LENTICEL BREAKDOWN IN GALA APPLES (SEPTEMBER 2004)

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Introduction:

Lenticel breakdown (LB) appears on fruit from specific orchards following packing and is related to the use of chemicals in the postharvest packing process (Figure 1). Packinghouse surveys revealed that cleaners are used at higher concentrations than label rate. In a number of trials, LB appeared on as much as 90% of the fruit with certain cleaners. Fruit temperature and type of packingline (pre-size) influenced the amount of LB.

Figure 1. Gala apple with Lenticel Breakdown (LB) damage.

Susceptibility of fruit to LB damage varies greatly; currently it is not known which orchard factors determine susceptibility. Orchards that have problem fruit one year are likely to have it in the future.

Strategies for dealing with LB on the packingline include:

1. Treat all Gala apples as if they are susceptible to LB damage
2. Use the Aniline Blue Dye Uptake Test (http://postharvest.tfrec.wsu.edu/aniline-blue.pdf) to determine susceptibility

Objectives:

Characterize the role of packingline stressors on the development of LB to increase the industry's ability to pack susceptible fruit. Specific attention was paid to:

- Dump tank acidifiers and concentration
- Fruit cleaner formulation and concentration
- Wax type
- Presize
- Apple and rinse temperature at time of packing
- Brush speed
- HyperClean

Significant Findings:

- In laboratory tests using fruit dipped in dump tank acidifiers, fruit developed more LB damage when dipped in Mineral-XX than when dipped in Tri-Circ at both label rate and higher concentrations.
- Fruit dipped into solutions of Real Clean or 180 Cleaner developed less LB than fruit dipped into D-Scale, Acidex or Field Clean. Fruit dipped into solutions of Acidex developed the most LB damage in this trial.
- When applied at label rate using a drip bar on a packingline, fruit treated with the cleaner Kleen-Pac AL+ developed more LB damage than fruit treated with New Foam 7.0, Phase II or D-Scale. D-Scale treated fruit had less LB damage than fruit treated with other cleaners.
- Many packinglines utilize cleaners at higher concentrations than label rate. Cleaners applied at higher concentrations caused more LB damage than when applied at label rate.
- When used with a cleaner, wax applied to warm fruit caused more LB damage than unwaxed cold fruit. The effect of wax formulation was inconclusive.
- Presized fruit was more susceptible to develop LB after packing than fruit packed without presizing.
- Cold apples that were rinsed with cold water had less LB damage than apples that were warmed in water (dump tank), rinsed with warm water and waxed.
- Moderate differences in brush speed (Golden vs. Red speeds) did not affect the amount of LB damage.
- When used with a cleaner, presized fruit treated with the HyperClean system developed more LB damage than presize fruit not treated with HyperClean.

Methods:

At harvest Gala apples were purchased from three orchards that had been recommended by Dr. Eric Curry as having had significant LB damage in several of the past three years. Fruit were stored in their original wooden bins in the WTFRC/Stemilt rooms in CA. None of the fruit was treated with SmartFresh™. This fruit was used for all the experiments described below.

For Experiments I and II, fruit from the three orchards was used straight from the field bins. On January 22, 2004, half the fruit from each orchard was presized using the Stemilt commercial presizer. The fruit was placed back into CA storage and bins were removed as needed for subsequent trials. For Experiments III and IV, both pre-sized and non-presized fruit from the same orchards were compared.

During visits to a number of packinghouses, it was learned that cleaners were being applied at higher than label rates. In some cases the packers would increase the concentration in the belief that it was important for the cleaner to develop suds. (This is not true with most modern cleaners.) In other cases the desire for an exceptional shine motivated the packer to increase cleaner concentration. In many cases the packingline technicians did not know the concentration stated on the label. To determine the effect of higher concentrations on the amount of LB damage, we used concentrations of 10 times and 4 times label rate. The 10x concentrations were used for cleaners whose label rates were 1% to 2%. The 4x concentrations were used for cleaners whose label rate was 5%. In this way, no more than a 20% solution of cleaner was applied to the fruit.

Methods Experiment I—Laboratory Study: Laboratory trials were performed in November and December 2003 by dipping apples in commercially used cleaners and dump tank acidifiers. A list of dump tank additives and cleaners used on commercial apple packinglines was obtained from Wilbur Ellis Co.; these chemicals were obtained from the manufacturers (Table 1). In this experiment we used only fruit that had not been presized.

Table 1. Products utilized in the Laboratory Study (Experiment I).

Product	Manu-facturer	Labeled Use	pH	Purpose	Label Conc.	High Conc.
Mineral-XX	Pace	Dump tank	Acidic	Loosen spray/irrigation deposits on fruit	1%	10%
Tri-Circ	CH2O	Dump tank	Acidic	Loosen spray/irrigation deposits on fruit	1%	10%
Acidex	Pace	Line Spray	Acidic	Cleaner	5%	20%
D-Scale	CH2O	Line Spray	Acidic	Cleaner	1%	10%
180 Cleaner	Pace	Line Spray	Acidic	Cleaner	2%	20%
FieldClean	Pace	Line Spray	Alkaline	Cleaner	5%	20%
RealClean	CH2O	Line Spray	Alkaline	Cleaner	1%	10%

Cold apples (34 ºF) were dipped into a warm water (90 to 110 ºF) solution of each cleaner and held for 10 minutes. Apples were placed on fiber trays without being rinsed and held at 70 ºF for two days prior to being evaluated for LB damage. Apple LB damage was rated on a 1 to 5 damage scale:

1. No LB damage
2. Few lenticels affected, diffuse, damage only in lenticel
3. Affected lenticels are widespread on apple, damage only in lenticel
4. Widespread lenticel damage and some surrounding tissue damage
5. Widespread lenticel damage and profuse tissue damage

Fruit rated with LB damage as 3, 4 and 5 were considered commercially unacceptable (Figure 2). This commercial level of LB damage is reported in the Results section.

Results Experiment I—Laboratory Study. The effect of packingline cleaners on LB damage is shown in Figure 3. For the dump tank acidifier solutions, fruit developed more LB damage when dipped in Mineral-XX than when dipped in Tri-Circ at both label rate and higher concentrations.

For the cleaner solutions, fruit dipped into Real Clean or 180 Cleaner developed less LB than fruit dipped into D-Scale, Acidex or Field Clean. Fruit dipped into solutions of Acidex developed the most LB damage in this trial.

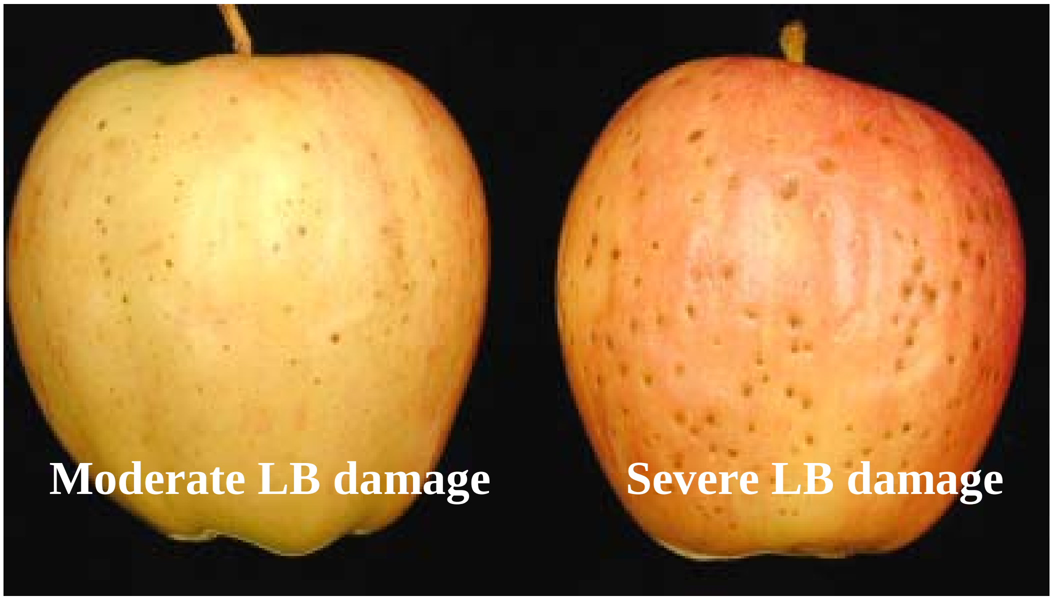

Figure 2. Apples with LB damage rated as 3 (LEFT: affected lenticels are widespread on apple, damage restricted to the lenticels) and 5 (RIGHT: widespread lenticel damage and profuse tissue damage) were both considered commercially unacceptable levels of damage.

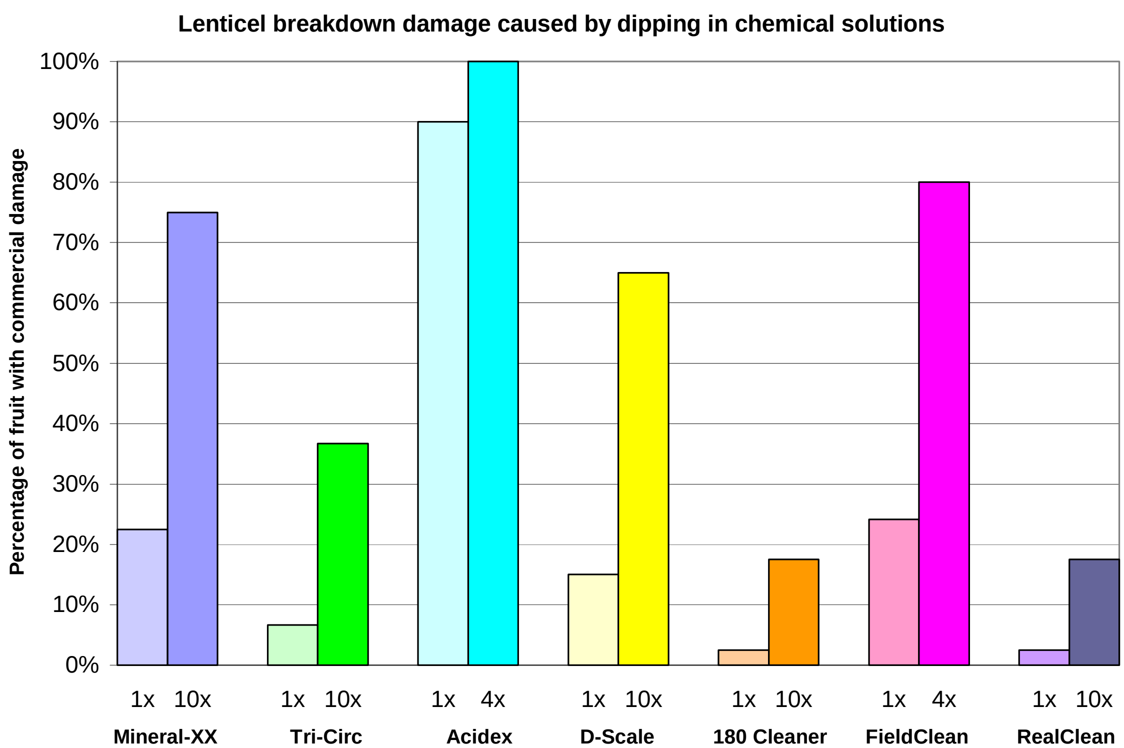

Figure 3. Effect of packingline chemicals and concentration on commercially unacceptable LB damage—fruit dipped in solution and not rinsed (Experiment I—Laboratory Study).

Methods Experiment II—Packingline Study I: The purpose of the Packingline Study I was to test the effect of various cleaners on LB damage using a packingline. Tests were conducted using non-presize fruit from February to March 2004 using the USDA packingline. Each cleaner was used at the label rate and again at either 4 or 10 times the label rate (Table 2). The brush bed on the packing line was coated with the test solution from a drip bar. The apples were placed on the brush bed and brushed for one minute. The fruit were then removed without rinsing and placed on trays to dry. After being held at room temperature for two to seven days, the apples were rated for damage. Apples were rated for LB damage on the same 1 to 5 scale used in Experiment I.

Table 2. Products utilized in Packingline Study I (Experiment II).

Product	Manu-facturer	Labeled Use	pH	Purpose	Label Concentration	High Concentration
Acidex	Pace	Line Spray	Acidic	Cleaner	5%	20%
D-Scale	CH2O	Line Spray	Acidic	Cleaner	1%	10%
Kleen-PAC AC	Solutec	Line Spray	Acidic	Cleaner	5%	20%
FieldClean	Pace	Line Spray	Alkaline	Cleaner	5%	20%
RealClean	CH2O	Line Spray	Alkaline	Cleaner	1%	10%
Kleen-PAC AL+	Solutec	Line Spray	Alkaline	Cleaner	5%	20%

Results Experiment II—Packingline Study I: Commercially unacceptable LB damage by cleaner is shown in Figure 4. Cleaners caused more damage at higher concentrations, except for D-Scale. In this study, D-Scale caused no damage at the higher concentration.

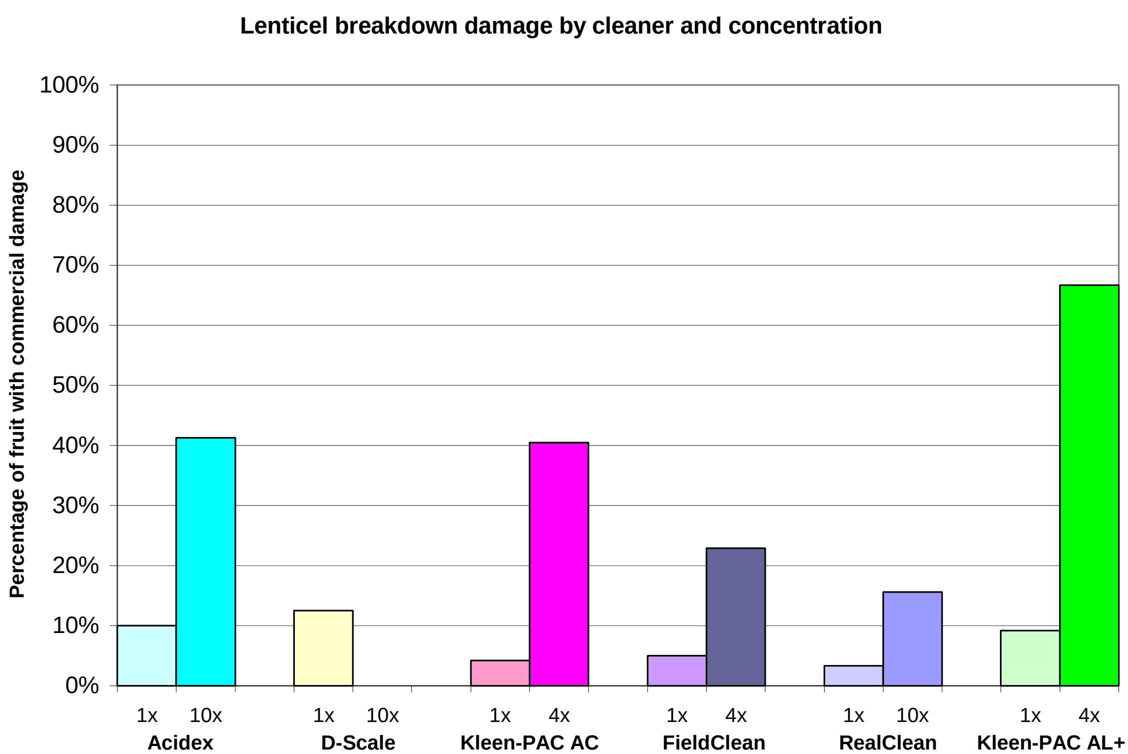

Figure 4. Effect of packingline chemicals and concentration on commercially unacceptable LB damage—fruit not rinsed (Experiment II—Packingline Study I).

Methods Experiment III—Packingline Study II: The purpose of the Packingline Study II was to test the effect of presize, fruit and rinse temperature, cleaner type and concentration and wax formulation on LB damage using a packingline. Tests conducted in March and April 2004 using the USDA packingline allowed us to simulate commercial conditions. In this experiment, widely used cleaners and waxes were applied and both the rinse water and fruit temperatures were varied. An alkaline cleaner (Kleen-PAC AL+), a neutral cleaner (New Foam 7.0), two acid cleaners (D-Scale and Phase II Acid), a carnauba wax (APL-Brite 400C) and a shellac wax (AP40) were used. Six lots of fruit (non-presize and presize from each grower) were treated with each cleaner at two concentrations (label rate and 4x or 10x label rate).

In the cold fruit study, fruit were taken straight from the cold room and placed on the packingline. A cleaner solution was dripped onto the brushes and apples. The apples were on the brush bed for 2 minutes before being rinsed for 30 seconds with tap water (approximately 55 ºF). The apples moved down the line for 2 minutes of brushing, then went through a 100 ºF dryer for 2 minutes before being placed on trays and into boxes.

In the warm fruit study, the apples were placed in a 90 ºF water bath for 2 minutes. This warmed the fruit to approximately 65 ºF at 1 mm below the skin. Cleaner solution was dripped onto the brushes and apples. The apples were on the brush bed for 2 minutes before being rinsed for 30 seconds with warm water (approximately 90 ºF). The apples moved down the line for 2 minutes of brushing before wax was applied by a wig wag nozzle. The apples then went through a 110 ºF dryer for 2 minutes before being placed on trays and into boxes.

The fruit were stored at 34 ºF for four days. The fruit was then stored at room temperature (approximately 70 ºF) for 2 days, and then evaluated for LB damage. Based on the amount of severe damage seen in earlier trials, the severity scale for LB was simplified to reflect commercial damage:

0 = no damage
1 = slight damage, commercially acceptable quality
2 = moderate damage, commercially marginal quality
3 = widespread or severe damage, commercially unacceptable quality

Results Experiment III—Packingline Study II: LB damage was more severe on the presized fruit. Presize versus non-presize LB damage for all growers is shown by cleaner (cleaners used at label rate) in Figure 5. All cleaners caused significantly more LB damage at higher concentrations (data not shown).

Fruit that was warmed at 90 ºF for two minutes (simulating warm water dump tank conditions) prior to being run over the packingline showed more LB on the presize fruit (Figure 6). Data shown in Figure 6 is cleaners used at label rates with carnauba or shellac wax. All cleaners caused significantly more LB damage at higher concentrations (data not shown). The effect of wax formulation (carnauba vs. shellac) on LB damage was inconclusive.

A photo of presized Gala apples versus non-presized apples (from the same orchard, using the same cleaner at high concentration) with LB damage is shown in Figure 7.

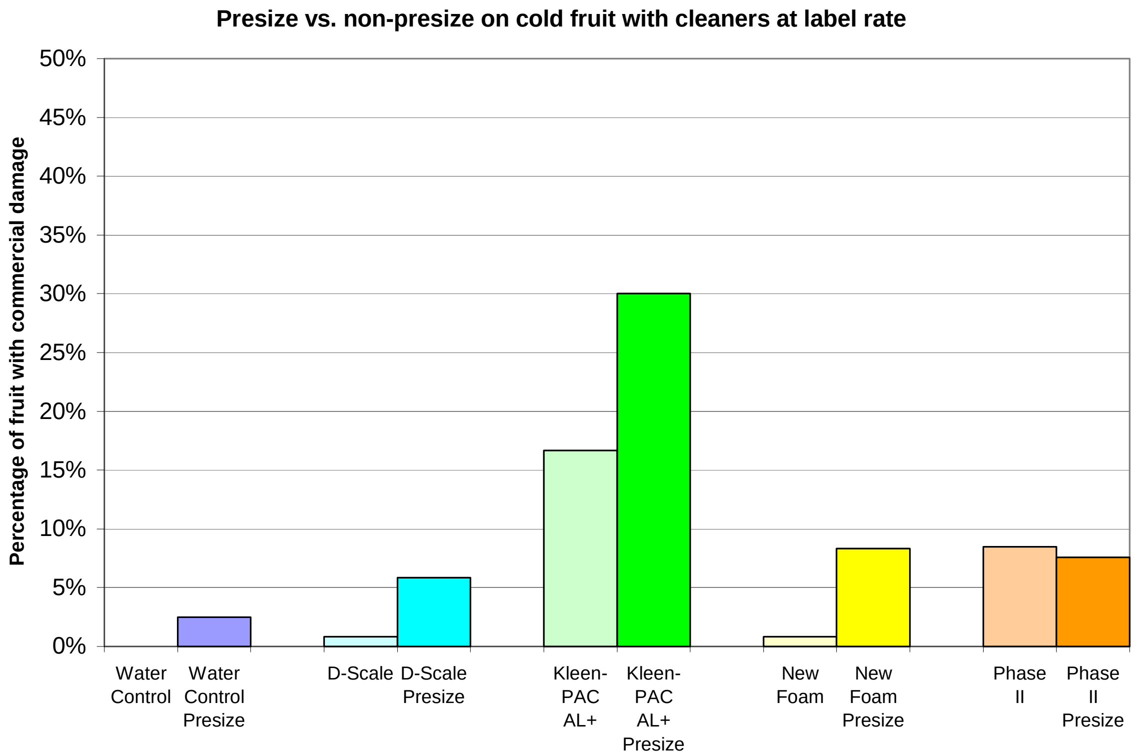

Figure 5. Effect of cleaner and presize on commercially unacceptable LB damage—fruit not waxed (Experiment III—Packingline Study II).

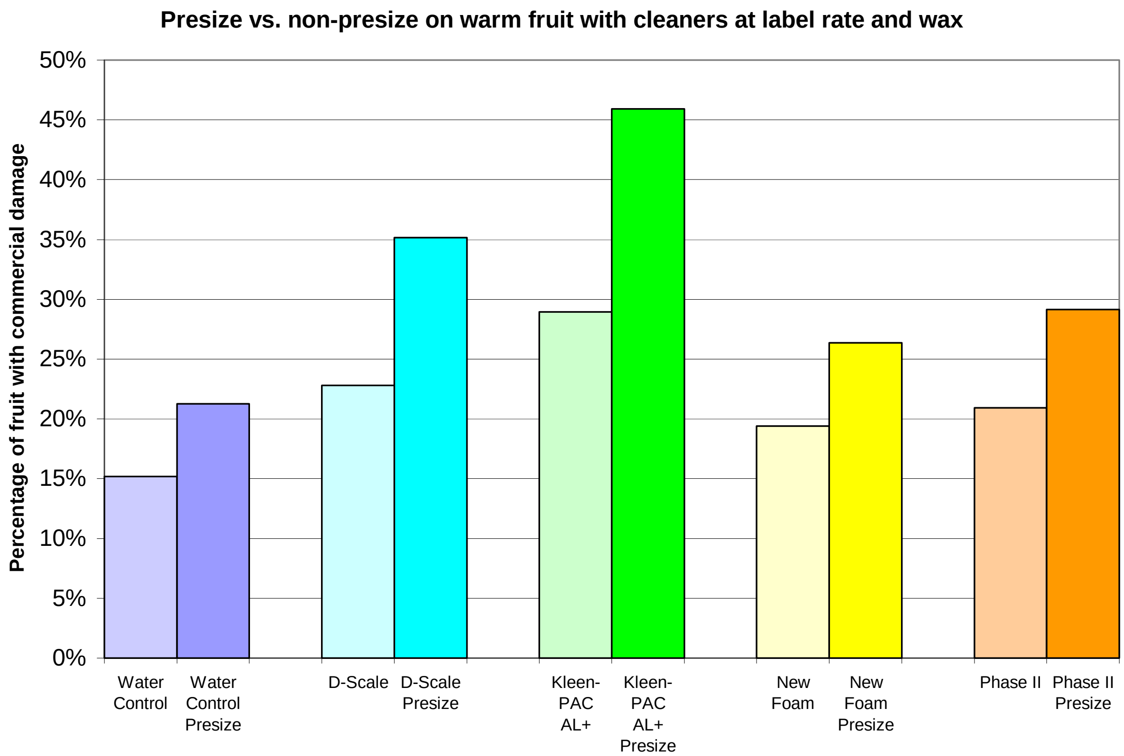

Figure 6. Effect of cleaner and presize on commercially unacceptable LB damage—warm fruit with a warm rinse and waxed with carnauba or shellac (Experiment III—Packingline Study II).

A. **Non-presize** Gala with high concentration cleaner and wax

B. **Presize** Gala with high concentration cleaner and wax

Figure 7. Effect of presize on LB damage (same orchard and cleaner in both photos).

Table 3 provides a summary of each cleaner used in Experiments I, II and III, along with the amount of commercially unacceptable damage to the fruit when used at the label rate and at a higher concentration (4x or 10x label rate, depending on cleaner).

Table 3. Percent of fruit with moderate to severe skin marking (considered a commercial cull) for each cleaner at label rate and at a higher concentration.

Cleaner	Type	pH	Experiment I Laboratory		Experiment II Packingline I		Experiment IIIa Packingline II COLD		Experiment IIIb Packingline II WARM + 400C		Experiment IIIc Packingline II WARM + AP40	
			Label	High	Label	High	Label	High	Label	High	Label	High
180 Cleaner	Line Spray	Acidic	3%	18%								
Acidex	Line Spray	Acidic	90%	100%	10%	41%						
D-Scale	Line Spray	Acidic	15%	65%	13%	0%	3%	34%	33%	46%	25%	54%
Field Clean	Line Spray	Alkaline	24%	80%	5%	23%						
Kleen-PAC AC	Line Spray	Acidic			4%	41%						
Kleen-PAC AL+	Line Spray	Alkaline			9%	67%	23%	98%	39%	83%	35%	91%
Mineral-XX	Dump tank	Acidic	23%	75%								
New Foam 7.0	Line Spray	Neutral					5%	99%	25%	88%	21%	83%
Phase II Acid	Line Spray	Acid					8%	10%	24%	24%	26%	23%
Real Clean	Line Spray	Alkaline	3%	18%	3%	16%						
Tri-Circ	Dump tank	Acidic	7%	37%								
Water	NA	NA					1%		14%		23%	

Methods Experiment IV—Commercial Packingline Study: A study was performed at the Northern Fruit commit-to-pack packingline in April 2004 to test whether applying cleaner and wax, changing brush speed or adding the HyperClean treatment would affect the amount of LB damage. HyperClean uses high volume high velocity water sprayed over the fruit on the brushes to remove decay and clean the fruit.

A bin from each of the six treatments (3 presize and 3 non-presize) was selected for use. For control fruit, a sample was taken prior to the bin being placed on the line, another sample was taken from the dump tank and a third sample was passed over the packingline using water only (no cleaner or wax). A portion of each bin of fruit was then passed over the packingline with a cleaner (D-Scale at label rate) and wax (carnauba) at two brush speeds. The "slow" speed is the brush speed normally used for Golden Delicious and the "fast" speed is normally used for Red Delicious. The HyperClean unit was used on half the fruit at each brush speed. Fruit evaluations were conducted after the apples had been placed in storage at 34 ºF for 3 or 4 days followed by 70 ºF for 24 hours. Sixty fruit from each treatment were examined for LB and scored on the same 0 to 3 scale used in Experiment III.

Results Experiment IV—Commercial Packingline Study: Fruit that was run over the commercial packingline using cleaner and wax had significantly more LB damage than fruit from either the dump tank control (fruit not passed over packingline) or water control (fruit passed over the packingline with water only—no cleaner or wax). See Figure 8.

Brush speed did not have any effect on the amount of fruit with LB damage (data not shown).

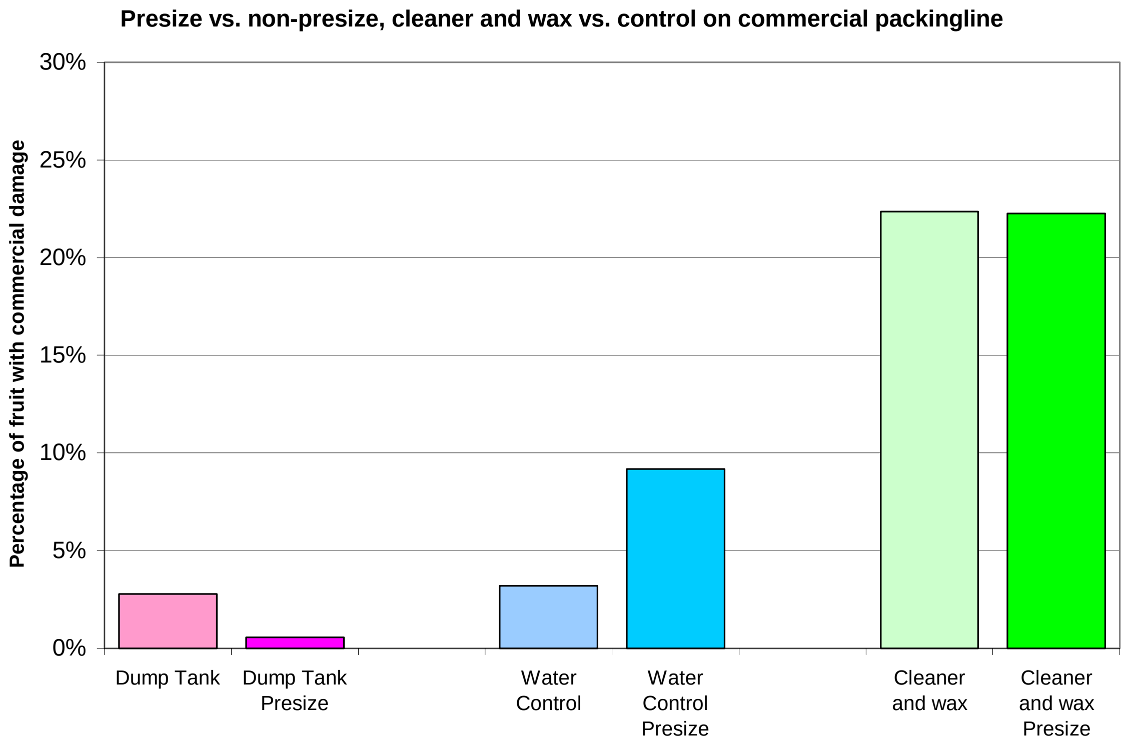

Figure 8. Effect of presize, cleaner and wax on commercially unacceptable LB damage—commercial packingline (Experiment IV—Commercial Packingline Study).

When used with a cleaner, presized fruit treated with the HyperClean system developed more LB damage than presize fruit not treated with HyperClean (Figure 9). The HyperClean treatment did not have a significant effect on non-presize fruit.

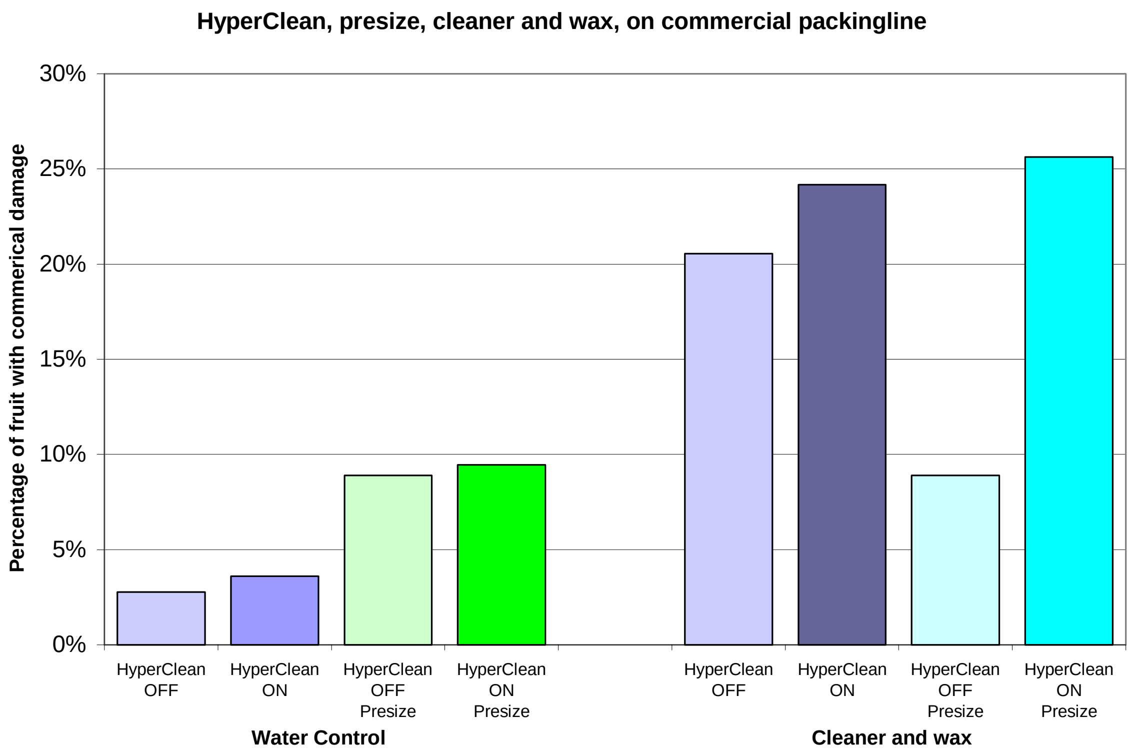

Figure 9. Effect of HyperClean, presize, cleaner and wax on commercially unacceptable LB damage—commercial packingline (Experiment IV—Commercial Packingline Study).

Methods Experiment V—Packinghouse Survey: Interviews were conducted with managers of 31 packinglines to ascertain their experiences with LB on Gala apples during the packing of the 2002 and 2003 crops. Face to face interviews were conducted in the spring 2004 using a questionnaire to obtain consistent information.

Results Experiment V—Packinghouse Survey: The interviews provided a revealing look at the practices followed by many of the packers of Gala apples. There are a number of ways to determine the practices followed by a commercial company. Probably the least reliable is that used in this study in which mangers were interviewed. A weakness of this process is that day-to-day practices may not precisely follow management guidelines. Another is that there are some technical details (time of fruit on brushes, settings of pumps, precise chemicals used) may be overlooked by management, since technical people can be left in charge with inadequate supervision and controls. However, this study provides some insight into some of the reasons that LB has become a problem.

For the most part general practices in most packinghouses were similar. Fruit storage conditions are similar, as is air temperature management. A strong difference is the use of PreSize vs. Commit-to-pack lines. Chemical use on the packingline is also different, particularly in the way in which fruit cleaning compounds are mixed and applied. SmartFresh™ use was not uniform across the industry.

Lenticel Breakdown was a problem in only about half (48%) of the packing facilities interviewed (Table 4). However, in those facilities it was a serious problem. Packers who reported problems with LB on Gala apples while packing the 2003 crop were more likely to have used SmartFresh™ on this fruit prior to storage. They also applied cleaners in concentrate form, rather than from a mixing barrel and applied the cleaner using a drip bar, rather than nozzles. They followed the cleaner with a very hot rinse of water and then waxed the fruit using carnauba wax.

Table 4. Summary of the factors that differed between the practices of those packers who reported having LB damage on Gala apples in 2003 and those who did not have problems.

LB	Sheds Affected (%)	Fruit Affected (%)	SmartFresh™ Applied (% Yes)	PreSize (%)	Cleaner: Concentrate Application	Cleaner: Drip Bar	Rinse Water Temp	Wax: Carnauba (%)
No Problem	52%	0	62%	50%	40%	55%	79 ºF	50%
Problem	48%	>20%	73%	50%	55%	70%	93 ºF	71%

Scientific experiments with suitable replication and controls should be conducted to determine whether the implications of these interviews hold up under scrutiny.

It is important to note that not all Gala apples were affected with LB, so the understanding of why certain lots are susceptible must be a matter of priority.

Discussion:

Some lots of Galas are much more susceptible to LB damage than others for reasons not yet understood. Although it is possible to use the aniline blue dye test developed by Dr. Curry to determine susceptibility, this has not been proven on a commercial scale. Therefore a prudent strategy is to treat all fruit as if it might be susceptible to LB damage.

Presizing susceptible fruit increased the amount of LB damage. However, it is not understood what it is about presizing that sets up the fruit for LB. Half of the packers that were interviewed for the survey presized Gala apples and did not report having fruit with LB damage. Gala apples should be packed on a commit-to-pack line when packing fruit from susceptible orchards.

Cold fruit held cold throughout packing and treated with cleaners applied at label rate had less LB damage than fruit that was warmed and treated with cleaner and wax during the packing process.

Packers should pay close attention to the type and concentration of the chemicals used in the packing process. During the survey (Experiment V—Packinghouse Survey) many managers were unable to remember which cleaners were being applied. Packinghouse visits revealed that many packers were using cleaners at much higher concentrations than the label directed. In these trials fruit treated with cleaners at high concentrations almost invariably developed more LB than those treated at label rate. Fruit treated with some cleaners even at label rate developed more LB than when treated with other cleaners.