Preharvest applications of dicamba at rates of 10 to 30 mg·liter^{-1} appear equal, or superior, to NAA for delaying fruit abscission without advancing maturity of the major fall apple cultivars. Although additional information concerning optimal timing and possible combination with NAA would be useful, our data indicate that dicamba effectively reduces preharvest fruit drop of apple and is worthy of serious consideration for U.S. Environmental Protection Agency registration.

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Thinning Activity of Benzyladenine on Several Apple Cultivars

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Abstract. Postbloom sprays of BA thinned ‘McIntosh’, ‘Delicious’, ‘Golden Delicious’, ‘Mutsu, ‘Empire’, and ‘Abas’ apples. BA at 75 to 100 mg·liter^{-1} was equal to NAA at 6 to 7.5 mg·liter^{-1} or carbaryl at 600 to 800 mg·liter^{-1}. BA increased fruit size, flesh firmness, and soluble solids concentration (SSC) on all cultivars evaluated. Since BA is applied during the time when cell division is occurring, it is concluded that the increased fruit size and flesh firmness were due to Increased cell numbers. Increased SSC was not due solely to increased leaf : fruit ratio. Thinning with BA was additive with other chemical thinners and no interactions were found on fruit abscission. In most eases, BA increased return bloom. Chemical names used: N-(phenylmethyl)1H-purine-6-amine [benzyladenine (BA)]; 1-naphthaleneacetic acid (NAA); 1-naphthalenyl methylcarbamate (carbaryl); butanedioic acid mono(2,2dimethylhydrazide (daminozide); (2-chloroethyl)phosphonic acid (ethephon).

Chemical thinning is one of the most important yet one of the most difficult plant growth regulator practices to perform in modem apple production (Looney, 1986). Cost of chemical thinning materials and their application are relatively low, yet the cost is perilously high if over-thinning or under-thinning occurs.

The chance of over-thinning with carbaryl is not great, since carbaryl is not a potent thinner and, at the concentrations generally used, its response is not concentration dependent (Forshey, 1987). Frequently, carbaryl may not thin adequately. This has been true in recent years when there is an increasing demand for larger fruit (Greene and Autio, 1988). NM and ethephon

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are more potent thinners, but they also may over-thin, especially when applied during high temperatures (Williams and Edgerton, 1981).

No chemical thinning agents have been registered recently for use in the United States. McLaughlin and Greene (1984) suggested that BA may be used as an effective chemical thinner on apples. Greene and Autio (1989) recently reported that BA effectively thinned 'McIntosh' apples. BA at 50 mg·liter^{-1} was more effective than NAA at 5 mg·liter^{-1}. BA and NAA thinned more effectively when each was combined with carbaryl.

This investigation was initiated to evaluate BA as a chemical thinner on several apple cultivars and to evaluate the thinning potential of BA when used in combination with other commercially used chemical thinning agents.

Materials and Methods

Several experiments were conducted over 6 years when BA and other chemical thinners or growth retardants were applied as dilute sprays to whole apple trees either in production or just coming into production.

Bearing trees

Experiment 1. 'Empire'/MM.106, Belchertown, Mass. Before bloom, two limbs, 10 to 15 cm in circumference, per tree were tagged, the circumference recorded, and all blossom clusters counted. At full bloom (FB) + 14 days, whole trees were sprayed to the drip point with BA at 0, 100, or 200 mg·liter^{-1} or carbaryl at 0 or 600 mg·liter^{-1} alone or in combination. Experimental design was a randomized complete block with seven replications. At the end of the June drop period, all fruit on tagged limbs were counted. At commercial harvest time, a 30-apple sample was randomly harvested from each tree and weighed. Ten representative fruit from each bag were selected and the flesh firmness determined with a Magness-Taylor penetrometer (tip diameter 11 mm) on two sides of each fruit. Juice was collected during the firmness test and soluble solids concentration (SSC) was determined by use of a hand refractometer on a composite juice sample. The total length (L,) and diameter (D) of 30 fruit was measured and the L : D ratio calculated. Yield for each tree was calculated by adding the number of hand-picked fruits and dropped fruit. Return bloom the following year was determined on the tagged limbs.

Experiment 2. 'McIntosh'/M.7, Belchertown, Mass. BA (0 or 75 mg·liter^{-1}), NAA (0 or 6 mg·liter^{-1}), and carbaryl (0 or 600 mg·liter^{-1}) were applied as whole-tree sprays at FB + 20 days in a factorial randomized complete-block design with six replications. Bloom, fruit set, and fruit quality measurements were determined as described in Expt. 1. In addition, 30 apples per tree were individually rated to the nearest 10% for the percentage red surface; we also judged whether the degree of redness of each of these fruits was sufficiently intense to be graded U.S. Extra Fancy.

Experiment 3. 'Hi Early Delicious'/seedling, Harcount, Victoria, Australia. BA (0, 100, or 200 mg·liter^{-1}), ethephon (0 or 100 mg·liter^{-1}), and carbaryl (0 or 800 mg·liter^{-1}) were applied in a factorial randomized complete block. with eight replications. The experimental procedures were similar to those described in Expt. 1. In addition, fruit symmetry was rated and the seed number counted on a 30-apple sample from each tree.

Experiment 4. 'Abas'/seedling, Knoxfield, Victoria, Australia. In a factorial experiment, BA (0 or 100 mg·liter^{-1}), ethephon (0 or 150 mg·liter^{-1}), and daminozide (0 or 1500 mg-liter^{-1}) were applied to whole trees in a randomized complete-block design with nine replications. Ethephon was applied at FB + 4 days, BA at FB + 13 and 23 days, and daminozide at FB + 23 days. Data collection was similar to that described for Expt. 1.

Experiment 5. Cultivar evaluation, Belchertown, Mass. Six trees each of 'Golden Delicious', 'Starkrimson Delicious', 'Starking Delicious', and 'McIntosh' on M.7 rootstock and 'Empire'/MM.106 were selected before bloom, and four limbs, 10 to 15 cm in circumference, per tree were tagged. All blossom clusters were counted on each limb. When fruit diameter was ≈ 10 mm, between FB + 16 to 19 days, BA at 100 mg·liter^{-1} was applied to two of the four limbs per tree. Two limbs per tree were untreated and served as the control. Fruit set and fruit evaluation was similar to that described for Expt. 1.

Trees just coming into production

Experiment 6. 'Mutsu'/M.7, Brookfield, Mass. A block of 6-year-old 'Mutsu' trees was partitioned into seven blocks (replications) of eight trees each. Twelve days after full bloom, when terminal growth was ≈ 10 to 15 cm, seven trees in each block were sprayed to the drip point with daminozide at 1500 mg·liter^{-1}. For six of the daminozide-treated trees, BA was included at 50, 100, or 200 mg·liter^{-1} (two trees treated per level). One tree was not sprayed and served as the control. Three weeks after the first application, one of the two BA-treated trees at each level in each block received a second spray of BA. Fruit were evaluated at harvest as in Expt. 1.

Experiment 7. 'Redspur Delicious'/M.7, Belchertown, Mass. Four-year-old trees were blocked into seven groups (replications) of eight trees each. Thirteen days after full bloom, four trees in each block were sprayed to the drip point with 1500 mg daminozide/liter. One tree sprayed with daminozide and one unsprayed tree in each block were treated with 0, 75, 150, or 300 mg BA/liter. Fruit set was determined on three limbs per tree after June drop. Return bloom and yield were determined the following year.

Experiment 8. 'Redspur Delicious'/MM.111. Five-year-old trees were partitioned into seven blocks (replications) of six trees each. Ten days after full bloom, three trees in each block were sprayed to the drip point with 1500 mg daminozide/liter. One tree sprayed with daminozide and one tree not previously sprayed were then treated with BA at 0, 150, or 300 mg·liter^{-1}. Fruit were evaluated as in Expt. 1.

All data were subjected to analysis of variance. Where interactions were nonsignificant, only main effect means are presented. Those means were separated by F test or single-degree-of-freedom orthogonal comparisons, depending on the number of levels in the experiment. In Expt. 6, single-degree-of-freedom linear comparisons were also used to separate means.

Results

BA and carbaryl significantly reduced crop load on 'Empire' (Table 1). The thinning response to BA was linear, with excessive thinning occurring at the highest BA rate. A full bloom + 14 days BA spray increased fruit weight, flesh firmness, SSC, and L : D ratio. Return bloom was increased by both BA and carbaryl, but neither increased yield the 2nd year. There were no interactions.

BA at 75 mg·liter^{-1} thinned 'McIntosh' comparably to NAA at 6 mg·liter^{-1}, while carbaryl at 600 mg·liter^{-1} was ineffective (Table 2). Although NAA and BA thinned comparably, only

Table 1. Effect of BA and carbaryl combination sprays on fruit set, fruit quality, fruit characteristics, and return bloom on 'Empire'/MM.106 apples. Expt. 1.

	1983						1984	
Treatment (mg·liter^{-1})	Fruit/cm limb circumf.[z]	Yield[y] (kg/tree)	Fruit wt[y] (g)	Flesh firmness[x] (N)	Soluble solids concn[x] (%)	L : D ratio[y]	Blossom cluster/ cm limb circumf.[z]	Fruit/cm limb circumf.[z]
BA								
0	7.6	98.2	139	78.0	11.0	0.85	10.2	3.3
100	4.8	64.8	174	79.3	11.4	0.87	13.0	4.1
200	2.9	53.6	190	79.3	11.3	0.86	12.5	3.5
Significance[w]	l***	l***	l***	l**	*	q**	l** q**	NS
Carbaryl								
0	5.9	81.6	163	78.9	11.2	0.86	10.5	3.6
600	4.3	62.6	173	78.4	11.2	0.86	13.3	3.7
Significance	*	*	*	NS	NS	NS	**	NS

[z]Means of 28 (BA) or 42 (carbaryl) observations.
[y]Means of 14 (BA) or 21 (carbaryl) observations.
[x]Means of 280 (BA) or 410 (carbaryl) observations.
[w]The response was linear (l) or quadratic (q).
*,**,***,NSSignificant within columns at P = 0.05, 0.01, or 0.001, or nonsignificant, respectively.

Table 2. Effects of NAA, carbaryl, and BA at 6, 600, and 75 mg·liter^{-1}, respectively, used alone and in combination on fruit set, yield, and fruit quality of 25-year-old 'McIntosh'/M.7. Expt. 2.

Treatment[z]	Fruit/cm limb circumf.[y]	Yield (kg/tree)[x]	Fruit wt[x] (g)	Flesh firmness[w] (N)	Soluble solids concn[x] (%)	Red color[v] (%)	U.S. Extra Fancy[v] (%)
Control	9.3	302	135	66.5	10.1	59	81
NAA	7.1	308	143	67.9	10.0	62	86
Carbaryl	8.6	270	139	67.9	10.2	60	77
BA	7.3	296	153	67.4	10.4	61	79
BA + carbaryl	5.0	274	162	68.3	10.4	56	74
BA + NAA	4.7	206	153	74.3	10.5	53	61
NAA + carbaryl	5.2	236	150	68.8	10.2	57	75
BA + NAA + carbaryl	4.7	226	156	69.7	10.4	58	73
Significance							
NAA −	7.5**	286	147NS	14.7NS	10.2NS	59NS	78NS
+	5.4	244	150	15.3	10.3	57	73
Carbaryl −	7.1NS	278	146NS	15.0NS	10.2NS	59NS	77NS
+	5.8	252	152	15.0	10.3	58	75
BA −	7.5***	278	142***	14.8*	10.1***	59NS	80NS
+	5.4	250	156	15.2	10.4	57	72

[z]Treatments applied 6 June 1988 (FB + 20 days) as a dilute spray. Weather conditions were sunny, breezy, and the temperature near 21C.
[y]Means of 12 observations with individual treatments (T1-T8) and 24 observations within pooled chemical thinner means.
[x]Means of six observations with individual treatments (T1-T8) and 24 observations within pooled chemical thinner means.
[w]Means of 120 observations with individual treatments T1-T8) and 480 observations within pooled chemical thinner means.
[v]Means of 180 observations with individual treatments (T1-T8) and 720 observations within pooled chemical thinner means.
*,**,***,NSMain effects within columns significant at P = 0.05, 0.01; or 0.001, or nonsignificant, respectively.

BA increased fruit weight. BA also increased flesh firmness and SSC. No thinning treatment altered development of redness or fruit that graded into the U.S. Extra Fancy category because of color intensity. There was a significant BA × NAA interaction on yield. BA alone did not significantly reduce yield. However, when NAA was included with BA, the yield per tree was reduced (data not shown).

Carbaryl and BA thinned 'Hi Early Delicious', while ethephon was ineffective (Table 3). Only BA increased fruit size at harvest. Both carbaryl and BA reduced seed number. BA increased flesh firmness, SSC, L : D ratio, and the number of fruit with asymmetric, shape. All treatments increased return bloom, although subsequent fruit set was not influenced. There were no interactions between BA and the other growth regulators.

Both BA and ethephon reduced fruit set and increased fruit weight on 'Abas' (Table 4). BA and daminozide increased flesh firmness. Ethephon and BA increased fruit SCC, while dami-

Table 3. Effects of ethephon, carbaryl, and BA on fruit set, fruit quality, fruit characteristics, and return bloom of ‘Hi Early Delicious’/seedling apples. Expt. 3.[z]

	1983								1984		
Treatment (mg·liter⁻¹)	Fruit/cm limb circumf.[y]	Fruit wt[x] (g)	Flesh firmness[w] (N)	Soluble solids concn[x] (%)	L : D ratio[x]	Seeds/ fruit[w]	Seedless fruit[w] (%)	Asymmetric fruit (%)	Blossom clusters/ cm limb circumf.[y]	Fruit/cm limb circumf.[y]	Fruit/100 blossom clusters[y]
Control	2.9 a	225 a	77.5 a	11.0 b	0.95 a	4.0 a	20.0 b	22 a	8.8 b	3.8 ab	52 a
Ethephon											
100	2.6 a	232 a	78.9 a	11.4 a	0.93 a	4.3 a	13.8 b	18 b	11.7 a	4.2 a	40 b
Carbaryl											
600											
BA	1.6 b	249 a	80.3 a	11.6 a	0.96 a	2.8 b	37.7 a	23 a	10.7 a	3.3 b	33 b
0	4.3	190	73.4	11.0	0.93	4.7	8.3	15	7.2	3.6	54
100	2.0	245	79.3	11.6	0.95	4.0	19.1	20	10.7	4.1	41
200	0.8	271	83.9	11.5	0.96	2.5	44.0	27	13.2	3.6	30
Significance[v]	l***,q*	l***,q**	l***	l***,q**	l***	l***	l***	l***	l***	NS	l***

[z]Mean separation within columns, Duncan’s multiple range test, $P = 0.05$.
[y]Means of 48 observations.
[x]Means of 24 observations.
[w]Means of 480 observations.
[v]The response was linear (l) or quadratic (q).
*,**,***,NS Main effects within columns significant at $P = 0.05$, 0.01, or 0.001, or nonsignificant, respectively.

Table 4. Effects of BA, ethephon, and daminozide on fruit set, fruit quality, fruit characteristics, and return bloom of ‘Abas’/seedling apple. Expt. 4.

Treatment (mg·liter⁻¹)	Fruit/cm limb circumf.[z]	Yield[y] (kg/tree)	Fruit wt[y] (g)	Flesh firmness[x] (N)	Soluble solids concn[y] (%)	Seed/ fruit[w]	Return bloom: Blossom clusters/cm limb circumf.[z]
BA							
0	7.8	33.0	89	83.9	13.2	6.6	1.0
	*	NS	***	***	**	*	NS
100	6.7	33.0	103	89.4	13.8	7.1	1.5
Ethephon							
0	8.1	36.4	89	87.1	13.2	7.0	0.7
	**	NS	**	NS	*	NS	NS
150	6.3	29.9	103	85.8	13.7	6.7	1.8
Daminozide							
0	7.4	34.2	98	82.5	13.7	7.1	0.4
	NS	NS	NS	***	*	*	NS
1500	7.1	32.2	94	90.8	13.2	6.6	2.0

[z]Means of 64 observations.
[y]Means of 32 observations.
[x]Means of 640 observations.
[w]Means of 960 observations.
*,**,***,NS Main effects within columns significant at $P = 0.05$, 0.01, or 0.001, or nonsignificant, respectively.

nozide reduced it. BA increased seed number, daminozide reduced it, and ethephon had no effect. No treatment influenced return bloom. There were no growth regulator interactions..

BA at 100 mg·liter⁻¹ significantly thinned and increased fruit weight of ‘McIntosh’, ‘Bisbee Delicious’, ‘Starking Delicious’, ‘Golden Delicious’, and ‘Empire’ (Table 5). Soluble solids concentration was increased in ‘Bisbee Delicious’, ‘Starking Delicious’, and ‘Golden Delicious’. BA did not alter seed number in any cultivar.

BA thinned young ‘Mutsu’ (Table 6) and ‘Redspur Delicious’ (Tables 7 and 8) trees at concentrations up to 300 mg·liter⁻¹. Two applications of BA increased fruit weight and SSC more than one application (Table 6). Daminozide increased flesh firmness. Return bloom was increased when daminozide was included with either one or two sprays of BA, although fruit set the year after application was increased only when BA was applied twice. There were no growth regulator interactions.

Daminozide did not influence fruit set, yield, or return bloom of ‘Redspur Delicious’ (Tables 7 and 8), although flesh firmness and SSC were increased and fruit weight was reduced (Table 8). BA increased return bloom and fruit set on ‘Redspur Delicious’ in 1984 but not in 1983. BA increased fruit weight, flesh firmness, SSC, and the number of “pygmy” fruit (Table 8).

Discussion

The thinning capability of BA on ‘McIntosh’ reported by Greene and Autio (1989) has been confirmed in this investiga-

Table 5. Effects of BA, applied as a fruit thinning spray, on fruit set, fruit size, and fruit characteristics of several apple cultivars. Expt. 5.

Cultivar	BA[z] (mg·liter−1)	Blossom clusters/cm limb circumf.[y]	Fruit/cm limb circumf.[y]	Fruit wt[y] (g)	Flesh firmness[x] (N)	Soluble solids concn[w] (%)	Seed no.[v]
McIntosh	0	8.1	9.3	119	83.5	9.5	7.1
		NS	**	**	NS	NS	NS
	100	7.7	5.7	142	83.9	9.5	6.6
Bisbee Delicious	0	13.3	8.0	131	86.7	9.3	5.5
		NS	*	**	NS	*	NS
	100	13.0	4.1	154	87.1	9.8	6.0
Starking Delicious	0	12.3	6.6	157	84.8	9.7	5.8
		NS	*	**	NS	**	NS
	100	12.0	1.5	203	85.3	10.4	6.2
Golden Delicious	0	15.8	13.5	114	83.5	11.7	7.5
		NS	**	*	NS	*	NS
	100	15.9	7.4	142	83.0	12.5	7.6
Empire	0	13.8	18.2	116	71.1	10.6	6.1
		NS	*	**	*	NS	NS
	100	13.5	8.4	154	73.4	10.9	6.3

[z]BA was applied when fruit were ≈ 10 mm in diameter. 'McIntosh' and 'Empire' were sprayed 26 May; 'Bisbee Delicious', 'Starking Delicious', and 'Golden Delicious' were sprayed 29 May.
[y]Means of 12 observations.
[x]Means of six observations.
[w]Means of 128 observations.
[v]Means of 180 observations.
*,**,NS Significant within columns within cultivars at $P = 0.05$ or 0.01 or nonsignificant, respectively.

Table 6. Effects of daminozide (D) at 1500 mg·liter^{-1} and combined with BA on fruit set, fruit quality, and return bloom of 'Mutsu' apples. Expt. 6.

		1982				1983		
Treatment (mg·liter−1)	No. of BA applications	Fruit/cm limb circumf.[z]	Fruit wt[x] (g)	Flesh firmness[x] (N)	Soluble solids concn[y] (%)	Blossom clusters/cm limb circumf.[z]	Fruit/cm limb circumf.[z]	Fruit/100 blossom clusters[z]
Control		2.7	188	81.6	11.1	7.0	1.6	21
D		2.4	178	89.6	11.1	9.9	1.5	14
+ BA 50	1	1.8	197	89.9	11.0	12.0	1.6	14
+ BA 100	1	1.7	204	91.3	11.0	10.9	2.4	20
+ BA 200	1	1.1	235	95.8	11.5	12.3	3.5	27
+ BA 50	2	1.7	201	91.3	11.6	14.0	3.1	21
+ BA 100	2	1.5	221	92.6	11.5	12.5	2.6	19
+ BA 200	2	0.9	266	94.9	11.8	12.7	4.0	32
Significance		***	***	***	**	***	*	*
D + BA	1							
Linear		***	***	***	NS	NS	*	*
Quadratic		NS	NS	NS	NS	NS	NS	NS
D + BA	2							
Linear		***	***	**	**	NS	NS	*
Quadratic		NS	NS	NS	NS	NS	NS	NS
BA 1× vs. BA 2×		NS	**	NS	***	NS	NS	NS
BA 1× vs. control		***	**	***	NS	***	NS	NS
BA 2× vs. control		***	***	***	**	***	*	NS
D vs. control		NS	NS	***	NS	*	NS	NS
BA 1× vs. BA 2× (same amount BA)		NS	NS	NS	*	NS	NS	NS

[z]Means of 14 observations.
[y]Means of seven observations.
[x]Means of 140 observations.
*,**,***,NS Significant within columns at $P = 0.05$, 0.01, or 0.001 or nonsignificant, respectively.

Table 7. Effects of daminozide and BA on fruit set, yield, and return bloom of 'Redspur Delicious'/M.7. Expt. 7.

Treatment (mg·liter^{-1})	1982 Fruit/cm limb circumf.[z]	1983 Blossom clusters/ cm limb circumf.[z]	1983 Fruit/cm limb circumf.[z]	1983 Fruit/100 blossom clusters[z]	1983 Yield[y] (kg/tree)
Daminozide					
0	0.30	9.5	4.0	48	51.6
	NS	NS	NS	NS	NS
1500	0.30	10.2	4.0	42	49.8
BA					
0	0.90	8.9	4.0	48	47.0
75	0.20	10.1	3.6	36	46.8
150	0.03	10.4	4.0	40	51.6
300	0.05	9.8	4.3	45	57.0
Significance[x]	l***	NS	NS	q**	NS

[z]Means of 56 (daminozide) or 25 (BA) observations.
[y]Means of 28 (daminozide) or 14 (BA) observations.
[x]The response was linear (l) or quadratic (q).
,*,NSMain effects within columns significant at $P = 0.01$ or 0.001, or nonsignificant, respectively.

tion and was also established on 'Empire', 'Mutsu', 'Delicious', 'Golden Delicious', and 'Abas'.

Carbaryl, NAA, and ethephon were used with BA in several experiments. While the precise response to thinning chemicals may vary from year to year and location to location, the relative effectiveness of BA as a thinner may be compared with other currently used compounds. 'Empire' was thinned comparably by BA at 100 mg·liter^{-1} and carbaryl at 600 mg·liter^{-1}. BA at 75 mg·liter^{-1} thinned 'McIntosh' comparably to NAA at 6 mg·liter^{-1} but better than carbaryl at 600 mg·liter^{-1}. Between 100 and 200 mg BA/liter thinned 'Hi Early Delicious' comparably to 800 mg carbaryl/liter and better than 100 mg ethephon/liter. Therefore, BA at 75 to 100 mg·liter^{-1} appears to compare very favorably with other commercially used thinners of apples.

Frequently, combination sprays of two or more chemical thinners are used on apples (Williams and Edgerton, 1981). This strategy allows the use of lower rates of individual chemical thinners and reduces the risk of over-thinning (Herrera-Guirre and Unrath, 1980; Holder et al., 1982). Combination sprays used in this study thinned more effectively than individual chemicals, and the thinning response was additive. There were no thinner interactions on fruit set in any of the experiments reported here.

BA thinned in all eight experiments reported here, and, in each instance, fruit size was increased. BA can increase fruit size independently of its effect on reducing crop load (McLaughlin and Greene, 1984). Although increases in fruit size may be abnormally large for the amount of thinning that occurred (Tables 3 and 4), we did not determine if BA had an effect on fruit size that was independent of its fruit-thinning effect.

In all instances, BA increased flesh firmness while also increasing fruit size. This result is contrary to that normally observed, since flesh firmness generally declines as fruit size increases. BA is a cytokinin and it is well documented that cytokinins increase cell division (Letham, 1969). Cell division is still occurring during the time (14 to 18 days after bloom) BA is applied as a thinner (Denne, 1963). Increased cell numbers following BA application undoubtedly contributed to increased fruit size. Further, increased cell numbers per volume of fruit could explain the increase in flesh firmness in this investigation and that reported earlier by McLaughlin and Greene (1984) and Greene and Autio (1989).

BA increased SSC in all experiments. It could be argued that the thinning activity of BA changed the leaf : fruit ratio so that there were more leaves to support fruit growth. However, this explanation may be only a partial one, since BA and NAA reduced crop load to a comparable level on 'McIntosh', yet SSC was increased only in BA-treated fruit.

BA is a component in the proprietary mixture containing GA_{4+7} and BA (Promalin) that is applied to elongate apples (Unrath, 1974). This product is generally applied at bloom for maximum response, but later applications may have some thinning effect (Unrath, 1974). The L : D ratio was increased in some experiments in this investigation, indicating that, in some years, increased fruit elongation may be one of the responses noted if BA is used as a chemical thinner.

Foliar sprays of BA increase flower bud formation in apple (McLaughlin and Greene, 1984; Greene and Autio, 1989). In most cases, the flower bud-promoting capability of BA was confirmed in this investigation. BA did not increase repeat bloom

Table 8. Effects of daminozide and BA on fruit set, fruit quality, and fruit characteristics of 'Redspur Delicious'/MM.111. Expt. 8.

Treatment (mg·liter^{-1})	1983 Fruit/cm limb circumf.[z]	1983 Yield[y] (kg/tree)	1983 Fruit wt[y] (g)	1983 Flesh firmness[x] (N)	1983 Soluble solids concn[y] (%)	1983 L : D ratio[y]	1983 Pygmy fruit[y] (%)	1984 Blossom clusters/ cm limb circumf.[z]	1984 Fruit/cm limb circumf.[z]	1984 Fruit/100 blossom clusters[z]
Daminozide										
0	2.8	43.2	171	75.7	10.4	0.99	11.5	2.8	1.3	67
	NS	NS	**	**	***	NS	NS	NS	NS	NS
1500	3.2	47.0	158	79.8	9.8	0.98	8.3	3.5	1.7	54
BA										
0	3.7	45.2	148	74.3	9.8	0.99	0.5	2.1	1.2	81
150	2.9	43.2	165	78.9	10.1	0.99	8.1	3.5	1.6	54
300	2.4	46.8	180	80.7	10.4	0.99	21.1	3.8	1.7	47
Significance[w]	l**	NS	l**	l***,q*	l***	NS	l***	l***	l*	NS

[z]Means of 42 (daminozide) or 28 (BA) observations.
[y]Means of 21 (daminozide) or 14 (BA) observations.
[x]Means of 420 (daminozide) or 280 (BA) observations.
[w]The response was linear (l) or quadratic (q).
*,**,***,NSMain effects within columns significant at $P = 0.05$, 0.01, or 0.001, or nonsignificant, respectively.

on 'Abas', but this cultivar is one that is noted for its extreme biennial-bearing characteristics. Ethephon also had no influence on return bloom of 'Abas'. BA did not increase flowering in one experiment with 'Redspur Delicious', but crop load the previous year was so low that even control trees returned with a heavy bloom.

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Vegetative Responses of Apple Trees Following Benzyladenine and Growth Regulator Sprays

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Abstract. **Benzyladenine (BA) stimulated lateral branching on young apple (Malus domestica Borkh.) trees at concentrations as low as 100 mg·liter^{-1}. BA reduced lateral shoot length indirectly through increased intersboot competition, whereas daminozide reduced lateral shoot growth as a direct effect of the chemical inhibition. Daminozide reduced the number of spurs that were induced by BA to grow into lateral shoots. BA reduced the size of terminal buds on spurs that were stimulated to grow into lateral shoots. When daminozide was included with BA, spur quality was increased, as determined by Increased bud size. The positive effect of daminozide on BA-treated spurs was indirect, and other growth retardants used in combination with BA may be equally effective at improving spur quality. It may not be possible to stimulate lateral branching with BA on young trees just coming into production without causing an unacceptable amount of thinning. However, on bearing 'Empire' trees, lateral shoot growth was increased with BA while still achieving an appropriate level of thinning. In general, there was no advantage to applying BA in a split application. Chemical names used: N-(phenylmethyl)-1H-purine-6-amine [benzyladenine (BA)]; butanedioic acid mono(2,2-dimethylhydrazide) (daminozide).**

Benzyladenine (BA) alone or in combination with GA.,+, increased lateral branching on young apple trees (Elfving, 1984; Forshey, 1982; Greene and Miller, 1988; Miller and Eldridge, 1986). These studies were performed on young, sparsely branched trees with the specified purpose of increasing potential bearing surface by stimulating lateral branch development. As trees come into production, emphasis generally shifts from enhanced canopy development to stimulation of flowering and spur development. BA induced lateral branching in 4-year-old 'Macspur McIntosh' at concentrations up to 500 mg·liter^{-1}, but crop load was reduced (Greene and Autio, 1989).

Branching can be promoted by BA at concentrations as low as 100 mg·liter^{-1} (Greene and Miller, 1988; Greene and Autio, 1989). However, the branching response may be either modified or eliminated by other factors, such as the presence of fruit on the treated limbs (Kender and Carpenter, 1972).

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The importance of strong, vigorous spurs for flower bud formation, fruit set, and fruit size has been recognized for many years (Yeager, 1916). The influence of light levels, spur age, and canopy position have been studied, especially on older spur-type trees (Barritt et al., 1987). Growth regulators may also influence spur vigor. Foliar sprays of aminoethoxyvinylglycine (AVG) increased bud size and leaf area on young 'Delicious' trees (Greene, 1983). BA application increased flower number and survival of king flowers following a frost on 'Golden Delicious' trees (McLaughlin and Greene, 1984).

This study was undertaken to determine the growth and spur quality responses following application of BA or BA-growth regulator combinations on bearing apple trees or trees that were just starting to come into production.

Materials and Methods

Bearing trees

Experiment 1. 'Empire'/MM.106, Belchertown, Mass. A block of mature 'Empire' trees were selected, and whole trees were treated with BA at 0, 100, or 200 mg·liter^{-1} or carbaryl at 0 or 600 mg·liter^{-1}, alone or in combination. The experimental de-