

Effects of Gibberellins A₄₊₇ and 6-Benzylamino Purine on Fruit Set, Fruit Characteristics, Seed Content, and Storage Quality of 'McIntosh' Apples¹

Duane W. Greene, William J. Lord, and William J. Bramlage

Department of Plant and Soil Sciences, University of Massachusetts, Amherst, MA 01003

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Abstract. Spraying trees of 'McIntosh' apple (*Malus domestica* Borkh.) with gibberellins A₄₊₇ (GA₄₊₇) + 6-benzylamino purine (BA) plus 1000 ppm daminozide 17 days after full bloom increased fruit set as GA₄₊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 GA₄₊₇ + BA was attributable to increased occurrence of seedless fruit. Responses to treatments appeared to be due primarily to the GA₄₊₇ component and did not occur when GA₄₊₇ + BA combination was applied after "June drop." Fruit flesh calcium concentration declined as GA₄₊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 GA₄₊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, GA₄₊₇, BA, and Promalin (GA₄₊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 GA₄₊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% O₂, 5% CO₂, 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) concen-

tration 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 GA₄₊₇ + BA and linear comparisons were made among the other treatments.

Fruit set. Increasing concentrations of GA₄₊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 GA₄₊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 GA₄₊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)/cm² for controls). Red coloration of the fruit was significantly increased (67 vs. 56% for controls) by the late application of GA₄₊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 GA₄₊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 GA₄₊₇ + BA plus daminozide application, the effect increasing linearly with GA₄₊₇ + BA concentrations. Neither daminozide, GA₄₊₇, nor BA alone produced this effect, nor did a late application of GA₄₊₇ + BA and daminozide. Browncore incidence was slightly increased (24% vs. 19% in controls) by the late but not by the early GA₄₊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. GA₄₊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 GA₄₊₇ + BA concentration increased. The reduced seed

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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 | NS |
| Daminozide (Trt 1 vs. 3) | NS | NS | NS | * | NS | NS | NS | NS | NS | NS | --- | NS | --- |
| GA + BA vs. GA alone (Trt 4 vs. 7) | NS | NS | * | * | * | NS | NS | NS | NS | NS | NS | NS | --- |
| GA + BA vs. BA alone (Trt 4 vs. 8) | NS | NS | * | * | ** | * | NS | ** | * | NS | ** | --- | NS |
| GA + BA, early vs. late (Trt 5 vs. 9) | ** | NS | * | ** | ** | ** | ** | ** | NS | ** | ** | --- | NS |

^zStorage in 0°C air, 95% relative humidity for 4 months.

^yStorage at 3.3°C, 3% O₂, 5% CO₂, 95% relative humidity for 8 months.

^xTreatment 5 was applied 17 days after full bloom; treatment 9 was applied 54 days after full bloom.

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 GA₄₊₇ component of the GA₄₊₇ + BA mixture and was produced only by the early application of the mixture. It was not clear whether GA₄₊₇ or BA caused the small reduction in seed number among seeded fruit, but Edgerton (3) found that GA₄₊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 GA₄₊₇ + BA treated apples, and that the seedlessness was caused primarily by GA₄₊₇.

We also noted that GA₄₊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 GA₄₊₇ + BA plus daminozide. There was a highly significant linear reduction of fruit Ca concentration as GA₄₊₇ + BA concentrations increased (Table 1). Looney (6) also found that this combination decreased fruit Ca concentration.

The adverse effect of GA₄₊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 GA₄₊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 GA₄₊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," GA₄₊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.

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