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In a Nutshell
Tulare County

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Dissecting Almond Hull Rot

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As the name suggests, hull rot of almond is the infection of the almond hull by one or more fungi, typically *Rhizopus stolonifer* (the bread mold fungus), or *Monilinia* spp. (mainly *M. fructicola*, the brown rot fungus). In addition to the rotting of the hulls, the leaves near the infected almond fruit wither and dry. These symptoms are usually visible a few weeks before harvest. As the disease progresses, the fungi produce toxins that are translocated down branches, killing fruiting twigs and spurs. While hull rot generally does not affect almond kernels, it may increase the number of stick tights and can affect future yields due to the loss of fruiting wood. Plant diseases are usually associated with stressed orchards in the presence of environmental and plant conditions favorable for disease development. However, this disease has been associated with well-managed orchards and is sometimes referred to as the "good growers' disease."

Figure 1. Black streaking caused by *R. stolonifer*. The streaking is a result of toxin (fumaric acid) movement and can be traced to infected peduncle (Photo credit: B. Holtz).

Figure 2. Infection of almond hull with *Monilinia fructicola*. Brown lesion is visible with fungal signs visible as brown to tan spores on the surface of the lesion (photo credit: Integrated Pest Management for Almonds, 2nd edition)

In the Southern San Joaquin Valley, *R. stolonifer* is the more prevalent fungus; it produces a toxin (fumaric acid) during infection that moves from the infected hull to the surrounding tissues and results in vascular necrosis. The symptoms are usually manifest as black streaks in the wood after bark removal (Figure. 1). Recently, however, other fungi, such as *Aspergillus niger*, have been associated with similar symptoms. In summer 2016, *R. stolonifer* was the most prevalent causal agent associated with hull rot on farm calls. *A. niger* was also associated with some incidence of hull rot, either alone or in combination with *R. stolonifer*. However, in 2017, *A. niger* was associated with more

Figure 3. Signs and symptoms of hull rot caused by *Rhizopus stolonifer.* Black spores are visible between the hull and the shell and symptoms of dry leaves are apparent (Photo credit: B. Holtz)

hull rot than *R. stolonifer* at sites in Fresno, Madera, and San Joaquin counties, as well as from a trial in Kern County. *A. niger* was first reported by Dr. Beth Teviotdale, emeritus UC Specialist, to cause hull rot in Kern County as early as 1990 and 1991. Preliminary pathogenicity tests conducted in 2017 indicate that fruits inoculated with *A. niger* become symptomatic and ongoing research addresses the factors affecting disease development.

Because *R. stolonifer* and *M. fructicola* have different management strategies, it is important to diagnose the pathogen associated with disease in a given orchard. The addition of *A. niger* as a hull rot pathogen makes disease control even more difficult than before. Correct diagnosis can be achieved by observing the signs and symptoms of the disease after the start of hull split. *Monilinia* spp. produce a brown lesion with sometimes visible tan spores and fungal growth on the outside and/or inside surface of the hulls (Figure. 2). In general, *R. stolonifer* appears as black fungal growth (black sporulation intermingled with mycelial strands between the hull and the shell) (Figure. 3). *A. niger* appears as flat jet-black spores and it is usually located between the hull and the shell without masses of mycelia (Figure. 4). If signs of the fungi are not macroscopically visible, it is advised to send the sample for isolation and incubation to determine the causal agent. If not well managed, hull rot is considered one of the most important and difficult to control diseases resulting in economic loss.

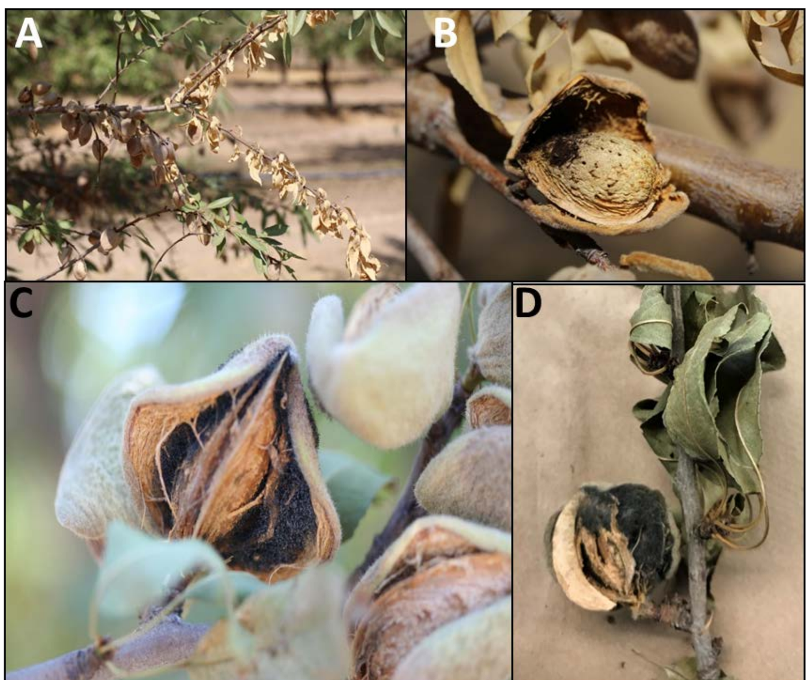

Figure 4. Symptoms of hull rot caused by *Aspergillus niger* (A and B) include dry leaves (A) and dead twigs (B). The spores are jet-black and flat between the hull and the shell (B)(Photos: Brent Holtz). Hull rot caused by R*hizopus stolonifer* (C and D) has black sporulation intermingled with mycelia strands between the hull and the shell (Photos: B. Holtz and M. Yaghmour)

Factors affecting fruit susceptibility

Studies by Dr. J. Adaskaveg, UC Riverside, illustrate the influence of developmental stage of hull split on disease progress. *R. stolonifer* requires a wound or natural opening (ie. hull split) for infection. The most susceptible stage of hull split is the b2 stage, which marks the beginning of splitting that forms a deep “V” along the suture (Figure 5). At this stage a natural wound allows for spores to enter and infect the healthy tissue and infection can progress concurrent with hull split progression. The influence of hull split developmental stage on susceptibility may be related to the hull moisture content.

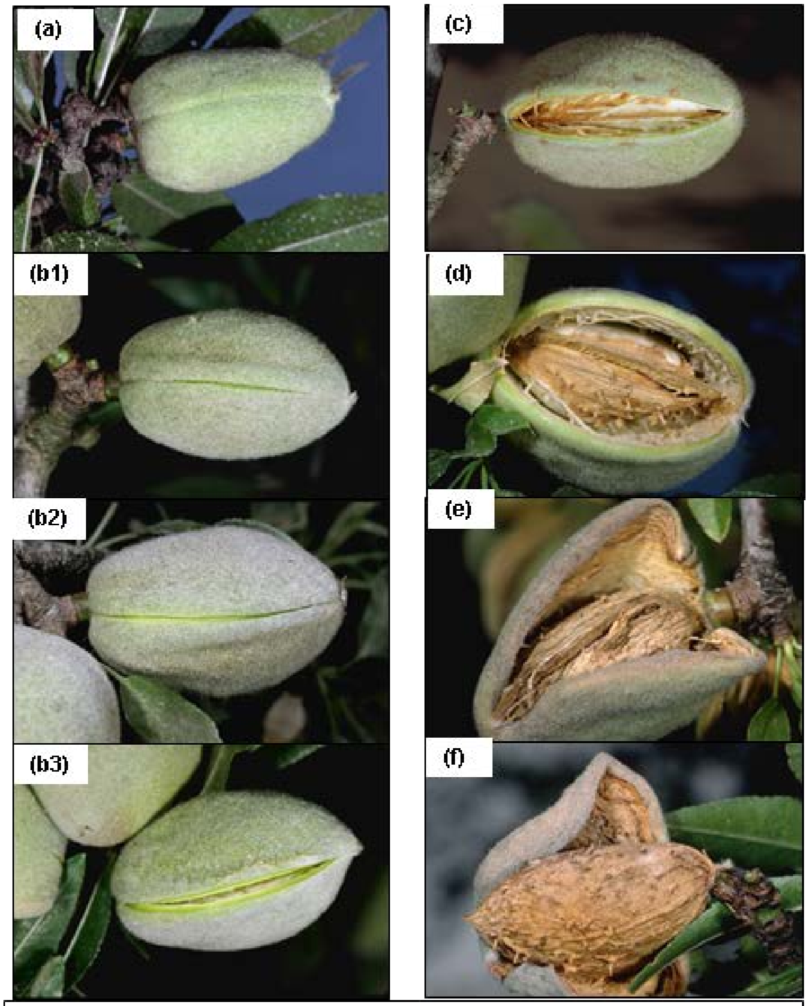

Figure 5. Stages of hull split. a. unsplit hull, b1. initial separation, b2. deep V split, b3. deep V split, but nut pops when squeezed, c. split, but less than 1 cm, d. split, more than 1 cm, e. initial drying stages, f. completely dry (photo credit: Integrated Pest Management for Almonds, 2nd edition)

Varieties exhibit differential susceptibility to hull rot. The major variety in California, Nonpareil, is the most susceptible, followed by Butte and Winters. Sonora is considered to have intermediate susceptibility. Wood Colony, Carmel, Padre, Fritz, and Monterey are considered to have low or very low incidence of hull rot. The early hull splitting varieties are usually the most susceptible while the later hull splitting varieties are more resistant (probably dependent on the water stress of the orchard at the time of hull split).

Effect of Nitrogen Fertilization and Irrigation on Disease Development

Studies conducted by Dr. B. Teviotdale and Dr. S. Saa, UC Davis, indicate that nitrogen (N) application in excess of crop demand increases incidence of hull rot in the orchard. In short, increased N application is positively associated with hull rot strikes. Hull rot incidence is higher in low crop years compared to high crop years. Saa's group found that increased N enhanced tissue susceptibility to the pathogen and prolonged certain stages of hull split. The role of N on developmental stage of hull split was not related directly to hull rot incidence. Further studies addressing the physiological effect of N on hull susceptibility may assist in identifying new methods of disease management.

In another study, Teviotdale's group demonstrated that induction of moderate water stress through deficit irrigation at the onset of hull split resulted in reduction of dead leaf clusters and dead fruiting wood (spurs) in the orchard.

Management of hull rot

Hull rot management programs should consider integration of cultural control methods complimented with chemical control to reduce disease incidence when appropriate, (http://ipm.ucanr.edu/PDF/PMG/fungicideefficacytiming.pdf). Excessive N fertilization should be avoided by following the N management plan based on crop load and application of N at the right rates and times during the season. Application of N after kernel development should be avoided. Nitrogen applied after kernel development in the summer will be directed to the hull and increase hull susceptibility to hull rot. Tree N status should be maintained within the UC critical value range of 2.2-2.5% in the July foliar analysis.

Another cultural control practice includes strategic deficit irrigation (SDI) during hull split. Applying moderate water stress may reduce hull rot by 80-90%. This can be achieved by irrigating when midday stem water potential is between -14 and -18 bars. This water stress should be applied at hull split and be maintained for approximately 2 weeks, until 90% of nuts have reached hull split. To achieve the desired mild stress, it is better to reduce the duration of irrigation and not the frequency of irrigation. After the two-week susceptible period, normal irrigation should be resumed until the harvest dry-down period.

Cultural control can be complimented with chemical control. According to the 2017 UC publication "Fungicides, Bactericides, and Biologicals for Deciduous Tree Fruit, Nut, Strawberry, and Vine Crops," the best time to apply chemical control for treatment of hull rot caused by *R. stolonifer* is in June when hull split is about 1-5%. Chemical control of hull rot caused by *Monilinia* spp. should take place 3-4 weeks before hull split. Currently strobilurin (FRAC 11), and DMIs (FRAC 3) fungicides are effective to control the disease as well as fungicides in the FRAC groups 3+7, 7+11, 3+11.Because the factors contributing to disease development by *A. niger* are currently under investigation, management strategies for *A. niger* are not yet available.

Understanding seasonal vegetative growth on almond

Elizabeth J. *Fichtner, UCCE Farm Advisor, Tulare and Kings Counties, and Bruce Lampinen, CE Specialist, UC Davis*

Evaluation of flowering and fruit set on almond allows for within-season assessment of orchard productivity; however, understanding the vegetative growth dynamics of almond allows growers to consider parameters affecting productivity years into the future. Vegetative growth of almond has two main components: vegetative shoot growth and spur production. Vegetative shoot growth provides the overall architecture of the canopy, and spur production generates the tissues that give rise to the majority of fruit in subsequent seasons. Both vegetative shoot growth and spur production are key components to the development of an economically sustainable and productive orchard.

Timing of vegetative growth. All buds (vegetative and flower) are formed during the prior season. Because almond has one of the lowest chill requirements of permanent crops grown in California, the chill requirement is generally fulfilled by January 1. As temperatures increase, growth initiation is induced, and bud break ensues, with flower buds breaking in advance of vegetative buds. Vegetative shoot growth proceeds at a somewhat uniform rate throughout the season on young trees, but the duration of spur elongation is short and generally complete by April or early May.

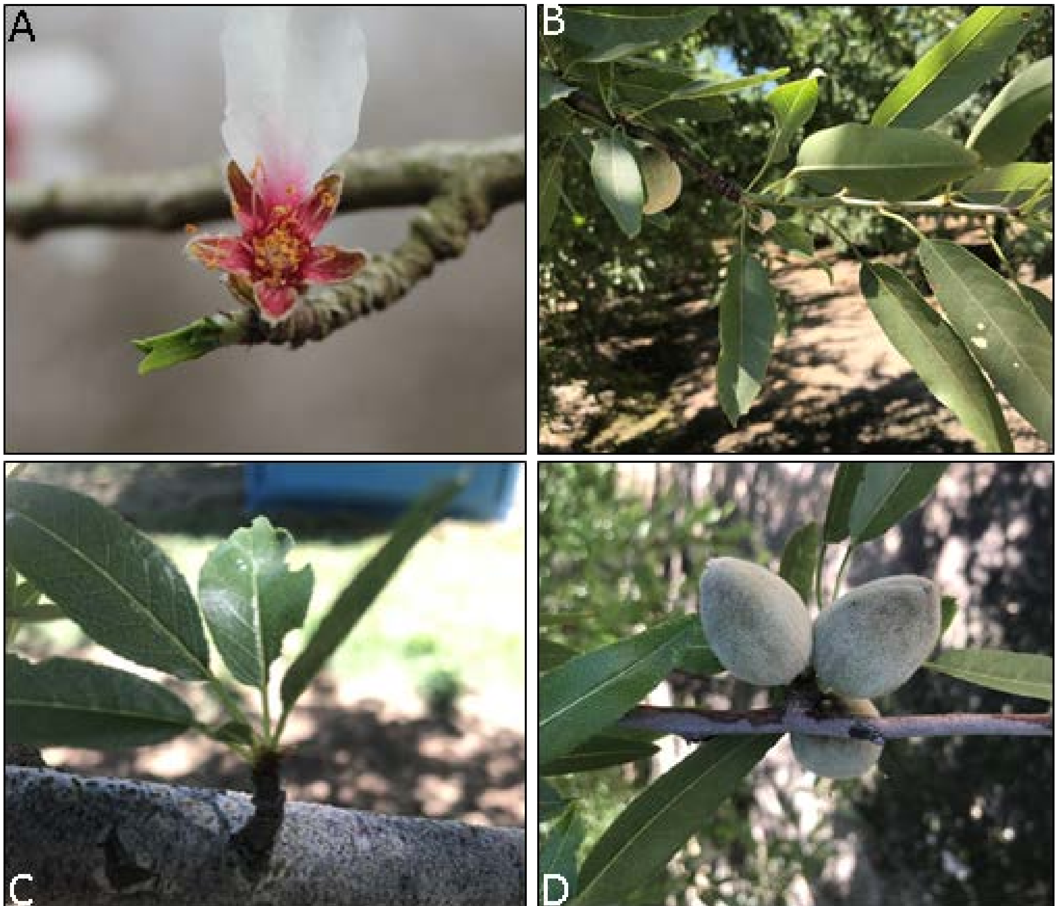

Figure 1. The apical bud on a spur is always vegetative (A). Spurs can give rise to long vegetative shoots (B), remain vegetative (C), or support nut development (D).

Vegetative buds. On almond, vegetative buds can be distinguished from flower buds by shape. Flower buds are thick and oval; vegetative buds are pointy and triangular. On shoots, flower buds are generally formed on either side of a vegetative bud. On spurs, the apical bud is always vegetative (Figure 1A), and this bud can give rise to either further spur growth (Figure 2) or a vegetative shoot (Figure 1B). Spurs in positions with high light interception are more likely to give rise to vegetative shoots than new spur growth.

Vegetative shoot growth. Vegetative buds may give rise to long vegetative shoots that support future spur production. During the early years of orchard establishment, long shoot growth is the main component of vegetative development on almond (Figure 3A, B, C). On mature trees, vegetative shoot growth occurs under conditions of low crop, high vigor, and in regions of the canopy where there is excessive light interception. Canopy regions with excess light include external/exposed areas and empty spaces resulting from broken limbs.

Spurs. Spurs are short, compact vegetative shoots, approximately 0.5-2 inches long (Figure 2). Spurs arise on vegetative shoots or on spurs produced in the prior season (Figure 2). Within a season, the duration of spur growth is generally short, with spur extension completed by April or early May. Spurs are always formed on the prior year's wood, and remain vegetative for 1-2 years prior to flowering. As a consequence, the process from vegetative shoot growth to spur production and flowering may take 4 seasons.

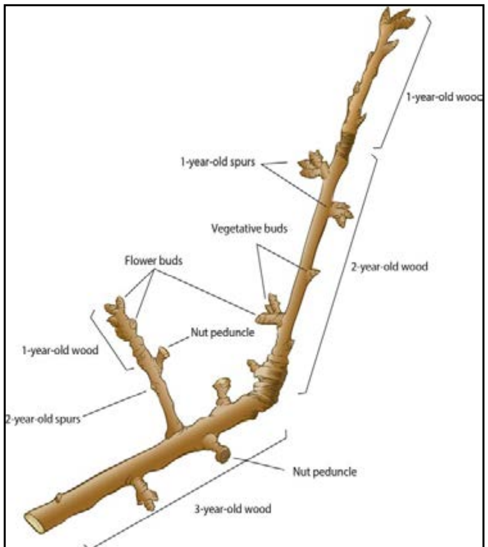

Figure 2. Spurs are always borne on the prior year's wood. (Illustration: Tombesi, et al. 2016)

Spurs support approximately 80% of the total almond yield in a given year, yet only about 20% of the total spur population on a tree supports nut production each year. The fact that only 1 in 5 spurs bear fruit in a season is explained by the dynamic status of spurs between years. A portion of spurs remain only vegetative in a given year (Figure 1C), whereas others may support 1-5 flowers that may develop into single fruit-bearing spurs or multiple fruit-bearing spurs (Figure 1D). Due to the reliance on a localized carbon economy, individual spurs tend to alternate bear, meaning that spurs that bear fruit one year tend not to flower or bear fruit the following year.

Comprehensive view on vegetative growth. In new almond plantings (Figure 3A), growers should expect the mainstay of vegetative growth to be production of long vegetative shoots (Figure 3B and C). Although the majority of the future crop is produced on spurs, it will take time for bearing spurs to be represented in the canopy. Consider that spurs are produced on the prior year's wood and will remain vegetative for 1-2 years before entering productivity. Patience is needed as these vegetative spurs store carbohydrates to support future nut development.

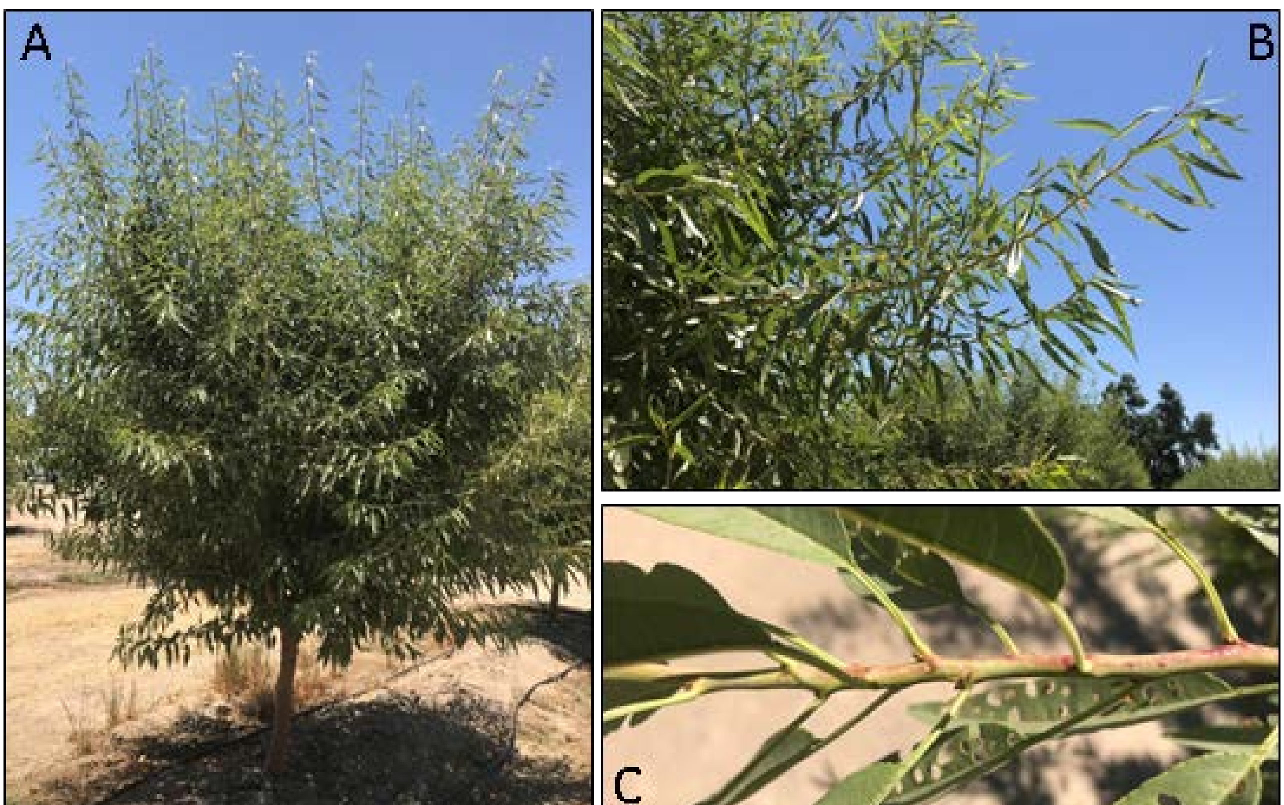

Figure 3. In young trees (A), the majority of growth is comprised of vegetative shoots (B and C).

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Boron Deficiency in Almonds and Pistachios

Phoebe Gordon, UCCE Farm Advisor, Merced and Madera Counties

Boron is a weird nutrient in orchard crops, particularly in California. It's needed in very small amounts, and some crops, like almonds, do not tolerate soil levels much above 1 ppm. To complicate things, boron tends to be deficient in some parts of the valley, such as sandy soils where canal water is the primary water source, and at toxic levels in areas in soils formed by old marine deposits.

Deformed leaves are a symptom of boron deficiency on pistachio. Photo: P. Gordon

Boron is an important nutrient to get right, however, as it is necessary for effective pollination. Mild deficiency symptoms can first manifest themselves as disappointingly low yields or heavier than normal 'June' drop. Boron is also necessary for cell wall development, so more severe deficiency symptoms can include deformed leaves and shoot and tip dieback.

Boron behaves differently across tree species. Understanding the differences in mobility is important because it determines what tissues you will be monitoring for deficiencies and toxicities, as well as how to rectify deficiencies. In most tree crops, for example pistachios, boron is immobile, which means once the plant has taken up the nutrient and transported it into the growing tissues, it stays there. This means that when evaluating deficiencies and toxicities, you should be monitoring leaves. Deficiency symptoms are cupped and deformed leaves, though they retain their green color. In more severe deficiencies, flower panicles can drop from the tree. Boron toxicity symptoms are necrotic leaf margins, however in pistachios, toxicity symptoms can still be associated with high yielding orchards. In plants where boron is immobile, foliar sprays will only affect the current season's growth, and severe deficiencies are better addressed through soil applications.

In almonds and other *Prunus* species, boron is mobile, since it is involved in the transport of photosynthesized sugars. You should be monitoring deficiencies and toxicities in the location where the season's photosynthate ends up: the fruit (and specifically, the hull). Severe deficiency symptoms manifest as shoot tip dieback, whereas more mild deficiencies can show up as internal gumming in the fruit. Severe toxicities will cause gumming in the trunk as well as tip dieback, though the reason why is unknown. Since boron is mobile, foliar sprays can affect future year's crops, though the effect is more limited than with soil applications.

In order to first assess your field's boron levels, it's important to have your soil and irrigation water tested. In some areas, groundwater is a significant source of boron. I would never advise embarking on a fertilization regime unless you know that both your water and soil levels are low. If both show low levels of boron, next you'll need to test your plants to assess how deficient they are in boron. As boron is immobile in pistachios, you should be monitoring leaf levels with your July leaf tests. Start thinking about it now – if you're like me, July will be here sooner than you think! In almonds, you should be monitoring boron with hull samples pulled at harvest time. I want to stress that boron deficiencies do not show up in almond leaves, so you can't rely on your spring time or July leaf samples to ensure your plants are adequately fertilized.

Crop	Leaf critical value	Hull critical value
Almond	N/A	80 ppm
Pistachio	90 ppm	N/A

This table states the critical values for almond and pistachio; these are values below which you will see deficiency symptoms manifest in the plant. Actual sufficiency values, which are levels where yield is not negatively affected are much higher; in pistachios it is between 150 and 250 ppm, and in almonds between 100 and 160 ppm.

To correct minor boron deficiencies, conduct spring foliar sprays in pistachios, using 2.5 to 5 lbs of Solubor in 100 gallons of spray at the bud swell period (early to mid-March, depending on spring temperatures). Use much lower rates in almonds – 1 to 2 pounds of Solubor in 100 gallons of water. Almond sprays should be timed after harvest before leaves fall for best effects, or at bud swell but before the trees are in bloom. Boron sprays during bloom can damage flowers and interfere with bee pollination.

Major boron deficiencies must be corrected via a soil application. In both almonds and pistachios, broadcast 50 lbs of Solubor per acre. Failure to broadcast applications can result in toxicity symptoms. Monitor leaf tissue levels closely to ensure the deficiency has been corrected. In pistachios, which have a greater need for boron and higher tolerance toxic levels, severe deficiencies may need to be treated with both soil and foliar sprays.

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