among the heads (IVa). Red cabbages fall in group IV of both seed and head. Three savoy cultivars are scattered among these seed groupings: 'Savoy King', group IV, 'Chieftain Savoy', group III, and 'Savoy Perfected Drumhead', group IIa. Perhaps this is an indication that savoy leaf character is inherited independently of glucosinolates, whereas red leaf is associated, if not linked, to a particular glucosinolate pattern.

Glucosinolate patterns for 9 compounds provide the basis for comparing cultivar and cultivar groupings. However, correlations between individual glucosinolates in the head versus seed for all cultivars may also be compared. A correlation between specific compounds observed in the leaf vs. the seed would suggest predictive value. These correlations were first computed using all 50 cultivars and then later omitting seed groups I and IV. Results are shown in Table 4. The generally higher correlation using all cultivars probably reflects the differences between group IV and other groups. Within the white cultivars largely group II, there are significant but low correlations involving seed and head. Butenyl-, 2-hydroxy-3-butenyl-, and 4-methylsulfinylbutyl-GS appear to be most often correlated between head and seed.

Cultivar groupings based on seed and head glucosinolate patterns are similar. Exceptions are Savoy King, Houston Evergreen, and Lovet. A comparison of groupings based on head and seed is useful in distinguishing the more divergent cultivars. The most consistent and well-defined group based on r contains varieties of group IV. Seed analyses can be used to pick varieties belonging to this group.

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Effect of Silver Nitrate, Aminoethoxyvinylglycine, and Gibberellins A_{4+7} plus 6-Benzylamino purine on Fruit Set and Development of 'Delicious' Apples[1]

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Abstract. **Sprays of silver nitrate ($AgNO_3$), aminoethoxyvinylglycine (AVG) and gibberellins A_{4+7} (GA_{4+7}) plus 6-benzylamino purine (BA) were applied with 0.1% Triton B-1956 at bloom to 'Richared Delicious' apple trees (*Malus domestica* Borkh.). AVG at 200 ppm alone or when applied with 50 ppm each of GA_{4+7} and BA increased fruit set whereas GA_{4+7} plus BA applied alone at 50 ppm caused fruit thinning. AVG reduced endogenous ethylene production and overcame the increased ethylene production brought about by GA_{4+7} plus BA application. AVG applied alone at 200 ppm or when combined with GA_{4+7} plus BA reduced fruit size and increased the L/D ratio at harvest.**

Many factors (7) may contribute to the poor fruit set of 'Delicious' apples that occurs in many parts of the U.S. (9, 11). Increased fruit set of 'Delicious' through use of growth regulators has been erratic. Enhanced flower bud formation has not always resulting in increased fruit set (10). Application of gibberellins in lanolin paste or by brush to emasculated apple flowers of several cultivars has induced parthenocarpic fruit set and development (4, 6, 13, 14, 20). GA_3 was less effective than GA_{4+7} (4, 20). Enhanced parthenocarpic fruit set also occurred when a cytokinin was included with the GA_{4+7} (20). However, application of aqueous sprays of GA_3 at petal fall (8) or GA_{4+7} + BA during bloom (13) can result in decreased fruit set of open pollinated trees.

Ethylene is involved in the senescence and abscission of flowers, and application of ethylene directly or indirectly can result in flower and fruit abscission (1). Silver nitrate ($AgNO_3$) and aminoethoxyvinylglycine (AVG) inhibit ethylene action (3) and ethylene production (2), respectively. Because ethylene is linked with flower abscission endogenous ethylene levels may be sufficiently high in the apple flower to limit fruit set. Application of either GA or cytokinins can elevate ethylene levels (1).

This investigation had 3 objectives: a) to determine if reducing endogenous ethylene levels in 'Delicious' apple flowers could increase fruit set; b) to determine if GA_{4+7} and BA application elevated levels of ethylene; and c) to establish if the reduced fruit set effects of GA or GA plus cytokinins (9, 13) could be counteracted by an inhibitor or ethylene synthesis.

Materials and Methods

1978. Six uniform limbs were selected on each of 6 mature 'Richared Delicious' trees, their diameters were measured and the total number of blossom clusters were counted at bloom. The following spray treatments containing 0.1% Triton B-1956 were applied to the drip point at full bloom (FB) + 1 day: 20 ppm $AgNO_3$; 200 ppm $AgNO_3$; 20 ppm AVG; 200 ppm AVG; and 200 ppm AVG + 50 ppm GA_{4+7} plus BA. A few additional flower clusters were sprayed with AVG to determine its effects on ethylene production. Flower clusters were harvested on

[1]Received for publication February 16, 1980. Aminoethoxyvinylglycine was supplied by Maag Agrochemicals, HLR Sciences, Inc., P.O. Box X, Vero Beach, FL 32960. GA_{4+7} and 6-benzylamino purine were applied as the proprietary mixture prepared by Abbott Laboratories, North Chicago, Ill. 60064.

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these branches 24 hr after application and placed in 50 ml Erlenmeyer flasks containing a test tube holding a strip of filter paper saturated with 40% KOH. Capped flasks were placed in the dark at room temperature for about 4 hr, and 1 ml of gas was taken from the flask with a syringe for ethylene measurement by gas chromatography. Fruit set was calculated as total number of fruit persisting on tagged limbs at the end of the "June drop" period. Twenty fruit were harvested at maturity from each tagged limb. The weight, length (L), and diameter (D), and seed number were determined for each fruit. Return bloom was determined on the same tagged limbs just prior to full bloom in 1979.

1979. The methods and trees used were similar to those used in 1978 with the following changes. Nine rather than 6 tree replications receiving no treatments the previous year were used. Treatments were applied at full bloom. Flowers or developing fruit were collected for weighing and ethylene determination 1, 4, 8, and 15 days after application. Fruit set counts were taken at weekly intervals starting 12 days after full bloom and continuing until the completion of "June drop", 54 days after full bloom.

Results

1978. Fruit set was increased with 200 ppm AVG alone or when used in combination with 50 ppm GA_{4+7} plus BA (Table 1). The lower concentration of AVG and $AgNO_3$ had no influence on fruit set. AVG reduced ethylene production 24 hr after application, the effect being greater at the higher concentration. Fruit treated with GA_{4+7} and BA plus AVG had the largest L/D ratio. The L/D ratio of fruit sprayed with 200 ppm AVG alone was less than that of fruits treated with the combination, but was significantly greater than that of the untreated fruit. No treatment affected the number of viable seeds per fruit, but all AVG treatments reduced return bloom.

$AgNO_3$ at 200 ppm injured flowers, browning and yellowing resembling that caused by sodium 4,6-dinitro-ortho-cresylate (DNOC) thinning sprays. The phytotoxic effects of 20 ppm $AgNO_3$ were apparent but much less pronounced.

1979. GA_{4+7} plus BA at 50 ppm, whether used alone or with 200 ppm AVG, had markedly increased set 12 days after bloom (Fig. 1). However, fruit abscised rapidly for the next 2 weeks on GA_{4+7} plus BA – treated branches, to a point where thinning was excessive. When AVG was included with GA_{4+7} + BA, thinning was greatly reduced. Final fruit set was about 3-fold as high on the GA_{4+7}-BA-AVG-treated branches as on the check branches. AVG alone did not significantly affect initial set 12 days after bloom, but increased final set 50%. Neither AVG at 20 ppm nor $AgNO_3$ at 10 ppm influenced fruit set (data not shown).

Ethylene production by flowers was reduced by 200 ppm AVG 24 hr after application (Table 2). GA_{4+7} + BA at 50 ppm increased ethylene production but this increase was prevented by 200 ppm AVG. Four days after treatment fruit treated with AVG or AVG plus GA_{4+7} + BA were producing less ethylene than check fruit. Ethylene produced by GA_{4+7} + BA-treated fruit alone had dropped to check levels, whereas those receiving $AgNO_3$ were producing more than the check. Ethylene production in GA_{4+7} + BA-treated fruit increased substantially 8 days

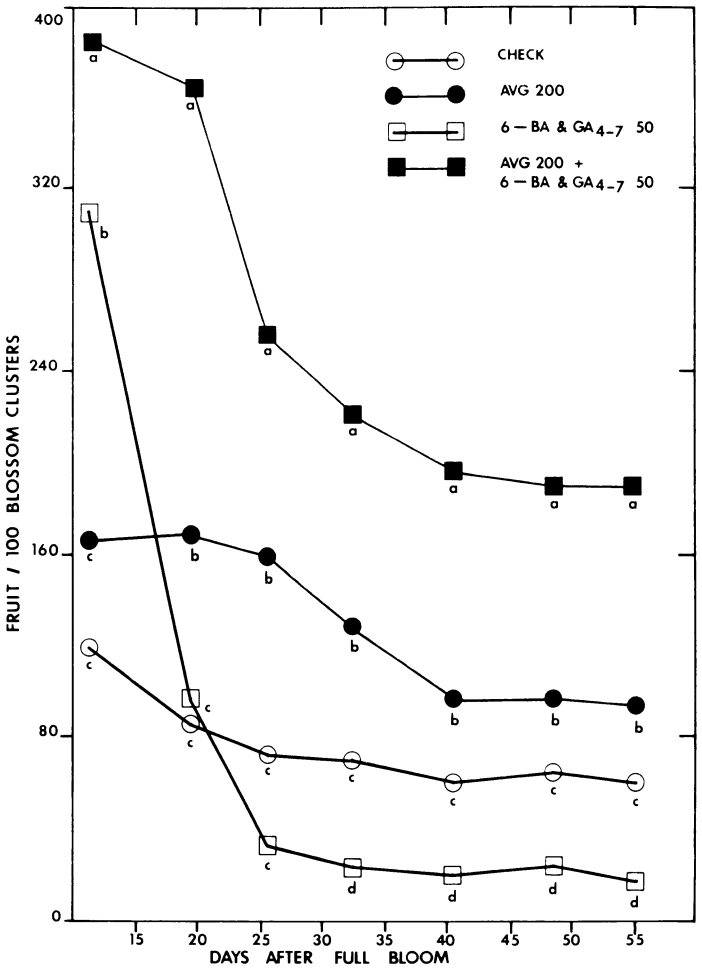

Fig. 1. Effect of aminoethoxyvinylglycine (AVG), gibberellins A_{4+7} (GA_{4+7}) and 6-benzylamino purine (BA) on fruit retention at intervals after full bloom, 1979. Fruit set means on the same day followed by a different letter are significant at the 5% level, Duncan's multiple range test.

Table 1. Effect of silver nitrate ($AgNO_3$), aminoethoxyvinylglycine (AVG), and GA_{4+7} + BA on fruit set, ethylene production 24 hours after application, fruit characteristics at harvest, and return bloom of 'Richared Delicious' apples, 1978.

Treatment (ppm)	Fruit/ cm limb circumf.	nl C_2H_4/ g·hr	Fruit wt (g)	L/D ratio	Seeds/ fruit	Blossom clusters/ cm limb circumf.
Check	2.8 c[z]	3.5 a	184.a	.90 c	4.6 a	10.6 a
$AgNO_3$ (20)	4.0 abc	––	171 ab	.91c	4.9 a	8.4 ab
$AgNO_3$ (200)	2.5 c	––	150 bc	.93 bc	3.8 a	8.5 ab
AVG (20)	3.9 bc	2.5 b	175 a	.91 bc	4.9 a	7.5 b
AVG (200)	5.5 ab	1.6 c	148 c	.94 b	5.1 a	6.6 b
AVG (200) + GA_{4+7} + BA (50)	5.8 a	––	151 bc	1.00 a	4.8 a	7.3 b

[z]Mean separation within columns by Duncan's multiple range test, 5%.

Table 2. Effect of aminoethoxyvinylglycine (AVG) and gibberellins A_{4+7} (GA_{4+7}) plus 6-benzylamino purine (BA) on ethylene production of 'Richard Delicious' flowers and young fruit, 1979.

Treatment (ppm)	Ethylene production (nl/g·hr) at full bloom +				
	1 day	4 days	8 days		15 days
Check	2.41 bc[z]	2.06 b	.80 b	.80 a[y]	.38 b
$AgNO_3$ (10)	3.87 b	4.05 b	.93 b	.93 a	.42 b
AVG (20)	1.41 cd	1.50 b	.28 b	.28 b	.39 b
AVG (200)	.60 d	.53 c	.18 b	.18 b	.34 b
GA_{4+7} + BA (50)	6.06 a	1.81 b	6.40 a	--	.84 a
AVG (200) + GA_{4+7} + BA (50)	1.82 cd	.37 c	.16 b	.16 b	.25 b

[z]Mean separation within columns by Duncan's multiple range test, 5%.

[y]A heterogeneity of errors was judged (5) because of the variability in C_2H_4 production by GA_{4+7} + BA-treated fruit, thus the analysis was repeated omitting the GA_{4+7} + BA treatments.

Table 4. Effect of silver nitrate ($AgNO_3$), aminoethoxyvinylglycine (AVG), and gibberellin A_{4+7} (GA_{4+7}) plus 6 benzylamino purine (BA) on characteristics of 'Richared Delicious' apples at harvest, 1979.

Treatment (ppm)	Fruit weight (g)	L/D ratio	Seeds/ fruit	Seedless fruit (%)
Check	138 ab[z]	.92 c	4.5 a	17 b
$AgNO_3$ (10)	135 ab	.93 bc	4.0 ab	21 b
AVG (20)	145 a	.93 bc	4.6 a	10 b
AVG (200)	113 b	.94 b	4.0 ab	12 b
GA_{4+7} + BA (50)	148 a	1.05 a	3.5 b	26 b
AVG (200) + GA_{4+7} + BA (50)	83 c	1.06 a	2.2 c	56 a

[z]Mean separation within columns by Duncan's multiple range test, 5%.

after application and remained high up to 15 days after treatment. Because of the variability in ethylene production by GA_{4+7} + BA-treated fruit, a heterogeneity of errors was judged (5); thus the analysis was repeated omitting the GA_{4+7} + BA treatment. When analyzed in this manner, less ethylene was produced by fruit treated with both levels of AVG and by the GA_{4+7} + BA-AVG treatments. The inhibitory effect of AVG on ethylene production had dissipated 15 days after treatment.

Calyx enlargement and increased fruit weight as a result of GA_{4+7} + BA and GA_{4+7} + BA plus AVG treatments were evident 4 days after bloom (Table 3). This effect persisted at 8 days but had dissipated by 15 days after full bloom. AVG at 200 ppm reduced fruit size 8 and 15 days after application, but this was overcome by GA_{4+7} + BA. Silver nitrate and 20 ppm AVG had no influence on fruit weight.

Treatments that increased fruit set reduced fruit size at harvest (Table 4). Fruits receiving GA_{4+7}, BA, and AVG were smallest. Even though GA_{4+7} and BA thinned, there was not a corresponding increase in fruit size. Fruit treated with GA_{4+7} and BA had the largest L/D ratio AVG alone at 200 ppm increased the L/D ratio but had not additional effect when combined with GA_{4+7} and BA. Seed number was reduced by GA_{4+7} and BA with or without AVG. AVG plus GA_{4+7} and BA increased the number of seedless fruit.

Discussion

AVG treatments that reduced ethylene production also increased fruit set, whether fruit set of check fruit was poor (Table 1) and where fruit set was adequate (Fig. 1), suggesting that endogenous ethylene levels in the flower and fruit of 'Delicious' may be sufficiently high to reduce initial fruit set. These data confirm the observation of Williams (19) that AVG may reduce the extent of "June drop" (19) and further suggests that AVG may increase initial fruit set as well.

Gibberellin A_{4+7} and BA increased initial fruit set above that of the check or AVG-treated branches. Increased fruit set of apples with gibberellins alone or when combined with cytokinins (4, 6, 8, 20) has generally resulted from treatments made via lanolin paste or with a brush. Lanolin paste application was more effective than sprays or limb injection (8). Spray application of GA_{4+7} and BA increased fruit set more than previously reported (20) regardless of the method of application. AVG completely overcame GA_{4+7} and BA-induced ethylene production and ultimately reduced ethylene production to levels similar to AVG treatment alone. Increased fruit set in this investigation was associated with reduced endogenous ethylene production. Increased fruit set was not observed when aqueous sprays of GA were applied to apples (8) and citrus (21).

Silver nitrate at 10 ppm increased ethylene production in apple fruitlets in 1979 and resulted in visible damage to flowers at 20 and 200 ppm in 1978. Although silver ion is generally considered to inhibit ethylene action (3), it may also inhibit ethylene production (15) or as was found in this investigation, may also increase ethylene synthesis (12). If ethylene levels are important in determining fruit set of apples then the amount of increase and its duration were apparently not sufficient in this investigation for silver ion to reduce set. Alternatively, elevated ethylene levels brought about by silver ion may have been counteracted by the inhibitory effect silver has on ethylene action.

Parthenocarpy has been responsible for increased fruit set as a result of GA or GA and cytokinins applications. Trees used in this investigation were open pollinated and flowers were not emasculated. Therefore, increased fruit set may or may not have result from parthenocarpy. However, over half of the fruit at harvest were seedless (Table 4). Many ovules in treated fruit examined 4, 8 and 15 days after application were black and never started to swell.

A normal "June drop" did not occur 3-6 weeks after bloom in 1979. How many, if any, of the seedless fruit resulted from the GA_{4+7} plus BA and AVG treatment is not known. GA_{4+7} plus BA did not enhance the effect of 200 ppm AVG on final fruit set in 1978. Initial fruit set was not recorded hence either GA_{4+7} and BA did not increase initial set, or the additional fruit that set as a result of the treatment abscised during the "June drop".

Fruit which abscise during the "June drop" period generally have few seeds (18). If a treatment increases fruit set, it normally prevents the drop of fruits with lower seed number. AVG

Table 3. Effect of silver nitrate ($AgNO_3$), aminoethoxyvinylglycine (AVG) and gibberellin A_{4+7} (GA_{4+7}) plus 6-benzylamino purine (BA) on early growth of 'Richared Delicious' apples.

Treatment (ppm)	Avg fruit weight (mg)		
	FB[z] + 4 days	FB + 8 days	FB + 15 days
Check	17 b[y]	34 b	70 ab
$AgNO_3$ (10)	15 b	31 bc	70 ab
AVG (20)	16 b	32 bc	63 b
AVG (200)	16 b	29 c	49 c
GA_{4+7} + BA (50)	25 a	40 a	78 a
AVG (200) + GA_{4+7} + BA (50)	22 a	40 a	75 a

[z]FB = full bloom.

[y]Mean separation within columns by Duncan's multiple range test, 5%.

increased fruit set without influencing the average number of seeds per fruit.

AVG alone at 200 ppm increased the L/D ratio of fruit at harvest (Tables 1, 4), confirming the observation of Williams (19). This is probably not a reflection of the difference in fruit load, for fruit on light cropping trees have a greater L/D ratio than those on heavily cropping trees (16). A carryover effect of ethephon can reduce the L/D ratio (17). Reduced levels of ethylene during the bloom and postbloom period as a result of AVG application may have resulted in slightly "typier" fruit. One cannot dismiss the possibility that AVG by itself may have a direct or indirect effect on fruit shape. Williams (19) found that AVG applied in the fall promotes bud break and vegetative growth the following season. Since fruitlets are anatomically considered an extension of the shoot, it follows that the fruit may be elongated when AVG is applied shortly after bloom or the previous fall.

AVG at 200 ppm increased fruit set in 1978 and 1979 and reduced fruit size 8 days after application in 1979 following application of 200 ppm AVG. A heavy crop load reduced fruit size (18). Therefore, this effect of AVG is apparently due to both a direct effect of the chemical and an indirect effect due to increased fruit set.

Orchardists may be concerned about using a commercial thinner after applying the proprietary mixture of GA_{4+7} plus BA out of concern for excessive thinning. The time course of fruit set (Fig. 1) and field observations indicate that fruit abscission, or at least pedicel yellowing, on GA_{4+7} + BA-treated fruit is apparent within 3 weeks after application. In most areas this would be sufficient time for a grower to assess initial set, evaluate thinning and still have sufficient time to apply a thinner such a carbaryl in ample time for the thinner to be effective.

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