HortScience 17(4):653–654. 1982.

Effects of Gibberellins A_{4+7} and 6-Benzylamino Purine on Fruit Set, Fruit Characteristics, Seed Content, and Storage Quality of 'McIntosh' Apples[1]

Duane W. Greene, William J. Lord, and William J. Bramlage
Department of Plant and Soil Sciences, University of Massachusetts, Amherst, MA 01003

Additional index words. Malus domestica, Daminozide, fruit firmness, senescent breakdown, calcium

Abstract. **Spraying trees of 'McIntosh' apple (*Malus domestica* Borkh.) with gibberellins A_{4+7} (GA_{4+7}) + 6-benzylamino purine (BA) plus 1000 ppm daminozide 17 days after full bloom increased fruit set as GA_{4+7} + BA concentrations increased from 0 to 100 ppm, but did not alter fruit size, shape, or quality at harvest. Increased poststorage development of senescent breakdown with increasing concentration of applied GA_{4+7} + BA was attributable to increased occurrence of seedless fruit. Responses to treatments appeared to be due primarily to the GA_{4+7} component and did not occur when GA_{4+7} + BA combination was applied after "June drop." Fruit flesh calcium concentration declined as GA_{4+7} + BA concentration increased.**

Fruit set of apples may be regulated with gibberellins and cytokinins (1, 2, 10) but the response has been erratic and unpredictable. A bloom application of 50 ppm of Promalin, the proprietary mixture prepared by Abbott Laboratories, North Chicago, IL 60064, reduced fruit set of 'Delicious' (3, 8). Edgerton (3) found that application of 50 ppm GA_{4+7} 23 days after full bloom increased fruit set of 'Golden Delicious', but earlier applications were ineffective. Preliminary field observations in Massachusetts indicated that delaying application of Promalin until after initial fruit set may increase final fruit set. A post-bloom spray of daminozide also may increase fruit set of apples (5). This present investigation was initiated to determine the extent to which fruit set could be increased by combination sprays of daminozide, GA_{4+7}, BA, and Promalin (GA_{4+7} + BA) applied after initial fruit set, to determine if fruit quality and subsequent storage life were affected, and to determine which was the most effective ingredient in these growth regulator combinations.

Two uniform limbs each from 56 mature 'McIntosh' apple trees on Malling (M) 7 rootstock growing in a block at the Horticultural Research Center, Belchertown, Mass., were selected and tagged, and just prior to full bloom total blossom clusters were counted and circumference was measured at the base of the limb. Blossom intensity ranged from 11.9 to 12.6 blossom clusters per cm limb circumference.

A series of treatments (treatments 2 through 8 in Table 1) were applied to drip as dilute sprays to whole trees on June 6, 1978, 17 days after full bloom. An additional treatment applied 1000 ppm daminozide and 50 ppm GA_{4+7} + BA on July 13, 54 rather than 17 days after full bloom. The design was a randomized block with 7 replications.

Fruit set was determined at completion of "June drop." On September 25, 25 fruit harvested from the tagged limbs were weighed, and their length (L) and diameter (D) were determined; red color was evaluated by estimating the percent of surface showing typical red color. Flesh firmness was determined with a Magness Taylor pressure tester, measuring both green and red sides of 10 uniform-sized fruit per sample. Juice was collected in a Petri dish during the 20 pressure tests per sample, and soluble solids content of the pooled sample was thrice measured with a hand refractometer.

About 20 kg of fruit from each tree were stored in 0°C air storage at a 95% relative humidity until January 17. Another 20-kg sample from each tree was stored in controlled atmosphere (CA) at 3% O_2, 5% CO_2, 3.3°, and 95% relative humidity until May 29. After removal from storage, flesh firmness was determined as above while fruit were still cold. The samples were kept at room temperature (20 to 25°) for 8 days before assessment for incidence of browncore and senescent breakdown. At removal from CA storage, 10 fruit of similar size per sample were analyzed for flesh calcium (Ca) concentration using the method of Weis et al. (9).

Data were analyzed by analyses of variance. Significant treatment effects were then partitioned into single degrees of freedom. Regression was used to test the effects of increasing concentrations of GA_{4+7} + BA and linear comparisons were made among the other treatments.

Fruit set. Increasing concentrations of GA_{4+7} + BA produced a linear increase in fruit set, whether set was expressed per hundred fruit clusters (Table 1) or per cm limb circumference (data not shown). The increased set was undoubtedly due to a reduction in the extent of "June drop," since initial set of fertilized flowers had already occurred before the treatments were applied, 17 days after full bloom, and since application of Promalin after "June drop" did not affect fruit set. There were indications that fruit set may have been enhanced by both 25 ppm GA_{4+7} and 1000 ppm daminozide, although the effects of these treatments were not quite significant. Others have reported that fruit set can be increased by postbloom applications of daminozide (5) and by 50 ppm GA_{4+7} (3).

Fruit quality at harvest. The growth regulators had little effect on fruit characteristics at harvest. Daminozide slightly but significantly increased fruit firmness (69.6 vs. 62.7 Newtons (N)/cm^2 for controls). Red coloration of the fruit was significantly increased (67 vs. 56% for controls) by the late application of GA_{4+7} + BA and daminozide, as daminozide can do when applied at this time and concentration (4). Under these particular growing conditions, no treatment affected fruit weight, L/D ratio, or soluble solids concentration (data not shown).

Fruit quality after storage. Following storage, the daminozide effect on fruit firmness had dissipated (Table 1). However, fruit sprayed with GA_{4+7} + BA had softened more during storage, with increasing softening as concentrations increased. The greatest effect of the treatments was a very marked increase in senescent breakdown incidence as a result of GA_{4+7} + BA plus daminozide application, the effect increasing linearly with GA_{4+7} + BA concentrations. Neither daminozide, GA_{4+7}, nor BA alone produced this effect, nor did a late application of GA_{4+7} + BA and daminozide. Browncore incidence was slightly increased (24% vs. 19% in controls) by the late but not by the early GA_{4+7} + BA and daminozide applications (data not shown).

Effects on seed number. One week after removal from CA storage, 30 fruit from each sample were cut equatorially; seed number was counted and presence or absence of internal disorders was noted. GA_{4+7} + BA decreased the total seed number per fruit, the reduction increasing as concentrations increased (Table 1). The effect was highly linear, with only a slight and barely significant quadratic effect. The percentage of seedless fruits increased linearly as GA_{4+7} + BA concentration increased. The reduced seed

[1]Received for publication Oct. 14, 1980. Massachusetts Agricultural Experiment Station Paper 2375. This research was supported in part by Experiment Station Project 410.

The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Table 1. Responses of 'McIntosh' apple trees and fruit to growth regulator applications.

Trt. no.	Growth regulator combinations (ppm)			Fruit set per 100 blossom clusters	Firmness (N/cm^2)		Senescent breakdown (%)		Seed number		Seedless fruit (%)	Senescent breakdown (%)		Flesh Ca (ppm)
	Daminozide	GA_{4+7}	BA		After air storage[z]	After CA storage[y]	After air storage[z]	After CA storage[y]	Per fruit	Per seeded fruit		Seedless fruit	Seeded fruit	
1	0	0	0	54	44.9	46.6	6	9	7.0	7.0	1	---	2	---
2	0	25	25	76	43.7	46.1	13	18	4.9	5.6	21	63	6	---
3	1000	0	0	70	45.3	46.9	0	3	6.7	6.9	0	---	3	221
4	1000	25	25	85	45.1	46.1	19	21	5.4	6.2	17	60	12	192
5	1000[x]	50	50	97	44.3	45.3	26	28	3.0	6.1	51	60	3	---
6	1000	100	100	114	41.5	45.1	45	41	1.7	5.5	66	58	7	134
7	1000	25	0	85	45.2	48.4	6	9	5.3	6.4	10	62	3	---
8	1000	0	25	66	44.9	46.2	3	5	6.7	6.2	1	---	7	---
9	1000[x]	50	50	66	45.8	47.8	8	5	6.5	6.7	0	---	8	---
Significance														
GA + BA concn (Trt 3 to 6):														
Linear				**	**	*	**	**	**	**	**	NS	NS	**
Quadratic				NS	NS	NS	NS	*	NS	NS	*	NS	NS	NS
Daminozide (Trt 1 vs. 3)				NS	NS	NS	*	NS	NS	NS	NS	---	NS	---
GA + BA vs. GA alone (Trt 4 vs. 7)				NS	NS	*	*	*	NS	NS	NS	NS	NS	---
GA + BA vs. BA alone (Trt 4 vs. 8)				NS	NS	*	*	**	*	NS	**	---	NS	---
GA + BA, early vs. late (Trt 5 vs. 9)				**	NS	*	**	**	**	NS	**	---	NS	---

[z]Storage in 0°C air, 95% relative humidity for 4 months.
[y]Storage at 3.3°C, 3% O_2, 5% CO_2, 95% relative humidity for 8 months.
[x]Treatment 5 was applied 17 days after full bloom; treatment 9 was applied 54 days after full bloom.
[w]Nonsignificant (NS) or significant at the 5% (*) or 1% (**) level.

number was not merely a reflection of the maturation of seedless fruit, since there was also a linear reduction of seed number in seeded fruit. The occurrence of seedless fruit was apparently caused by the GA_{4+7} component of the GA_{4+7} + BA mixture and was produced only by the early application of the mixture. It was not clear whether GA_{4+7} or BA caused the small reduction in seed number among seeded fruit, but Edgerton (3) found that GA_{4+7}, applied 2–3 weeks after full bloom, reduced seed number of 'Golden Delicious'. Seedless fruit were highly susceptible to senescent breakdown: 60% of seedless fruits developed the disorder, regardless of treatment. In contrast, seeded fruit had a mean incidence of 6% breakdown, regardless of treatment. It is apparent that the production of seedless fruit was responsible for the increased incidence of senescent breakdown of GA_{4+7} + BA treated apples, and that the seedlessness was caused primarily by GA_{4+7}.

We also noted that GA_{4+7} + BA treated fruit had increased incidence of bitterpit, which is a symptom of Ca deficiency in the fruit. We therefore analyzed fruit Ca concentrations in fruit treated with 0, 25, and 100 ppm GA_{4+7} + BA plus daminozide. There was a highly significant linear reduction of fruit Ca concentration as GA_{4+7} + BA concentrations increased (Table 1). Looney (6) also found that this combination decreased fruit Ca concentration.

The adverse effect of GA_{4+7} + BA on fruit quality after storage apparently resulted from the retention of seedless fruit that normally would have fallen during "June drop." Why these seedless fruit were highly susceptible to senescent breakdown is not clear. In our experience, the mean Ca levels in the GA_{4+7} + BA treated fruit were not so low as to cause the high incidence of breakdown that occurred in these samples. However, we did not analyze the Ca in seeded vs. seedless fruit in these samples, so we do not know if the seedless fruit had lower Ca levels than the seeded fruit. If the seedless fruit had very low Ca levels, they alone may have been responsible for the declining mean Ca concentrations as concentration of applied GA_{4+7} + BA increased.

Seeds are sites of hormone production in fruit (7), hence one might speculate that hormones produced by seeds may delay fruit senescence. An alternate hypothesis is that seeds may influence breakdown susceptibility by influencing mineral distribution. However, we cannot discount the possibility of a cellular dilution of fruit Ca levels in these fruits as suggested by Looney (6); even though there was no effect of treatments on either fruit weight or shape, we did not measure cell number or size in these fruit.

One approach to increasing fruitfulness of apple cultivars is to increase fruit set through the use of growth regulators. This may be achieved by causing parthenocarpic fruit set by bloom sprays or by reducing "June drop" with treatments applied after initial fruit set. In either case, crop size could be increased by retaining fruit with a reduced number of seeds or no seeds at all. Our results indicate that by causing fruit with a low seed number to adhere during "June drop," GA_{4+7} + BA can increase fruit set. However, our results and those of Looney (6) show that this increased cropping may carry an inherent risk: the retained seedless fruit may have a high potential for rapid deterioration during and after storage.

Literature Cited

1. Bukovac, M. J. 1963. Induction of parthenocarpic growth of apple fruits with gibberellins A_3 and A_4. Bot. Gaz. 124:191–195.
2. Dennis, Jr., F. G., and L. J. Edgerton. 1962. Induction of parthenocarpy in the apple with gibberellin, and the effects of supplementary auxin application. Proc. Amer. Soc. Hort. Sci. 80:58–63.
3. Edgerton, L. J. 1981. Some effects of aminoethyoxyvinylglycine, 6-benzylamino purine and gibberellins on fruit set and vegetative growth of applies. Acta Hort. 120. (In press)
4. Edgerton, L. J. and M. B. Hoffman. 1965. Some physiological responses of apples to N-dimethylamino succinaminic acid and other growth regulators. Proc. Amer. Soc. Hort. Sci. 86:28–36.
5. Forshey, C. G. 1975. Vegetative growth control in apple trees. Proc. N. Y. State Hort. Soc. 120:152–158.
6. Looney, N. E. 1979. Some effects of gibberellins A_{4+7} plus benzyladenine on fruit weight, shape, quality, Ca content and storage behavior of "Spartan" apple. J. Amer. Soc. Hort. Sci. 104:389–391.
7. Luckwill, L. C., P. Weaver, and J. MacMillan. 1969. Gibberellins and other growth hormones in apple seeds. J. Hort. Sci. 44:413–424.
8. Unrath, C. R. 1974. The commercial implication of gibberellins A_4A_7 plus benzyladenine for improving the shape and yield of 'Delicious' apples. J. Amer. Soc. Hort. Sci. 99:381–384.
9. Weis, S. A., M. Drake, W. J. Bramlage, and J. H. Baker. 1980. A sensitive method of measuring changes in calcium concentration in 'McIntosh' apples demonstrated in determining effects of foliar calcium sprays. J. Amer. Soc. Hort. Sci. 105:346–349.
10. Williams, M. W. and D. S. Letham. 1969. Effect of gibberellins and cytokinins on development of parthenocarpic apples. HortScience 4:215–216.