Postharvest Physiological Disorders and Mineral Nutrients

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Apple fruit can be susceptible to many different physiological disorders that can affect the skin, cortex and core areas alone or in combination. These disorders result in significant commercial losses to growers and storage operators. The type of disorder that is expressed is often a function of the variety, as most, if not all, disorders appear to be affected by the genetic makeup of the fruit. Harvest date is also an important factor as fruit maturity, usually in relation to the increase of ethylene production and the associated respiratory climacteric, can greatly affect the susceptibility of fruit to disorder development. An additional factor is climate during the growing season are specific temperatures that the fruits are sometimes experiencing in the orchard in the month or so before harvest.

> **"Several postharvest disorders are related to fruit mineral concentration including bitter pit and senescent breakdown. Other disorders such as watercore, superficial scald and low temperature breakdown or flesh browning are indirectly affected by fruit mineral concentration and are more strongly affected by other factors."**

In the case of apples, we then impose a range of storage environments — air and controlled atmosphere (CA) storage — at different temperatures. The appropriate storage periods for fruit, in either air or CA, can vary with variety and also by postharvest treatment such as diphenylamine (DPA). More recently, 1-methylcyclopropene (1-MCP), known commercially as SmartFresh, has also had a large impact on storage management. In the storage environment we are imposing stressful low temperature conditions and then in CA storage, close to stress tolerances of low oxygen and high carbon dioxide, all of which can alone or in combination result in the development of physiological storage disorders in the fruit.

The focus of this overview is on physiological disorders and mineral nutrients. I have divided treatment of this subject into four parts:

1. Relationships between individual mineral nutrients and physiological disorders;
2. Specific disorders and mineral nutrients;
3. Effects of cultural practices on mineral nutrients; and
4. Managing calcium in the orchard.

Relationships Between Individual Mineral Nutrients and Physiological Disorders

Figure 1. External and internal bitter pit

Nitrogen. Fruit with high N may have a higher incidence of bitter pit, cork spot, internal breakdown, internal browning, superficial scald, soft scald, soggy breakdown, decay, and for pears, core breakdown, alfalfa greening, freckle pit, green stain, and decay. Most of these effects are probably secondary and result from the high tree vigor resulting in lower Ca in larger fruit. Fruit with high N in general tend to be larger, softer, have poorer color, and they are more subject to premature drop.

Calcium. Fruit with low Ca may have a higher incidence of bitter pit, cork spot, senescent breakdown, scald, low temperature breakdown, superficial cork, freckle pit, alfalfa greening, green stain, and decay.

Potassium. Fruit with high K may have a higher incidence of bitter pit, cork spot, senescent breakdown, low temperature breakdown, coreflush, brown core, and decay. The mode of action of high K is an interaction with Ca in the cells and induced Ca deficiency.

Magnesium. Fruit with high Mg may have a higher incidence of bitter pit, cork spot, senescent breakdown, low temperature breakdown, coreflush, brown core, and decay. High Mg interacts with Ca in the cells and induces Ca deficiency.

Phosphorus. Fruit with low P may have a higher incidence of senescent breakdown and low temperature breakdown.

Boron. Fruit with high B may have a higher incidence of water core at harvest, and water core-breakdown after storage. Fruit with high B tend to ripen earlier and be subject to preharvest drop. The problem usually results from excess B application to alleviate B-deficiency problems.

Specific Disorders and Mineral Nutrients

For the sake of simplicity, I divide the disorders into two groups: those that are considered to be directly affected by mineral nutrients; and those for which nutritional status while important, is probably associated secondarily with disorder development.

Physiological Disorders That Are Directly Affected by Mineral Nutrients

The 'poster child' for this category is bitter pit (Figure 1), which is variously a pre- and/or post-harvest disorder depending on variety. The other disorder that is considered in this category is senescent breakdown.

Bitter pit. Susceptibility of fruit to bitter pit has three components – genetic, climatic and orchard management. The most susceptible varieties in New York are Mutsu, Northern Spy, Cortland, Jonagold and Honeycrisp. Even within these varieties, seasonal differences are common, with hot dry summers much more associated with higher disorder incidence than cooler summers. In this light, growers should be considering changes in weather patterns as part of their plans for Ca spray applications as increasing bitter pit levels appear associated with the warmer weather conditions that we are experiencing in recent years. However, a huge factor, and challenge for growers is orchard management to minimize the risk. Block-to-block variation in bitter pit development can be large because orchard management is not homogeneous. In addition to Ca availability in the soil, Ca levels in the fruit are affected by any horticultural practice at affects tree vigor and the balance between fruit and vegetative materials. The goal of orchard operations should be to manage this balance by ensuring uniform, moderate tree vigor. The application of Ca sprays reduces bitter pit incidence, and will be covered briefly in the last section. Postharvest Ca drenches or dips can further decrease bitter pit in those varieties where the disorder develops during storage.

Senescent breakdown. In general, senescent breakdown (Figure 2) is associated with fruit that has been stored too long. The cortical tissues of the fruit are typically dry and mealy. Senescent breakdown occurs earlier and with greater severity in large fruit that are harvested too late. Overall, the disorder is less common in recent years than earlier because fruit are cooled more rapidly and air storage periods shorter than traditionally. Nevertheless, Ca can directly reduce senescent breakdown incidence applied both pre- and post-harvest. The comments made later about Ca sprays for bitter pit also apply for senescent breakdown.

Figure 2. Senescent breakdown

Physiological Disorders That Are Indirectly Affected by Mineral Nutrients

Susceptibility of fruit to some disorders, superficial scald for example, appear more related to antioxidant activity of the skin, and effects of nutrient composition are modest. You will read claims that Ca reduces scald, but this reduction is meaningless from a commercial point of view. Severity of disorders such as low temperature breakdown and others that are indirectly affected by mineral nutrient composition, can be decreased by postharvest Ca application. However, most of these demonstrations involve much higher Ca applications (e.g. potentially phytotoxic concentrations and infiltration under vacuum conditions in the laboratory) than can be achieved under routine commercial conditions.

Superficial scald. The major factors in scald development are variety, climate, harvest time, storage period, cooling rate, ventilation, and ethylene in the storage environment. High N and low Ca can make scald susceptibility worst, but more clearly in cooler growing regions than warmer ones.

Watercore. Watercore development is associated with more mature fruit at harvest, cool night time temperatures during the harvest period, and stress conditions in the orchard. Development of watercore can be delayed by Ca sprays, but the effects of night time temperatures will eventually overwhelm the Ca effects in susceptible fruit. Thus, even fruit with high Ca levels can develop watercore in high risk seasons. Fruit with severe watercore should not be stored of long periods, especially in CA storage, as they can develop watercore-associated breakdown.

Low temperature breakdown/Flesh browning. Evidence exists that some reduction of low temperature breakdown can be reduced by preharvest P and Ca spray, and postharvest Ca drenches, but commercially consistent and significant effects are hard to find. Of particular interest in New York is the issue of flesh browning in Empire apples. Postharvest Ca applications have not resulted in any reduction of browning. However, a two-year trial funded by the NYFVI is underway to investigate the possible role of micronutrients in susceptibility of fruit to browning.

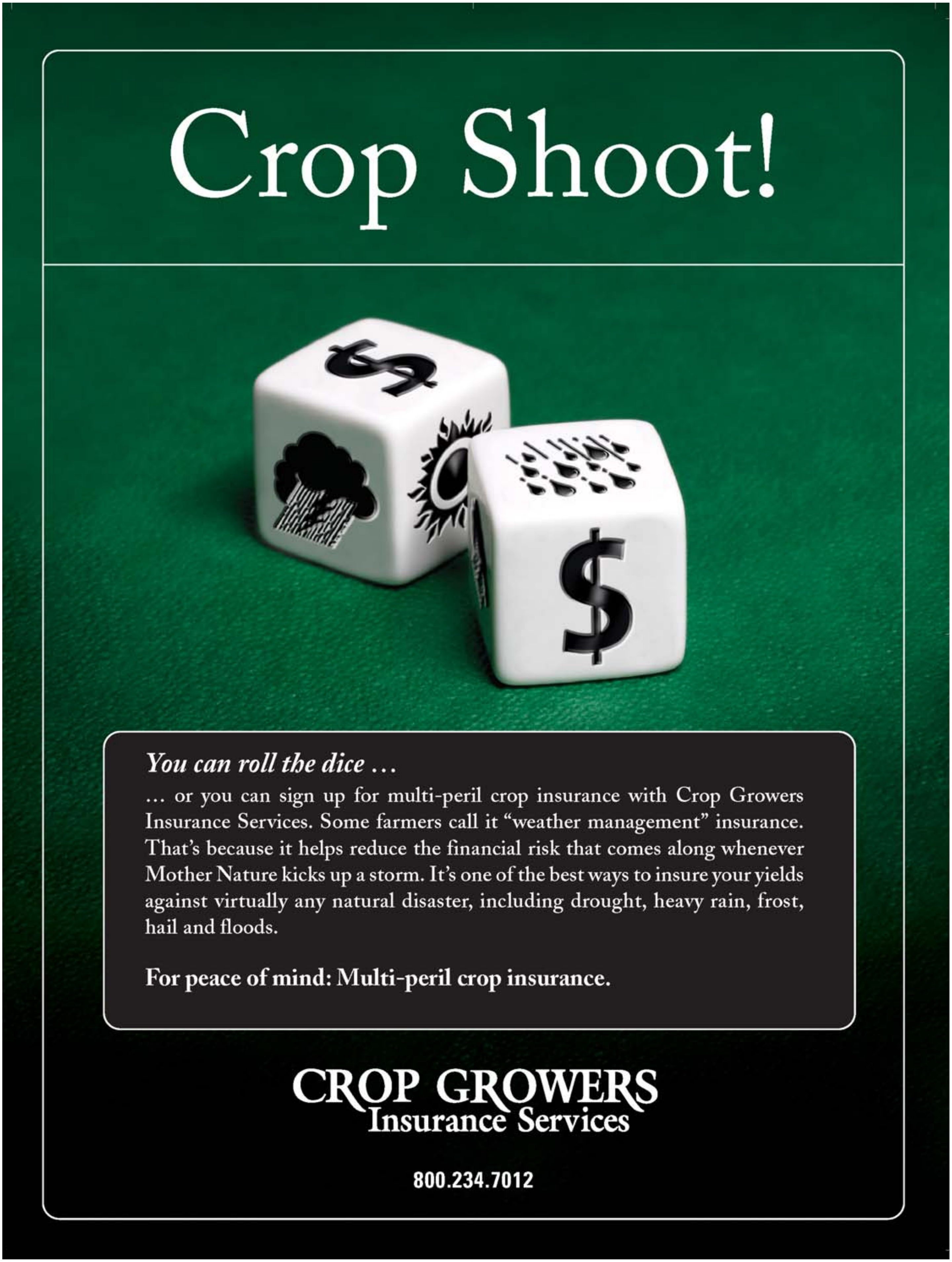
Effects of Cultural Practices on Mineral Nutrients

Rootstocks/tree age. Both time of ripening and mineral composition, and subsequently incidence of storage disorders of fruit can be affected by rootstock. Many effects, but not all, can be attributable to tree vigor and thereby indirect effects on fruit. Young trees are usually relatively vigorous, regardless of rootstock. Fruit from such trees tend to have higher N and lower Ca concentrations, with poorer keeping quality and greater susceptibility to storage disorders.

Soil management. Fruit from trees grown in sod tend to have lower N, higher P and Ca, and develop fewer postharvest disorders than those grown with grass-free strips. Irrigation can improve mineral uptake by preventing moisture stress, but if excessive can produce excess tree vigor and fruit size, with lower fruit Ca.

Training/pruning. Little systematic evidence about the effects of tree training on fruit quality exists. However, any effects would probably be associated with Ca composition and time of ripening, since training systems involve manipulation of tree vigor. Pruning systems are well known to affect fruit quality and incidence of postharvest disorders. Severe winter pruning can result in lower fruit Ca if vigorous vegetative growth is stimulated, whereas summer pruning can result in higher fruit Ca.

Pollination/seed number. Higher seed number is associated with higher Ca, even though fruit size is greater. This occurs because seeds are the sites of auxin synthesis and auxin influences movement of Ca in to the fruit. It has been shown that fruit with higher seed numbers have lower senescent breakdown development and lower susceptibility to low oxygen injury.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Managing Calcium in the Orchard

Current recommendations for Ca application are:

- 3-4 cover sprays of 1-2 lbs of $CaCl_2$ (78%) or its equivalent per 100 gallons (dilute basis) at 14 day intervals beginning 7-10 days after petal fall.
- 2 additional sprays of 3-4 lb per 100 gallons at 4 and 2 weeks prior to harvest.

The goal is to provide 7.5-13.4 lb of actual Ca per acre. Note that $CaCl_2$ increases the solution pH and so 2/3 oz of vinegar per lb of $CaCl_2$ is recommended to readjust the pH. Addition of an adjuvant will decrease risk of foliar injury.

$CaCl_2$ or $CaNO_3$ salts are recommended for proven effectiveness and lower cost, but other formulations are available. You should compare the cost and actual Ca levels in these other formulations. Basic principles to be considered when spraying Ca, regardless of the Ca source that you choose are:

- Complete coverage of the fruit is essential because Ca spray deposits on leaves do not benefit the fruit.
- Making frequent applications is more important than exact spray timing. No growth stage is more important than another, and therefore your goal should be spread applications throughout the growing season.
- Effectiveness of Ca sprays increases with increasing Ca concentrations, but is limited by Ca-associated damage. Follow label instructions.
- Avoid spraying when temperatures are above 80°F, particularly when humidity is high.
- Sprayer calibration is critical as errors are magnified at higher Ca concentrations.
- Exercise caution if you are applying Ca as part of a complex mix, to ensure that active compounds are not negatively affected. Check labels for compatibility, and if in doubt look for precipitation. Do not mix $CaCl_2$ with Solubor™.

Bibliography

Autio, W.R. and W. J. Bramlage. 2001. Foliar calcium sprays for apples. U. Mass Fact sheet F-19R. www.umass.edu/fruitadvisor/factsheets/folcalcium.pdf

Bramlage, W.J. 1993. Interactions of orchard factors and mineral nutrition on quality of pome fruit. *Acta Horticulturae* 326:15-28.

Bramlage, W.J. and S. A Weis. 2004. Postharvest fruit quality and storage life in relation to mineral nutrients. *New York Fruit Quarterly* 12(2): 11-12.

Stiles W. C. and W. S. Reid 1991. Orchard nutrition management. Cornell Cooperative Extension Bulletin 219.

Watkins, C., J. Schupp, and D. Rosenberger. 2004. Calcium nutrition and control of calcium-related disorders. *New York Fruit Quarterly* 12(2): 15-21.

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