

scion explants showed any symptoms. Seven to 10 days after inoculation, the leaves rubbed with juice from the SGV infected source showed symptoms described by Lister (8) for SGV infection on *C. quinoa*. They include an initial development of local lesions on the inoculated leaves followed by an epinasty of the growing point, tip distortion, and a mottle on the leaves.

A similar technique of micrografting of apple has been described by Alskieff and Villemur (2). In their study they grafted the scion explants to the epicotyl, just above the cotyledons whereas our technique involves adventitious shoot development and increases the percentage of successful grafting (23 vs 65%). *In vitro* micrografting of apple is suggested as a technique to produce virus-free trees from some explants of infected cultivars whose cultured shoots are difficult to root.

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Effect of Growth Regulators on the Development of 'Delicious' Apples¹

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Additional index words. *Malus domestica*, butanedioic acid mono-(2,2-dimethylhydrazide), (2-chlorethyl)phosphonic acid, gibberellin A₄A₇, 6-benzylamino purine, α-(2,4,5-trichlorophenoxy)propionic acid

Abstract. The color and shape of 'Delicious' apples were improved with a combination treatment of (2-chlorethyl)phosphonic acid + α-(2,4,5-trichlorophenoxy)propionic acid (ethephon/fenoprop) and gibberellin A₄A₇ plus N-(phenylmethyl) 1H-purin-6-amine (GA₄,7/BA). All ethephon/fenoprop treatments improved red color development. The length/diameter (L/D) ratio of fruit treated with GA₄,7/BA, GA₄,7/BA plus ethephon/2,4,5-TP, and GA₄,7/BA plus ethephon/2,4,5-TP plus daminozide was greater than untreated fruit. The L/D ratio of fruit treated with GA₄,7/BA plus daminozide did not differ from those not treated. The length, diameter, and weight of fruit treated with daminozide alone was less than for untreated fruit. Diameter of fruit treated with GA₄,7/BA + daminozide or daminozide + GA₄,7/BA + ethephon/fenoprop was less than for untreated fruit.

Poor fruit shape and color development limit the market of 'Delicious' apples. High post-bloom temperatures in the Southeast result in 'Delicious' apples being flatter in shape and lacking calyx points typical of fruit grown in the Northwest (14). A proprietary mixture of GA₄,7/BA, marketed as Promalin by Abbott Laboratories, North Chicago, Illinois, has been used to promote development of the calyx points, and increase fruit length, L/D ratio, and weight without altering fruit diameter or color (9, 11, 12, 15). Applications during bloom were more effective than pre- or postbloom sprays (11, 14).

Foliar sprays of ethephon and daminozide, alone or in combination, have been used to influence red color development, maturity, and quality of apples. Ethephon (generally combined with a suitable auxinic "stop-drop" agent) enhanced red color development (1, 3, 4, 6, 8, 10, 12), percent soluble solids (3, 7, 8, 13), and hastened maturity (6, 10), but decreased firmness (1, 3, 8, 10, 12, 13). Daminozide enhanced red color development, but not to the same extent as ethephon (2, 8), increased fruit firmness (2, 5, 7, 8, 15). When daminozide and ethephon were combined, greater red color development occurred than when either was used alone (1, 8, 10, 12) and the combination resulted in partial cancellation of their individual effects on fruit firmness and fruit drop (8, 10).

This experiment was conducted to determine the effect of GA₄,7/BA,

daminozide and ethephon/fenoprop, applied alone or in combination on fruit shape, quality, and color development of 'Delicious' apples grown in central Alabama.

GA₄,7/BA (50 ppm of each) was applied on April 5, at the "king" blossom stage. Daminozide (1500 ppm) was applied on July 1, 6 weeks prior to the anticipated harvest date. Ethephon (300 ppm)/fenoprop (20 ppm) was applied on August 6, 12 days prior to the anticipated harvest date. Each growth regulator or growth regulator mixture was applied alone and in all possible combinations as separate sprays at the appropriate time. Each treatment was replicated 8 times in a randomized complete block design using whole tree plots of 14-year-old 'Miller's Sturdee Spur Delicious' on Malling-merton (MM) 106 rootstock.

Twenty fruit were randomly harvested from each treatment replication at normal harvest maturity (August 18). These fruits were assessed for: fruit firmness, percent soluble solids, length, diameter, L/D ratio, weight, percent of fruit surface with red color development and percent of fruit surface with a solid red blush and seed color. Ten fruit were harvested from each replicate on August 14, 18, and 21 to determine the intensity of red color.

Firmness was measured by use of an Instron Model 1122 Universal Testing Instrument with a 11 mm plunger. Soluble solids were measured by use of a hand refractometer. The percentages of the fruit surface with some red color development and solid red blush were subjectively rated. The intensity of red color on the red side as well as on the green side of the fruit was measured with a Hunter Color Difference Meter D25 D2 by placing the fruit surface directly on the glass cover of the port.

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Table 1. The effect of growth regulators on fruit firmness, size, shape, and color development of 'Delicious' apples.

Treatment ^z			Fruit firmness (kg/cm ²)	Fruit size		Fruit L/D ratio	Wt per fruit (g)	Subjective color development (%) ^y	
Daminozide	GA _{4,7} /BA	Ethephon/ fenoprop		Length (cm)	Diameter (cm)			Red blush	Total red surface
—	—	—	6.57 b ^x	6.4 abc	7.3 a	.88 de	179 a	21.9 b	48.7 c
+	—	—	7.59 a	5.8 d	6.8 c	.86 e	135 c	16.1 b	48.5 c
—	—	+	6.18 b	6.5 ab	7.2 ab	.90 cd	160 ab	41.9 a	74.0 a
—	+	—	6.91 ab	6.6 a	6.9 abc	.97 a	151 abc	23.0 ab	48.3 c
+	+	—	6.62 b	6.0 cd	6.6 c	.91 bcd	140 bc	28.0 ab	57.3 c
+	—	+	6.60 b	6.3 abcd	7.1 abc	.89 cde	157 abc	38.5 a	74.5 a
—	+	+	5.88 b	6.8 a	6.9 abc	.98 a	162 ab	39.1 a	68.4 ab
+	+	+	6.61 b	6.2 bcd	6.6 c	.94 ab	142 bc	37.9 a	72.2 ab

^zDaminozide (1500 ppm) was applied 6 weeks prior to anticipated harvest. GA_{4,7}/BA (50 ppm) was applied at the "king" blossom stage. Ethephon (300 ppm)/fenoprop (20 ppm) was applied 12 days prior to anticipated harvest.

^yColor ratings were made by subjectively rating the percent of the fruit surface with some red color development and the percent of the fruit surface with a solid red blush.

^xMean separation, within columns, by Duncan's multiple range test, 5% level.

Fruit treated with daminozide or GA_{4,7}/BA alone were significantly firmer than fruit receiving other treatments (Table 1). Fruit firmness was not affected by other treatments. There was no treatment effect on percent soluble solids and seed color (data not shown).

The L/D ratios of fruit treated with GA_{4,7}/BA, GA_{4,7}/BA + ethephon/fenoprop and GA_{4,7}/BA + ethephon/fenoprop + daminozide were 0.97, 0.98, and 0.94 respectively; all above the minimum value of 0.93 generally required for fruit to conform to type (9). All other treatments resulted in fruit with L/D ratios below the accepted minimum value.

Fruit length, diameter, and weight were decreased when treated with daminozide alone (Table 1). Ethephon/fenoprop and GA_{4,7}/BA treatments applied alone and in combination did not effect fruit size or weight. When daminozide was applied to GA_{4,7}/BA-treated fruit the length was significantly less than when GA_{4,7}/BA was applied alone or with ethephon.

Ethephon/Fenoprop (alone or in combination with the other growth regulators) caused an increase in both the percentage of the fruit surface with some red color and a red blush (Table 1). Daminozide and GA_{4,7}/BA applied alone or in combination had no effect.

Hunter Color Difference Meter read-

ings indicated that only ethephon/fenoprop alone or in combinations with daminozide and/or GA_{4,7}/BA at the early harvest date, August 14 (Table 2) increased the amount of red color on treated fruits. This increase in color value due to ethephon/fenoprop diminished at the latter harvest dates except on the red side of fruit treated with ethephon/fenoprop alone. Daminozide applied alone delayed red color development of fruit at last 2 harvest dates.

This experiment indicates that the color and shape of 'Delicious' apples can be improved with combined treatments of ethephon/fenoprop and GA_{4,7}/BA in the very warm Southeast. Daminozide alone did not improve red color development nor was there an additive effect on color development when combined with ethephon/fenoprop as previously reported (1, 8, 10, 12). GA_{4,7}/BA alone and in the various combinations improved the fruit L/D ratio. Daminozide adversely affected fruit size and weight as reported by other workers (2, 5, 7, 8, 15) and countered the beneficial effect of GA_{4,7}/BA on fruit size and L/D ratio.

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Table 2. The effect of growth regulator treatments on the amount of red color development of 'Delicious' apples. Data are mean values for 10 fruit in each of 8 replications.

Treatment			Red color ^z (tan ⁻¹ a/b)					
			August 14		August 18		August 21	
			Fruit side	Fruit side	Fruit side	Fruit side	Fruit side	Fruit side
Daminozide	GA _{4,7} /BA	Ethephon/ fenoprop	Red	Green	Red	Green	Red	Green
—	—	—	46.7 b ^x	—4.8 b	54.4 b	3.0 bc	52.0 bc	0.5 bc
+	—	—	32.5 b	—8.2 b	44.8 c	—4.5 c	41.4 d	—6.5 c
—	—	+	63.1 a	16.1 a	63.5 a	15.6 a	63.4 a	13.5 ab
—	+	—	32.8 b	—9.1 b	50.4 bc	4.4 abc	59.0 abc	1.9 bc
+	+	—	39.5 b	—4.5 b	51.8 bc	6.5 abc	45.7 cd	2.1 bc
+	—	+	62.7 a	17.6 a	61.6 ab	18.1 a	60.3 ab	8.7 abc
—	+	+	61.2 a	12.0 a	61.8 ab	11.0 ab	60.8 ab	18.8 a
+	+	+	61.1 a	11.1 a	63.5 a	11.6 ab	59.2 ab	7.9 abc

^zColor values were obtained by use of a Hunter Color Difference Meter D25 D2.

^xMean separation within columns, by Duncan's multiple range test at the 5% level.