Stimulation of Lateral Bud Growth of Apple Trees by 6-Benzylamino Purine[1]

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Abstract. Orchard and greenhouse experiments were conducted to determine the influence of foliar applications of 6-benzylamino purine (BA) on branching of young apple trees. BA at 100 and 500 ppm, applied to actively growing shoots stimulated lateral bud growth on these shoots during the current season. The presence of fruit, termination of shoot growth, and the localization and non-persistence of BA reduced its effectiveness in breaking apical dominance. For optimum response to BA, multiple spray applications to actively growing shoots in a non-fruiting condition were required. Spray applications of BA failed to induce lateral bud growth on previous season's wood.

The apple cvs. Cortland, Tydeman's Early, Monroe, and Wayne, among others, generally produce long, unbranched, and upright branches in their formative years, which leads to many undesirable traits. The lack of lateral bud growth (spurs) reduces the fruiting potential. 'Wayne' has a particularly upright growth habit with narrow crotch angles and little spur formation in the interior of the tree[3]. Its excessive vigor causes shading, a deterrent to flower bud development.

Although growth retardants may be of value in reducing terminal growth (1), they do not stimulate lateral shoot growth. Cytokinins, however, have been shown to overcome apical dominance in plants (6, 7) and several reports have indicated these chemicals can specifically stimulate lateral bud growth in apple (5, 8, 9).

Our purpose was to explore the use of cytokinins as an aid in overcoming the problems of undesirable growth habits in apple trees. The cytokinin BA was used as a foliar spray in orchard and greenhouse to study its effect on branching and to analyze factors influencing its effectiveness.

Stimulation of laterial buds in apple seedlings (greenhouse).

Methods. Seeds from a single apple cross, 'Golden Delicious' x 'Jonadel', were germinated in peat pots in the greenhouse in March 1968. In May 1969, 35 1-year-old dormant seedlings selected for uniformity were planted into 6-inch clay pots containing a peat-loam-sand mixture. Solutions of 6-benzylamino purine (BA[4]) and kinetin, both at 50 and 100 ppm, were applied as foliar sprays. All solutions, including a distilled water control, contained Tween 20 at 0.1%. Treatments were applied to the entire seedling to run-off 6 times at weekly intervals (June 16 to July 22). The 5 treatments were replicated 7 times and were arranged in a randomized complete block on the greenhouse bench. On September 10 measurements were made of linear growth of the main stem, trunk diam, and number and length of lateral shoots.

Results. BA at 50 and 100 ppm significantly increased the number of lateral shoots produced on 1-year-old apple seedlings (Table 1). Kinetin at the same concn, however, was not effective in stimulating lateral bud growth. BA at 100 ppm also reduced the growth of the main leader. All treatments except kinetin at 100 ppm, reduced the mean lateral shoot growth when compared to control trees. Stem diam was not influenced.

Orchard effects of BA

Methods. BA solutions of 100 and 500 ppm the latter concn as dispersible solutions, with 0.1% Tween 20, were applied to 3-year-old 'Wayne' and 'Monroe' apple trees on MM 111 roots in the orchard at Geneva, N.Y. Two matched upright branches on each tree were selected. Prior to the first treatment, the barren area of the previous year's wood was delimited to observe effects of BA on older wood. Foliar applications were made with a knapsack sprayer at 7-day intervals for either 1, 2, 3, or 4 consecutive weeks, starting on May 28, during which time the shoots were actively growing. Treatments were replicated 5 times. In the fall, measurements were made of the number and length of new shoots.

In a second orchard study, BA at concn of 100 and 500 ppm was applied to 3-year-old Wayne/MM 106 trees to study its effects on lateral branching. Three-tree sets were treated with BA every 2 weeks 1, 2, 3, or 4 times beginning 2 weeks after full bloom. Entire trees were sprayed to runoff. Thirteen treatments were replicated 3 times.

Results. BA as a foliar spray did not release lateral buds on older wood. It did, however, markedly stimulate lateral bud growth on currently growing shoots of both 'Wayne' and 'Monroe' (Table 2). When more than 1 application of BA at 100 or 500 ppm was made, the number of lateral shoots was significantly increased over controls. All repeat applications were equally effective on both cultivars, except the double application at 100 ppm on 'Monroe' was not as effective in inducing bud growth as the 3 and 4 weekly applications. The multiple application-treatments at 500 ppm were more effective in releasing lateral buds than 100 ppm in the cv. Wayne. This difference was not statistically significant with 'Monroe'. Control shoots showed no branching.

Buds first emerged at the basal nodes after treatment with BA and continued to emerge acropetally in a consecutive fashion as illustrated in Fig. 1. With 'Wayne' the percentage of buds released increased as the number of BA applications increased from 1 to 3. The fourth application did not further stimulate bud growth (Table 2). The multiple sprays of BA significantly increased the length of the branched portion of the current season's shoots on both cultivars. The length of laterals was significantly increased by BA.

The presence of developing fruit on the branch, in all cases, negated any branching effect due to BA (Fig. 1).

In the second orchard experiment, BA applied as a foliar spray once or as multiple applications up to 4 consecutive 2-week intervals failed to induce lateral branching. The 2-week

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[3]Way, R. D., J. N. Cummins, R. L. LaBelle, and J. Einset. Growing and processing the 'Wayne' apple (manuscript in preparation.)

[4]The source of BA in all experiments reported herein was the experimental compound SD 4901, which was kindly supplied by Shell Development Company.

Table 1. Effect of BA and kinetin on the growth of apple seedlings in the greenhouse.

Treatment	No. of lateral shoots	Length of main stem	Mean length of lateral shoots	Trunk diam
		(cm)	(cm)	(cm)
Control	4.8	63.1	18.6	0.47
BA @ 50 ppm	10.1	46.0	11.0	0.39
BA @ 100 ppm	12.9	40.6	10.1	0.37
Kinetin @ 50 ppm	6.7	47.8	11.3	0.43
Kinetin @ 100 ppm	6.6	49.4	12.6	0.42
L.S.D. at 0.05P	4.9	18.9	6.5	N.S.

intervals between BA applications apparently provided insufficient stimulus to induce branching.

Effect of stage of shoot development on lateral bud release

Methods. Thirty-two, 2-year-old Spijon/EM VII apple trees were used for this greenhouse experiment. All but 3 vigorous, upright terminal shoots were removed. When the unbranched shoots were 20 to 40 cm long and still actively growing, a single leaf per shoot was tagged and dipped into a 100 ppm BA solution containing Tween 20 at 0.1% for 10 seconds. The solution was prevented from contacting the petiole or axillary bud. This treatment was repeated twice daily for 4 consecutive days. Leaves of all stages of maturity from the oldest basal leaf to the terminal growing point were selected for treatment. A duplicate set of shoots which had set a terminal bud and ceased extension growth was selected to compare BA treatments on actively vs. nonactively growing shoots. Untreated controls and shoots with decapitated apices were included. As an additional treatment, alternate leaves on the shoot were dipped in BA to observe translocation of the BA stimulus. The 32 treatments were completely randomized and replicated 3 times. Observations on bud activity were made over a 4-week period.

Results. The axillary buds of all expanded leaves individually treated daily for 4 consecutive days on actively growing shoots grew vigorously within 4 days following the last treatment (Table 3). The buds of all untreated leaves on the same shoot remained dormant for the duration of the experiment as illustrated in Fig. 2. All control shoots remained unbranched. Lateral bud growth on terminally dipped shoots was stimulated only in 1 case. Decapitation of the apex resulted in vigorous growth of the uppermost 2 or 3 buds.

With alternately dipped leaves only the buds sublended by treated leaves were released leaving the control buds unaffected.

Of the lateral buds induced to grow by BA there was no significant difference in the resultant shoot lengths, regardless of positions on the shoot. The time required for release was progressively longer in younger buds and decreased in a basipetal direction (increasing bud maturity).

When growth had ceased and terminal buds had formed, BA had no influence in overcoming apical dominance.

Discussion

BA applied to the foliage of actively growing apple shoots significantly stimulated lateral branching in the current season. These findings are in accord with those previously reported by Poll (5).

Various factors were found to limit the effectiveness of BA in inducing branching, namely the presence of fruit, termination of extension growth of the shoot, little or no translocation of the chemical, and frequency of application.

When a developing fruit was present on the terminal position of shoots of 'Wayne' and 'Monroe', BA was ineffective in stimulating axillary bud emergence (Fig. 1). A different hormonal balance was apparently created by the young fruit

Table 2. Effect of BA as a foliar spray on lateral shoot development on current season's wood of 'Wayne' and 'Monroe' apple trees.

BA treatment	No. of weekly applications	No. of laterals per shoot	Mean length of laterals	Total shoot length branched	% buds released
(ppm)			(cm)	(cm)	
		Wayne			
Control	0	0.0	0.0	0.0	0.0
100	1	0.0	0.0	0.0	0.0
100	2	3.0	2.8	13.8	14.3
100	3	4.0	6.8	16.7	18.2
100	4	3.0	4.2	14.2	11.4
500	1	2.0	1.9	9.7	10.0
500	2	7.0	5.5	28.2	30.9
500	3	6.5	5.6	30.6	31.7
500	4	6.0	8.3	28.7	25.1
L.S.D. P = 0.01		2.8	2.7	13.9	14.0
		Monroe			
Control	0	0.0	0.0	0.0	0.0
100	1	0.0	0.0	0.0	0.0
100	2	2.0	3.8	20.0	11.1
100	3	5.0	4.9	32.2	24.4
100	4	6.3	6.9	46.5	27.8
500	1	3.4	5.8	26.3	18.5
500	2	5.8	11.5	37.7	26.9
500	3	6.4	12.7	39.7	29.8
500	4	5.4	9.4	34.3	25.5
L.S.D. P = 0.01		2.6	5.6	17.3	10.8

Fig. 1. Branches of 'Monroe' apple trees depicting control (left), BA treated fruiting branch (center) and BA treated nonfruiting branch (right). Note that fruiting negated the branching effect of BA. Branching did not occur on older wood (arrow). BA was applied at 100 ppm for 4 consecutive weekly intervals, beginning May 28.

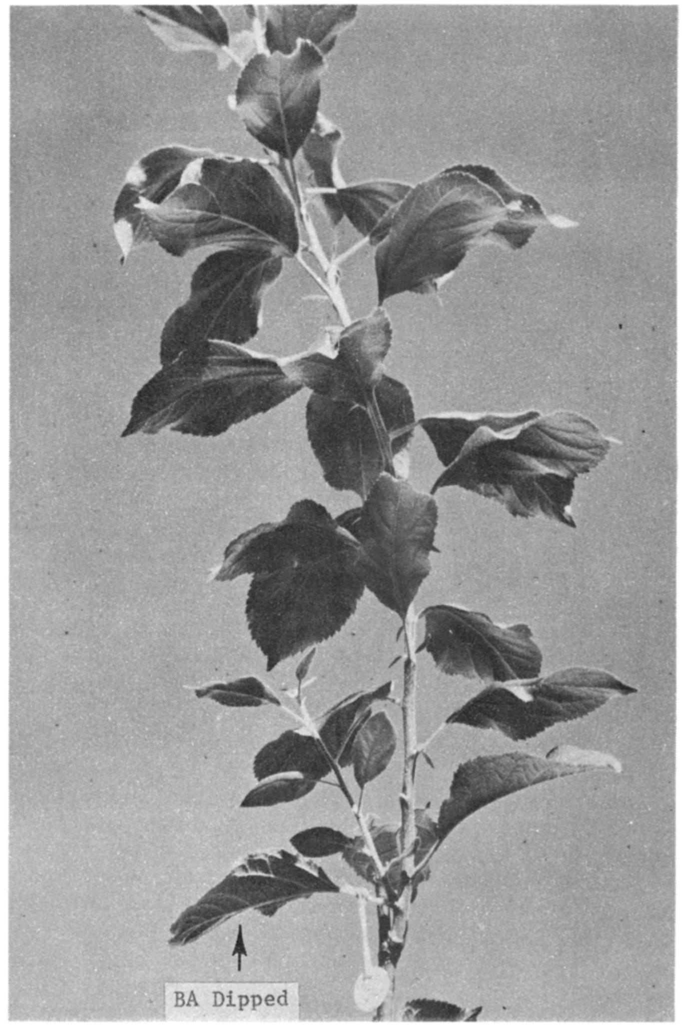

Fig. 2. Branch of 'Spijon' apple tree showing a lateral shoot emerged from the axillary bud of a BA treated leaf (arrow). Note nontreated buds were not released.

thus negating the BA-induced branching effect observed on non-fruiting branches. Young trees from 1 to 3 years of age, however, do not generally fruit heavily and therefore this factor would not seriously restrict chemical training of young apple trees with BA.

The divergent response of growing and nongrowing shoots to BA may be associated with the presumably high gibberellin activity in the apices of growing shoots which was available to stimulate lateral shoot elongation. Axillary buds on nongrowing shoots may have been induced to grow but low gibberellin activity prevented their elongation. Williams and Billingsley (9) found that a combination of exogenous GA and cytokinin was needed to allow lateral shoots to elongate from dormant apple buds. Combinations of these 2 substances were also shown to induce runner formation in strawberry (3). In the present study, lateral shoots induced by BA did not stop growth early as reported by Williams and Billingsley (9) for dormant buds treated with BA. Apparently the endogenous gibberellin supply in growing shoots was not a limiting factor. These results suggest a sequential role for these hormones, the cytokinins to initiate mitosis and gibberellin for subsequent growth by elongation.

The data from our greenhouse studies show that foliarly applied BA produces only a localized stimulus and buds within about 5 cm of the point of application respond. When an individual leaf was dipped into a BA solution only its axillary bud was stimulated to grow. When 2 leaves were dipped on either side of an untreated leaf, the axillary bud of the latter failed to emerge.

Friedrick et al. (2) found that 6-benzyladenine-8-^{14}C was transported both acropetally and basipetally in 1-year-old apple shoots. The strongest concn, however, was immediately below the site of application (7-10 cm) and quantity transferred further was very small. Pieniazek and Jankiewicz (4) found a stimulation of apple buds in the apical direction. We detected bud activity only immediately below the point of application, which concurs with the translocation studies of Friedrick et al. (2).

Buds on wood of previous year's growth and older did not respond to foliarly applied BA. Williams and Billingsley (9), however, using lanolin as a carrier found BA applied directly to buds on dormant branches to be effective on older wood.

Because the effects of individual foliar applications of BA are of temporary duration and influence only actively growing shoots, it is apparent that a constant cytokinin supply must be afforded to the bud to break apical dominance. Optimum timing of multiple applications are of utmost importance to affect the desired physiological response.

Although recommendations have been made for treatment of dormant buds with lanolin containing BA on 1-year-old trees to

Table 3. Mean length in cm of lateral shoots emerged from axillary buds of individually BA-dipped leaves on actively growing shoots of 'Spijon' apple trees in the greenhouse (mean of 3 replications).

BA-treated leaf[x]	Bud position[z]												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	5.3	–[y]	–	–	–	–	–	–	–	–	–	–	–
2	–	5.8	–	–	–	–	–	–	–	–	–	–	–
3	–	–	6.4	–	–	–	–	–	–	–	–	–	–
4	–	–	–	5.4	–	–	–	–	–	–	–	–	–
5	–	–	–	–	4.9	–	–	–	–	–	–	–	–
6	–	–	–	–	–	6.6	–	–	–	–	–	–	–
7	–	–	–	–	–	–	4.5	–	–	–	–	–	–
8	–	–	–	–	–	–	–	3.1	–	–	–	–	–
9	–	–	–	–	–	–	–	–	5.3	–	–	–	–
10	–	–	–	–	–	–	–	–	–	3.0	–	–	–
11	–	–	–	–	–	–	–	–	–	–	7.6	–	–
12	–	–	–	–	–	–	–	–	–	–	–	3.5	–
13	–	–	–	–	–	–	–	–	–	–	–	–	4.5
Alternate leaves													
3 + 5	–	–	5.8	–	6.0	–	–	–	–	–	–	–	–
5 + 7	–	–	–	–	5.0	–	4.6	–	–	–	–	–	–
11 + 13	–	–	–	–	–	–	–	–	–	–	7.6	–	4.5
terminal	–	–	–	–	–	–	–	–	2.6[x]	–	–	–	–
terminal decapitated	–	–	–	–	–	–	1.7	5.3	3.0	–	–	–	–

[z]1 = basal node, 2 to 13 = progressively younger.
[y]Indicates no bud activity.
[x]Only 1 replication exhibited bud activity.

stimulate laterals for training purposes (8, 9), foliar applications to induce branching on young established trees may also be of value. Such treatments might be of particular benefit on cultivars which produce long, barren shoots early in their development, e.g. 'Wayne', 'Monroe', 'Cortland', et al. For subsequent studies with cytokinins as foliar sprays on apple tree branching, the data reported herein suggest that BA at 100 ppm be applied at no longer than 7-day intervals to actively growing shoots as repeat applications. The greater the number of applications made, the greater the number of lateral shoots which may be expected. Applications should be terminated when terminal shoot growth ceases. Heavily fruiting trees should not be treated.

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