

The Commercial Implications of Gibberellin A4A7 Plus Benzyladenine for Improving Shape and Yield of 'Delicious' Apples¹

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Abstract. Gibberellin A4A7 (GA4-7) and benzyladenine (BA) were applied to 'Starkrimson Delicious' apples from 1969 through 1972. In initial tests, GA4-7 + BA (50 to 200 ppm each) increased fruit length, fruit wt and length/diam ratio (L/D) but did not alter diam or fruit color. Firmness and seed numbers were reduced only at 200 ppm. At concn above 50 ppm flower initiation was substantially reduced. Concentrations of 25 ppm were as effective as 50 ppm but concentrations below 25 ppm were not effective. To be most effective, these materials must be applied between full bloom and petal fall. In general, a single application was more effective than split applications. Repeated annual applications of 50 ppm resulted in continued good response and no adverse effects. In one of the 4 years tested, fruit set but not commercial crop, was significantly reduced by applications of GA4-7 + BA. Air blast applications were as effective as hand gun applications even when the amount of spray mixture/acre was substantially reduced. The average fruit weight response in all experiments reported was 12 and 20% at 25 and 50 ppm, respectively. The improved fruit shape and increased fruit mass could justify the use of GA4-7 + BA in apple producing areas where post bloom temp conditions reduce "typiness".

Bukovac and Nakagawa (1) first showed that exogenous applications of GA4 to open pollinated apple fruit increased fruit length without influencing fruit diam. With localized application, cell enlargement was restricted to the vicinity of the treatment site, resulting in asymmetric fruit. Stembridge and Morrell (3) reported that GA4-7 applications at 50 to 100 ppm were effective in altering fruit shape while GA3 at 100 ppm was not effective. The relative effectiveness of GA4-7 vs. GA3 supports the observation (2) that GA4 and GA7 occur in immature apple seeds. Williams and Stahly (4) showed that BA at 100 to 500 ppm, GA4-7 at 100 ppm and combined GA4-7 + BA treatments were all effective in increasing the L/D ratio with combined treatments giving greatest effect. Under Washington conditions, with cool post bloom temp, the concn used resulted in some excessive calyx lobing, giving a knobby appearance.

Stembridge and Morrell (3) reported that while both GA4-7 and BA applications increased L/D ratio and the prominence of calyx lobing, combined application of the 2 materials was most effective. Sprays applied during bloom were more effective than pre or post bloom sprays. A combined GA4-7 + BA application at 100 ppm reduced fruit set 1 of 2 years tested. They concluded that a concn of 50 ppm could improve fruit shape without altering seed number, fruit set, firmness or fruit diam. However, in these trials, the treatments which increased calyx lobe prominence resulted in more fruit asymmetry. Return bloom was not affected by 100 ppm GA4-7 or BA.

The purpose of this study was to determine in detail, the concn and timing of GA4-7 + BA applications for max fruit response and the magnitude and consistency of the response in terms of the implication for commercial use.

Materials and Methods

In all experiments reported here, both gibberellin A4 and A7 (GA4-7)⁴ and 6-benzyladenine (BA)⁴ were applied together as a

combined foliar spray. Formulated material contained equal parts of GA4 and GA7. Total GA concn was in a 1:1 ratio with BA. Thus, an application concn of 50 ppm GA4-7 + BA contains 25 ppm GA4 + 25 ppm GA7 + 50 ppm BA (1:1:2). No surfactant was used. All tests were conducted on whole tree reps of 8 to 15-year old 'Starkrimson Delicious' using a randomized complete block design. Applications were applied as a dilute hand gun application (except 1972 air blast application test). Samples of 25 fruits selected at random from each tree rep were collected at harvest. Immediately following harvest, samples were placed in 0°C refrigerated storage until analyses were completed.

In 1969 initial studies were conducted with 4 tree reps, using GA4-7 + BA concn of 0, 50, 100, and 200 ppm. Applications were made at full bloom (FB). At harvest, the following data were obtained: *wt*, *length*, *diam*, *length/diam ratio (L/D)*, *calyx lobe formation* (1-9 scale, no lobing to max lobing), *symmetry* (1-4 scale, deformed to symmetrical as rated visually by 2 independent judges), *color percent* of the apple surface exhibiting solid red color to the nearest 5%). The calyx end of fruits were then removed until a solid disc of apple flesh tissue was exposed on the calyx end. Then fruit length remaining (*fruit body length*) was measured. *Calyx length* was computed by subtracting body length from overall length. *Fruit firmness* was measured by standard Magness-Taylor pressure tester with 1.11 cm (7/16 in.) plunger. Fruit were opened and *number of developed seeds/fruit* counted. In spring of 1970, 400 spurs/tree rep were observed on limbs randomly selected on all sides of the tree at bloom time, and the percent which initiated flowers was computed. The data were converted to show percent of control. In all succeeding experiments only wt/fruit, fruit length, fruit diam parameters were measured and L/D ratios and percent wt increase over control were computed. The fruit measurement methods described above were used in all experiments.

In 1970, concn studies were conducted at 2 locations with 10 tree reps using 25 and 50 ppm applications of GA4-7 + BA applied at FB. A detailed time of application study was conducted at 50 ppm of GA4-7 + BA using 6 tree reps. Times of application began at .63 to 1.27 cm (1/4 to 1/2 inch) green stage, continued on an every 3rd day schedule until full king bloom opening (FKB), then changed to an alternate day schedule through petal fall (PF), then applications were applied at PF + 3, 7, 14, 21 and 28 days.

In 1971, single applications of 12.5, 25, 37.5 and 50 ppm,

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⁴Formulated mixture supplied by Amdal Company, North Chicago, Illinois.

applied at partial PF, were compared with split applications of 25 and 50 ppm of GA₄-7 + BA applied at FB and PF. In 1972 this same study was repeated omitting the single 12.5 ppm treatment. Eight tree reps were employed in this study. In 1970 and 1971, the same 4 tree reps which had received 50 ppm of GA₄-7 + BA in the 1969 experiment were repeated to determine the effect of annual applications. Applications were applied at FB all 3 years. In 1971 and 1972 flower set data were collected on the "single vs. split application" plots. One thousand flowers/tree rep were counted on randomly selected limbs and these limbs tagged at FB. Following GA₄-7 + BA research treatments, growers chemical thinning spray (1 lb. of Sevin) and the "June drop" period, the no. of fruit remaining from the 1000 flowers was counted and a percent fruit set computed. In 1972 an air blast sprayer was used to confirm previous results under commercial application conditions. Six tree reps (with appropriate borders for drift) were used in this study. Table 1 summarizes experimental parameters of all experiments described above.

Table 1. Treatments applied, 1969-1972.

Year	No. locations	No. rep. trees	Concn (ppm)	Timing ^z
1969	1	4	0, 50 ^y , 100, 200	FB
1970	2	10	0, 25, 50	FB
	1	6	0, 50	Half-inch green to PF plus 28 days
1971	1	8	0, 12.5, 25, 37.5, 50 12.5, 25	Partial PF FB + PF (double application)
1972	1	8	0, 25, 37.5, 50 12.5, 25	FB FB + PF
	1	6	0, 37.5	Partial PF

^zFB = full bloom; PF = petal fall.

^ySame trees retreated 1970 and 1971 at FB.

Results and Discussion

1969. Effect of concn on various fruit characteristics. All concn significantly increased overall fruit length and wt, although fruit diam was not affected (Tables 2 and 3). This resulted in a significant increase in the L/D ratio. Nearly all length increase was in the fruit body. Body length was affected at all concn, while calyx lobe length was directly related to concn. Calyx lobe length stimulation showed a trend at 50 and 100 ppm and became significant at the 200 ppm level (Table 2). This is contrasted to the visual calyx lobe ratings which showed significantly greater ratings at all concn (Table 3). Apparently only a small numerical increase in lobe length is necessary to substantially change the visual appearance and prominence of the calyx lobes. The total increase in fruit length and resulting influence on fruit wt both showed a highly significant change. Treated fruit weighed 15 to 20% more than the control (Table 2). Fruit symmetry was increased at concn of 50 and 100 ppm but dropped off at 200 ppm (Table 3). Visual observation of treated samples indicated that some fruit treated with 200 ppm had exaggerated extension of 1 or 2 calyx lobes resulting in reduced symmetry as compared to 50 and 100 ppm treated

fruit. These results disagree with findings of Stembridge and Morrell (3) who reported reduced fruit symmetry in their study. While a strong case cannot be made for substantial symmetry improvement, certainly GA₄-7 + BA treatments were not detrimental to symmetry in this study.

Fruit color was not affected by GA₄-7 + BA applications and firmness was significantly affected only at the 200 ppm level. Firmness measurements taken in 1970, at lower concn (25 to 50 ppm) (data not shown), again showed no significant differences. There was a decreasing trend in no. of developed seeds/fruit which became significant at the 200 ppm level. The amount of return bloom in 1970 was significantly reduced by applications of 100 and 200 ppm GA₄-7 + BA in 1969. These results also conflict with those of Stembridge and Morrell (3) who reported no effect. Considering overall fruit quality and return bloom, the positive responses to GA₄-7 + BA (fruit length, wt and L/D ratio) are of greatest magnitude with the 50 ppm treatment. Thus, the concn used in succeeding experiments were restricted to 50 ppm and below.

Effect of time of application on L/D ratio. Time of application of GA₄-7 + BA had a marked affect on L/D ratio (Fig. 1). Significant increases were obtained on all dates except applications No. 1, 5, 19 and 20. Response reached a max at 50% PF (application no. 13), with 38% greater fruit wt over the control. Application between full king bloom and petal fall (application no. 11-14) resulted in approx 75% or more of the max response. The average fruit wt increase for these 4 applications was 40.5 g or a 30% improvement over the control [fruit wt data not given for time of application experiment since it corresponded closely to L/D ratio data (Fig. 1)]. Thus, for max effectiveness, GA₄-7 + BA should be applied between FB and PF. This agrees with Stembridge and Morrell's findings (3).

1970-72. Effects of concn and single vs. split applications on L/D ratio and fruit wt. L/D ratio and wt/fruit were significantly stimulated at each location (Table 4). A 15 and 17% increase in fruit wt over the control resulted at 25 and 50 ppm, respectively.

Because of the max and relatively uniform response between FB and PF, additional experiments were designed to compare the effect of single vs. split applications. Neither a single appli-

Table 2. Effect of GA₄-7 + BA applications on fruit size, shape, and wt of 'Starkrimson Delicious' apples (1969).

GA ₄ -7 + BA (ppm of ea.)	Wt/fruit (g)	% inc in wt over control	Diam. cm	Overall length cm	Body length cm	Calyx lobe length cm	Overall length/diam
0	184	0	7.59	7.04	6.10	.94	0.927
50	211**	20**	7.77	7.80**	6.78**	.99	1.002**
100	215**	17**	7.82	7.65**	6.60**	1.04	0.977**
200	212**	15**	7.67	7.75**	6.60**	1.14*	1.010**
LSD .05	17	8	N.S.	.28	.20	.15	.029
LSD .01	25	12	N.S.	.41	.30	.28	.043

*Significantly different from control at 5% level.

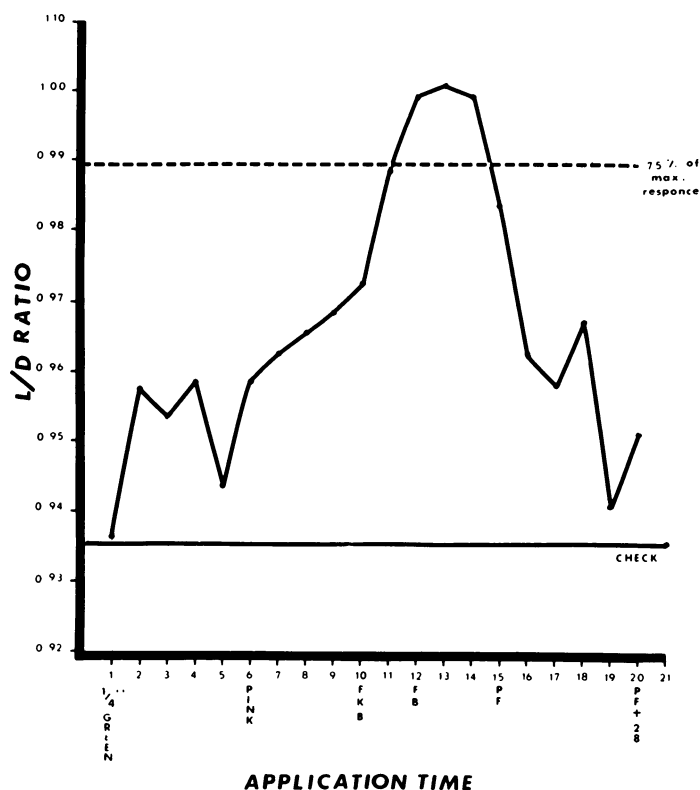
**Significantly different from control at 1% level.

Table 3. Effect of GA₄-7 + BA application on fruit quality, appearance, seed development and flower initiation of 'Starkrimson Delicious' apples (1969).

GA ₄ -7 + BA (ppm of ea.)	Calyx lobing rating	Fruit symmetry rating	% red color	Firmness kg	No. of developed seeds/fruit	Flower initiation (% of control)
0	3.50	3.05	93.8	7.71	5.6	100
50	6.57**	3.25	95.5	7.39	4.8	105
100	6.38**	3.33**	97.0	7.35	5.1	20**
200	7.10**	3.13	97.3	7.26*	4.1*	31**
LSD .05	.72	.22	N.S.	.40	1.5	10
LSD .01	1.07	.34		.64	2.2	17

*Significantly different from control at 5% level.

**Significantly different from control at 1% level.

Fig. 1. The influence of time of application of 50 ppm GA₄-7 + BA on L/D ratio of 'Starkrimson Delicious' apples in 1970.

cation at 12.5 ppm in 1971 nor a split application at 25 ppm in 1972 significantly increased fruit wt. (Table 4). Therefore a min concn of 25 ppm is probably necessary to induce a consistent response. In 1971, single vs. split application results were inconclusive (Table 4). In 1972 split applications amounting to 25 and 50 ppm were significantly less effective than a single application at the same concn (Table 4). Thus single applications are preferable to split applications. These results again differ from those of Stembidge and Morrell (3) who reported split applications to be superior. In terms of commercial importance, the results reported herein would not justify the cost of a second spray application.

Cumulative effects of repeated applications over a 3-year period on L/D ratio and fruit wt. The same significant increase in L/D ratio and fruit wt continued through the 2nd and 3rd year of repeat applications (Table 5). The decrease in magnitude of difference in fruit wt during the 3rd year (1971) is attributable to the relatively higher L/D ratio of untreated fruit, as compared to previous years. Therefore, annual applications of 50 ppm or below of GA₄-7 + BA can be used to improve "typiness" (L/D ratio) and increase fruit wt without being detrimental to return bloom (Table 3 and observation of trees in succeeding years) or reducing the significance of the response.

Effect on fruit set. No differences in fruit set were observed in 1969 or 1970 from any applications and there was a "normal" load of fruit on all trees under test in these years. Check trees set a heavy crop in 1971. All concn of GA₄-7 + BA that improved fruit wt reduced fruit set (Table 6), and therefore resulted in some increase in fruit diam (data not shown). This thinning action was noted visually before fruit set data were collected. After fruit set was recorded, the grower chemically thinned all plots with Sevin and then hand thinned these plots.

Table 4. Effects of concentration and split vs. single applications of GA₄-7 + BA on fruit characteristics of 'Starkrimson Delicious' apples.

Concn (ppm)	Timing	Year								
		1970			1971			1972		
		L/D	Wt/fruit (g)	% increase over control	L/D	Wt/fruit (g)	% increase over control	L/D	Wt/fruit (g)	% increase over control
0	FB	.928	143	0	0.936	171	0	.933	116	0
12.5	FB	—	—	—	1.008**	182	6	—	—	—
	FB + PF	—	—	—	0.989**	201*	17**	0.966**	122	4
25	FB	.966**	164**	15**	1.000**	188*	10*	1.014**	130**	12**
	FB + PF	—	—	—	1.016**	195*	14**	1.000**	125*	8*
37.5	FB	—	—	—	1.005**	194*	14**	1.010**	132**	14**
50	FB	1.007**	167**	17**	1.049**	223*	30**	1.015**	135**	16**
LSD .05		—	—	—	.021	22	7	.023	8.1	7
.01		.054	12.2	12	.052	38	14	.031	11.7	11

*, **Values significantly different from control at 5% and 1% levels, respectively.

Table 5. Effect of repeated annual applications of GA₄₋₇ + BA at 50 ppm on fruit characteristics of 'Starkrimson Delicious' apples.

Parameter	Treatment	Year		
		1969	1970	1971
L/D	0	0.927	0.915	0.957
	50 ppm	1.002**	0.988*	1.049*
LSD	.05	.027	.067	.061
	.01	.043	.124	.101
Wt/fruit	0	184	150	147
	50	221**	195*	160*
LSD	.05	17	32	12
	.01	25	59	18

*Values significantly different from control at 5% level.

**Values significantly different from control at 1% level.

Table 6. Effect of GA₄₋₇ + BA on fruit set (percent of control) of 'Starkrimson Delicious' apples, data recorded 6 weeks post bloom.

ppm	Timing	% of fruit set	
		1971	1972
0		18.4	26.9
12.5	FB	18.8	2
12.5	FB + PF	6.7**	25.6
25	FB	7.4**	26.0
37.5	FB	8.0**	27.0
25	FB + PF	8.8**	22.3
50	FB	6.4**	20.2
LSD .01		7.4	N.S.

²This concn not used in 1972.

**Values significantly different from control at 1% level.

Little thinning was necessary in plots which showed significant GA₄₋₇ + BA thinning (Table 6), as the GA₄₋₇ + BA had generally reduced fruit load to 1 fruit/spur. GA₄₋₇ + BA treatments did not appear to reduce yield at harvest. In 1972 no fruit thinning occurred from these same treatments (Table 6).

Since no thinning occurred in 1969, 1970 or 1972, and that which occurred in 1971 was not detrimental, the potential thinning effect of GA₄₋₇ + BA does not appear to be of concern. The same variable response in fruit set was reported by Stembridge and Morrell (3); however, only concn above 50 ppm exhibited thinning.

Effect of rate of application with air blast sprayer on L/D ratio and fruit wt. Air blast sprayer applications of GA₄₋₇ + BA solution resulted in a positive response as with previous hand

Table 7. Effect of rate of application of GA₄₋₇ + BA (37.5 ppm) with an air blast sprayer on fruit characteristics of 'Starkrimson Delicious' in 1972.

Gallons of spray per acre	L/D	Wt/fruit (g)	% increase in wt over control
Control	0.926	108	0
375	0.989**	118*	9*
190	0.980**	120**	11**
125	0.992**	131**	21**
LSD .05	.015	8.3	6.2
.01	.021	11.3	10.1

*, **Values significantly different from control at 5% and 1% levels, respectively.

gun applications (Table 7), thus this method of application appears feasible. Response was inversely proportional to quantity of material applied. Applying the material to some flowers and not to others, or applying different amounts to different flowers may give a greater stimulation and competitive advantage than if all flowers were treated equally. Such an experiment needs to be repeated with fruit set measurements and total yield determinations, to fully understand its implications.

For 'Red Delicious', a single application of 25 to 50 ppm of GA₄₋₇ + BA applied between FB and PF appears practical, especially in areas where high post bloom temp normally results in poorly shaped fruit. Improved "typiness" and greater fruit length could improve fruit yield vol at harvest. If the "average" increases in fruit wt are calculated for all experiments conducted at 25 and 50 ppm the results show an overall 12 and 20% increase, respectively. Since all test plots had sufficient fruit load to require hand thinning, fruit load and fruit no. should have been equalized on all treatments and fruit wt increases should be representative of increased yield potential. Experiments need to be conducted to confirm this implied yield increase.

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