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Stimulation of Lateral Branch Development on Tissue Culture-derived Apple Trees

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Abstract

Rooted tissue culture-derived (TCD) apple (*Malus Xdomestica* Borkh.) plants (15 cm tall) of 'Gala' and 'Royal Gala' were either pruned or left unpruned and treated with dikegulac at 5 levels (0, 500, 1000, 1500, 2000 mg/l). Controls were treated with water. Dikegulac-treated plants produced up to 6 branches per stem. Control plants did not branch. The longest branches were observed at the 500 mg/l treatment level. Branch length decreased as the dikegulac concentration increased. Following branch measurement all plants were pruned to soil level and regrowth was examined twenty weeks later. The regrowth length of dikegulac-treated plants was about twice that of control. Leaf area and stem diameter of dikegulac-treated plants were significantly larger than control. These results suggest that dikegulac can be used to obtain high quality multiple-branched apple trees.

Introduction

Dikegulac-sodium (PBI Gordon Corp., Kansas City, MO, USA) is a commercial systemic plant growth regulator that can be applied as a foliar spray to reduce or break apical dominance and to enhance lateral branching. It is absorbed by the leaves and translocated through the phloem to the shoot tips where it inhibits DNA synthesis (2, 3) and reportedly kills terminal buds and promotes branching of certain plants. including pecans (10), azaleas (5, 16), cane cuttings of *Draceana fragrans* (7), tomato (6), pepper (11), and asparagus (8, 9). Algerian ivy plants treated with dikegulac produced more new shoots per node than similar plants treated with GA_{4+7}, 6-BA, or Promalin (1).

The strong apical dominance exhibited by many young apple trees can result in delayed bearing and poor canopy development. Overcoming apical dominance and the promotion of lateral growth are major objectives in the cultural management of an intensive orchard system (12). The use of well-branched nursery trees for orchard planting can shorten the time required for commercial fruit production (4, 13).

This study was initiated to determine whether dikegulac could improve the growth and branching of tissue culture-derived (TCD) self-rooted apple shoots ex vitro.

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Materials and Methods

Two cultivars of apple plants (*Malus Xdomestica* Borkh) were used in this experiment, 'Gala' and 'Royal Gala.' The plants were tissue culture-derived (TCD), (17). The rooted TCD plants (15 cm tall) were maintained in pots (15 cm) for 34 weeks under greenhouse conditions of 18°C night and 24°C day temperatures. The plants were fertilized with 200 mg/l of nitrogen weekly with a water soluble fertilizer. In the second week of August, 1989 (0 week), they were divided into two groups: one group had its apical meristem pruned off, the other group remained unpruned. The day after pinching, all plants were treated with a single high pressure foliar spray of dikegulac (0, 500, 1000, 1500, or 2000 mg/l) to incipient runoff. Tween-20, 0.1% (V:V), was added as a surfactant. After 14 weeks, data concerning branch number, branch length, plant height, stem diameter and leaf area were recorded (leaf area was determined with a digital analyzer Model 3100 Area Meter). In the second week of December, 1989, all plants were pruned to ground level to encourage a single straight trunk. Branch number, branch length, plant height, leaf area and stem diameter were determined 20 weeks later (34 weeks) with a verneer caliper at 30 cm above the soil level.

The experiment consisted of 15 single-plant replicates per treatment arranged in a factorial experiment. A Mean Procedure Analysis from the SAS Program (14) was used to compile the mean for each variable per plant. Data were tested by the General Linear Models Procedure and regression analysis.

Results and Discussion

Dikegulac-treated plants branched from axillary buds and produced up to 6 branches from a single stem. Control plants did not branch (Table 1). There was no significant difference between the number of branches produced by pruned and unpruned plants of 'Gala,' regardless of the level of dikegulac concentration. With 'Royal Gala,' unpruned plants produced significantly more branches than pruned plants at the highest dikegulac concentrations (Table 1).

Table 1. The influence of dikegulac on branch number of pruned and unpruned tissue culture-derived 'Gala' and 'Royal Gala' apple trees 14 weeks after dikegulac treatment.

Treatment mg/l	Branch number			
	Gala		Royal Gala	
	Pruned	Unpruned	Pruned	Unpruned
Control	0.0 a	0.0 a	0.0 a	0.0[z]
500	6.2 c	5.0 b	4.2 b	4.0
1000	6.2 c	5.0 b	4.4 b	5.2
1500	5.1 b	5.2 b	4.6 b	5.6
2000	4.8 b	5.5 b	4.8 b	5.8
Significance				
Linear	*	*	*	*
Quadratic	NS	NS	NS	NS
Cubic	NS	NS	NS	NS

[z]Mean separation in columns by LSD at P = 0.05 level.
NS, *, Nonsignificant or significant at P = 0.05, respectively.

A linear relationship between the dikegulac concentration and branch number was observed. With 'Gala,' the relationship was negative (pruned r = 0.869 Y = 6.6000 - 8.2000e-4x; unpruned r = 0.863 Y = 5.6000 - 3.4000e-4x); in contrast, with 'Royal Gala,' relationship was positive (pruned r = 0.863 Y = 3.7000 + 1.1600e-3x; unpruned r = 0.896 Y = 3.9000 + 4.4000e-4x) (Table 2).

For both cultivars, the longest branches were observed at the lowest dikegulac level (500 mg/l) and branch length decreased as the dikegulac concentration was increased. At the 500 mg/l level branch length (22 and 23 cm) for pruned and unpruned, respectively, of 'Royal Gala' was greater than that of 'Gala' (16.25 and 20 cm) for pruned and unpruned, respectively

Table 2. The influence of dikegulac on branch length of pruned and unpruned tissue culture-derived 'Gala' and 'Royal Gala' apple trees 14 weeks after dikegulac treatment.

Treatment mg/l	Branch length (cm)			
	Gala		Royal Gala	
	Pruned	Unpruned	Pruned	Unpruned
Control	0.0 a	0.0 a	0.0 a	0.0 a[z]
500	5.7 b	5.2 b	10.0 b	10.0 b
1000	8.0 c	5.4 b	10.0 b	12.0 c
1500	8.2 c	7.0 c	14.0 c	14.0 d
2000	16.2 d	20.2 d	23.0 d	22.0 e
Significance				
Linear	*	*	*	*
Quadratic	NS	NS	NS	NS
Cubic	NS	NS	NS	NS

[z]Mean separation in columns by LSD at P = 0.05 level.
NS, *, Nonsignificant or significant at P = 0.05, respectively.

(Table 2). There were significant differences in branch length within the dikegulac treatments. A linear relationship between the dikegulac concentration and branch length was observed ('Gala' pruned: r = 0.89 Y = 17.55 - 0.0064x; unpruned: r = 0.83, Y = 21.06 - 0.0093x; 'Royal Gala' pruned: r = 0.96 Y = 24.5 - 0.0078x; unpruned r = 0.91 Y = 25 - 0.0086x). The effectiveness of dikegulac in increasing lateral branch number was directly related to the killing of the terminal bud and the subsequent release of lateral buds from apical dominance. Dikegulac-treated plants were shorter than control (Table 3). This agrees with previous studies where dikegulac was reported to kill terminal buds and to promote branching at the expense of stem elongation (15).

After pruning to the soil level, a positive increase in plant height associated with an increase in the dikegulac concentration was observed (Table 3). The height of all dikegulac-treated plants was about twice that of control for both 'Gala' and 'Royal Gala.' The largest plants had been treated with the highest concentration of dikegulac. There were significant differences at different levels of treatments of pruned and unpruned plants.

The stem diameter of all dikegulac-treated plants was greater than that of control plants (Table 4) at both 14 and 34 weeks. The stem diameter increased as the dikegulac concentration increased. The largest stem diameters were observed at the highest concentration of dikegulac. There were significant differences at different levels of treatments of pruned and unpruned plants.

The leaf area of dikegulac-treated plants before pruning (14 weeks) was smaller than that of control after pruning (Table 5). However, after pruning to the soil level, the new growth's leaf area increased significantly. The leaf area increased linearly as the dikegulac concentration was increased. The largest leaves were observed at the highest dikegulac concentrations (Table 5). There were significant differences in leaf area observable at different levels of treatments of pruned and unpruned plants.

It is evident from the above data that dikegulac had a strong and long-term effect on the growth of TCD apple cultivars. The large plants which developed after dikegulac application were healthy, vigorous, had large dark green leaves, and were outstanding in all aspects which we judged. Some of these plants were moved to the University of Illinois farms. These plants survived well and are now growing vigorously.

At the 34-week stage, 20 weeks after pruning to the soil level, dikegulac-treated plants were about 100 cm taller and had more branches than control. This may be due to an increase in carbohydrate storage in roots of dikegulac-treated plants resulting from the increased leaf area and branches.

The results obtained in this study indicate that dikegulac can play an im-

Table 3. The influence of dikegulac on plant height of pruned and unpruned tissue culture-derived 'Gala' and 'Royal Gala' apple trees 14 and 34 weeks after dikegulac treatment.

Treatment mg/l	Plant height (cm) 14 Weeks after treatment				34 Weeks after treatment[w]			
	Gala		Royal Gala		Gala		Royal Gala	
	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned
Control	17.0 a	16.0 a	18.0 a	17.3 a[z]	85.0 a	83.0 a	73.0 a	71.0 a
500	24.1 b	20.2 b	21.1 b	20.4 b	150.2 b	148.2 b	143.2 b	139.2 b
1000	28.2 c	24.0 c	25.2 c	24.4 c	155.3 c	153.1 c	151.2 c	155.2 c
1500	50.1 d	37.0 d	45.0 d	37.5 d	167.1 d	165.1 d	159.1 d	161.5 d
2000	80.0 e	55.2 e	67.2 e	55.0 e	175.4 e	172.0 e	169.3 e	166.0 e
Significance								
Linear	*	*	*	*	*	*	*	*
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS

[z]Mean separation in columns by LSD at P = 0.05 level.
[w]After 14 weeks these plants were pruned to the soil level.
NS, *, Nonsignificant or significant at P = 0.05, respectively.

portant role in the production of multiple-branched TCD apple trees for commercial application. Apical dominance was successfully overcome by the application of the chemical-pinching agent, dikegulac. In this study the stimulation of branching, caused by dikegulac, confirms once more the systemic character of this chemical (3, 9).

The overall effect of dikegulac on TCD apple trees is best defined by its effectiveness in increasing the number of new branches as compared to the control. This result suggests either the

Table 4. The influence of dikegulac on stem diameter of pruned and unpruned tissue culture-derived 'Gala' and 'Royal Gala' apple trees 14 and 34 weeks after treatment.

Treatment mg/l	Stem diameter (mm) 14 Weeks after treatment				34 Weeks after treatment[w]			
	Gala		Royal Gala		Gala		Royal Gala	
	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned
Control	5.0 a	4.1 a	4.1 a	4.3 a[z]	5.2 a	5.1 a	4.2 a	5.0 a
500	8.1 b	9.1 b	8.2 b	8.3 b	13.1 b	12.0 b	15.3 b	14.6 b
1000	9.0 c	9.0 b	8.5 b	8.7 b	15.0 c	15.0 c	16.9 c	17.8 c
1500	9.2 c	9.2 b	9.7 c	9.1 bc	15.1 c	16.2 d	17.8 d	18.2 c
2000	10.3 d	9.3 b	11.2 c	9.4 c	17.2 d	17.0 e	18.2 d	18.4 c
Significance								
Linear	*	*	*	*	*	*	*	*
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS

[z]Mean separation in columns by LSD at P = 0.05 level.
[w]After 14 weeks these plants were pruned to the soil level.
NS, *, Nonsignificant or significant at P = 0.05, respectively.

Table 5. The influence of dikegulac on leaf area of pruned and unpruned tissue culture-derived 'Gala' and 'Royal Gala' apple trees 14 and 34 weeks after treatment.

Treatment mg/l	Leaf area (cm^2) 14 Weeks after treatment				34 Weeks after treatment[w]			
	Gala		Royal Gala		Gala		Royal Gala	
	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned	Pruned	Unpruned
Control	12.8 c	13.9 c	10.6 c	11.5 b[z]	34.3 a	35.9 a	32.7 a	31.8 a
500	9.6 bc	10.5 b	7.3 b	7.7 a	45.6 b	51.8 b	50.6 b	50.5 b
1000	8.9 bc	9.9 ab	7.2 b	7.6 a	51.9 c	54.3 c	54.9 c	57.1 c
1500	8.9 b	9.5 a	6.3 a	7.5 a	57.2 d	59.6 d	59.9 d	63.9 d
2000	8.4 a	9.1 a	6.3 a	7.2 b	67.9 e	69.9 e	67.4 e	71.9 e
Significance								
Linear	*	*	*	*	*	*	*	*
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS	NS	NS	NS

[z]Mean separation in columns by LSD at P = 0.05 level.
[w]After 14 weeks these plants were pruned to the soil level.
NS, *, Nonsignificant or significant at P = 0.05, respectively.

end of the residual effects of the chemical or the depletion of the carbohydrate reserve in the roots. Dikegulac appears to have a place in the production of improved quality apple plants. It also helps to reduce maintenance costs and allows for the possibility of using fewer plants in a given area.

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