# Daminozide and Senescent Breakdown of McIntosh Apples

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**ABSTRACT**

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The incidence of senescent breakdown in McIntosh apples after storage was associated with internal daminozide residues resulting from field treatment.

Occurrence of brown core in stored apples has been associated with field treatment with daminozide. This relationship between daminozide application and brown core (2,3,7,8) may be only through the effect of the treatment on fruit development because it is known that the growth regulator delays ripening, and early-harvested McIntosh apples may develop more brown core than those harvested later (7,9). The relationship between internal (senescent) breakdown and daminozide application (3,5), however, appears to be less direct and is potentially more harmful, so much so that at one time it was suggested that daminozide-treated apples not be put in controlled-atmosphere (CA) storage (1). At the current orchard rates of daminozide used, the hazard appears slight, and treated McIntosh apples are routinely placed in CA storage. There is still uncertainty, however, regarding the role of daminozide in the "Soft McIntosh" disorder described by Smock (9) or in general senescent breakdown. Because daminozide often is applied as a concentrate spray, there is the possibility of application of an above-recommended dosage. Because of cost and technical problems in the analysis of daminozide, most public literature relating daminozide application to the occurrence of disorders is circumstantial and is not correlated to daminozide concentration in the fruit. This report describes the relationship of daminozide concentration in the fruit to internal senescent breakdown during two harvest-storage seasons in Ontario.

## MATERIALS AND METHODS

McIntosh trees on Robusta 5 rootstock (about 25 yr old) were selected on the basis of uniformity for the trial at the Agriculture Canada Smithfield Experimental Farm. There were five replicates per treatment consisting of one tree per treatment. Control trees were unsprayed. Different trees were used in the 2 yr.

Daminozide was applied dilute (1X) or concentrated (5X) to supply the recommended 2.85 kg a.i./ha. Daminozide was applied on 27 July 1977 and 2 August 1978. In 1977, fruit samples were harvested on 20 and 27 September, held in commercial CA storage until 8 February 1978, then placed in cold storage at 0.5 C until 5 May, followed by 1 wk in air at 20 C before examination for disorders. In 1977, samples for daminozide analyses were harvested on 31 August and 6 October. In 1978, fruits were harvested on 5, 19, and 26, September, samples were taken for daminozide analyses, and the remaining fruits were immediately placed in air storage at 0.5 C and about 90% relative humidity. In early April 1979, samples were removed from storage and held at approximately 20 C for 4 days before evaluation for disorders.

All fruits in 25-fruit samples were cut across the stem-to-calyx axis and rated 1, 2, or 3, according to the incidence of senescent breakdown. A rating of 1 signifies only very slight injury, 3 indicates a fruit so injured as to be unusable, and a rating of 2 designates fruit showing symptoms between these extremes. Fruits with ratings of 2 and 3 were judged to have senescent breakdown. The numbers were added and expressed as a percentage of the total for 25 apples. For analyses of variance the percentages were transformed by the arc sine $\sqrt{X}$ transformation (10). After statistical analyses, the means were transformed back to the original units. Comparisons with single degrees of freedom were made by functional analyses of variance (4). Analyses were for each harvest date

**Table 1.** Daminozide concentrations (ppm fr wt) and incidence of senescent breakdown (%) of McIntosh apples held in commercial controlled-atmosphere storage from harvest to 8 February, then held in air at 0.5 C until May, plus 1 week in air at 20 C

| | Harvest date (1977) | |
|---|---|---|
| | **31 August** | **6 October** |
| Daminozide concentration (ppm)[a] | | |
| Control | 3.0 | 4.4 |
| 1X | 5.2 | 5.0 |
| 5X | 7.1 | 5.8 |
| Mean of 1X + 5X | 6.2 | 5.4 |
| Statistical significance | | |
| Control vs. mean of 1X + 5X | **[b] | NS |
| 1X vs. 5X | ** | NS |
| Breakdown (%)[c] | | |
| | **20 September** | **27 September** |
| Control | 18 | 28 |
| 1X | 44 | 46 |
| 5X | 45 | 61 |
| Mean of 1X + 5X | 44 | 53 |
| Statistical significance | | |
| Control vs. mean of 1X + 5X | NS (4.82)[d] | NS |
| 1X vs. 5X | NS | NS |
| Correlation coefficients between daminozide concentrates on 31 August and incidence of breakdown | * | NS (0.4720)[e] |

[a] After field applications of daminozide as Alar 85 on 27 July 1977, as dilute (1X, 0.38 kg in 454 L of water), and concentrate (5X, 1.90 kg in 454 L) to cover; control was unsprayed.

[b] * Significant at $P = 0.05$; ** $P = 0.01$; NS, not significant at $P = 0.05$.

[c] See text for details.

[d] Calculated F value, significant at $P = 0.10$; necessary value for significance at $P = 0.05$ is 5.32.

[e] Calculated $r$ value, significant at $P = 0.10$; necessary value for significance at $P = 0.05$ is 0.5139.

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separately. For the 1977–1978 season, the correlation coefficients were calculated between the daminozide concentrations on 31 August and breakdown after storage apples harvested on 20 and 27 September. For the 1978–1979 season, correlation coefficients were calculated between the daminozide concentrations in the fruit and breakdown of fruit at the same harvest dates (5, 19, and 26 September).

For analyses of daminozide residues in the fruit, 10-fruit samples were analyzed fresh or held at −23 C until analysis, which was done as described by Ripley et al (6). With this analytical method, the controls (untreated fruit) also contained endogenous material identified as "apparent" daminozide. In Tables 1 and 2, these values are given and are also used in calculating the correlation coefficients between daminozide concentration and the transformed percentage breakdown.

**Table 2.** Daminozide concentrations (ppm fr wt) and incidence of senescent breakdown (%) of McIntosh apples after air storage at 0.5 C until April 1979, plus 4 days in air at 20 C

| | Harvest date (September 1978) | | |
|---|---|---|---|
| | 5 | 19 | 26 |
| Daminozide concentration (ppm)[a] | | | |
| Control | 1.5 | 1.4 | 1.7 |
| 1X | 2.9 | 2.7 | 3.4 |
| 5X | 11.3 | 6.7 | 7.9 |
| Breakdown (%)[b] | | | |
| Control | 6 | 13 | 39 |
| 1X | 26 | 37 | 58 |
| 5X | 30 | 57 | 85 |
| Mean of 1X + 5X | 28 | 47 | 72 |
| Statistical significance[c] | | | |
| Daminozide concentrations | | | |
| Control vs. mean of 1X + 5X | ** | ** | ** |
| 1X vs. 5X | ** | ** | ** |
| Breakdown | | | |
| Control vs. mean of 1X + 5X | * | * | * |
| 1X vs. 5X | NS | NS | NS |
| Correlation coefficients between daminozide concentrates and incidence of breakdown | NS | ** | ** |

[a] After field applications of daminozide as Alar 85 on 2 August 1978 as dilute (1X 0.38 kg in 454 L of water), and concentrate (5X, 1.90 kg in 454 L) to cover; control was unsprayed.
[b] See text for details.
[c] * Significant at $P = 0.05$; ** $P = 0.01$; NS, not significant at $P = 0.05$.

## RESULTS AND DISCUSSION

In three out of five analyses of variance, there was a significant ($P = 0.05$) effect of daminozide treatments upon increasing senescent breakdown. In one analysis the effect was significant at $P = 0.10$. In three out of the five correlations, there was a significant ($P = 0.05$) correlation between daminozide concentration and breakdown, and in one case (Table 2), the correlation coefficient was significant at $P = 0.10$.

The data show that daminozide application may cause an increased incidence of senescent breakdown, particularly in fruit harvested late and/or stored for a long time. Considering the number of physiological factors that interact to produce fruit susceptible to breakdown and the postharvest influences on symptom development, it is not very surprising that daminozide application does not always result in injury. The susceptibility to breakdown appears to be related to the daminozide concentration in the fruit.

Because of the relationship of daminozide concentration to the incidence of breakdown, the time of sampling for both is critical. As seen in Table 1 and 2, actual daminozide concentration in the fruit tends to decrease as the interval between spraying and harvest increases, while the concentration of the background material giving an apparent daminozide reading tends to increase as the fruit ages on the tree (Table 1 and [6]). Because it is not known at what stage of fruit development daminozide may initiate physiological changes that predispose fruit to breakdown, knowledge of the proper time for sampling is critical. Evaluation of senescent breakdown requires proper timing as well—examination too early in storage may result in detection of little injury, whereas evaluation too late may result in most fruit, irrespective of treatment, showing breakdown.

Daminozide is a commonly used stop-drop spray. Because of the amount used commercially without evidence of problems and the number of times we have *not* found injury in storage trials, the risk of increased fruit injury after daminozide application is acceptable, considering the benefits of its use. Like other growth regulators, however, it must be applied at the proper time and in the proper concentration in order to avoid undesirable effects. The experiments reported here illustrate the possible disadvantage of applying the growth regulator as a concentrate spray because the residues were considerably higher for the 5X than the 1X application. The expected daminozide concentration in fruit at harvest is 1–2 ppm, which is considerably less than found in our tests, although the maximum level was still well within the tolerance of 30 ppm. Residue measurable at harvest, however, depends not only on the initial concentration applied but also on the time between application and harvest. It is possible that the weather, particularly temperature, may also influence the metabolism of daminozide within fruit on the tree.


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