date, polyamines have not affected cell enlargement *in vitro* (5).

Polyamines are natural growth regulators which may stimulate certain developmental processes of plants. The results demonstrate for the first time the positive effects of these substances under orchard conditions; beneficial effects have already been established from *in vitro* studies on both animal and plant organisms. The concentrations used, however, must be strictly correlated with the endogenous concentrations in the plants or plant parts to be tested, because, as demonstrated in *in vitro* studies (5), they are effective only when unfavorable environmental conditions reduce endogenous levels.

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# Effects of Dilute and Concentrated Sprays of NAA and Carbaryl in Combination with Daminozide and Pesticides on Fruit Size and Return Bloom of 'Starkrimson Delicious' Apple[1]

**B. L. Rogers and A. H. Thompson**

*Department of Horticulture, University of Maryland, College Park, MD 20742*

*Additional index words.* *Malus domestica*, napthaleneacetic acid, butanedioic mono-(2,2-dimethylhydrazide), 1-naphthyl N-methyl carbamate

*Abstract.* **Naphthaleneacetic acid (NAA) and 1-naphthyl N-methyl carbamate (carbaryl) applied separately in both dilute and concentrated sprays significantly increased fruit size; however, when butanedioic mono-2,2-dimethylhydrazide (daminozide) was added, fruit size remained about the same as on unsprayed check trees. Crop load was not significantly affected by any of these treatments. Dilute and concentrated sprays of carbaryl produced more return bloom than did NAA. The most effective treatments were combinations of NAA and carbaryl, either dilute or concentrated. Combining first-cover pesticides [azinphosmethyl (guthion) and cis-N-(trichloromethyl)thio)-4-cyclonexane-1,2-dicarboximide (captan)] with NAA, and captan with carbaryl, produced satisfactory thinning.**

Spur-type 'Delicious' set fruit more heavily than nonspur types, and are more resistant to thinning sprays. NAA, and particularly naphthalene acetamide, may cause pigmy fruit (2, 8) on all strains of 'Delicious'. Carbaryl does not cause pigmies; it is the preferred thinning agent, but it often fails to thin spur types adequately. Carbaryl has been mixed with adjuvants and other thinning agents in attempts to increase thinning (2, 8, 10). Historically, most experimental apple thinning has been with dilute sprays; however, concentrated applications have been effective on several cultivars (7, 9). With modern air-blast sprayers, concentrated applications at low volume are used almost exclusively.

Daminozide is used as a mid-season spray to increase fruit firmness at harvest. When used early in the season it suppresses shoot growth and increases flower bud initiation but has the disadvantage of reducing fruit size (3, 4, 12). As an adjunct to chemical thinning sprays, daminozide should have the potential of increasing the amount of return bloom (6). The main purpose of this work was to study fruit size and return bloom as influenced by dilute and concentrated sprays of NAA and carbaryl applied with and without daminozide.

Heavily blooming, mature trees in moderate vigor on seedling rootstocks, located on Calvin-Berks channery loam soil, were selected for study in 1979. During bloom these trees received a commercial application of gibberellin $A_4$ $A_7$ plus N-(phenyl methyl) 1 H-purine, a proprietary mixture marketed as "Promalin". Although this product can reduce fruit set, thinning treatments were applied 12 days after full bloom, when it appeared that fruit set was heavy. NAA and carbaryl were applied, with and without daminozide, in dilute sprays at 35 kg/cm$^2$ sprayed with a single-nozzle gun to run-off, and in low volume from an air-blast machine at 9.35 hl/ha (100 gal/acre). Active ingredients in dilute sprays were NAA 15 ppm, carbaryl 60 g/hl, and daminozide 1000 ppm; for comparison, these amounts were tripled in the concentrated sprays. Tween 20 (polyoxyethylene monolaurate sorbitan) was used at 63 ml/hl (1/2 pt/100 gal) with NAA in both dilute and concentrated sprays, but was omitted when NAA was combined with pesticides. Guthion and captan, in concentrated treatments, were used at 90 and 360 g/hl, respectively. Some concentrated spray treatments involving rates of carbaryl were repeated in 1980 on similar trees in another orchard on Litz shaly loam soil.

Shortly before harvest, the circumferences of 25 randomly chosen fruit were taken at 1.5 to 2 m height around the periphery of each tree, an accurate method of sizing fruit on the tree (11). Crop load was rated on a

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Table 1. Effects of thinning chemicals and daminozide, applied as dilute vs. concentrated sprays, on fruit size, crop load, and return bloom, 1979–1980.

| Chemical[z] | Daminozide[y] | Method of spray | Fruit circumf. (cm) | Crop[x] load | Return[w] bloom |
|---|---|---|---|---|---|
| 1. NAA (plus Tween 20) | – | dilute | 18.6 cd[v] | 9.1 ab | 17 a |
| 2. NAA (plus Tween 20) | – | concn. | 18.6 cd | 8.5 bc | 22 ab |
| 3. Carbaryl (60g) | – | dilute | 19.0 de | 8.3 bc | 41 cde |
| 4. Carbaryl (180g) | – | concn. | 18.4 bc | 9.0 ab | 33 bcd |
| 5. NAA (plus Tween 20) | + | dilute | 18.1 abc | 8.6 abc | 43 de |
| 6. NAA (plus Tween 20) | + | concn. | 17.6 a | 9.4 a | 25 abc |
| 7. Carbaryl (60g) | + | dilute | 18.1 abc | 8.4 bc | 54 ef |
| 8. Carbaryl (180g) plus captan | + | concn. | 18.1 abc | 8.8 ab | 41 cde |
| 9. NAA + carbaryl (60g) | – | dilute | 19.3 e | 7.9 c | 57 ef |
| 10. NAA + carbaryl (180g) | – | concn. | 19.0 de | 7.8 c | 61 f |
| 11. None (check) | – | --- | 18.0 ab | 9.1 ab | 16 a |

[z]NAA, 5 ppm dilute; 15 ppm concn. Tween 20, 63 ml/hl in dilute and concn. sprays.
[y]1,000 ppm dilute; 3,000 ppm concn.
[x]0 (none) to 10 (very heavy); 80 (full crop).
[w]0 (none) to 100 (all spurs flowering).
[v]Means separation within columns by Duncan's multiple range test, 5% level.

Table 2. Effects of pesticides on response to NAA and carbaryl in concentrated sprays.

| Chemical | Pesticide[z] | Fruit circumf. (cm) | Crop[y] load | Return[x] bloom |
|---|---|---|---|---|
| None | --- | 18.0 a[w] | 9.1 a | 16 a |
| NAA, 15 ppm (+Tween 20) | --- | 18.6 b | 8.5 a | 22 ab |
| NAA, 15 ppm | Guthion + Captan | 18.5 ab | 9.1 a | 40 c |
| Carbaryl (180g/hl) | --- | 18.4 ab | 9.0 a | 33 bc |
| Carbaryl (180g/hl) | Captan | 18.3 ab | 9.2 a | 42 c |

[z]Guthion, 90 g/hl; Captan, 360 g/hl.
[y]0 None to 10 (very heavy); 8 (full crop).
[x]0 (none) to 100 (all spurs flowering).
[w]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 3. Effects of identical carbaryl rates applied in different orchards in different years[z].

| Carbaryl (active ingredient per hl) (g) | Fruit circumf. (cm) | | Crop load[y] | | Return bloom[x] | |
|---|---|---|---|---|---|---|
| | Orchard A 1979 | Orchard B 1980 | Orchard A 1979 | Orchard B 1980 | Orchard A 1979 | Orchard B 1980 |
| 0 | 18.0 a[w] | 19.1 a | 9.1 a | 8.6 a | 16 a | 6 a |
| 45 | 18.7 a | 19.3 a | 9.1 a | 8.1 a | 20 ab | 20 ab |
| 90 | 18.1 a | 19.5 ab | 9.0 a | 8.1 a | 44 c | 26 b |
| 180 | 18.4 a | 19.7 b | 9.0 a | 7.9 a | 33 bc | 47 c |

[z]Applied by air-blast sprayer at 9.35 hl/ha (100 gal/acre).
[y]0 (none) to 10 (very heavy); 8 (full crop).
[x]0 (none) to 100 (all spurs flowering).
[w]Mean separation within columns by Duncan's multiple range test, 5% level.

scale of 0 (none) to 10, with 8 representing what was considered to be an ideal crop. Return bloom was rated on a scale of 0 to 100, the latter representing all spurs flowering. Each treatment consisted of 9 randomized single-tree plots.

Fruit set was heavy and fruit small in 1979, but no pigmy fruits were found as a result of treatment. Small size is indicated by the mean circumference of 18 cm on check fruits (Table 1). NAA sprays significantly increased fruit size, a response which did not occur when daminozide was included. A similar response was recorded for carbaryl sprays with and without daminozide. The combination of NAA with carbaryl, applied dilute, produced the largest fruit. Fruit size tended to be smaller from the concentrated sprays than from comparable dilute sprays, although significantly so in only one instance (trt 3 vs. 4). Only the NAA-carbaryl combination reduced crop load significantly, but these trees produced an ideal crop, while all other treatments were somewhat overloaded.

Return bloom was not influenced by effective thinning with NAA, but was increased by carbaryl thinning (Table 1). Daminozide significantly increased return bloom from dilute NAA, but not concentrated NAA. Daminozide also increased return bloom when combined with carbaryl, but not significantly so (trt 3, 4 vs. 7, 8). While some return bloom response to daminozide is shown, it is not a promising treatment because of the suppression of fruit size at harvest.

The combination of captan with carbaryl in a concentrated thinning spray did not produce significant responses different from carbaryl applied alone (Table 2). Combining guthion and captan with NAA did not influence fruit size, but greatly increased the amount of return bloom. In another experiment using dilute sprays, this same combination increased fruit size significantly, yet failed to produce any return bloom, whereas other treatments responded normally (10). We have no explanation for this erratic behavior. This point needs further study.

Identical rates of carbaryl in concentrated sprays in separate orchards and different years indicated that 45 g/hl was too low for a significant response; however, all rates in both orchards caused some increase in fruit size with significance being achieved at 180 g/hl in orchard B only (Table 3). Crop load was not altered significantly, yet return bloom was profoundly affected with significant increases at both 90 and 180 g/hl in both orchards. Carbaryl at 45 g/hl applied at a volume of 9.35 hl/ha, amounted to only 0.42 kg/ha (0.37 lb/acre), a very low rate. In contrast, a dilute application at 37.4 hl/ha (400 gal/acre) at the standard rate of 60 g/hl (1/2 lb/100 gal) would be 2.24 kg/ha (2 lb/acre).

Many experiments with apple have shown that the concentration of carbaryl in dilute thinning sprays is not critically related to results obtained (1). This study, involving concentrated sprays, indicated that carbaryl concentration should be at least 90 g/hl when applied at a volume of 9.35 hl/ha, which would be 0.84 kg/ha (0.74 lb/acre). Uniformity of results, a desired goal in chemical thinning, has been elusive because of a great number of biological and meteorological variations. Further refinements in application techniques might be a useful approach. For example, a recent report indicated that more uniformity in thinning might be obtained by adjusting spray volume to total tree canopy, rather than to area sprayed (5).

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# Reduction in Russetting of 'Golden Delicious' Apples with 2,4,5-TP and Other Compounds[1]

**R. E. Byers, K. S. Yoder, and G. E. Mattus[2]**
*College of Agriculture and Life Sciences, Virginia Agricultural Experiment Station, Virginia Polytechnic Institute and State University, Winchester Fruit Research Laboratory, 2500 Valley Avenue, Winchester, VA 22601*

*Additional index words.* *Malus domestica*, fruit russet, growth regulators

***Abstract.*** **Fruit of apple (*Malus domestica* Borkh. cv. Golden Delicious) sprayed with triethanolamine salt of silvex [2-(2,4,5-trichlorophenoxy) propionic acid] (2,4,5-TP), a finely dispersed aluminum oxide (Sun Clear), and potassium salt of a fluorochemical carboxylic acid (L-4749) had better finish than controls. Fruit size and seed numbers were significantly reduced by higher rates of 2,4,5-TP. Sprays of a mixture of anion acrylic polymer binding agents (Acrylocoat), poly-1-p-methen-8-9 diyl (Vapor Guard), and a nonionic dimethyl polysiloxane (Dow Corning Silicone 24) increased russeting on 'Golden Delicious' apple fruit. Fruit enclosed in a paper bag 16 days after bloom gave a greater reduction in russet than any spray treatment.**

Russetting of the apple surface detracts from the appearance of fresh market fruit, reduces shelf life, and results in lower consumer preference. In addition, U.S. Grade standards restrict the sale of russetted fruit to lower-grade classes, which results in great economic loss to fresh-market fruit growers. Reviews (1, 5, 11) and other research papers (2, 3, 4, 6, 10, 12) suggest that russetting results morphologically from undifferentiated cell divisions below the epidermis as a result of injury caused by free water, humidity, pesticides, excessive nitrogen levels, or other injuries. Cracking of the cuticle and epidermis is thought to expose hyperdermal layers where wound reactions result in pellogen production and subsequent rupturing of more cuticle and browning of exposed cells. Several workers have greatly reduced russet by protecting individual fruits with paper bags or rain shelters (4, 10, 12). Creasy (2) found that russetting was highly correlated with high humidity and precipitation during a short period of 16–20 days after bloom. However, fruit-bagging experiments by Creasy and Swartz (3) showed that russet development is determined in the period from 25 to 50 days after bloom. Shaheen et al (8) also showed that the transition from the stomatal trace to lenticels was completed by about 55 days after anthesis. Lenticel russet also detracts from the fruit appearance, even though grade standards are based on net-type russet. A reduction in russet has been provided by sprays of silicon dioxide (4, 7), gibberellin $A_{4+7}$ (9), and Tuzet [a fungicide mixture containing methylarsine-bis-dimethyl-(dithiocarbamate), ziram, and thiram] (14).

The objective of these experiments was to identify other materials which might reduce russet of 'Golden Delicious' fruits. The plant growth regulator 2, 4, 5-TP was selected as a candidate inhibitor of russet since we have observed that apples sprayed with this compound have an increased waxy feel when the compound is applied prior to harvest as an inhibitor of preharvest apple drop. Acrylocoat (4%), Vapor Guard (4%), Dow Corning Silicone-24 (2%), L-4797 (1% or 2%), and Sun Clear (2%) were selected for their film-forming properties in an attempt to inhibit external water contact with the fruit surface. Acrylocoat is used in some pesticide applications for increasing retention of pesticides to plant surfaces. Vapor Guard has been used primarily as an antitranspirant. The fluorochemical carboxylic resins (L-4797) have been used to treat furniture fabrics for water and oil repellency. This chemical, when sprayed on a paper towel and dried, will inhibit rewetting of the towel by water; it also does not form a heavy film, since air will readily pass through the towel. Sun Clear is applied to surfaces inside greenhouses to reduce surface tension of water to minimize water dripping from roof structures.

A planting of 10-year-old 'Golden Delicious'/MM 111 trees near Winchester, Va., was selected for uniformity of terrain, tree size, and vigor. In addition, airblast applications were made to 11-year-old spur-type 'Golden Delicious' in 1982. A Swanson 3-point hitch airblast sprayer was used to spray each of 10 whole-tree replicates in 1981 and 8 replicates in 1982 in randomized complete block designs (Table 1A, 2A). The sprayer was calibrated for 253 liters/ha (165 gal./acre) using a two-fan delivery. In 1981, treatments were applied 7, 15, 22, 27, and 42 days after bloom, except for 2,4,5-TP which was applied 27 days after bloom. In 1982, treatments were applied on 4, 12, 19, 27, and 35 days after full bloom.

Since sprayer agitation caused a floating precipitate of the L-4797 formulation in the airblast experiment (Table 1A), a small propellant hand-operated sprayer was used to treat individual apples with this formulation. Iso-propanol was also used in 1981 in an attempt to prevent precipitation. In 1981, treatments were applied 21, 28, 34, and 39 days after bloom, and in 1982, they were applied 20, 27, and 34 days after bloom in a row near the airblast treatments. In 1981,

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