Influence of Light and Spray Coverage on Red Color Development of Ethephon-treated 'McIntosh' Apples[1]

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Abstract. **(2-Chloroethyl)phosphonic acid ethephon at 150 ppm increased red color on shaded 'McIntosh' apples although color development was slow. Eleven days after ethephon treatment 64% of the shaded fruit on 10-year-old semi-dwarf trees met the color standards for U.S. Extra Fancy Grade while only 37% met this standard 14 days after application on the large trees. No shaded fruit on the check trees were U.S. Extra Fancy. Increased red color on 'McIntosh' fruit occurred when ethephon was applied either to the fruit or the leaves.**

Increased red coloration of ethephon-treated apples has been reported frequently (1, 3, 7). Nevertheless, ethephon's ability to increase color of fruit located in the shaded interior of trees and the site of ethephon absorption for red color promotion has been inadequately studied.

Light is essential for red color development on apples (6) and the amount formed is directly related to light exposure (5, 8). Heinicke (5) defined 3 distinct light zones in apple trees affecting fruit color: less than 40% full sunlight (FS), inadequate for sufficient color to market fruit; 40 to 60% FS, a zone in which adequate color forms; and above 60% FS, which is optimum for coloration. Previously, to determine a color response to ethephon, apples were sampled from "selected limbs" or from the periphery of the tree where light exposure was optimum (1, 3, 7). However, Heinicke (4) showed that even 10-year-old apple trees on Malling 9 rootstocks may have some foliage exposed to less than 30% FS (4) and as tree size increased, shading increased (5).

Unrath (10) reported that ethephon spray must come in direct contact with 'Starkrimson Delicious' to be effective. To the contrary, when ^{14}C-ethephon was brushed on leaves and fruit of 'Cortland' apples and sweet or sour cherries, small amounts moved directly into the fruit but the majority of the ethephon came from the leaves (2). We therefore initiated studies to (a) determine the effectiveness of ethephon for increasing red color on shaded 'McIntosh' apples, and (b) to establish the major absorption site(s) of ethephon when used to increase red color on 'McIntosh' apples.

Influence of shaded fruit. Twelve 10-year-old trees on semi-dwarf rootstocks (average limb spread 4.5 m) and 12 mature trees on seedling roots (average limb spread 10 m) were sprayed with 1000 ppm succinic acid-2,2-dimethylhydrazide (SADH) in mid-July, 1973. On Sept. 5, 10 shaded fruit located in the interior of each tree were tagged and red color estimated. Five semi-dwarf and 5 standard randomly selected tree reps received 150 ppm ethephon and 20 ppm naphthaleneacetic acid (NAA) applied at 1× with a commercial sprayer to the drip point. The % red color was again estimated on tagged fruit 7 and 12 days after treatment. In 1974, the experiment was repeated using similar trees except that 10 ppm 2,4,5-trichlorophenoxypropionic acid (fenoprop) was applied with ethephon rather than NAA. Both the amount of red color and its intensity were estimated 7, 11, and 14 days after treatment.

Seven days after application in 1973 the shaded fruit receiving ethephon had developed more color than control fruit (Table 1) but the % red color averaged less than that required for U.S. Extra Fancy apples (50% color typical of the cultivar). Exterior fruit on these trees had sufficient quantity and intensity of color to be harvested at this time. Although red color of fruit on the large and small trees was comparable on the day of treatment, color developed more slowly on the large than on the semi-dwarf trees. However, when fruit on large trees were allowed to remain 5 more days, the ethephon-treated fruit had 50% color, twice as much as the non-treated control (Table 1).

In 1974, the shaded fruit on the semi-dwarf trees had 58% red color 7 days after the ethephon application in comparison to 33% on the control fruit (Table 1). None of these ethephon-treated fruit had sufficient color intensity to grade U.S. Extra Fancy. It was 4 days later before sufficient intensity of color developed on the ethephon-treated fruit to meet this grade. At that time about 64% of the fruit graded U.S. Extra Fancy while none of the control fruit met this standard. On the large, standard trees only 37% of the ethephon-treated fruit graded U.S. Extra Fancy for color 14 days after treatment (Table 1).

Previous experiments have shown that 150 ppm ethephon softens 'McIntosh' within 7 days and 75 ppm within 14 days after application. Two weeks after ethephon application, over 60% of the ethephon-treated fruit on the large standard trees had insufficient color to grade U.S. Extra Fancy (Table 1). Since the ripening effect of ethephon becomes greater with time (3), shaded fruit may never obtain the amount and intensity of color required for U.S. Extra Fancy fruit without becoming excessively soft and suitable only for immediate sale.

Influence of spray coverage on 'McIntosh' trees. On Sept. 11, 1973, 5 uniform branches were selected on each of 6 trees that previously received a mid-July application of 1000 ppm SADH. A solution containing 150 ppm ethephon with 10 ppm fenoprop was prepared and 4 branches on each tree received one of the following treatments: (a) both leaves and fruit sprayed to the drip point; (b) fruit covered with plastic bags and leaves sprayed to the drip point (plastic bags removed after the spray had dried); (c) entire fruit dipped in the soln; and (d) each fruit dipped only to its shoulder in the soln. One branch per tree was untreated and served as the control. Red color was estimated on 20 tagged fruit/branch prior to treatment and 8 days later. The experiment was repeated on Sept. 5, 1974 using similar trees in the same orchard. In addition, 5 limbs on 6 trees were used to duplicate the above experiment using a solution containing only 10 ppm fenoprop.

In 1973 red color was increased by all ethephon-fenoprop treatments and treatments to the leaves, whole fruits, or leaves and fruit were equally effective (Table 2). However, in 1974 the application to both leaves and fruit was more effective than application to either the leaves or fruit.

Fenoprop alone is known to increase red color development on apples (9) but in this experiment it had no effect within 8 days after application (Table 2). Consequently, it appears that the ethephon in the ethephon-fenoprop solution was responsible for the large increases in red color and not fenoprop. However, a synergistic effect between ethephon and fenoprop is possible.

The fruit coloration responses noted in this experiment suggest that ethephon is absorbed about equally by leaves and fruits. Other investigators have reported that leaves are the most important organ for ethephon absorption by 'Cortland' apple, sweet and sour cherries (2). Leaves and fruits were both effective in absorbing ethephon in summer squash, cucumber and tomatoes (11). With 'Starkrimson

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Table 1. The influence of ethephon stop-drop treatments on red color development of shaded 'McIntosh' apples and the percent of U.S. Extra Fancy fruit.[z]

Treatment[y]	% red color, 1973			% red color, 1974				% U.S. Extra Fancy fruit, 1974	
	Sept 5	Sept 12	Sept 17	Sept 5	Sept 12	Sept 16	Sept 18	Sept 16	Sept 19
				10-year semi-dwarf trees					
Ethephon	3a[x]	42a	–	3a	58a	76a	–	64b	–
Control	4a	33b	–	3a	33b	28b	–	0a	–
				40-year standard trees					
Ethephon	3a	29a	50a	1a	16a	28a	52a	1a	37b
Control	3a	16b	26b	1a	9b	10b	21b	0a	0a

[z]U.S. Extra Fancy apples must have red color typical of the cultivar on 50% of the fruit surface.

[y]Ethephon, 150 ppm and NAA, 20 ppm; and ethephon, 150 ppm, fenoprop, 10 ppm in 1973 and 1974, respectively.

[x]Mean separation for tree type, within a column, by Duncan's multiple range test, 5% level.

Table 2. Influence of site of ethephon and fenoprop application on red color development of 'McIntosh' apples.

Treatment[z]	Red color increase (%)		
	Ethephon and fenoprop		Fenoprop
	Sept 11-19, 1973	Sept 5-9, 1974	Sept 5-13, 1974
Control	15c[y]	16c	18ab
Applied to half the fruit	23b	37b	24a
Applied to the whole fruit	27ab	38b	24a
Leaves only sprayed	33a	40ab	14b
Leaves and fruit sprayed	27ab	51a	24a

[z]Ethephon, 150 ppm and fenoprop, 10 ppm.

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

Delicious' apple the fruits seemed to be the major absorption site (10), but while it appears that plant species and even cultivars within species may differ somewhat, one must suspect that both leaf and fruit surfaces are capable of ethephon absorption in most plants.

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Apple Quality after Storage in Air, Delayed-CA or CA[1]

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Abstract. **Fruit of apple (*Malus domestica* Bork) stored in air for 3 to 4 months at 0°C before being placed in CA (delayed-CA) generally were of intermediate quality between apples stored in CA soon after harvest and those stored in air. Apples from CA had lower respiration rates, higher acidities, and were rated harder and juicier by taste panelists than apples stored in air. Four cultivars responded similarly to these storage conditions.**

'Stayman Winesap' apples stored in controlled atmospheres (CA) followed by storage in air were intermediate in quality between those stored in air or CA (4). 'McIntosh' apples stored immediately in CA were firmer after storage than those held in air for 1 to 2 mo before being placed in CA (8). The effect of storage in CA after prolonged storage in air (delayed-CA) has not been fully explored for all cultivars. The recommendation that apples be placed in CA as soon as possible after harvest (9) is not always followed for economic reasons. Several states regulate labelling of fruit as "CA-stored" by specifying the required O_2 level, time from room closure to reach a given O_2 level, and a minimum holding time after establishment of CA. Not all states specify the maximum time limit between harvest and placement in CA. Thus the requirements for the CA-label, which has a price advantage, can be met by placing previously air-stored fruit in the CA room after the first lot of CA-qualified apples has been removed (7). We have studied the effects of delayed-CA storage on apples.

'Golden Delicious', 'Delicious', 'Rome Beauty', and 'Stayman Winesap' apples were harvested from 3 orchards in Virginia and West Virginia and held at 0°C in air at Beltsville until all cultivars had been collected. 'Golden Delicious' and 'Delicious' were held 1 and 3 weeks longer, respectively, than other cultivars prior to beginning the tests.

Two 10-apple samples of each cultivar from each orchard were randomly assigned to the following 0°C treatments: no storage, 6 months air, 3 months in air then 3 months in CA (delayed-CA), and 6 months in CA. One

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