

STRESS-INDUCED DISORDERS: EFFECTS ON APPLE FRUIT QUALITY

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The emphasis in this paper is on the effects of environmental stresses on apple quality. Apples can be damaged either pre-harvest or post-harvest by certain stresses. In some instances, pre-harvest stress conditions predispose the apple to develop symptoms of a disorder only after picking or storage. Thus, it is important for both growers and packers to be aware of these potential problems.

In this paper, the term “disorder” refers to those problems in fruit not caused by pathogens. Symptoms are induced by fruit reacting to some kind of stress connected with temperature, light, humidity, atmosphere, or handling. The emphasis in this paper will be on those disorders associated with heat (especially as it relates to fruit surface temperature) and light.

Although we will emphasize the disorder called sunburn in this paper, it will become apparent to the reader that apples that have been sunburned may also develop or show several other heat and/or light-induced disorders. These other disorders will appear either concomitantly or later in maturity or even in cold storage (postharvest)

Sunburn of apple. Sunburn is usually the largest source of cullage in apples with losses in Washington State averaging about 10% of the crop. During 2003, over 25% of the crop was sunburned in several orchards. In apples with more than one disorder, sunburn damage is under-reported by the packinghouse, as apples are culled for only one disorder even though the apple may have sunburn, bird pecks, stem punctures or other damage. We have identified three types of sunburn in apples (Figure 1).



Figure 1. Three types of Sunburn (from left to right): Sunburn Necrosis, Sunburn Browning, and Type 3 Sunburn.

The first type is sunburn necrosis and is heat-induced. When the fruit surface temperature (FST) of an apple reaches 126 °F for only 10 minutes, thermal death of cells in the peel occurs, and a necrotic (dark brown or black) spot appears later.

The second type of sunburn is sunburn browning. This is the most common type of sunburn, and results in a yellow, brown, or dark tan spot on the sun-exposed side of the apple. Frequently, sunburn browning does not become visible until a few days after the disorder is induced on the apples. Sunburn browning requires ultraviolet-B (UV-B) radiation and a certain threshold temperature of the skin. This threshold temperature varies with cultivar (variety), and ranges from 114 to 120 °F for a 1-hour period. ‘Cameo’ and ‘Honeycrisp’ have the lowest threshold temperatures and ‘Pink Lady’ has the highest threshold temperature we have observed. During 2003, there were 39 days on which the fruit surface temperature exceeded 114 °F for at least 15 minutes (Figure 2). Note that the difference between maximum air temperature and daily FST was normally at least 20 °F (Figure 2). However, air temperature alone does not accurately predict maximum FST. Other meteorological factors such as solar radiation, relative humidity, and wind speed also affect the FST on a given day. We have found that the maximum fruit surface temperature is attained between 2 PM and 5 PM (data not shown).

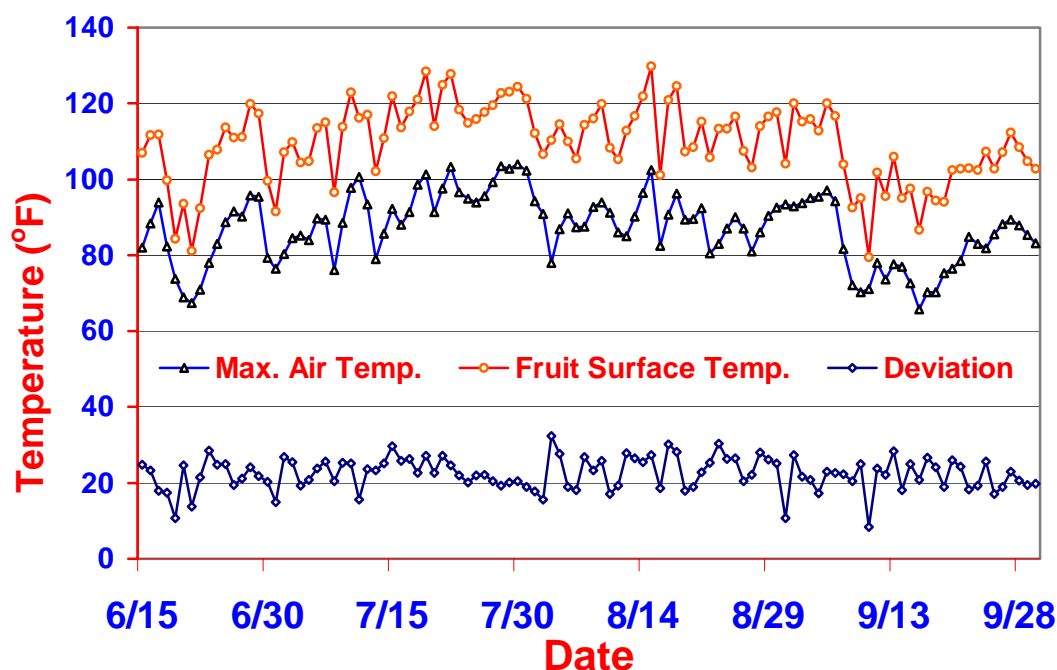


Figure 2. Seasonal profile of maximum air temperature versus maximum fruit surface temperature on the sun-exposed side of an apple. The lower line shows the difference daily between maximum air temperature and maximum fruit surface temperature.

Type 3 sunburn (Figure 1) is not dependent on the FST and does not require ultraviolet radiation. However, it is induced when apples are suddenly exposed to full sunlight. These apples have been shaded and are not acclimated to sun exposure. This sunburn occurs during hand thinning if the top apple of a cluster is removed and suddenly exposes an apple underneath that has been

shaded. It can occur during summer pruning when apples are suddenly exposed, or it can occur after harvest in apples that are left sitting in the sun in an exposed bin in the field, on a truck during transport, or on the dock at the packing shed. It is important to keep fruit shaded after picking to prevent this late-season sunburn. Induction of type 3 sunburn is not temperature dependent, and can occur when temperatures are low in the fall. It requires only light. We have observed Type 3 sunburn during October when the air temperature was only 64 °F, and fruit surface temperature was only 88 °F.

To assist us in evaluating the incidence of sunburn browning, Schrader and McFerson devised a system that shows four classes of sunburn browning (classes 1 through 4) and necrosis (class 5, Figure 3).



Figure 3. Six classes of sunburn used to evaluate sunburn incidence in apples.

'Fuji' Stain. A second disorder that is heat induced is 'Fuji' stain. One type of stain appears predominately in the halo area around the sunburned spot on 'Fuji' apples (Figure 4). We have found that incidence of this type stain that appears during cold storage is strongly related to the degree to which apples were sunburned (Figure 5). This type stain is induced by high FST. There are other types of stain that appear on other parts of an apple, and their causes are under investigation.



Figure 4. Type 1 'Fuji' stain. Note the stain appears in the area that was previously sunburned, suggesting that high fruit surface temperature induced the stain disorder.

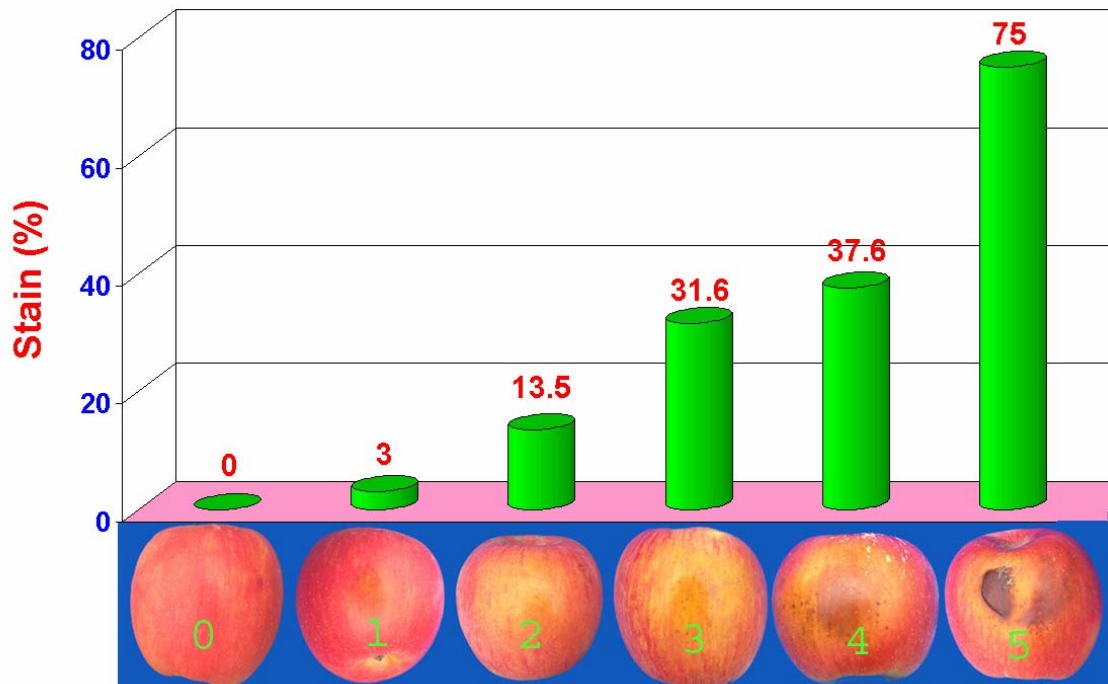


Figure 5. The relationship of 'Fuji' stain (developing in cold storage) versus the severity of sunburn at the time apples were placed in cold storage.

Lenticel Marking. Another disorder induced by heat stress is lenticel marking (Figure 6). This has been observed in nearly all cultivars studied. Again, as the severity of sunburn increases, so does the incidence of lenticel marking (Figure 7).



Figure 6. Lenticel marking on an apple that has been sunburned.



Figure 7. Effect of increasing severity of sunburn on the incidence of lenticel marking in ‘Fuji’ apples.

Bitterpit in ‘Jonagold.’ Another disorder that is enhanced by heat is bitterpit in Jonagold. Although calcium deficiency is reported to cause bitterpit, we observed increased bitterpit in 2003 in apples that were exposed to high temperatures and water stress as they neared maturity. Under these stress conditions, the peel may not develop color normally, but instead have a blotchy appearance (Figure 8).



Figure 8. ‘Jonagold’ bitterpit and blotchy color development under heat stress during 2003.

Splitting of 'Fuji.' During 2003, we also observed splitting of 'Fuji' apples on the sunburned side of the apples, suggesting that this disorder was also caused by heat stress (Figure 9).



Figure 9. Splitting/cracking of 'Fuji' apples on the sun-exposed and sunburned side of fruit.

Water Core. Water core is a physiological disorder associated with internal moisture stress. High temperatures cause premature localized conversion of starch to sugar and pronounced sap leakage from cells, or an influx of sap into intercellular spaces. This often causes a glassy appearance to appear on the surface of the apple (Figure 10).

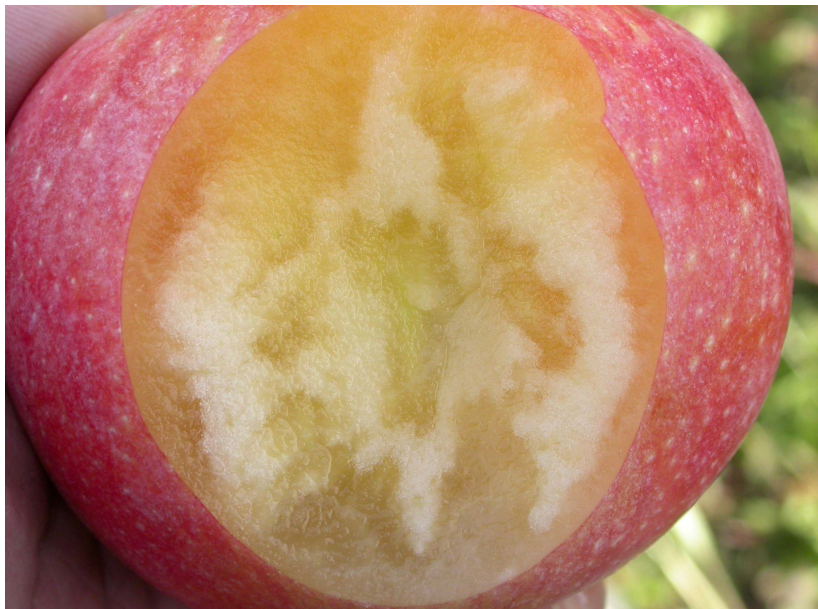


Figure 10. Water core in 'Honeycrisp' apples after heat stress during 2003.

Sunburn Scald in ‘Granny Smith.’ Another heat-induced disorder is referred to in Australia as Sunburn Scald (Hall and Scott, 1989). ‘Granny Smith’ apples are especially susceptible to this disorder that appears during cold storage on the side of the apples that was sun-exposed on the tree. We observed this disorder as apples were removed from cold storage in Wenatchee in spring 2003 (Figure 11).



Figure 11. Sunburn scald in ‘Granny Smith’ apples.

What can be done to prevent these disorders from occurring on apples? Most of the disorders appear on the sun-exposed side of fruit. If sunburn is prevented, these disorders seldom appear. This suggests that management practices are needed that keep fruit from attaining a high peel temperature. Several practices are available. Evaporative cooling; use of sunburn protectants such as RAYNOX™, Surround WP or Vapor Gard; bagging; or use of shade cloth help reduce incidence of sunburn and also reduces the incidence of the other disorders described in this article. During 2003, the use of RAYNOX™ with evaporative cooling was shown to be the most effective treatment for reduction of sunburn and other heat-induced stresses (data not shown).

In summary, there are several heat-induced disorders in apples. Some appear in fruit prior to harvest whereas others do not appear until after harvest and cold storage. Incidence of sunburn often provides an early warning that other disorders will appear later. Suppressing heat and light damage appears to reduce all of the disorders discussed earlier.

References Cited:

Hall, E.G. and Scott, K.J. 1989. Pome Fruit. In: Beattie, B.B., McGlasson, W.B., and Wade, N.L. (eds.) Postharvest Diseases of Horticultural Produce. Vol. 1. Temperate Fruit. CSIRO, Australia.