rooted and 84% of the rooted cuttings were acceptable for transplanting. Percentage of rooted cuttings from the apical to medial and apical to basal shoot position decreased 22% and 38%, respectively, although the percentage of rooted and acceptable cuttings and root ratings from the lower two positions were similar. Diameter of the cutting was negatively correlated to percent rooted ($r = -0.66$) and acceptable ($r = -0.69$) cuttings. The percentage of cuttings that survived transplanting to pots ranged from 94% to 99%. Thirty-one, 52, and 66% of plants derived from basal, medial, and apical cuttings produced at least 150 mm of shoot growth; the length of the shoots averaged 110, 280, and 410 mm for the three types of cuttings, respectively.

The results with IBA and NAA were similar to those of Costa and Baraldi (2) for nonwounded three-node 'Hayward' cuttings rooted in medium with the ratio 2 peat : 1 perlite (v/v). Increasing IBA concentration from 1.0 to 5.0 $g \cdot liter^{-1}$ also significantly improved the percentage of rooting of one-node, wounded 'Abbott' cuttings (6). A combination of IBA at 3.0 $g \cdot liter^{-1}$ and NAA at 3.0 $g \cdot liter^{-1}$ had been reported to be superior to IBA at 6.0 or 8.0 $g \cdot liter^{-1}$ for rooting one-node 'Chico Hayward' cuttings (1); however, this was not the case for IBA/NAA combinations used in this study on two-node 'Hayward' cuttings.

The decline in rooting percentages between mid-summer and September collections had been reported previously in Italy for longer cuttings (2, 7). However, no decline in percentage of rooting was observed between one-node cuttings of 'Hayward' or 'Abbott' collected in January and March in New Zealand (6). The growing medium was maintained at 23 ± 2°C throughout the course of that study (6), unlike in this and other studies (2, 7), where medium temperatures reflected seasonal declines in air temperatures. Propagation date had very little effect on percent rooting of 'Hayward' when the medium was at 26° to 30° (3). In fact, high rooting percentages (60%–90%) were obtained at these temperatures with very low concentrations (0.5 to 2 $g \cdot liter^{-1}$) of IBA (3). Perhaps, even during very hot summers, where the mean maximum growth medium temperature reached 23.5°, rooting would have been improved if the medium had been maintained at 23° to 30°. Still, cuttings made from the most mature shoots may respond more like hardwood than semi-hardwood cuttings.

Timely collection of canes from the field may be the first critical step in obtaining maximum numbers of high quality, semi-hardwood rooted cuttings. When collected in early summer (mid-June to mid-July), two-node cuttings made from the apical to medial portions of the shoot, wounded through the lower bud and opposite side of the stem, dipped in IBA at 6.0 to 8.0 $g \cdot liter^{-1}$ and rooted in verminculite can yield up to 84% acceptable cuttings for transplanting. Ninety-nine percent of those cuttings survived transplanting and 66% produced shoots at least 150 mm in length 8 weeks after transplanting. Therefore, 58% of the original cutting stock produced vigorous, new plants. Collection of canes later in the season can result in a considerable drop in acceptable cuttings, which may be well below commercially desirable levels.

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Fruit Abscission, Fruit Quality, and Residue Levels of Dichlorprop Used to Control Preharvest Drop of Apple

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Abstract. **Five apple (*Malus domestica*) cultivars were treated with NAA at 10 $mg \cdot liter^{-1}$ and dichlorprop at 5, 10, and 15 $mg \cdot liter^{-1}$ during 2 years. Although the response varied with cultivar, NAA generally delayed fruit abscission compared to the control. Preharvest drop was usually reduced by dichlorprop at 5 $mg \cdot liter^{-1}$ more effectively than by NAA. Preharvest drop of 'Stayman', 'Rome Beauty', and 'Winesap', but not 'Delicious', was inversely related to concentration of dichlorprop. Fruit redness, flesh firmness, soluble solids content, and starch ratings were not affected consistently at harvest or during storage by any treatment for any cultivar. Residue levels of dichlorprop in the fruit were related to treatment concentration and persisted until harvest. Chemical names used: naphthalene acetic acid (NAA); 2-(2,4-dichlorophenoxy) propanoic acid (dichlorprop).**

Because apples often abscise before becoming adequately red and mature for harvest, plant growth regulators have been used commercially since the 1940s to delay fruit abscission. NAA was the first synthetic auxin to be used for preharvest drop control (8), but it was effective for only 7 to 10 days after treatment (15, 18). 2-(2,4,5-trichlorophenoxy)propionic acid (fenoprop) was effective 3 to 10 days after treatment and prevented fruit abscission for 3 to 6 weeks (15, 18). Although NAA and fenoprop have been used by commercial apple producers for several decades to prevent preharvest drop, fenoprop was not used on fruit intended for long-term storage due to accelerated fruit maturity (18).

In the 1960s, butanedioic acid mono(2,2-dimethylhydrazide) (daminozide) was found to delay fruit abscission and suppress fruit softening when applied before fenoprop (4, 17). Chemical control of fruit drop has received little attention during the past 20 years because combinations of fenoprop, NAA, and daminozide have effectively prevented preharvest fruit abscission. The registration of fenoprop for preharvest drop control of apples was recently suspended. The registration for daminozide is currently being reviewed and its future availability for use on apples is uncertain.

Preharvest drop of apples has once again become a serious problem because in many

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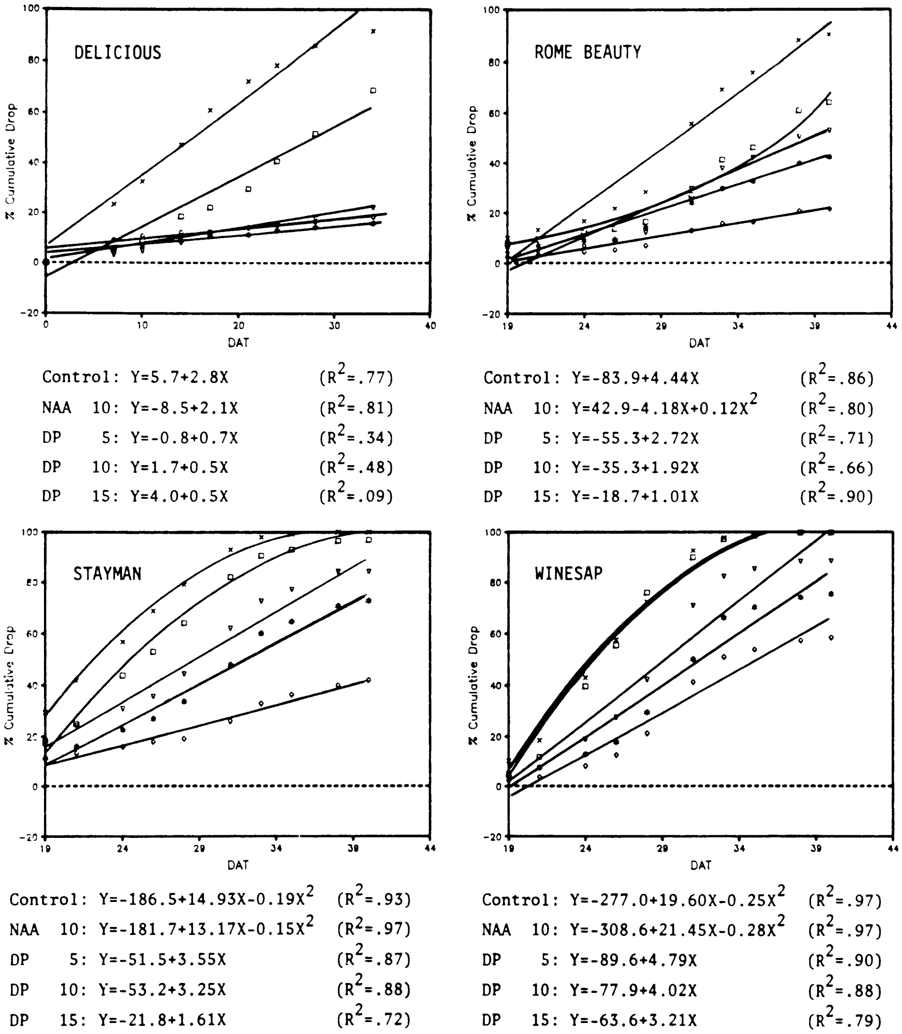

Fig. 1. Treatment means for percent cumulative fruit drop following applications of NAA and dichlorprop (DP) for four apple cultivars in 1986. Prediction lines for each treatment were generated from linear and nonlinear regression models using days after treatment (DAT) as the independent variable: x = control; □ = NAA, 10 ppm; ▽ = dichlorprop, 5 ppm; # = dichlorprop, 10 ppm; ◇ = dichlorprop, 15 ppm.

Table 1. Residue levels of dichlorprop in whole macerated 'Delicious' apple fruit at various times after treatment (1986).

Dichlorprop concn (mg·liter^{-1})	Time of sampling after treatment 2 hr	7 days	14 days	21 days
	μg·kg^{-1}			
0	0	0	0	0
5	1	3	2	3
10	3	4	3	5
15	5	6	13	13

years NAA is inadequate, especially for processing cultivars where stop-drop materials have been used to hold fruit on the trees for longer periods than for fresh fruit. Apples grown for fresh consumption must be harvested at optimum maturity. Treating midseason cultivars grown for fresh market, such as 'Jonathan', 'Delicious', and 'Golden Delicious', with the relatively short-lived NAA usually provides acceptable drop control. Processing cultivars, such as 'Rome Beauty', 'York Imperial', and 'Stayman', mature late and are often subject to heavy fruit drop. Labor shortages and poor weather often delay harvest of processing cultivars beyond the effective period for NAA.

Dichlorprop has effectively delayed abscission of 'McIntosh' fruit (12). Therefore, the objectives of this study were to determine the optimum concentration of dichlorprop for delaying fruit abscission, to study its influence on fruit maturity, and to follow the decrease in residue following treatment of several apple cultivars.

Nineteen-year-old 'Starking Delicious', 'Golden Delicious', 'Winesap', 'Rome Beauty', and 'Stayman' trees on MM.111 rootstock growing at Blacksburg, Va. were used to compare dichlorprop and fenoprop for preharvest drop control in 1985. Trees were visually divided into quarters. Two treatments plus a control were applied to quarter-tree-units of each tree. The spray was applied with a handgun to runoff at a rate of 4040 liters·ha^{-1}. The remaining tree quarter was not used. Each cultivar was treated as a separate experiment with five replications in a randomized complete block design. Trees served as blocks. 'Delicious' and 'Golden Delicious' were treated on 3 Sept. 1985, 135 days after full bloom (DAFB), whereas the other cultivars were treated on 23 Sept. (155 DAFB). Treatments were dichlorprop or fenoprop at a rate of 10 mg·liter^{-1} each for 'Delicious', dichlorprop or NAA at rates of 10 mg·liter^{-1} for 'Golden Delicious', and dichlorprop or fenoprop at 20 mg·liter^{-1} for the other cultivars. Water sprays served as controls.

The dropped fruit under each tree quarter were counted and removed periodically until all fruit were harvested, about 40 days after treatment (DAT). The cumulative percent of fruit originally on a tree quarter, and which had dropped by each date before harvest, was calculated. Regression models were developed for each treatment per cultivar using DAT as the independent variable and percent cumulative fruit drop as the dependent variable.

On the normal harvest date for each cultivar (12 Sept. for 'Delicious' and 'Golden Delicious' and 14 Oct. for other cultivars), 10 fruit per tree quarter were harvested and evaluated for percent of the surface that was red, soluble solids content, firmness, and starch. The first criterion was estimated visually for each fruit. Flesh firmness was measured on two sides of each fruit with an Effigi fruit tester fitted with an 11.1-mm tip. Soluble solids content was estimated with an Atago hand-held refractometer. Each fruit was cut in half horizontally and severity of watercore was rated on a scale of 1 to 7 (1 = none and 7 = severe). Flesh starch was evaluated by dipping half of each fruit in iodine solution for 1 min; the degree of staining was rated on a scale of 1 to 9, where 1 = staining of the entire cut surface and 9 = absence of starch (16). Data were analyzed by ANOVA and means compared with Duncan's multiple range test at the 5% level of significance.

Ten-year-old 'Fullred Delicious'/seedling trees at Winchester, Va. were treated on 9 Sept. 1986 (140 DAFB). Treatments consisted of a control, dichlorprop (BAS 044 18 H, BASF Wyandotte Corp.) at the rates of 5, 10, and 15 mg·liter^{-1} a.i. and NAA at 10 mg·liter^{-1}. Treatments were applied to whole trees with an airblast sprayer at a rate of 2805 liters·ha^{-1}. There were six single-tree replicates per treatment in a randomized complete block design. Untreated buffer trees were left between treated trees within and between treated rows. Three limbs per tree, with 10 to 20 fruit per limb, were marked and fruit were counted before treatment and periodically thereafter for 4 weeks. On each date, data were expressed as the cumulative percent of the fruit that abscised from each limb.

One week after treatment, 20 fruit measuring 70 mm in diameter were sampled from around each tree. The maturity of a sample of 10 fruit per tree was evaluated on the following day. The remaining 10 fruit were stored at 1°C for evaluation on 12 Dec.

Twenty-year-old 'Stayman', 'Winesap', and 'Rome Beauty' trees on MM.111 rootstock growing at Blacksburg, Va. were treated on 29 Sept. 1986 (160 DAFB). The treatments included a control, dichlorprop at rates of 5, 10, and 15 $mg \cdot liter^{-1}$, and NAA at 10 $mg \cdot liter^{-1}$. Treatments were sprayed to runoff to quarter-tree units and they were applied with a handgun at the rate of 4040 $liters \cdot ha^{-1}$. For each cultivar there were five replicates in a randomized complete block design. Two adjacent trees in a row served as a block. Two treatments plus a control were applied to each tree. The fruit on the ground under each tree quarter were counted and removed at 2- to 4-day intervals for 6 weeks. On 12 Nov. all fruit remaining on the trees were harvested and counted. The cumulative percent fruit drop on each date was based on the number of fruit that were originally on the tree quarters.

Ten days after treatment 20 fruit were sampled from each tree quarter and maturity for a 10-fruit sample was determined immediately. The remaining fruit were stored at 1°C until being evaluated on 15 Dec.

Fruit drop data for each treatment per cultivar were fitted to linear or nonlinear models using DAT as the independent variable. Fruit quality data were analyzed by ANOVA followed by Duncan's multiple range test.

Dichlorprop residue was determined on a sample of five fruit that were harvested from each tree at various intervals after treatment in 1986. One composite fruit sample per treatment per harvest date was frozen in a plastic bag for residue analysis at the Virginia Polytechnic Inst. and State Univ. Pesticide Residue Laboratory. The dichlorprop was extracted in ether, esterified with diazomethane, and detected as chloride by gas chromatography (7).

Although results differed slightly for cultivars, tree sections treated with dichlorprop and fenoprop had dropped fewer fruit than the control sections by 14 to 25 days after treatment, but the response to the two materials did not differ at the 5% level of significance in 1985 (data not shown). Cumulative percent fruit drop for all treatments increased linearly over time for 'Delicious' in 1986 (Fig. 1). The slope for the control differed significantly (5% level) from that for all dichlorprop treatments, but slopes did not differ among the dichlorprop concentrations. The intercept, but not the slope, for NAA differed from the control. Cumulative percent fruit drop increased nonlinearly over time for 'Stayman' and 'Winesap' control trees and those treated with NAA, whereas fruit drop was linear over time for dichlorprop treatments (Fig. 1). Although the different cultivars responded differently to the treatments, dichlorprop at 5 $mg \cdot liter^{-1}$ was generally more effective than NAA. Drop control improved with increasing concentrations of dichlorprop for 'Rome Beauty', 'Stayman', and 'Winesap', but not for 'Delicious'. Dichlorprop applied at rates of 10 to 40 $mg \cdot liter^{-1}$ also reduced fruit drop of 'McIntosh' comparable to fenoprop for up to 3 weeks and was often better than NAA at 20 $mg \cdot liter^{-1}$ (12). We are unaware of published data for dichlorprop on late-season cultivars, but there was considerable work with 2,4-D in the 1940s. (2,4-dichlorophenoxy)acetic acid (2,4-D) was a more effective stop drop material than NAA for 'Stayman' (11) and 'Winesap' (2, 3) but not for 'McIntosh' (6), 'Oldenburg' (2), 'Delicious', 'York', or 'Golden Delicious' (11). Edgerton (5) found that leaves of 'McIntosh', but not 'Stayman' or 'Winesap', decarboxylated 2,4-D and rendered it ineffective. Dichlorprop effectively prevented fruit drop on 'McIntosh' (12) and all cultivars tested in our study.

Fruit quality and storability of all these late-season cultivars were not consistently influenced by any treatment in either year of this study (data not shown). Previous reports indicated that fenoprop and NAA advanced maturity and sometimes induced cracking of summer apple cultivars (1, 9, 13), but there was usually little effect on later ripening cultivars (1, 3, 10, 14, 15). The effectiveness of dichlorprop for reducing preharvest drop without adversely affecting fruit maturity of summer apple cultivars is unknown and must be examined.

Residue levels of dichlorprop were similar to those given in a previous report with 'McIntosh' (12), and the levels persisted for 3 weeks after harvest (Table 1).

Preharvest applications of dichlorprop at rates of 5 to 20 $mg \cdot liter^{-1}$ appear superior to NAA and similar to fenoprop for delaying fruit abscission without advancing maturity of the major fall apple cultivars. Our data indicate that EPA registration of dichlorprop can be substituted for fenoprop as a commercial stop drop material on apples.

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