EFFECTS OF DPA DRENCHING ON NEWER APPLE VARIETIES

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INTRODUCTION

The antioxidant, diphenylamine (DPA), has been used for reducing scald in long-term-stored apples for over 50 years. Its use on Red Delicious has been fully documented in a number of studies and proven applicable in minimizing scald damage to the apple most commonly produced in Washington State. Although the use of DPA has been found helpful in reducing scald on other apple varieties, the refinement of concentrations in drench tanks for scald susceptible varieties such as Fuji and Granny Smith has not been fully investigated. Current label rates mirror those commonly used for the mainstay Red and Golden Delicious. The label of one brand of DPA suggests 2000 ppm for Red Delicious and Fuji, and consultation with a pomologist for use on Golden Delicious and Gala. The suggested concentration for Granny Smith is 2200 ppm DPA.

Suggestions for DPA upper-end thresholds are likely derived from a potential for phytotoxic effects when high concentrations are applied. Experience with increased concentrations of DPA suggests a high level of chemical burn on apples. In addition, recommended levels of DPA have been known to induce severe chemical burn problems when drainage is inhibited, or DPA solution is trapped between apples, next to bin walls, or in corners. Upon evaporation of the solution, concentrated DPA is left to damage apple surfaces.

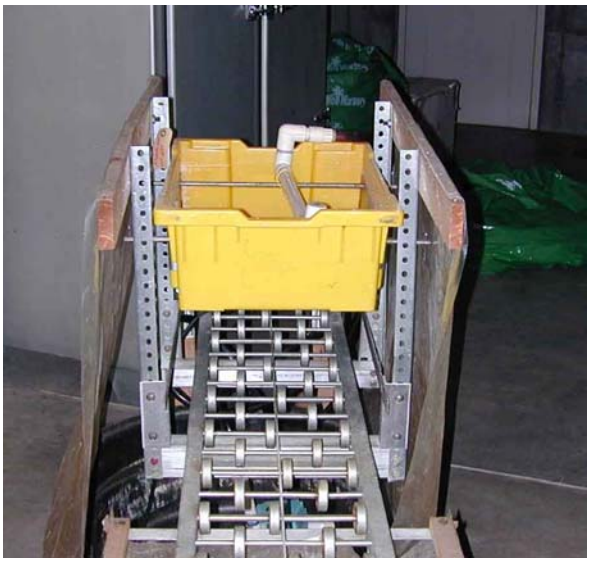
Even with the effectiveness of antioxidant use, there have been a number of other methods proposed to manage storage scald in apples, largely driven by a movement in some markets to disallow detectable DPA residue. DPA may be the most effective method of controlling scald, even if reduced concentrations are required to meet market demands.

The purpose of this research is to determine the solution concentration required to control scald and to define the effect of solution concentration on phytotoxicity. Five apple varieties were tested in 2000 and four in 2001. The methods and results for each year are discussed below.

METHODS—2000 CROP DRENCHING

Five varieties, Braeburn, Cameo, Fuji, Gala and Pink Lady® brand apples were selected for DPA drenching. To maximize apple uniformity, each variety was selected from a single orchard. Within six days of harvest, apples were collected and randomized into plastic vented cherry lugs. The lugs were filled to provide at least two layers of fruit to ensure contact between apples and contact with lug walls. Three different formulations of DPA, Pace Shield 31% (not available commercially in the U.S.), Pace Shield 15% and Cerexagri No Scald were used at concentrations of 1000, 2000 and 4000 ppm to drench fruit. A 4000-ppm solution was not used on Gala. Thiabendazole (TBZ) was added to all drench solutions at the label rate to control decay.

Chemicals were mixed in a 17-gallon tank with a drill/paint mixer. The drencher was a simple hand-operated device (Figure 1). All treatments were drenched for 1 minute and left to dry for no less than 5 minutes. After draining, the lugs were wrapped in perforated plastic bags to reduce fruit shrivel and stored at approximately 32 ºF in the lab cold room.



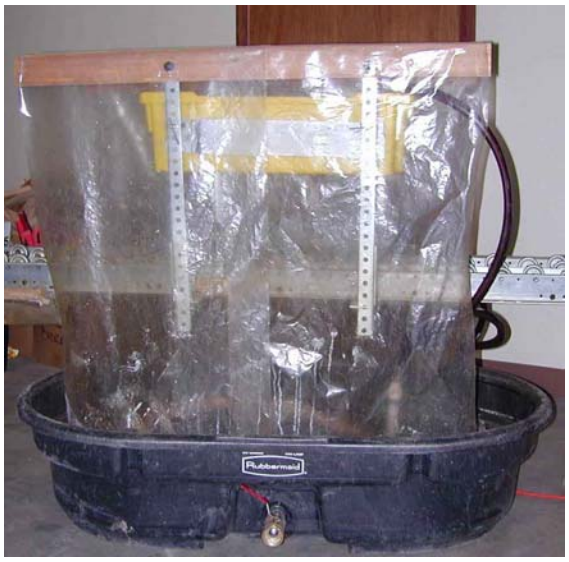


Figure 1. Top and side view of hand-operated drencher.

Table 1. Expected and actual concentration of drench tank DPA solutions, 2000.

Variety	Expected Conc. (ppm)	Solution concentration (ppm)		
		Shield 15%	Shield 31%	No Scald
Braeburn	1000	1127	1104	1151
	2000	2206	2300	2089
	4000	4035	4223	3918
Cameo	1000	1057	1010	1033
	2000	2112	2065	1924
	4000	4223	3871	3871
Fuji	1000	963	705	963
	2000	1760	1972	2159
	4000	3754	4176	4027
Gala	1000	1080	963	963
	2000	1924	1878	2112
	4000	N/A	N/A	N/A
Pink Lady®	1000	1127	1315	940
	2000	2159	2933	2230
	4000	4223	4655	3871

Before drenching, each solution in the tank was tested for DPA concentration with a DPA test kit provided by Cerexagri (Table 1).

The temperature of the fruit at the time of drenching ranged from 43 ºF to 67 ºF and the temperature of the drench solution ranged from 53 ºF to 67 ºF. After the highest concentration of DPA was used, a one-gallon can of 'Surround' Kaolin clay was added to the solution to compare 'clean' and 'dirty' drench tanks.

After drenching, six apples from each treatment (two from each lug) were placed in mesh bags, coded, and sent to Murphey Analytical Laboratories for chemical analysis to determine the DPA residue of each treatment (Table 2).

Table 2. DPA residue on fruit surfaces, 2000.

Variety	Drench Conc. (ppm)	DPA Residue Concentration (ppm)		
		Shield 15%	Shield 31%	No Scald
Braeburn	1000	0.5	< 0.2	0.8
	2000	1.6	2.8	1.4
	4000	2.5	2.6	3.6
Cameo	1000	< 0.2	0.3	< 0.2
	2000	< 0.2	< 0.2	< 0.2
	4000	0.3	< 0.2	0.5
Fuji	1000	0.7	0.7	1.6
	2000	1.6	0.7	2.3
	4000	5.3	2.1	3.9
Gala	1000	0.5	1.0	< 0.2
	2000	< 0.2	1.0	1.4
	4000	N/A	N/A	N/A
Pink Lady®	1000	<0.2	< 0.2	0.5
	2000	1.1	0.6	0.9
	4000	1.7	1.8	2.8

The drenched fruit was stored for approximately four months at 32 ºF, with the exception of Gala, which was stored for 70 days at 32 ºF. Seven days after the apples were removed from cold storage, 10 apples from each lug were examined for scald, chemical burn, background color, firmness, and internal disorders. The remainder of fruit in each bin was also examined for scald, chemical burn and internal disorders. Color was measured using the Minolta CR-300 Chroma Meter and expressed as a hue angle. Firmness was measured using the Fruit Texture Analyzer (FTA). Scald, chemical burn and internal browning were rated on a 0 to 3 scale, with 0 = clear and 3 = severe.

Data were analyzed on the SAS system using LSD procedure mean separation at $P = 0.05$.

METHODS—2001 CROP DRENCHING

Four varieties, Braeburn, Fuji, Granny Smith and Pink Lady® brand apples, were selected for DPA drenching in 2001. To maximize apple uniformity, each variety was selected from a single orchard. Within two days of harvest, three bins of each variety were collected and randomized into wooden cherry bins. The bins were filled to provide at least two layers of fruit to ensure contact between apples and contact with bin walls. Some bins contained plastic liners, which were removed prior to drenching. The bottom liners remained in several of the Pink Lady® brand apple bins. These liners did not cover any of the drain vents; however they might have caused drench solution to remained pooled in the bottom of the bins (see *Pink Lady® brand apples* discussion section).

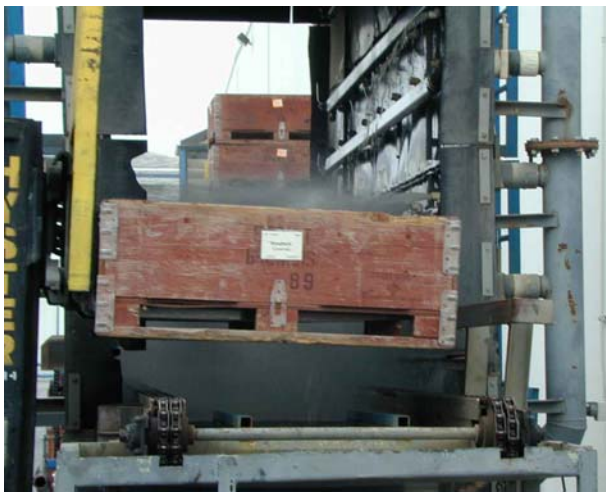


Figure 2. Commercial drencher.

Cherry bins were loaded singly on a chain-driven commercial drencher (Figure 2) with a run-period of 90 seconds. Prior to drenching, the drench tank solution was tested using a DPA test kit provided by Pace International (Table 3). Braeburn, Fuji and Pink Lady® brand apples were drenched in 0 ppm, 1000 ppm, 2000 ppm or 4000 ppm DPA. Granny Smith apples were drenched at the first three

Table 3. Expected and actual concentration of drench tank DPA solutions, 2001.

Expected DPA conc. (ppm)	Solution DPA Concentration (ppm)			
	Braeburn	Fuji	Granny	Pink Lady
0	0	0	0	0
1000	1020	1020	1020	960
2000	2000	2000	2000	1850
2200	N/A	N/A	2220	N/A
4000	4100	4100	N/A	3700

concentrations and at 2200 ppm (the maximum recommended label rate) instead of 4000 ppm. The DPA formulation for all drenches was either No Scald or Shield 15%. TBZ was added to all drench solutions at the label rate to control decay. The fruit was approximately 46 ºF at the time of drenching. To determine if fruit temperature affected DPA residue levels, one additional bin each of Fuji, Braeburn and Granny Smith was held overnight at approximately 35 ºF (labeled "cold") before being drenched in 2000 ppm DPA. The temperature of the drench solution was 61 ºF in all cases.

After drenching, two 6-apple samples were taken from each bin and sealed in plastic bags. A complete sample set was sent to two different analytical labs for analysis of fruit DPA residue concentration. Results of DPA residue analyses from both labs are displayed in Table 4.

Table 4. DPA residue results from two analytical laboratories, 2001.

		DPA Residue (ppm)				DPA Residue (ppm)	
Variety	Treatment	Lab 1	Lab 2	Variety	Treatment	Lab 1	Lab 2
Braeburn	Control	0.3	0.0	**Granny**	Control	0.2	0.0
	Control	0.5	0.0		Control	1.1	0.0
	Control	0.4	0.0		Control	0.2	0.0
Braeburn	1000ppm DPA	0.6	1.4	**Granny**	1000ppm DPA	0.6	2.1
	1000ppm DPA	1.4	1.7		1000ppm DPA	0.9	1.7
	1000ppm DPA	0.6	1.1		1000ppm DPA	1.1	1.6
Braeburn	2000ppm DPA	1.2	2.7	**Granny**	2000ppm DPA	2.1	2.9
	2000ppm DPA	1.3	2.7		2000ppm DPA	1.4	3.3
	2000ppm DPA	1.9	1.5		2000ppm DPA	2.6	2.0
Braeburn	Cold 2000ppm	1.9	2.2	**Granny**	Cold 2000ppm	2.9	2.8
Braeburn	4000ppm DPA	3.0	4.0	**Granny**	2200ppm DPA	1.8	6.1
	4000ppm DPA	1.7	5.3		2200ppm DPA	2.4	5.2
	4000ppm DPA	3.0	3.8		2200ppm DPA	5.4	3.4
Fuji	Control	0.3	0.0	**Pink Lady®**	Control	N/A	0.1
	Control	0.7	0.0		Control	N/A	0.2
	Control	no data	0.0		Control	N/A	0.1
Fuji	1000ppm DPA	0.3	0.0	**Pink Lady®**	1000ppm DPA	N/A	0.9
	1000ppm DPA	0.5	0.0		1000ppm DPA	N/A	1.2
	1000ppm DPA	0.2	0.0		1000ppm DPA	N/A	1.7
Fuji	2000ppm DPA	1.6	3.6	**Pink Lady®**	2000ppm DPA	N/A	2.1
	2000ppm DPA	1.3	3.3		2000ppm DPA	N/A	1.9
	2000ppm DPA	1.5	1.8		2000ppm DPA	N/A	1.8
Fuji	Cold 2000ppm	2.4	3.0	**Pink Lady®**	N/A	N/A	N/A
Fuji	4000ppm DPA	2.4	0.0	**Pink Lady®**	4000ppm DPA	N/A	3.0
	4000ppm DPA	3.1	0.0		4000ppm DPA	N/A	2.8
	4000ppm DPA	2.3	1.8		4000ppm DPA	N/A	2.2

Apples were held at 34 ºF for approximately five months. One day after removal from storage, 25 apples from each bin were evaluated for chemical burn and firmness. After a seven-day holding period at room temperature (68 to 70 ºF), 100 fruit from each bin were evaluated for scald and internal disorders. Procedures and scoring used for fruit quality analysis in 2000 were repeated in the 2001 season unless otherwise noted.

Chemical burn was evaluated on the 4000 ppm DPA treatment in each variety (2200 ppm for Granny Smith), and then each successively lower concentration was evaluated until no significant chemical burn was found in each treatment. If no significant chemical burn was found, lower concentration treatments were not evaluated.

For the statistical evaluation, analysis of variance and mean separation procedures were completed on Microsoft Excel.

2000 RESULTS

General results for the 2000 DPA drenching study are listed below, followed by specific results for each variety.

- **Scald**—There was not a significant amount of scald apparent in the 2000 season. With the exception of Fuji, scald was not present. Table 5 shows the incidence of scald by variety and DPA concentration, independent of DPA formulation.
- **DPA Formulation**—Most fruit characteristics were not consistently affected by the DPA formulation used. Differences in incidence of chemical burn among formulations were significant in all varieties, although there was not a uniform pattern of injury among varieties affected by formulation (Table 6).
- **Effects of Kaolin Clay in Drench Tank**—There were no differences in apple quality due to clay added to the drench solution.

Table 5. Percentage of apples with scald after drenching and storage in 2000, by DPA concentration.

DPA (ppm)	Percent of apples with scald				
	Braeburn	Cameo	Fuji	Gala	Pink Lady®
0	0	1	12 a	0	0 b
1000	0	0	11 ab	0	1 a
2000	0	0	9 ab	0	0.5 b
4000	0	0	5 b	N/A	0 b

Table 6. Percentage of apples with chemical burn after drenching and storage in 2000, by DPA type.

DPA type	Percent of apples with chemical burn				
	Braeburn	Cameo	Fuji	Gala	Pink Lady®
Water	0 c	7 b	1 c	0 b	0 c
Shield 15%	19 a	18 a	32 ab	10 ab	8 b
Shield 31%	12 b	22 a	26 b	14 a	16 a
No Scald	5 c	13 ab	36 a	5 ab	17 a

Braeburn

In treated Braeburn apples there were sharp increases in chemical burn with each incremental increase in DPA concentration (Table 7). Drenching in 1000 ppm DPA solution resulted in only 2% of apples burned, whereas 9% and 29% displayed chemical burn in the respective 2000 and 4000 ppm DPA treatments.

DPA concentration did not have an effect on internal browning, although there was a higher incidence in treated apples (3 to 6%) than in control apples (1%) (Table 8). Hue angle and firmness were not affected by DPA concentration.

Cameo

Severe chemical burn occurred at 4000 ppm, although there was little damage in other concentrations of DPA (Table 7). Internal browning ranged from 6 to 13% and was not related to DPA concentration (Table 8). Hue angle was higher at all DPA concentrations (more green color) than the control apples (Table 9).

Firmness was slightly lower in concentrations of DPA greater than 1000 ppm than with no DPA applied, although the differences may not be detectable by consumers (Table 10).

Fuji

In Fuji apples, 12% of the control fruit developed scald. The 1000 and 2000 ppm DPA solutions resulted in 11% and 9% of the fruit developing scald (not statistically different than the control), while only 5% of apples drenched in 4000 ppm DPA developed scald (Table 5).

Chemical burn increased with DPA application, starting with 19% average in 1000-ppm DPA concentrations (Table 7). Forty-one percent of apples drenched in 4000 ppm DPA were damaged. Internal browning in Fuji was severe, although higher concentrations of DPA resulted in greater control (Table 8). Hue angle and firmness were not affected by DPA.

Gala

Chemical burn was higher in apples drenched in 2000 ppm DPA (17%) than 1000 ppm DPA and water (0%) (Table 7). There was no damage from internal browning present in any treatment and hue angle and firmness were not affected by DPA.

Pink Lady® Brand Apples

Chemical burn was more prevalent with increasing DPA concentration, increasing from 3% fruit damaged at 1000 ppm DPA to 28% fruit damaged at 4000 ppm DPA (Table 7). Because little internal browning was observed, effectiveness of DPA as a deterrent was not assessed (Table 8).

Hue angle was higher (greener color) on apples drenched in increasing concentrations of DPA (Table 9). There were no differences in firmness values due to DPA concentration (Table 10).

Table 7. Percentage of apples with chemical burn after drenching and storage in 2000, by DPA concentration.

DPA (ppm)	Percent of apples with chemical burn				
	Braeburn	Cameo	Fuji	Gala	Pink Lady®
0	0 b	7 b	1 d	0 b	0 c
1000	2 b	7 b	20 c	0 b	3 c
2000	9 ab	7 b	33 b	17 a	10 b
4000	29 a	37 a	41 a	N/A	28 a

Table 8. Percentage of apples with internal browning after drenching and storage in 2000, by DPA concentration.

DPA (ppm)	Percent of apples with internal browning				
	Braeburn	Cameo	Fuji	Gala	Pink Lady®
0	1 c	13	70 a	0	2
1000	6 a	10	33 bc	0	1
2000	4 ab	10	37 b	0	0
4000	3 bc	6	25 c	N/A	1

Table 9. Hue angle after drenching and storage in the 2000 season.

DPA (ppm)	Average Hue Angle*				
	Braeburn	Cameo	Fuji	Gala	Pink Lady®
0	70.0	60.5 b	84.7 a	81.5	78.0 bc
1000	67.0	86.1 a	82.8 ab	83.2	76.8 c
2000	70.0	78.9 a	79.5 b	81.1	81.3 b
4000	72.2	75.5 a	80.4 b	N/A	88.2 a

*Higher hue angle indicates more green color

Table 10. Average fruit firmness after drenching and storage in the 2000 season.

DPA (ppm)	Average fruit firmness (lbf)				
	Braeburn	Cameo	Fuji	Gala	Pink Lady®
0	12.7	11.5 a	13.7	12.5	17.3
1000	12.7	11.2 ab	13.4	12.6	17.3
2000	12.7	10.8 b	13.4	12.7	17.6
4000	12.5	10.9 b	13.3	N/A	17.5

2001 VARIETY RESULTS

Braeburn

Scald was suppressed with the use of DPA (Table 11). Application of DPA reduced scald incidence from 26% in control fruit to 5% or less in all other treatments. Fourteen percent of apples drenched in 4000 ppm DPA were damaged by chemical burn (Table 12). Internal browning was not significant in this variety (Table 13).

Fuji

Scald incidence was similar among all treatments and the control; only 5 to 7% of Fuji apples were affected (Table 11).

More Fuji apples (18%) sustained chemical burn than did other varieties drenched in 4000 ppm DPA solution (Table 12). Internal browning was not controlled by DPA, with higher percentages of apples damaged at 2000 and 4000 ppm (36% and 37%, respectively) than apples drenched in water or 1000 ppm DPA (25% and 26%) (Table 13), thus the relationship between DPA concentration and internal browning is unclear.

Granny Smith

The control apples showed severe scald (Figure 3). Scald was significantly reduced with even 1000 ppm DPA solution (Table 12).

No chemical burn occurred in Granny Smith, although the highest concentration used was 2200 ppm. Internal browning decreased with increasing DPA concentration (Table 13).

Pink Lady® Brand Apples

Scald was not present in any treatment of Pink Lady® brand apples (Table 11).

Pink Lady® brand apples were least affected by chemical burn with only 7% of all apples drenched in 4000 ppm DPA solution displaying damage (Table 12). Chemical burn only occurred in bins where the plastic liner was not removed prior to drenching.

Figure 3. Scald on Granny Smith control treatment, 2001 season.

Internal browning was reduced with the use of DPA. Internal browning was detected in 65% of apples drenched in the control solution, whereas only 20% were affected by internal browning when drenched in 2000 or 4000 ppm DPA solutions (Table 13).

Table 11. Percentage of apples that developed scald after drenching and storage, 2001.

Concentration DPA (ppm)	Percent Scald			
	Braeburn	Fuji	Granny	Pink Lady®
0	26 a	5 b	49 a	0
1000	5 b	5 b	4 b	0
2000	1 bc	7 a	1 b	0
2200	N/A	N/A	0 b	N/A
4000	0 c	5 b	N/A	0

Table 12. Percentage of apples with chemical burn at highest DPA concentration after drenching and storage, 2001.

Variety	DPA (ppm)	Percent Apples Burned
Braeburn	4000	14 ab
Fuji	4000	18 a
Granny Smith	2200	0
Pink Lady®	4000	7 b

Table 13. Percentage of apples that developed internal browning after drenching and storage, 2001.

Concentration DPA (ppm)	Percent Internal Browning			
	Braeburn	Fuji	Granny	Pink Lady®
0	0	25 b	87 a	65 a
1000	0	26 b	76 ab	37 b
2000	1	36 a	64 b	20 c
2200	N/A	N/A	45 c	N/A
4000	1	37 a	N/A	21 c

DISCUSSION

The questions asked in these experiments were: (1) whether or not formulations of DPA differed in the primary function of controlling scald in long-term-stored apples and (2) if any elements within the formulation resulted in differing apple quality. In addition, the refinement of effective, non-phytotoxic applications of DPA to varieties with a shorter history of applied and experimental use was investigated.

Braeburn

Scald incidence in 2001 was reduced from 26% to 5% when a 1000 ppm DPA drench solution was applied, with similar results at a concentration of 2000 ppm (Table 11). Significant chemical burn was apparent on Braeburn apples after drenching in 4000 ppm DPA in both seasons (Table 7 and Table 12), although, chemical burn was more severe in the 2000 season, displaying darkened skin and lenticels and lesions across burned areas (Figure 4). With only 2% chemical burn at 1000 ppm in the 2000 season and none observed in 2001, coupled with control of scald, a low-concentration application of DPA was effective to reduce damage.

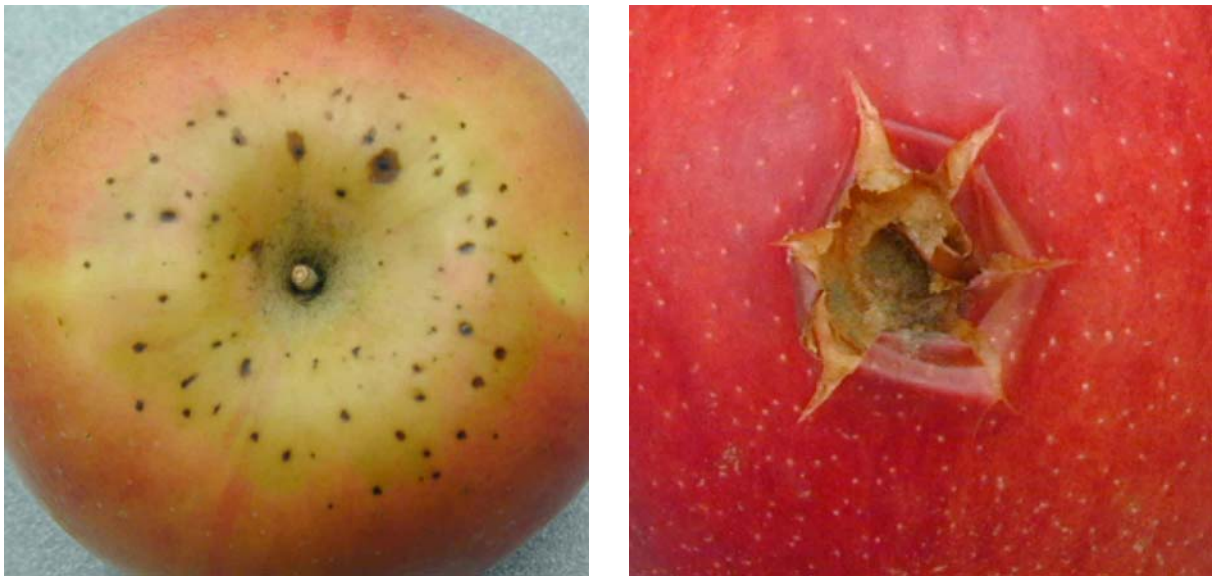


Figure 4. Chemical burn and lesions on Braeburn following 4000 ppm DPA drench and storage, 2000 season.

Cameo and Gala

In the 2000 season no benefit was apparent in applying DPA to Cameo or Gala. Cameo apples did not develop internal browning or scald. Gala apples drenched in 2000 ppm DPA developed chemical burn, and the 70-day storage period used was probably not long enough to develop internal browning or scald.

Fuji

The most striking and consistent observations from this experiment are the reactions of Fuji apples to DPA applications. In both years chemical burn on Fuji was more profuse than in other varieties (Table 7 and Table 12). Although more prevalent, severity of chemical burn was different in successive years. Fuji apples drenched in 2000 ppm and 4000 ppm DPA solutions in the 2000 season, were severely burned, with profuse lenticel marking and dark skin burn (Figure 5a). The chemical burn shown in Figure 5a follows the line of concentrated DPA residue that pooled in the bottom of the plastic lug (see *Solution Draining*, below). Conversely, Fuji apples drenched in the 2001 season were inflicted with fewer darkened lenticels and some skin burn and only those drenched in 4000 ppm DPA were affected (Figure 5b).

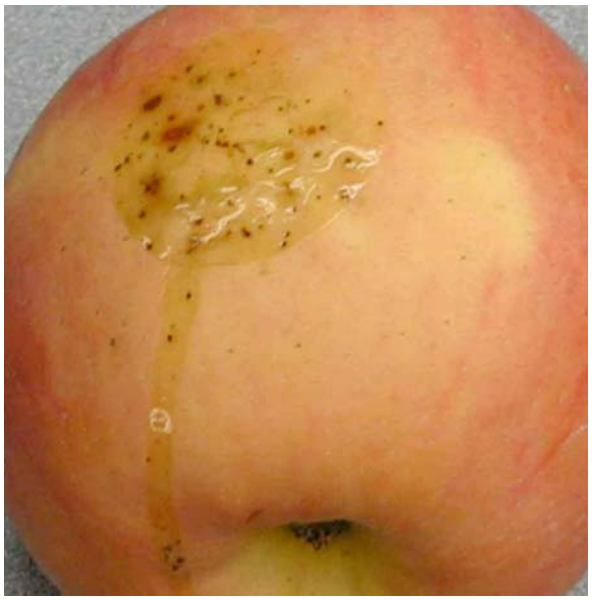


Figure 5a. Chemical burn on Fuji following 2000 ppm DPA drench and storage, 2000 season.

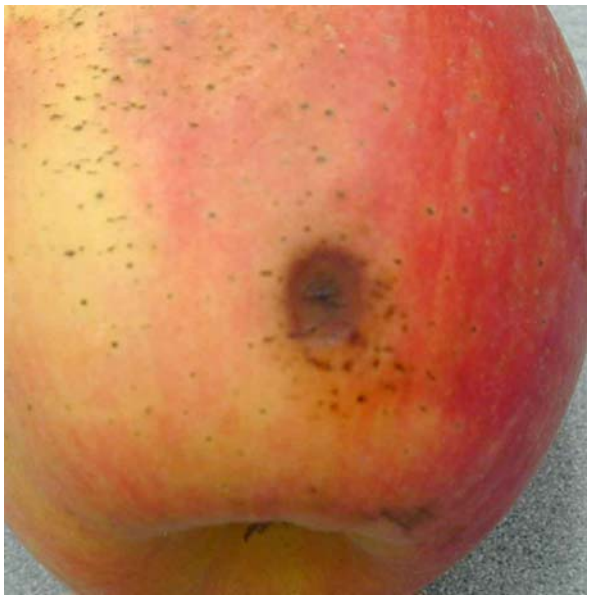


Figure 5b. Chemical burn on Fuji following 4000 ppm DPA drench and storage, 2001 season.

Inconsistent results in internal browning between seasons and lack of scald control in the 2001 season, coupled with the high susceptibility for chemical burn, would suggest that in years of low scald potential DPA may be a detriment rather than a benefit to Fuji apples.

Granny Smith

As opposed to other varieties, 49% of Granny Smith apples in this trial were affected by storage scald (Table 11). Scald control was similar among all DPA treatments in Granny Smith, indicating that there was no additional scald benefit at 2200 ppm or 2000 ppm DPA. Internal browning, on the other hand, was better controlled with increasing DPA concentrations (Table 13); 2200-ppm DPA applications were more effective than 2000-ppm applications in this study.

Pink Lady® Brand Apples

Scald control was not assessed in Pink Lady® brand apples due to lack of scald on any apples. In both seasons fewer Pink Lady® brand apples were damaged by chemical burn than other varieties (Tables 7 and 12). The damage observed in both seasons was severe, manifested primarily as areas of darkened skin (Figure 6), rather than the lenticel marking

Figure 6. Chemical burn on Pink Lady® brand apples following 2000 ppm DPA drench and storage, 2001 season. A plastic liner remained in bottom of the bin during drenching and storage.

common in damaged Fuji. Internal browning was reduced from 65% of apples damaged to only 20% using 2000 or 4000 ppm DPA in the 2001 season (Table 13). The low presence of chemical burn coupled with internal browning control would suggest application of DPA at 2000 ppm, with no greater benefit achieved at higher concentrations.

2000 and 2001 Drenches

Data and visual observations from the 2000 season display a higher incidence and severity of chemical burn in most varieties, at concentrations as low as 1000 ppm DPA. Pink Lady® brand apples drenched in the 2001 season developed more severe chemical burn than other apples (Table 12). This is likely due to the plastic liners that remained in the bottoms of some bins during drenching and storage. No other varieties were drenched in 2001 with the plastic liners intact and only bins of Pink Lady® brand apples with the liners exhibited any chemical burn (see *Solution Drainage*, below).

Solution Drainage

Although plastic cherry lugs filled with apples in the 2000 season were allowed to drain for at least five minutes before being placed into bags, drainage may have been inadequate, or evaporation and further drainage in storage may have been reduced due to the plastic covering. This may have resulted in the higher severity of chemical burn than in the 2001 season. Figure 5a shows lenticel damage resulting from a Fuji resting in a pool of sticky DPA residue during storage.

In 2001, some Pink Lady® brand apples were drenched in cherry bins with plastic liners covering portions of bins that did not contain drain holes. Severe chemical burn was observed on apples in contact with plastic liners (Figure 6), whereas little damage was apparent on other fruit. In effect, all drain channels were clear, but damage may have occurred due to DPA accumulation.

These observations reveal the importance of allowing DPA residue to drain, while suggesting a need to determine what factors constitute ‘good’ drainage

DPA Residue Sampling

DPA manufacturers recommend fruit residue values directly out of the drencher to be within the range of 2 to 7 ppm. As is common among fruit packers, apples in this study were sent to one lab for analysis of DPA residue in 2000 and to two DPA analytical labs in the 2001 season. In both seasons, test results were rarely in the suggested range except when 4000 ppm DPA was applied (Table 2 and Table 4), although DPA solution test kit results (Table 1 and Table 3) indicate proper solution concentration. Additionally, samples of apples from the same lot were consistently different between the two analysis labs (Table 4).

Temperature of Drenched Apples

Drenching recommendations suggest apple temperature be above 45 ºF, due to ineffective retention of DPA at low temperatures. In this study the three lots of apples drenched at 35 ºF retained a concentration of residue equal to, or higher than comparable concentrations at ambient temperature. No tests were conducted at different solution temperatures or apple temperatures above 61 ºF.

CONCLUSION

We have completed two years of a three-year study to determine the effects of DPA on apple quality and disorders. We have learned that DPA application has not affected fruit firmness and only rarely affected skin color. It is disturbing that obtaining the recommended DPA residues proved to be a challenge. The results of analytical labs did not agree, although solution concentrations were correct.

Unfortunately, except for a small amount of scald on Fujis in 2000 and significant scald on Granny Smith and Braeburn in 2001, scald was not a problem in either year following five months of air storage. It was not possible to determine the effect of DPA concentration on scald in most varieties. Scald the 2000 season Fujis was controlled at 4000 ppm DPA, although this resulted in high amounts of chemical burn. In 2001, scald on Granny Smith and Braeburn was controlled by as low as 1000 ppm DPA.

There have been reports that DPA reduces internal browning in apples. We saw a reduction in internal browning in Pink Lady® brand and Granny Smith apples with increasing concentration. However, in the same year DPA treated Fuji apples had a larger number of apples with internal browning and there was no internal browning in Braeburn.

Chemical burn was largely the result of the application of high levels of DPA (4000 ppm) and was compounded when drainage was impeded. Chemical burn appeared as lenticel marking as well as skin marking.

There are differences in responses of varieties to DPA application. There was little effect of DPA on Gala and Cameo. There is a clear benefit to Granny Smith and Braeburn on scald control, and to Granny Smith and Pink Lady® brand apples on internal browning reduction. However, the picture is far less clear on Fuji, which is very sensitive to lenticel marking, chemical burn and internal browning. The physiological disorder of Fuji Stain is often confused with scald and is not controlled by DPA. It is possible that some of the skin browning scored as scald could have been Fuji Stain in these experiments since it is so hard to determine the difference.

For the 2002 season we will be examining the effect of DPA concentrations on scald, internal browning, chemical burn and lenticel marking on Braeburn, Fuji and Pink Lady® brand apples. We will also determine whether there is a difference in chemical burn on fruit stored in plastic bins vs. wooden bins.