırım et al., 2010). Another approach to stimulate lateral branch formation is to inhibit transport of auxins which stimulate apical dormancy. It was reported in previous studies that 2,3,5-triiodobenzoic acid and n-propyl-3-t-butylphenoxyacetate and similar chemicals inhibited polar auxin transport and increased the number of lateral branches (Jacyna and Dodds, 2001). Cyclanilide (Cyc) has emerged as a bio-regulator inhibiting auxin transport and it was

reported in previous studies that Cyc stimulated shooting of lateral buds in different fruit species (Tamas, 1995; Mickelbart, 2011). On the other hand, effects of such chemicals usually vary based on species and cultivars (Wustenberghs and Keulemans, 1999). Previous studies were mostly carried out over the trees grafted on clonal dwarfing rootstocks. On the other hand, in Turkey, nursery trees grafted on seedling rootstocks are still used at considerable rates in apples and pears. These trees generally yield late because of strong vegetative growth. Therefore, in nursery trees grafted on strong rootstocks, breaking apical dormancy and stimulating lateral-branch formation are even more important. This study was conducted to investigate the effects of Cyc and Pr treatments at different doses on lateral branch formation in Golden Delicious and Starking Delicious apple cultivars and Williams and Deveci pear cultivars grafted on seedling rootstocks.

Materials and methods

Plant material

This study was conducted in a commercial nursery orchard in Tokat (Turkey) located between 40° 18' north latitude and 36° 13' east longitude in 2015. Experimental site has a loamy soil texture with moderate lime, low organic matter, sufficient P₂O₅ and K₂O levels. Annual average temperature (based on 55-years data) is 12.6 °C, average relative humidity is 62.8% and average precipitation is 432.1 mm (Tokat Meteoroloji Station). In the study years average temperature, average relative humidity and average precipitation are measured as in 13.1 °C, 62.7% and 318.1 mm, respectively. Fertilization was performed in all experimental plots in accordance with the results of soil analyses. Irrigations were performed with drip irrigation. Golden Delicious (GD) and Starking Delicious (SD) apple cultivars were grafted on apple seedling rootstocks (*Malus domestica* L), Williams and Deveci pear cultivars were grafted on pear seedling rootstocks (*Pyrus communis* L.) with T-budding.

Treatment

Concentration

Apple nursery trees were subjected to 250, 500, 750 and 1000 mg L⁻¹ Perlan (18.8% 6-benzyladenine (BA) and 18.5% GA4+7) and 25, 50, 75 and 100 mg L⁻¹ Cyclanilide (Cyc) treatments; pear trees were subjected to 250 and 500 mg L⁻¹ Perlan and 5, 10, 15 and 20 mg L⁻¹ Cyclanilide treatments. All experimental solutions were applied with 0.1% surfactant. Control trees were subjected to only distilled water treatments with surfactant.

Experimental design

Nursery trees were planted with 80 cm plant spacing and 15 cm row spacing. Standard cultural practices were performed regularly. All treatments were performed in the first week of July when the trees reached to a height of 70-80 cm from the soil surface. Treatments were sprayed about 15-20 cm above the canopy.

Investigated parameters

At the end of growth season, tree trunk diameter, tree height, lateral branch length, height of the first branch, crotch angle, number of lateral branches were determined.

Trunk diameter was measured with a caliper from 5 cm above the graft union. Tree height was measured as the height from the graft union to tip of the tree. Lateral branches longer than 10 cm were counted in each tree to get number of lateral branches per tree. Their lengths were measured to get average lateral branch length. The crotch angle was measured with a protractor. The height of first branch was taken as the distance from the bud union to the first induced feather longer than 10 cm.

Statistical analysis

Experiments were conducted in randomized block design with 3 replications with 10 trees in each replicate. The normality of the data was confirmed by the Kolmogorov-Smirnov test and the homogeneity of variances by the Levene's test. Except for number of lateral branches, resultant data were subjected to variance analysis. Means were separated by Duncan's multiple range test. Since the number of lateral branches did not have a normal distribution, they were analyzed with Friedman test.

Results

As compared to control treatment, neither Cyc nor Pr treatment resulted in significant changes in trunk diameters of either apple cultivars (*Table 1*). A similar response was observed in tree heights. Relative to control treatment, decreases in tree height were observed only with 100 mg L⁻¹ Cyc and 750 mg L⁻¹ Pr treatments of SD cultivar. Experimental treatments did not result in significant differences in lateral branch lengths of GD. Although some treatments created differences in lateral branch lengths of SD cultivar, both Cyc and Pr treatments did not result in significant changes in lateral branch lengths as compared to control treatments.

Table 1. Effects of cyclanilide and perlan treatments on trunk diameter, sapling height, lateral branch length of Golden Delicious and Starking Delicious apple cultivars

Treatments (mg L ⁻¹)	Trunk diameter (mm)	Tree height (cm)	Branch length (cm)
	Golden Delicious		
Control	14.1 ab*	171.5 a	41.9 a
25 Cyc	13.6 ab	159.7 a	30.8 a
50 Cyc	15.62 a	171.6 a	33.5 a
75 Cyc	14.65 ab	154.8 a	31.6 a
100 Cyc	14.8 ab	157.5 a	29.9 a
250 Pr	16.0 a	174.3 a	33.8 a
500 Pr	16.3 a	180.6 a	30.5 a
750 Pr	14.6 ab	160.3 a	39.1 a
1000 Pr	12.0 b	140.9 a	38.6 a
	Starking Delicious		
Control	16.3 ab	211.7 a	50.6 ab
25 Cyc	16.9 a	198.1 ab	49.9 ab
50 Cyc	15.0 ab	179.1 ab	40.5 ab
75 Cyc	15.1 ab	175.8 ab	36.3 ab
100 Cyc	13.1 ab	160.0 b	32.6 b
250 Pr	13.5 ab	173.9 ab	56.3 a
500 Pr	15.2 ab	191.3 ab	38.1 ab
750 Pr	12.6 b	150.6 b	29.3 b
1000 Pr	14.5 ab	170.2 ab	30.3 b

*Means in the same columns with the same letter do not differ according to Duncan's test at P < 0.05

Low Cyc doses did not have significant effects on the first lateral branch height. However, higher doses (75 and 100 mg L⁻¹) result in significant decreases in both cultivars (Table 2). All Pr doses did not cause a significant change in the first lateral branch height of GD apples. In the SD apple tree, while 1000 mg L⁻¹ Pr treatment decreased the first lateral branch height, effects of the other doses were not significant when compared to control treatment. Crotch angles of SD cultivar significantly decreased only with 750 mg L⁻¹ Pr treatment. Effects of the other treatments were not found to be significant.

Table 2. Effects of cyclanilide and perlan treatments on the first branch height and crotch angle of Golden Delicious and Starking Delicious apple cultivars

Treatments (mg L ⁻¹)	Height of the first branch (cm)	Crotch angle (°)
	Golden Delicious	
Control	71.2 a*	56.2 ab
25 Cyc	55.0 abc	58.4 ab
50 Cyc	39.9 abc	59.2 ab
75 Cyc	33.9 bc	61.6 a
100 Cyc	20.7 c	62.2 a
250 Pr	69.2 ab	55.1 ab
500 Pr	72.0 a	55.4 ab
750 Pr	63.1 ab	57.6 ab
1000 Pr	61.1 ab	51.1 b
	Starking Delicious	
Control	102.0 ab	77.5 a
25 Cyc	64.6 bcd	73.5 a
50 Cyc	68.3 bcd	71.0 a
75 Cyc	42.9 d	67.9 a
100 Cyc	31.2 d	65.6 a
250 Pr	111.3 a	67.5 a
500 Pr	98.2 ab	70.6 a
750 Pr	85.8 abc	44.4 b
1000 Pr	53.5 cd	66.0 a

*Means in the same columns with the same letter do not differ according to Duncan's test at P < 0.05

Entire Cyc treatments remarkably increased the number of lateral branches in both apple cultivars. While the number of lateral branches was 2.5 in control treatment of GD cultivar, the value increased to 12.7 with 100 mg L⁻¹ Cyc treatment. In GD cultivar, significant differences were observed in number of lateral branches among the Cyc application concentrations. Number of lateral branches in 50, 75 and 100 mg L⁻¹ Cyc treatments was remarkably higher than both the control and 25 mg L⁻¹ Cyc treatment. Similarly, Cyc treatments increased number of lateral branches also in SD cultivar, but the differences between Cyc doses were not found to be significant. On the other hand, effects of Pr doses on number of lateral branches varied based on the cultivar and treatment dose. Relative to control treatment, only 250 mg L⁻¹ Pr treatment significantly increased number of lateral branches in GD cultivar (Fig. 1).

No treatment was significantly different from each other and control with respect to trunk diameters and tree heights in Deveci and Williams pear cultivars. The differences in lateral branch lengths of the treatments were not found to be significant in Williams cultivar. In Deveci cultivar, 250 mg L⁻¹ Pr-treated trees had significantly higher tree

height than 15 and 20 mg L⁻¹ Cyc-treated trees, but no treatment caused a significant change relatively to control (Table 3).

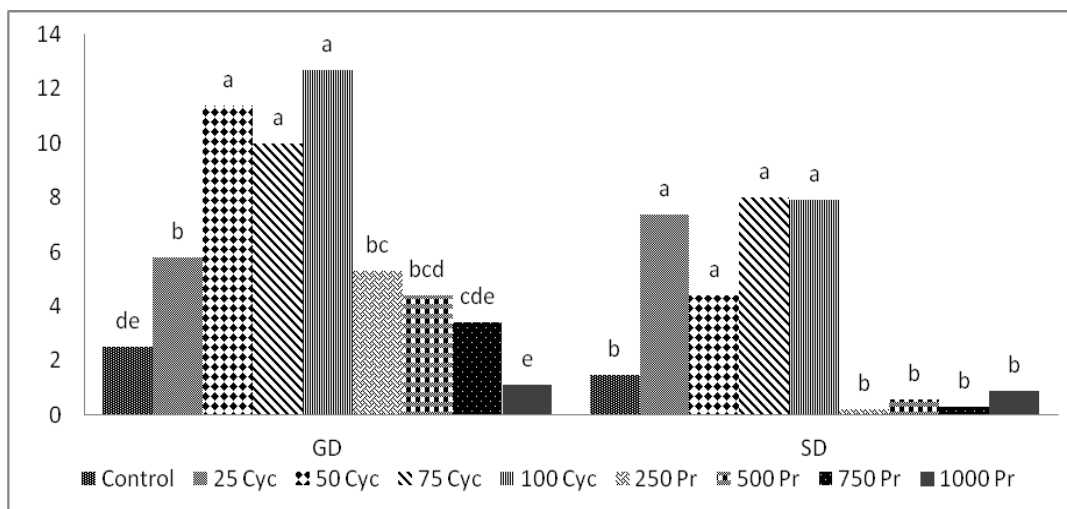


Figure 1. Effects of cyclanilide and perlan treatments on the number of lateral branches of Golden Delicious and Starking Delicious apple cultivars

Table 3. Effects of cyclanilide and perlan treatments on trunk diameter, sapling height and lateral branch length of Deveci and Williams pear cultivars

Treatments (mg L ⁻¹)	Trunk diameter (mm)	Tree height (cm)	Branch length (cm)
	Deveci		
Control	12.84 a*	153.27 a	25.36 ab
5 Cyc	10.78 a	115.60 a	25.51 ab
10 Cyc	11.12 a	114.33 a	21.25 ab
15 Cyc	12.87 a	123.47 a	19.04 b
20 Cyc	11.49 a	115.07 a	18.31 b
250 Pr	11.31 a	123.93 a	29.69 a
500 Pr	12.03 a	140.20 a	25.57 ab
Williams			
Control	12.16 a	126.80 a	12.50 a
5 Cyc	13.46 a	123.60 a	22.20 a
10 Cyc	13.90 a	114.47 a	18.86 a
15 Cyc	11.88 a	106.80 a	17.91 a
20 Cyc	11.57 a	101.07 a	16.54 a
250 Pr	11.07 a	113.27 a	14.00 a
500 Pr	11.65 a	123.53 a	-

*Means in the same columns with the same letter do not differ according to Duncan's test at P < 0.05

The first branch height and crotch angle of Williams cultivar under Cyc and Pr treatments were similar to the control treatments. In Deveci cultivar, on the other hand, Pr treatments yielded similar values with the control saplings, but Cyc treatments (except for 5 mg L⁻¹ Cyc) significantly reduced the first branch heights. Although the crotch angles of 15 mg L⁻¹ Cyc-treated trees were significantly higher than the crotch angles of 5 mg L⁻¹ Cyc-treated trees, both treatment did not differ from control treatment respect to crotch angle (Table 4).

Table 4. Effects of cyclanilide and perlan treatments on the first branch height and crotch angle of Deveci and Williams pear cultivars

Treatments (mg L ⁻¹)	Height of the first branch (cm)	Crotch angle (°)
	Deveci	
Control	127.00 a*	35.93 ab
5 Cyc	93.33 ab	34.07 b
10 Cyc	72.35 b	45.67 ab
15 Cyc	71.05 b	49.42 a
20 Cyc	64.43 b	43.61 ab
250 Pr	97.93 ab	38.31 ab
500 Pr	113.53 a	43.00 ab
	Williams	
Control	47.80 a	41.17 a
5 Cyc	69.75 a	51.46 a
10 Cyc	48.97 a	50.97 a
15 Cyc	54.01 a	47.72 a
20 Cyc	42.07 a	44.19 a
250 Pr	59.00 a	40.00 a
500 Pr	-	-

*Means in the same columns with the same letter do not differ according to Duncan's test at P < 0.05

The experimental treatments had significant effects on number of lateral branches in both pear cultivars. Except for 5 mg L⁻¹ Cyc treatment, other Cyc treatments significantly increased number of lateral branches in Deveci cultivar. In this pear cultivar, while the number of lateral branches per tree was 0.93 in control treatment, the value increased to 5.68 with 15 mg L⁻¹ Cyc treatment. Number of lateral branches in Pr-treated trees of Deveci cultivar was similar with the control treatment. In Williams cultivar, all Cyc treatments significantly increased number of lateral branches. However, both Pr doses significantly reduced the number of lateral branches. As compared to 5 mg L⁻¹ Cyc treatment, 10 and 15 mg L⁻¹ Cyc treatments were significantly more effective on increasing number of lateral branches (*Fig. 2*).

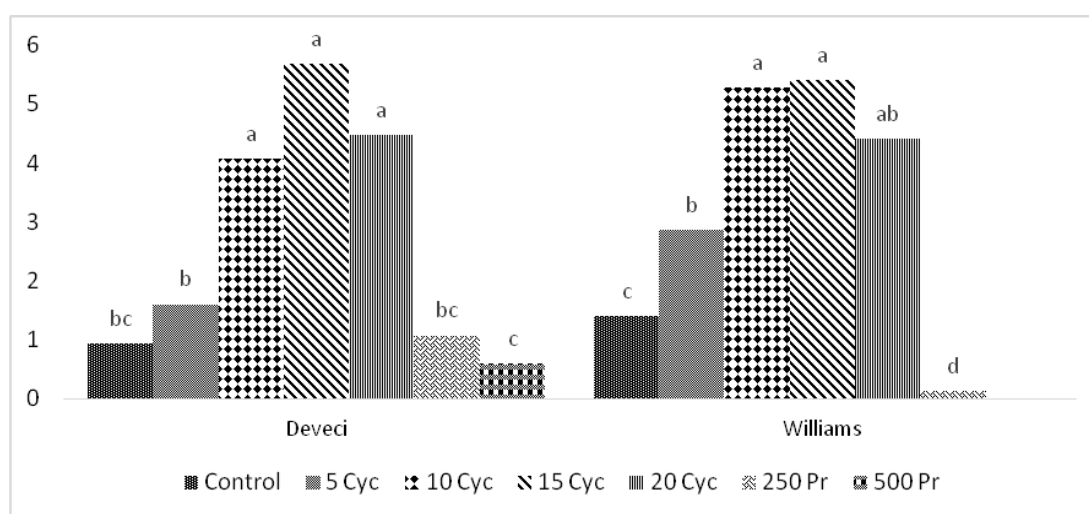


Figure 2. Effects of cyclanilide and perlan treatments on the number of lateral branches of Deveci and Williams pear cultivars

Discussion

Cropping is usually delayed in orchards established with trees with less number of lateral branches (Elfving, 2010). Therefore, some plant growth regulators are used to reduce the effects of apical dormancy and thus to stimulate lateral branch development. It was reported in previous studies that benzyladenine (BA) applied either alone or together with gibberellic acid (GA_{4+7}) increased number of lateral branches in apple and pear saplings (Neri et al., 2004; Koyuncu and Yıldırım, 2008; Yıldırım et al., 2010). In present study, the effects of Pr treatments varied based on species and cultivars. More efficient and stable outcomes were achieved from Cyc treatments. Even remarkable at higher doses, all Cyc treatments distinctively increased number of lateral branches both in apples and pears. A similar case was reported by Elfving and Visser (2006a) for cherry saplings. Previous researchers also indicated that Cyc treatments yielded better outcomes for lateral branch development than Promalin (BA+ GA_{4+7}). Researchers also indicated that the effects of Promalin varied based on species, but Cyc had more stable outcomes for different species (Elfving and Visser, 2006a, b; Ipek et al., 2017; Lordan et al., 2017).

Previous researchers indicated that the effects of both Pr and Cyc on trunk diameter and tree height varied depending on species, cultivars, rootstocks and treatment doses (Gastol and Poniedzialek, 2003; Rossi et al., 2004; Elfving and Visser, 2006a, b; Kalyoncu et al., 2011; Sazo and Robinson, 2011; Moghadam and Zamanipour, 2013; Lordan et al., 2017). However, none of these studies mentioned about a negative impact of those treatments on nursery tree quality parameters. In present study, both Pr and Cyc treatments generally did not have any negative effects on trunk diameter and tree height of apple (GD and SD) and pear (Deveci and Williams) cultivars.

Some researchers reported that BA and Promalin treatments increase lateral branch lengths of apple saplings (Greene et al., 1990; Kalyoncu et al., 2011). Gastol and Poniedzialek (2003) carried out a study with 3 different apple cultivars and indicated that effects of Promalin treatments on lateral branch lengths varied with the years and climate conditions. Elfving and Visser (2005) reported that different Cyc doses did not result in significant changes in lateral branch lengths of Cameo apples grafted on M26 rootstocks, but significantly reduced lateral branch lengths of Fuji apples. Despite the differences in lateral branch lengths of treatments in Deveci pear and Starking Delicious apple cultivar, none of the treatments resulted in significant changes in lateral branch lengths of apples and pears as compared to the control treatments. Such findings revealed that response of nursery trees to Pr and Cyc treatments with regard to lateral branch length might vary based on the rootstocks and cultivars.

Although being changed based on intended market, the first branch height is a significant criterion for all markets. Contradictory outcomes were reported in previous studies about the effects of Pr and Cyc treatments on the first branch heights (Elfving and Visser, 2005, 2006b; Yıldırım et al., 2010; Sazo and Robinson, 2011). Except for Williams cultivar, Cyc treatments decreased the first branch height of the nursery trees, on the other hand Pr treatments generally did not have significant effects on the first branch heights. In previous studies, positive effects of Promalin and Cyc-like growth regulators on crotch angles were reported (Gürz, 2005; Yıldırım et al., 2010). However in this study, no results were obtained to support that both Pr and Cyc could have a beneficial effect on crotch angles of nursery trees of apple and pear cultivars.

Conclusion

Although there are several studies indicating that external application of growth regulators effective in apical dormancy may stimulate lateral branch formation in fruit trees, effects of such growth regulators usually vary based on the rootstock and cultivars. Present findings revealed that all Cyc doses could be used to increase number of lateral branches in apple (Golden Delicious and Starking Delicious) and pear (Deveci and Williams) cultivars grafted on seedling rootstocks; Cyc doses could be used as an efficient tool to reduce the first branch height in two apple cultivars and Deveci pear cultivar. Also, these growth regulators stimulated shooting of lateral buds through inhibiting apical dormancy and did not have any negative impacts on tree heights.

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