Almonds production in the California Central Valley

Brandi Payne

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Almonds production in the California Central Valley

by

Brandi N. Payne

A creative component submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Agronomy

Program of Study Committee:
Allan J. Ciha, Major Professor
Mark Westgate

Iowa State University
Ames, Iowa
2019

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INTRODUCTION

Global warming, drought, aging orchards, and new invasive pests and disease have changed many cultural practices of the almond production system changed in recent years. Almonds are a growing global commodity and a very important part of the California economy. The crop is the third largest agricultural commodity produced in the state accounting for 25% of the state total exports (Sumner et al., 2016). The total impact of the industry to the California economy totals 21.5 billion dollars of revenue. The State of California is the number one global producer in the world contributing 80% of the world almond supply (Sumner et al., 2016).

Almonds are a high valued food crop in California. The almond industry is growing larger each year. Since 2008 in which the USDA NASS/PRO estimated that there were 640,000 of bearing acres to over 1,000,000 of bearing acres in 2018 (USDA, NASS.2018). The USDA NASS 2016 estimates that almond value per acre to be $5,487 in the 2016/2017 year (USDA, NASS.2018). Compared to corn in the 2016/2017 production year in which the USDA NASS/PRO estimating the value of corn production per acre to be $425.59 (USDA, NASS.2018).

Tree nut snacks like almonds, and alternative dairy products, like almond milk, continue to rise in popularity with global consumers. The industry is responding in a positive way by growing the number of acreage over the past 10 years by replacing stone and pome fruit acreage in the Central Valley. New growers are entering the industry yearly, and the industry continues to face challenges from pest and disease pressures as the acres grows. Increasing the education of not only new growers but improving the practices of current growers, aims to make the industry more sustainable by implementing best practices.

TOPIC SELECTION

I decided to choose a learning module because I recently moved to the California Central Valley. Born and raised in the Midwest and being educated in corn and soybean universities my knowledge of growing specialty crops (vegetables, fruit, vines, and tree nuts) was limited to a hobby garden I kept in my backyard. I thought that
choosing a learning module would provide me an opportunity to learn more about one of the most important crops in the Central Valley. Almonds in California are expanding in acreage each year, and quickly becoming one of the most important commodities California produces. Given the economic importance of the crop and growing acreage, I thought that choosing to focus my topic on almonds made sense not only providing personal growth for myself, but also provide value to my local working group and customers I work with.

**WHY A LEARNING MODULE?**

I thought that learning about and showing the entire production of an almond orchard would be a good way to demonstrate the management and planning to not only producers, but also consumers. Consumers are especially vigilant these days in demanding more information on where their food is coming from and learning about how the food is being grown. Many people eat and consume almonds, or almond products as a snack, beverage or meal, however many people do not know how the crop is produced in an agricultural system.

The large diversity of crops being grown in the Central Valley limits the number experts you can find in single region. Many growers seek out guidance from Certified Crop Advisors and Pest Crop Advisors to help make expert guided decisions during the growing season. A learning module I believe will be a good way to educate interns, farm managers, temporary workers, and customers with important and changing aspects of the almond cropping system.

Things change yearly at times and production manuals are only updated approximately every 10-20 years.

Many general agronomic practices will not change from year-to-year. However, for new interns and farm staff the module will serve as an introduction to general crop care and cropping system milestones that should be reached during each growing year. I have a number of book resources and contacts from the almond industry and production farmers that can help with proper documentation as well as provide subject matter expert advice on the almond production system. My contribution will be to organize and
centralize the information in a user-friendly learning module that will provide up-to-date cultural practices as well as current problematic pest and disease updates.

ABOUT THE LEARNING MODULE

The module intends to be a comprehensive overview of the entire almond production system from planning to harvest. The first chapter of the module covers an introduction of the origin and importance of the crop to California. Almonds originated from the lower mountain slopes and deserts of central and southwest Asia. They primarily are bitter seeded, however, early civilizations selected for the sweeter varieties to be grown in cultivation. Early settlers brought almond trees to the California Central Valley and found that the trees thrived in the climate in the region. The Spanish missions were able to establish the tree in the Central Valley until the mid-1800’s when other growers in the Central Valley were recorded to have established orchards in the northern Sacramento Valley (Micke, 1996).

The second chapter of the module overviews almond tree growth and development. Rootstocks are the foundation of a highly productive orchard. There are two techniques for rootstock propagation which include seed or vegetative propagation. Hybrid rootstock varieties, like peach-almond or plum-almond hybrids, are changing the industry by capitalizing on natural nematode resistance or increased plant vigor (Micke, 1996). Land preparation and different orchard design advantages are discussed then planting, and immediate post planting management are covered. The most in-depth subsection in chapter two describing variety selection, and the number of characteristics that need to be considered when choosing the varieties to be planted.

An overview of the crop phenology is provided showing an outline on the tree’s lifecycle. The reproduction is more complex than an annual crop. The second-year wood is the fruit bearing wood so, the reproduction cycle is a compound 2-year cycle where the previous year’s management impacts the current year’s yield producing potential.

Chapter three focuses on nutrient management and deficiencies in almond trees. Trees need a continuous supply of nutrients and photosynthates in order to maintain a healthy tree and good fruit production. Although deficiencies do happen, the most
common deficiencies in California are N, Zn, and K. Boron deficiencies are common on the east side of the valley and boron toxicities can occur on the west side of the valley (Micke, 1996). Advisors and growers use various ways to diagnose nutrient deficiencies. The first being visual observations, soil samples and analysis, and leaf samples and analysis. For the diagnosis of N deficiency, the leaf sample and analysis are the most reliable way to determine the status of plant available N rather than soil sampling where unavailable N can potentially give an inaccurate picture of N soil status (Micke, 1996).

The fourth chapter covers the irrigation management and considerations that need to managed. Almond trees can use up to 54 inches of water per year. The approximate average rainfall amount in the Central Valley is around 11.5 inches per year (Micke, 1996). This is far less than the amount required for almond trees to be highly productive so managing the irrigation is important for the achieving the desired yield. The most common way to design a watering schedule is to use the evapotranspiration index minus any rainfall plus any system losses (Micke, 1996). During the summertime in the Central Valley, the temperature soars over 100 degrees Fahrenheit, and considering that water resources are limited, growers need to identify the allowable depletion amount to conserve water reserves.

The fifth chapter is about harvest. Topics like the timing of harvest and how to manage the two different varieties planted in the field. The stages of nut maturity and what stages of nut maturity to look for as signs for potential harvest times. As well as, the “how” of the field operation and equipment sequences of nut shaking, blowing sweeping, pickup, and eventual delivery to huller. Nut quality is the most important characteristic to protect at harvest. Consideration of the shake timing and the amount of time spent of the orchard floor is the most important thing to think about when planning the timing of harvest.

The sixth chapter is pertaining to overall orchard management. Orchard management is quite different than growing row crops, and orchards require special tasks that meet their unique needs. Training of the primary limbs and pruning tasks are critical for maintaining the longevity and health of a tree. During the first pruning after
planting, the three primary limbs should be selected. The secondary limbs are selected during the second season then, from that season onward each year the trees should be pruned and shaped to protect them from splitting, uprooting or damage from harvest shaking (Micke, 1996). Sanitation is another specialized task unique to managing orchards covered in the sixth chapter. The most important practice is the removal of mummy nuts following harvest. Mummy nuts are the leftover nuts that remain either on the tree or on the orchard floor after harvest (Micke, 1996). Mummy nuts harbor the navel orangeworm pest that is the most economically damaging pest to almonds. The yearly task of knocking the leftover nuts still hanging from the tree and removing those nuts from the orchard is performed to reduce potential pest pressure the following year.

The eighth chapter gives an overview of some of the most important diseases in almond production, and how to manage them. In some years, disease pressure and management efforts are much more intensive. The variable responsible for the inconsistency is the weather particularly the amount of precipitation. For good disease management, maintaining a monitoring program with weekly scouting events to monitor disease progression throughout the season is important for timely intervention if needed.

Chapter nine focuses on important insect in the almond production system. All parts of the almond tree can be attacked by insects including the wood, leaves, and fruit. One of the most damaging insects, navel orangeworm, affects the fruit. Near hull split the insect lays its eggs near the suture split, and it larvae bores through the hull feeding on the nutmeat (Strand, 2002). The damage the larvae inflicts on the nut renders enough damage to make the nut unsellable resulting in decreased yield for the grower.

A good insect management program involves regular scouting during the target insect active period to monitor their populations. The monitoring of the insect population should result in better decision making better targeted control methods.

**VALUE OF THE MODULE**

The learning module is valuable for a number of reasons. The first reason being the module is a great introductory tool overviewing the key aspects of the entire almond production system in the California Central Valley. Orchard management is much
different than that of row crops requiring special tasks, a much longer growing season, and much higher harvest quality standard required by the end consumers. The pest and disease management is much more intense, and a robust scouting and monitoring program should be used to help make better control decisions.

The module will serve as an educational tool for educating research staff and interns coming to work at the research farm. There are usually 40-60 different crop types growing on the farm at one time. This module can serve as a teaching tool about almonds, one of the most economically important research crops being grown on the farm.

SUMMARY

The intended use of this module is for an educational reference for those interested in the almond production system in the California Central Valley. As the acreage in California continues to grow educational material will aid in educating the consumer about the growing of their favorite nut snack. Today’s consumer is demanding more openness and knowledge as to how their food is being grown. The California Almond Board is the advocate protecting the industry from misrepresentation in the media, aiding growers to achieve California’s agricultural sustainability initiatives, and implementation of industry best practices. Also, as consumer tastes change and global markets expand, the demand for almonds and almond products will likely increase, meaning larger number of acres in need of good stewardship. Grower education needs to continue to be a priority to ensure lasting protection the industry, and production practices for future generations.
REFERENCES


REFERENCES CONT.


APPENDIX A

Permission granted for photo use

Brandi Payne <bpayne30@gmail.com> Mon, Dec 31, 2018 at 6:18 AM
To: fruitsandnuts@ucdavis.edu
To UC Davis Fruit and Nut Research and Information Center
My name is Brandi Payne I am a graduate student at Iowa State University and I am preparing to complete my creative component/thesis entitled Almond Production in the Central Valley, which will be completed by February 1st, 2019. I would like your permission to include the following images from your organization that is posted on this website for my creative component. I would like to use the following images with your permission: URL: http://fruitsandnuts.ucdavis.edu/pages/almond/

I understand that you control the rights to this image. The use of this image will be used for educational and/or training purposes and will be published on a digital repository. You will be given credit for all the images taken above.
I would be very grateful if you could grant permission for use of this image, stating any credit lines that you require. If you do not control these rights, please let me know to whom I should apply.
If you have any question or concerns, please feel free to contact me @ bpayne30@gmail.com
Thank you for considering this request.
Brandi Payne

Fruits and Nuts <fruitsandnuts@ucdavis.edu> Mon, Jan 14, 2019 at 10:59 PM
To: Brandi Payne <bpayne30@gmail.com>
Hi Brandi,
Sorry, I marked this email as "get back to" and I didn't get back to it. Feel free to use those images for your thesis.
Thank you for asking.
Fruit and Nut Research and Information Center
Department of Plant Sciences

Office: 
E-mail: 
Web: http://fruitsandnuts.ucdavis.edu
Twitter: @FruitandNut_UCD
Facebook: https://www.facebook.com/ucfnric/
APPENDIX A

Brandi Payne <bpayne30@gmail.com> Mon, Dec 31, 2018 at 7:14 AM
To Joe Connell
My name is Brandi Payne I am a graduate student at Iowa State University and I am preparing to complete my creative component/thesis entitled Almond Production in the Central Valley, which will be completed by February 1st, 2019. I would like your permission to include the following images from your organization that is posted on this website for my creative component. I would like to use the following images with your permission: URL: http://ccfruitandnuts.ucanr.edu/files/239294.pdf
I understand that you control the rights to this image. The use of this image will be used for educational and/or training purposes and will be published on a digital repository. You will be given credit for all the images taken above. I would be very grateful if you could grant permission for use of this image, stating any credit lines that you require. If you do not control these rights, please let me know to whom I should apply.
If you have any question or concerns, please feel free to contact me @ bpayne30@gmail.com
Thank you for considering this request.
Brandi Payne

Dear Brandi,
As far as I'm concerned you're welcome to use the images posted on the fruits and nuts website contained in my pruning PowerPoint. Of the photos shown below the one of the split mature tree is one I recall taking personally. The other image of the first year trained tree is one where I was unable to locate the original. I may or may not have taken it but I also don't have any information that it was taken by someone else.
Sincerely,
Joseph Connell, Farm Advisor Emeritus
UC Cooperative Extension, Butte County

Brandi Payne <bpayne30@gmail.com> Sat, Dec 15, 2018 at 11:22 AM
To: daviddoll01@gmail.com
To Mr. David Doll
My name is Brandi Payne and I am preparing to complete my creative component/thesis entitled Almond Production in the Central Valley, which will be completed by February 1st, 2019. I would like your permission to include the following images from your organization that is posted on this website for my creative component. I would like to use the following images with your permission: URL: http://thealmonddoctor.com/
APPENDIX A

I understand that you control the rights to this image. The use of this image will be used for educational and/or training purposes and will be published on a digital repository. I would be very grateful if you could grant permission for use of this image as soon as possible, stating any credit lines that you require. If you do not control these rights, please let me know to whom I should apply.
If you have any question or concerns, please feel free to contact me @

Thank you for considering this request.
Brandi Payne

David Doll <daviddoll01@gmail.com> Sun, Dec 30, 2018 at 12:06 PM
To: Brandi Payne <bpayne30@gmail.com>
Brandi,
Hopefully you are doing great.
I dont have an issue with the use of these images, as long as credit is given to either the website or to me.
Thank you for asking. Have a great New Year!
David

Brandi Payne <bpayne30@gmail.com> Mon, Dec 31, 2018 at 7:02 AM
To: Jewanert@ucanr.edu
To University of California Department of Agriculture and Natural Resources
My name is Brandi Payne I am a graduate student at Iowa State University and I am preparing to complete my creative component/thesis entitled Almond Production in the Central Valley, which will be completed by February 1st, 2019. I would like your permission to include the following images from your organization that is posted on this website for my creative component.
I would like to use the following images with your permission: URL:
I understand that you control the rights to this image. The use of this image will be used for educational and/or training purposes and will be published on a digital repository. You will be given credit for all the images taken above. I would be very grateful if you could grant permission for use of this image, stating any credit lines that you require. If you do not control these rights, please let me know to whom I should apply.
If you have any question or concerns, please feel free to contact me @

Thank you for considering this request.
Brandi Payne
APPENDIX A

Danielle M Lightle <dmlightle@ucanr.edu> Fri, Jan 11, 2019 at 11:36 AM
To: "bpayne30@gmail.com" <bpayne30@gmail.com>
Cc: Jeannette Ellen Warnert <jewarnert@ucanr.edu>

Brandi,

You are welcome to use the images. The photographer is myself (Dani Lightle). If you need the originals, let me know.

Best,

Dani

Brandi Payne <bpayne30@gmail.com> Mon, Dec 31, 2018 at 6:04 AM
To: bhanson@ucdavis.edu

To Mr. Bradley Hanson

My name is Brandi Payne I am a graduate student at Iowa State University and I am preparing to complete my creative component/thesis entitled Almond Production in the Central Valley, which will be completed by February 1st, 2019. I would like your permission to include the following images from your organization that is posted on this website for my creative component.

I would like to use the following images with your permission: URL: https://ucanr.edu/sites/PAWMB/A/Gallery/

I understand that you control the rights to this image. The use of this image will be used for educational and/or training purposes and will be published on a digital repository. You will be given credit for the images taken above. I would be very grateful if you could grant permission for use of this image, stating any credit lines that you require. If you do not control these rights, please let me know to whom I should apply.

If you have any question or concerns, please feel free to contact me @

Thank you for considering this request.

Brandi Payne

Brad Hanson <bhanson@ucdavis.edu> Wed, Jan 2, 2019 at 8:03 AM
To: Brandi Payne <bpayne30@gmail.com>
Cc: Brad Hanson <bhanson@ucdavis.edu>

Hi Brandi,

You are very welcome to use those images in your thesis. For attribution, you can use something simple like “Photos courtesy of Brad Hanson, University of California-Davis” (or similar).

Best regards,

Brad

Bradley D. Hanson, Extension Weed Specialist
Plant Science Dept.; University of California, Davis
office: [number]
email: [email]
web: http://hanson.ucdavis.edu/
APPENDIX A

blog: http://ucanr.org/blogs/UCDWeedScience
twitter: @UCWeedScience

****Contacted this company twice with no response on 12/31/2018 and 01/11/2019****

Brandi Payne <bpayne30@gmail.com> Mon, Dec 31, 2018 at 6:55 AM
To: agromillora@agromillora.com

To Agromillora
My name is Brandi Payne I am a graduate student at Iowa State University and I am
preparing to complete my creative component/thesis entitled Almond Production in the
Central Valley, which will be completed by February 1st, 2019. I would like your
permission to include the following images from your organization that is posted on this
website for my creative component. I would like to use the following images with your
permission: URL: https://twitter.com/rootpac?lang=en
I understand that you control the rights to this image. The use of this image will be used for
educational and/or training purposes and will be published on a digital repository. You will be
given credit for all the images taken above. I would be very grateful if you could grant
permission for use of this image, stating any credit lines that you require. If you do not
control these rights, please let me know to whom I should apply.
If you have any question or concerns, please feel free to contact me @

bpayne30@gmail.com

Thank you for considering this request.
Brandi Payne

Brandi Payne <bpayne30@gmail.com> Fri, Jan 11, 2019 at 9:45 AM
To: agromillora@agromillora.com

To Agromillora
My name is Brandi Payne I am a graduate student at Iowa State University and I am
preparing to complete my creative component/thesis entitled Almond Production in the
Central Valley, which will be completed by February 1st, 2019. I would like your
permission to include the following images from your organization that is posted on this
website for my creative component. I would like to use the following images with your
permission: URL: https://twitter.com/rootpac?lang=en
I understand that you control the rights to this image. The use of this image will be used for
educational and/or training purposes and will be published on a digital repository. You will be
given credit for all the images taken above. I would be very grateful if you could grant
permission for use of this image, stating any credit lines that you require. If you do not
control these rights, please let me know to whom I should apply.
If you have any question or concerns, please feel free to contact me @

bpayne30@gmail.com

Thank you for considering this request.
Brandi Payne

****Contacted the Board twice with no response on 12/31/2019 and 01/11/2019****
APPENDIX A

Brandi Payne <bpayne30@gmail.com> Mon, Dec 31, 2018 at 7:08 AM

To: [Redacted]

To The California Almond Board

My name is Brandi Payne I am a graduate student at Iowa State University and I am preparing to complete my creative component/thesis entitled Almond Production in the Central Valley, which will be completed by February 1st, 2019. I would like your permission to include the following images from your organization that is posted on this website for my creative component. I would like to use the following images with your permission: URL: http://www.almonds.com/

I understand that you control the rights to this image. The use of this image will be used for educational and/or training purposes and will be published on a digital repository. You will be given credit for all the images taken above. I would be very grateful if you could grant permission for use of this image, stating any credit lines that you require. If you do not control these rights, please let me know to whom I should apply.

If you have any question or concerns, please feel free to contact me @ bpayne30@gmail.com

Thank you for considering this request.

Brandi Payne

Brandi Payne <bpayne30@gmail.com> Fri, Jan 11, 2019 at 9:43 AM

To: [Redacted]

To The California Almond Board

My name is Brandi Payne I am a graduate student at Iowa State University and I am preparing to complete my creative component/thesis entitled Almond Production in the Central Valley, which will be completed by February 1st, 2019. I would like your permission to include the following images from your organization that is posted on this website for my creative component. I would like to use the following images with your permission: URL: http://www.almonds.com/

I understand that you control the rights to this image. The use of this image will be used for educational and/or training purposes and will be published on a digital repository. You will be given credit for all the images taken above. I would be very grateful if you could grant permission for use of this image, stating any credit lines that you require. If you do not control these rights, please let me know to whom I should apply.

If you have any question or concerns, please feel free to contact me @ bpayne30@gmail.com

Thank you for considering this request.

Brandi Payne
Almonds Production in the California Central Valley

Brandi N. Payne
Author Profile

Author Name: Brandi N. Payne
Professional Title: Senior Research Associate
Affiliation (Company / Department): Corteva Agriscience

Current professional work / research interests:

I have spent my professional career working for Corteva Agriscience. Most of my time has been spent working in research and development for corn. I started my career working at a breeding station in the Midwest managing yield trials then in 2015, I decided to take a new direction moving into a role of a Trait Introgression Biologist on the Island of Molokai where I managed the building and growing of traited corn inbred projects. In 2018, due to the merging of Dow and Dupont I have taken another new direction in my career by taking a position as a Senior Research Associate in Predictive Ag for specialty crops in Fresno California. My research now mainly focuses on transformational sciences and field based development of digital solutions for specialty crop growers. Digital agriculture is an emerging area of agriculture that is integrating new technologies and historical/real-time environmental and farm generated data to help farmers make better management decisions. Some of the things I have done in the past year include the development of predictive pest models, using in-field sensors, multispectral imaging, and robotic/mechanization of agricultural processes.
Introduction
Almond Tree Growth and Development
Nutrition Management
Irrigation Management
Harvest
Overall Orchard Management
Diseases
Pests
Summary

Almonds in Bloom. Photo Courtesy of David Doll
Introduction

History

Originated from Central and Southwest Asia deserts and lower mountain slopes like those of Turkmenistan, Uzbekistan, Tadzhikistan, Kirghizia, Iran, and Afghanistan.

Predominately bitter seeded, early civilizations selected sweet kernel varieties to bring under cultivation. Almond cultivation spread throughout the Mediterranean adapting the plant to drought and poor soil environments. Early colonists brought almonds to the U.S, but they misunderstood the need for cross-pollination, disease and frost problems prevented almonds from being established.

It was the Spanish missions that found they thrived in the California Central Valley, and were home to some of the most significant plantings of the tree in the early 1800’s. The earliest orchard on record was along the Bear River in the foothills of the Sacramento Valley in 1843.
Introduction
California Almond Facts and Economic Impacts

California’s 2017 almond acreage was estimated at 1,330,000 acres with an estimated 1,000,000 acres were bearing and 330,000 acres were non-bearing. An estimated 2018 of bearing at 1,070,000 acres. The total impact on the value of California output, including direct, indirect, and induced economic output, is about $21.5 billion.

The whole almond industry, including processing and marketing, generates about 104,000 jobs statewide. Almonds generate about 15% of the value of California farm output and almost 25% of agricultural exports.
Introduction

California Almond Facts and Economic Impacts

The U.S. remains #1 in global almond production with 1.33 million acres. Spain’s almond acreage is the largest in the world, averaging 1.4 million acres, however, it produces a lower average yield compared to California. In 2018, the largest almond crop ever produced in California totaled 2.32 billion pounds. Since 1976, almond average yield have more than doubled.

1976 ≈ 1,100 pounds/acre
2017 ≈ 2,270 pounds/acre

Fresno, Kern, Stanislaus, and Merced cultivars total 64% of the statewide almond bearing acreage, producing over 1,000,000 pounds of almonds annually.
Introduction

California Almond Facts and Economic Impacts

Almonds are a part of a healthy diet. The most marketed health benefit being the heart health benefits for maintaining a healthy blood cholesterol and body weight.

Global interest has increased and the almond market continues to expand across the globe. Four new country approvals, Japan, Germany, Mexico, and Italy, came in 2017 and exploratory markets opened in South America.
Almond Tree Growth and Development

Root Stock Propagation

Rootstocks are used to insure successful orchard establishment. Properly chosen rootstock offers characteristics of improved anchorage, disease or nematode resistance, yield, nutrition uptake, and tolerance to soil conditions.

There are two techniques nurseries use to generate rootstock for transplant by seed or by vegetative propagation (clonal). Producing rootstock by seed is difficult, so the industry standard is vegetative propagation by hardwood cuttings. Workers will go out to a stock block around October-November to cut and collect 0.5-1.0 diameter sections of 1-year old wood using pruning shears.

The sections will then be defoliated and the wood cut into 12-16 in. long pieces. The basal end of the cuttings will be dipped into rooting hormone and the cutting will be planted 6 in. deep and 6 in. apart. Later, they will be joined with a chosen almond variety using budding or grafting.
Almond Tree Growth and Development

Root Stock Propagation cont.

As the industry evolves, Peach-Almond hybrids are the newest rootstock quickly becoming the most commonly used in California.

The first generation of the hybrid is produced by cross pollinating an almond tree and Nemared peach tree. Almond and hybrid seeds are produced. The seeds are collected and replanted, then the almonds are rogued out and the hybrids are kept.

The advantages of the hybrid is that they offer 100% nematode resistance, drought tolerance, deep rooting, high vigor, tolerance to calcareous soils, fewer mummy nuts and better anchorage. They are produced using both seed and hardwood cutting propagation.
Almond Tree Growth and Development

Planting - 2-3 years of non-bearing

Prepping the field requires several passes with equipment. San Joaquin soils have a cemented hardpan, therefore deep ripping is critical. Typically, the site is cross ripped on 4 or 5 foot centers. A typical prep schedule would be: deep rip, disc, cultivator, scrape, level then berm formation. Fumigation could be an additional step, if needed.

When the tree holes are dug, a wire is stretched across the top of the berm marking and centering the holes. A typical orchard design is 24 x 24 feet spacing in square design.

Planting can happen by hand or machine. Trees must have the uppermost roots just under the soil surface. Tree holes are only deep enough to accommodate tree roots. Plant spacing should be adjusted depending in the soil fertility.
Almond Tree Growth and Development

Planting - 2-3 years of non-bearing

Traditionally, the square planting has been the standard planting design that growers use in the central valley. The advantage of using a square orchard design is the ease of management for cultivation, mowing, and harvest. However, the disadvantage of a square design is tree crowding before the canopy is closed.

As things change in agriculture, improvements in mechanization are changing how almonds are being grown. A new design being used is high density hedgerows on a trellis which allows for mechanized harvesting resulting in reduced shaking injury.

Mechanical harvest of high density hedgerows. Photo courtesy of @RootPac
After planting, an irrigation event with 2-5 gallons of water will occur to help settle the trees in the holes.

Workers will then cutback the newly transplanted trees to 28-30 inches in height leaving on 3-4 branches with 1-2 bud per branch. This prepares the tree structure for developing the primary scaffolds of growth.

Each tree is then staked and a trunk protector is wrapped around each tree.

No fertilizer should be applied until the tree is established. Once the tree is established spring and summer fertilizer applications should occur to encourage strong growth.
Almond Tree Growth and Development

Variety Selection – a critical choice

All almond varieties will have an initial non-bearing period of 2-3 years after transplant and a bearing orchard can remain productive for **20-25 years**.

Things to consider when selecting an almond variety:
- Time of bloom
- Pollen compatibility
- Time of maturity
- Ease of nut removal
- Marketability
- Resistance to...
  - Pest
  - Disease
  - Other disorders

Nonpareil is the #1 planted variety in the Central Valley.

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Table 1. Time of Bloom

<table>
<thead>
<tr>
<th>Early (-6 &amp; earlier)</th>
<th>Early Mid (-5 to -1)</th>
<th>Mid (0 to +2)</th>
<th>Late Mid (+3 to +4)</th>
<th>Late (+5 to +7)</th>
<th>Very Late (+8 &amp; later)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jordanolo&lt;br&gt;Nel Plus Ultra</td>
<td>Millow&lt;br&gt;Pearless&lt;br&gt;Sonora&lt;br&gt;Winters</td>
<td>Aldrich&lt;br&gt;Carmel&lt;br&gt;Fritz&lt;br&gt;Harvey&lt;br&gt;Jeffries&lt;br&gt;Merced&lt;br&gt;Nonpareil&lt;br&gt;Price&lt;br&gt;Sauret#1&lt;br&gt;Solano&lt;br&gt;WoodsColony</td>
<td>Butte&lt;br&gt;Carrion&lt;br&gt;Drake&lt;br&gt;LeGrand&lt;br&gt;Monarch&lt;br&gt;Monterey&lt;br&gt;Norman&lt;br&gt;Sauret#2&lt;br&gt;Tokyo</td>
<td>Livingston&lt;br&gt;Mission&lt;br&gt;Mono&lt;br&gt;Padre&lt;br&gt;Ruby&lt;br&gt;Thompson</td>
<td>Planada&lt;br&gt;Ripon</td>
</tr>
</tbody>
</table>


Note: This table is based primarily on results of the Mission Regional Variety Trial. The numbers in the column heads indicate the days before (-) or after (+) peak Nonpareil bloom.
Almond Tree Growth and Development

Variety Selection – The Considerations

**Time of Bloom** - Growers typically match two varieties that bloom close together to allow for the maximum flower receptivity overlap increasing the bee tendency of flying between the two varieties.

**Pollen Compatibility** - Almonds are notoriously poor self-pollinators. Almond varieties are categorized into groups similar to heterotic groups in corn. A group of almond varieties will contain the heritage line and its mutants like a family tree. Since almonds do not self pollinate well, two varieties selected from the same family will not be a suitable choice to choose when considering pollen compatibility.

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**Table 2. Pollen Compatibility**

<table>
<thead>
<tr>
<th>Nonpareil</th>
<th>Mission</th>
<th>Ne Plus Ultra</th>
<th>Thompson</th>
<th>Carmel</th>
<th>Solano</th>
<th>Monterey</th>
</tr>
</thead>
<tbody>
<tr>
<td>IXL</td>
<td>Ballico</td>
<td>Merced</td>
<td>Granada</td>
<td>Carmel</td>
<td>Eureka</td>
<td>Monterey</td>
</tr>
<tr>
<td>Jefferies*</td>
<td>Languedoc Mission</td>
<td>Ne Plus Ultra</td>
<td>Harvey</td>
<td>Carrion</td>
<td>Jefferies*</td>
<td>Butte</td>
</tr>
<tr>
<td>Long IXL</td>
<td></td>
<td>Norman</td>
<td>Mono</td>
<td>Jefferies*</td>
<td>Kapareil</td>
<td>Jefferies*</td>
</tr>
<tr>
<td>Nonpareil</td>
<td></td>
<td>Price</td>
<td>Robson</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profuse</td>
<td></td>
<td>Ripon</td>
<td>Sauret#2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tardy</td>
<td></td>
<td>Rosetta</td>
<td>Thompson</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>WoodsColony</td>
<td></td>
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</tbody>
</table>
Almond Tree Growth and Development

Variety Selection – The Considerations

**Time of Maturity** - Since there are two different varieties in the field, time of maturity should be considered for efficient management of harvest, well timed post-harvest irrigation, post-harvest disease and pest sprays, and timely orchard sanitation practices.

**Ease of nut removal** - This is critical for efficient harvest without injury to the trees and the decrease of mummy nuts that can increase overwintering of disease inoculum and can harbor Navel Orangeworm – the most destructive pest in almonds, that reduces the quality of nuts and increases nut damage reducing yield.

**Marketability** - When producing food the consumer’s taste and demand for quality plays a big part in the management decisions. Having a variety that is in high demand will pay more per pound than a variety that consumers do not care for. Nonpareil is the most marketable nut and is used in products were the whole nut is visible and is what consumer want in nut products.
Almond Tree Growth and Development
Overall Crop Phenology

The growing season is long in the Central Valley, approximately 9 months. The second year wood is the production wood for fruit development.

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dormant</td>
<td>Bud swell</td>
<td>Green tip</td>
<td>Bloom</td>
<td>Pink</td>
<td>Petal fall</td>
<td>Fruit development</td>
<td>Suture development</td>
<td>hull split</td>
<td>harvest</td>
<td>dormant</td>
<td></td>
</tr>
</tbody>
</table>
Almond Tree Growth and Development

Planting to Production – 2-year reproduction cycle

The first season in the reproduction cycle is all about wood growth establishing bearing potential. The spurs and shoot are developed then they rest until chilling hours requirements are met. The second season is establishing reproductive and yield potential. The flowering bud potential will awaken in July from the previous year to begin differentiation and rest for needed chilling hours though the winter until February the following spring.

When growing almonds the previous year spur and shoot development directly effects this years flowering potential which is essential for yield potential. The second year wood is the only wood that is fruit bearing each season.

YEAR 1
WOOD

YEAR 2
WOOD

Dormant Spur. Photo taken by Brandi Payne
Almond Tree Growth and Development

Planting to Production – 2-year reproduction cycle

During the second season once chilling hours are met, the flowering buds will emerge and bloom in February. Bees are essential for high pollination success. Contractors from 30 different states bring bees in for the pollination season in the Central Valley. Post pollination and after nut drop is when the kernel development occurs that determines any potential defects, size, shape, and weight of the nut.
Nutrition Management

Deficiencies in Almonds

Almond trees require a continuous supply of photosynthates and elemental nutrients for the continuous growth of a healthy tree. A deficiency of an essential nutrient can lead to the interruption of plant and fruit growth.

There are several different ways growers use to monitor or diagnose nutrient problems. The three most commonly used tools are visual observations, soil analysis, and leaf analysis.

Once the visual symptom appears in the tree, the affect on the tree health and yield will already have been effected.

The soil analysis and leaf sampling analysis tests are critical for monitoring the balance of nutrients to ensure adequate nutrient availability to achieve maximum tree and fruit growth. The most common deficiencies in California are N, Zn, and K. Boron deficiencies are common on the east side of the valley and boron toxicities can occur on the west side of the valley.
Nutrition Management

Signs of Nitrogen Deficiencies

The sandy loam soils of the California Central Valley are prone to nitrogen loss by leaching or volatilization.

One of the most reliable ways to determine the nitrogen status of a tree is to use a leaf sample analysis. Sufficient nitrogen concentration levels should be in the 2.2-2.5 percentage range. Symptoms of early nitrogen deficiency are small, pale yellowish leaves, and less than normal shoot growth.

The canopy foliage could be sparse. Then in the fall, the tree could senesce early and defoliation could happen earlier than normal. The picture above shows yellowing foliage from nitrogen stress after a large rain event.
Low Zinc is one of the most common deficiencies in California. Symptoms usually appear early in the season.

Overall, the growth of the tree will appear variable. There will be an observed delay of the vegetative and flowering buds opening causing late bloom resulting in poor pollination. The vegetative buds will have small chlorotic deformed leaves that appear in tufts.

Terminal dieback can occur. Nuts on deficient trees are much smaller than normal resulting in reduced harvest quality.

Correcting Zn deficiencies after symptoms are observed can be done with two applications applied two weeks apart of 10 lbs Zn/100 gal. water per acre. However, maintaining a good soil sampling analysis and winter / spring fertility program are the best prevention.
Nutrition Management

Signs of Potassium Deficiencies

Young trees are most susceptible to potassium deficiencies. Trees will start showing symptoms in late spring to early summer. Leaves will become pale green and the shoot and leaves will be smaller in size compared to a healthy tree.

In severe cases, the tips and margins of the leaf become necrotic showing “Viking’s prow” which is when the leaf tip curls upward. The worst symptom is reduced nut size which will decrease the quality of harvest.

To avoid K deficiencies, a good soil analysis coupled with leaf tissue analysis is a good way to monitor the availability and presence of K in the orchard. Applications of potash or other K fertilizer should be applied to keep the leaf tissue analysis results in a range of 1.4%-1.6% for best results. K levels higher than 1.6% can actually lead to yield reduction, if K fertilizer is applied in excess.
Nutrition Management

Signs of Boron Deficiency

The sandy soils of the California Central Valley often see signs of boron deficiency in tree nut crops. Moderate boron deficiency does not show any foliar symptoms. However, it is usually identified by low fruit set and high rates of nut drop. The tree will put on excessive vegetation with low or no fruit productivity. In some varieties, the endocarp of the nut will have a gummy brown spot areas and gum may extrude out of the nut surface.

In some varieties, the buds may form blossoms but never set nuts and the spurs that develop during this time will be nonproductive. In extreme cases, the embryos of the affected nuts could abort causing all the nuts to drop before June resulting in the loss of the entire crop. The leaves will display tip scorch, with the leaf tips curling upward causing defoliation.

Hull samples for boron analysis should be taken at harvest to determine if spring boron fertigation application is needed. Hull sample analysis values should range from 100-160 ppm in a sufficiently fertilized tree.
Irrigation Management

The Fundamental Principles of Irrigation

Almond trees can use up to 54 inches of water per year. The approximate average rainfall amount in the Central Valley is around 11.5 inches per year. This is far less than the amount needed for an almond tree to be highly productive.

Developing a water budget to balance the gains and losses of water in an orchard is the technique many Central Valley growers are using. The use of new technology, like soil moisture sensors, are used to check the accuracy of the water schedule.

The water budget uses the crop Evapotranspiration Index (ETc) minus the effective rainfall plus system losses.

\[
\text{Water Budget} = \text{ET}_c - \text{effective rainfall} + \text{system losses}
\]
Irrigation Management

Allowable depletion

The heat of the Central Valley during the summer can average in the 100+°F through July and August. The Evapotranspiration Index will outpace the ability to replace the water in the soil profile.

Allowable depletion is a safe depletion amount of total water percentage in the root zone guarding any yield reduction. The typical root zone of an almond tree is around 3-5 feet called the root ball.

Determining the amount of allowable depletion will depend on the soil type, soil texture, and the weather demand at which the rate of total water percentage in the root zone is decreased. In most cases in the Central Valley, a 50% depletion of total available water content is reasonable while still safeguarding yield.
Irrigation Management

Avoiding Water Stress During Key Growth Cycle Times

The Central Valley has limited water resources so, growers must avoid water stress at the wrong time during the plants growing cycle. There are three critical times that water stress should be avoided, the early spring, during nut development, and post-harvest.

In the early spring, the trees require little water and the evaporative demand is low so deficit irrigation should be avoided. During this time, the trees are in need of carbohydrates to fuel early season vegetative growth. Rapid leaf growth is needed to maximize the tree’s photosynthesis capabilities.

Stress during nut development should be avoided to prevent kernel abortion, partially filled or shriveled nuts. The full length and growth should be complete by early June. There is a two month period between mid-June and harvest when deficit irrigation timings will only result in modestly lower kernel weights and reduced hull splitting.
Irrigation Management
Avoiding Water Stress During Key Growth Cycle Times

Approximately **2-3 weeks before harvest**, full irrigation watering should start again. Helping to improve hull splitting and avoid too much depletion of the soil profile water content.

Visually monitoring the tree for plant health and signs of stress should happen regularly to avoid premature defoliation and nut drop reducing yield.

The third key time to avoid water stress is **post-harvest**. Almond trees are not tolerant of water stress post-harvest. Watering just before harvest and immediately post-harvest should occur to avoid interruption of flower bud development for the next year’s production cycle. Water stress during this time could reduce potential yield for the next year.

Post-harvest irrigation event. Photo Courtesy of David Doll
Almond Harvest

Timing

Young trees will experience their first commercial harvest in the fourth growing season.

Exposing the young trees to a shaker too early could cause damage to the trunk. Depending on the tree’s maturity, a grower should estimate a harvest date and schedule the last pre-harvest irrigation event.

There must be approximately 2 weeks of no irrigation prior to harvest to minimize any bark damage incurred by the shaker. The tree bark will tighten as the moisture in the soil depletes causing the tree to be less prone to damage.
Almond Harvest

Stages of Nut Maturity

**Hull Split**: The first sign of nut maturity is an indented V followed by a opening of the ventral suture of the hull. This happens about 30 to 45 days prior to harvest. The fleshy outer hull will completely open revealing the inner shell enabling the drying process to increase during the last month.

**Abscission**: The forming of the separation zone between the fruit and the peduncle. Once fully formed, the nut is only hanging onto the tree by a few remaining fibers. This makes the nut easily detached from the tree at harvest during shaking.
Almond Harvest

Harvest Timing

Typically, there are two varieties planted in every orchard which adds a layer of complexity. Growers will plant one row of variety A, then the next row of variety B alternating the entire field.

There are two harvest events. The varieties will be shaken and harvested separately to avoid mixing of the two nut varieties. Identifying the right time to shake the tree is needed to achieve maximum nut removal.

Shaking the tree when the nuts are too green or too dry will result in too many nuts remaining on the tree. A good shaking time will result in 99%-100% of the nuts being removed from the tree. Typically, the hull and kernel moisture will be below 10% at harvest. Hull and kernel moisture drops rapidly after hull split in mid-July. By mid to late August, the hull will be below 20% moisture.
Determining when to send the equipment into the field, growers will test the trees by manually shaking the limbs by hand to see how easily the nuts are removed from the limb. If the grower likes the results from the test, he will usually bring the shaker into the field and do a test shake on 1 or 2 tree. If 99% of the nuts are removed on the test trees, then it is time to harvest.

Other things the grower is checking for are signs of damage to the tree by the shaker, like tears in the bark, wet bruises, wet lines on the shaker pads or when tapping on the bark a hollow sound is returned.

Hollow bark could indicate that the shaker damaged and lifted the bark from the wood of the trunk. If a grower observes these signs on the test trees, harvest will be delayed to avoid damaging the trees by the shaker.
Almond Harvest

Harvest timing

After shaking, a sweeper-blower will come in behind the shaker to move the nuts off the berm and sweep the nuts into windrows for drying.

The nuts will remain on the orchard floor for drying for anywhere between 1-2 weeks. When the nuts are ready to pick up from the ground, the grower will use a pickup machine that runs over the top of the windrows picking the nuts up from the ground and placing them into a trailing wagon which holds them for transport to the huller.

Once at the hullers, the nuts will be fumigated and stored indoors until they are hulled and sent to the processor.
Almond Harvest
Potential Damage

Harvest time is a critical time for potential crop damage. Crop damage can result in lower USDA quality scores at the processor, docking the grower on his price per pound.

Rain at harvest time is an annoyance. If rain is forecasted shaking should be avoided until the threat has passed. If rain occurs when nuts are already in windrows, the nuts need to have the contact with the ground broken to circulate air and remove any trash or litter from the tops of the piles.

Using a rake or blowing the piles around will help circulate the air and dry the nuts out again avoiding any mold problems or the nuts sticking in the mud. Navel orangeworm is one of the worst pests in almonds and is most active at harvest time. The larvae eat the kernel causing damage. The worm damage allows for aflatoxin to develop contaminating kernels.

Almonds the final product for consumers. Photo courtesy of The Almond Board
Overall Orchard Management
Training Young Trees

Pruning after the first growing season will ultimately determine the shape and performance of the tree. The first pruning will determine the primary scaffolds (main limbs) which will form the framework of the tree. All non-primary limbs should be removed during the first pruning.

There are three goals to the first pruning of young trees. The first being the selection of primary limbs with as much space between them as possible. Wide spacing ensures the best chance of strong branch attachment that will not split as the tree matures. A balanced framework with three limbs oriented about 120 degrees apart will provide the best chance of reducing the chance of splitting branches, leaning trunks, and crossed limbs during the first heavy crop. The ideal primary limb attaches to the trunk and grows at a 45 degree angle.
Overall Orchard Management

Training Young Trees

The second goal is to **limit the primary scaffolds**. No tree should have more than 3 primary limbs. More than three primary limbs could limit access to shaking equipment at harvest. The tree could become too large for trunk shaking due to excessive growth.

The third goal is after the primary scaffolds have been selected, **all other non-primary limbs should be removed**. Leaving some small lateral branches on the selected primary limbs will promote growth and be the first to develop spurs and produce nuts.

During the second season pruning, the secondary scaffolds are chosen (2 per primary limb). A secondary branch is an upright lateral branch that forms a ‘Y’ off the primary limb. Pruning of any other limbs that would compete with the selected scaffolds should be removed as well as any badly crossed branches.
Overall Orchard Management

Orchard Sanitation

Sanitation is one of the most important management tools for pest control due to the long productive life of an orchard. Keeping the orchard floor, especially around irrigation nozzles, clean of unwanted weeds will ensure proper watering of trees and reduce possible crown rot or vole infestations. Removal of bird nests will reduce crop destroying birds. Removal of stumps and brush piles will limit refuge for ground squirrels and risk for wood boring insects.

However, the most important practice is the removal of mummy nuts following harvest. Mummy nuts are the leftover nuts that remain either on the tree or on the orchard floor after harvest. Field crews should be sent out with poles to knock off any remaining nuts left hanging on the trees. The mummies on the orchard floor should be blown to the middle of the row to be destroyed or left to deteriorate. A level of two or fewer mummies per tree should be achieved in order to reduce overwintering sites for Navel orangeworm.
Almond Diseases

Major Almond Diseases- Phytophthora Root and Crown Rot

*Phytophthora* *spp.* (Phytophthora) is a fungal disease that kills more almond trees in California than any other disease. It does not require wounds to penetrate a host and occurs during cool to moderate soil temperatures and excessive water conditions. Root and crown rots disrupt uptake and transport of water and nutrients from the roots.

**Symptoms:** Rotting of the root and crown, and trunk or branch cankers with excessive gumming. A slow decline of the overall tree health leading to the eventual collapse and death of the tree. The bark and outer wood of infected roots are reddish-brown, firm, and brittle.

**Control:** Phytophthora management can be done with proper watering to avoid accumulation of water around the crowns of trees. Low areas in an orchard with potential for flooding and standing water should be left unplanted or have drainage installed. Irrigation sprinklers should have a low angles or water guards that directing the water away from the trunk. Once the disease is present in an orchard, it is nearly impossible to eradicate, so prevention is the best control measure.
Almond Diseases
Major Almond Disease - Ceratocystis Canker

*Ceratocystis fimbriata* (Ceratocystis Canker) a fungal disease develops on trunks and branches that have been damaged by equipment, pruning or mechanical shakers. The disease is always associated with bark injuries.

**Symptoms**: Elongated water-soaked area with amber colored at the margins. Infected bark turns dark brown and sunken. Gum balls are the biggest differentiating feature of this type of canker. Ceratocystis canker grows slowly through the entire year usually from the site of a wound.

**Control**: The most effective form of control is to avoid any form of injury to the trunk or scaffolds. Avoid pruning before rainy weather when possible. If a canker develops, there is a possibility to cut out removing the infected wood best performed during December-February. Insect vectors and pathogen are less active during this time of year.
Almond Diseases

Major Almond Disease - Bacterial Blast

The occurrence of this bacterial disease *Pseudomonas syringae pv. syringae* (Bacterial Blast) is entirely dependent on the weather conditions. The ideal conditions for disease development are cold and rainy during the bloom period. Water spreads the disease, so early blooming almond varieties are most susceptible. These varieties are most likely to be damaged by frost during blooming allowing entry for the pathogen.

**Symptoms:** The disease will appear during or shortly after bloom killing buds, blossoms, shoots, and young leaves. Buds and blossoms will turn black and fall off the tree. The leaves will develop dark spots that rot out leaving a hole in the leaf. Spurs and young shoots could die leaving dead wood with black leaves and flowers in need of removal from the tree.

**Control:** Since the disease can be unpredictable and weather condition dependent the control measures are minimal. The only chemical control to fight this disease is a copper spray application which can be phytotoxic to the plant and is not recommended. Protecting the blossoms from frost injury is really the best control measure for bacterial blast.
**Almond Diseases**

**Major Almond Disease - Shot Hole**

*Wilsonomyces carpophilus* (Shot Hole) is the most widespread fungal disease on the west coast. It only infects the current season’s growth, and is most severe in long periods of wet weather.

**Symptoms:** Small brown spots or lesions will emerge on the fruit, blossoms, twigs, and leaves. During early stages of the disease the lesions are surrounded by a zone of light green/yellow tissue. Later, the leaf tissue in the lesions dies turning light brown surrounded by a dark margin and eventually falling out leaving a “shot hole” in the leaf. Sometimes the tissue remains intact, developing a fruiting structure for spore production in the center of the lesion. Similar lesions can also develop on twigs and fruit.

Shot hole symptoms. Photo courtesy taken by Jack Kelly Clark
Almond Diseases

Major Almond Disease - Shot Hole

**Control**: Control measures for shot hole involve a robust monitoring program during the spring and fall. If the disease is identified in the fall, an application of fungicide the following spring during petal fall can help treat the infection. If there is no infection identified in the fall, a fall fungicide application can be applied as a preventative then, no spring fungicide treatment would be necessary.

Water increases the presence of the disease, so cultural control of reducing irrigation periods and never allowing sprinkler water to hit the base of the tree is a good preventative strategy.
Collectotrichum acutatum (Anthracnose) occurs sporadically throughout the Central Valley. Wet springs can exacerbate this fungal disease and in unusually wet springs, the disease can be a serious problem.

**Symptoms**: Tree indicators will be blossom blight, fruit infections, and dieback of foliage and fruit wood. Affected blossoms wither and turn dark. Fruit infections appear as circular, sunken, rusty-orange lesions on the hull. Symptoms will first appear about 2-3 weeks after petal fall. Infections on young fruit will kill the fruit causing the fruit to shrivel and turn rusty-orange. Infections on older fruit will cause amber colored gumming. Adjacent twigs to infected kernels can cause the twig to dieback causing dead wood.

**Control**: Orchards with a history of anthracnose, fungicide treatments are recommended during pink bud stage with a systemic fungicide. Then, a second fungicide application is made at full bloom using a mixture of a contact and a systemic fungicide different from the one used in the first application. Then every 10-14 days, applications should persist until the rain stops. Prune out any dead diseased wood and dead fruit after the season to reduce inoculum levels.
Almond Pests

Major Almond Pests - Navel Orangeworm

*Amyelois transitella* (Navel orangeworm), a moth species, is the **primary** insect pest in California almonds. This pest was discovered feeding on navel oranges, however, the preferred host for this insect is almonds, walnuts, and pistachios.

The adult moths are dull grayish with irregular silver-gray and black patterns on the forewings and legs. Larvae are milky white to pink with a dark brown head capsule having a pair of crescent shaped marks on the second segment behind the head. The first instar of the larvae damage the almonds by directly boring into the nut and feeding on the nutmeat.

Each generation lasts approximately 2 months and, there are 3-4 generations per year depending on temperatures. Larvae overwinter in mummy nuts remaining in the orchard after harvest. Feeding and development will continue through the winter and new brood moths will emerge in March or April.
Almond Pests

Major Almond Pests - Navel Orangeworm

Management: Having a good orchard sanitation program removing the mummy nuts after harvest or harvesting soft shell varieties early are two good cultural controls that should be used to reduce Navel orangeworm populations. Good sanitation standards are achieving an average of 2 or less mummies per tree. Orchards with an average greater than 2 should apply an early spring egg lay insecticide spray.

Properly timed insecticide sprays at May egg lay, hull split, and post-harvest should be used as a part of an IPM monitoring program. A new technology being rapidly adopted is the use of mating disruption pheromones that disorient the male in search of a female aiding in population management when paired with a well executed insecticide program.

Navel orangeworm adult moth. Photo courtesy of Jack Kelly Clark
Almond Pests

Major Almond Pests - San Jose Scale

*Quadraspides perniciosus* (San Jose scale) inflicts mainly deciduous trees. The expansive acreage of almonds throughout the state make almonds a major host.

San Jose scale emerges as mobile crawlers from beneath the adult female scale cover. They are tiny and bright yellow approximately the size of a pin head. When they locate a good feeding site they will settle losing their legs, eyes, and antennae. They secrete a waxy substance that covers the body called the “white cap stage” which later turns darker called “dark cap stage.” Males emerge as winged adults and females remains wingless. There are 3-4 generations per season lasting 7-8 weeks per generation.

The pest damages the trees by sucking plant juices and, injecting toxins in the tree contributing to the death of twigs, limbs, and to the overall decline in tree vigor, growth, and productivity.
Almond Pests

Major Almond Pests - San Jose Scale

**Management:** Insecticide sprays of broad spectrum products or oil can be sprayed during dormancy or in the spring depending on the level of infestation.

There are many natural enemies that can keep San Jose scale under control so any insecticide product should be chosen that will not disrupt the beneficial populations. A low to moderate population of scale can be managed with oil sprays during the dormant season. Broad spectrum insecticide should only by used on high population due to the impact on beneficial populations. A good IPM monitoring program should be established to monitor the populations and take actions when needed.
Almond Pests

Major Almond Pests - Peach Twig Borer

*Anarasia lineatella* (Peach twig borer) is a major pest in almonds and stone fruit in California. This pest has a relationship with the other major almond pest Navel orangeworm; after the fruit is damaged by the Peach twig borer, it is the preferred fruit for egg laying of the Navel orangeworm.

The nocturnal adult moth has gray-mottled forewings with a snout-like projection from the head. The females lay eggs on the twigs, fruit, and leaves. Larvae are small brown caterpillars with white intersegment bands and a black head capsule. The larvae cause shallow channels and tiny grooves on the nutmeat. They also burrow into the tips of growing shoots causing damage, wilting, and shoot death. Larvae overwinter in tiny cells called *hibernacula* which look like tiny chimneys of frass. They also bore into the 1-4 year old wood or, in bark crevices of the trunk. There are four generations per year.
Almond Pests

Major Almond Pests - Peach Twig Borer

**Management:** A good IPM monitoring program should be in place to determine the population of this pest. Early spring monitoring program should look for tip strikes during bloom and shoot strikes during April. Populations are considered moderate to high when scouting if there are four or more strikes per tree easily spotted in multi areas in a mature orchard. Control actions should be considered.

The preferred time to spray insecticides are during dormancy with non-organophosphates, however, spring sprays at larval emergence, during the growing season or at hull split should be considered if needed. Avoiding bloom sprays is a good practice in efforts to reduce bee mortality. Typically, one well timed targeted spray can provide sufficient control.
There are four species of mites that cause damage in Central Valley orchards. The pest depends on the weather conditions, cultural practices, and the level of predators. The web spinning species *Tetranychus urticae* (two-spotted), and *Tetranychus pacificus* (Pacific spider mite) are the most wide spread through out the entire Central Valley.

The red or orange oval shaped adult females over winter under bark scales, on ground litter or orchard floor vegetation from year to year. Male mites are much smaller, and do not over winter. In the spring, females emerge and feed on young almond leaves. Females will lay their eggs on foliage underside, and their color will range from yellow to green, to black during the season. There are 8-10 generations per season. Mites damage the leaf by sucking cell contents from the leaves. Evidence of tree mite populations can be identified by leaf stippling, yellowing, and eventual defoliation.
Almond Pests

Major Almond Pests - Mites

Management: The dry, low humidity, high temperature Central Valley summers provide ideal conditions for mite populations to increase rapidly. Growers should take in consideration important cultural controls like avoiding dusty field conditions, maintaining good ground cover, avoiding water stress, and disrupting beneficial species with broad spectrum insecticides. Using a good IPM monitoring program with weekly monitoring from May to August will help identify infestation early which is key to whole orchard control.

Use of oil sprays during dormancy or miticide treatments in hot spot or whole orchard treatments, if needed, depending on populations throughout the season. Be particularly aware of protecting the beneficial species if the decision is made to use pesticides. Insects like the lacewing or the sixspotted thrip are mite predators that can have a profound effect on keeping mite populations under control.
Almond Pests

Major Almond Pests - Ants

There are many different kinds of ants found in orchards, however, the most destructive species are the *Solenopsis xyloni* (Southern fire ant).

The **Southern fire ant** is 0.07-0.25 inches long with an amber head and thorax with black abdomen. The ants swarm vigorously when disturbed, and deliver a painful sting to predators. Their nests are usually located in clumps of weeds, or on the edge of the irrigation circle on the top of berms. They are most active in the morning and sunrise. The ants cause the most damage after the trees have been shaken and the nuts are drying on the orchard floor. Varieties with soft open shells are the most easily damaged. The ants can enter the shells eating and hollowing out the meat of the nut leaving only the outer shell.
Management: Monitor in the spring, April-May, for ant activity to identify the population level. If ant activity is present, bait application for control should be applied shortly after to ensure control of the insect population early. An easy way to spot ant hills is after an irrigation event because the soil will be freshly disturbed at the top of the mound.

Good weed management throughout the season should be maintained. Limiting the time the nuts dry on the orchard floor is important for protecting the harvest from ant damage.
Summary

Sustainability initiatives continue to gain traction throughout the industry. So the implementation of IPM management techniques, evapotranspiration driven irrigation scheduling, and air quality dust reduction will be important tools helping to protect the industry from controversy for future generations. As well as, provide industry safeguards to future climate change events.

The learning module aims to help potential growers interested in planting their first almond orchard, or current growers identify key times during the planning, or seasonal lifecycle when management decisions will need to be made to protect the yield and quality of their crop. Growing almonds in production requires intense management and a high quality final product to meet consumer standards.

Consumer taste matters. Photo courtesy of the Almond Board of California
Summary

The long life of growing almonds in the Central Valley requires intensive planning from orchard design, and cultivar selection to bearing years overall orchard management. Decisions early on in the planning process has a 20-year consequence if not researched properly or executed purposefully.

The learning module provides a good format for a quick synopsis of the overall production system for employee training, grower learning or public education.

Consumers or new potential growers interested in how their food products are produced on the farm should find this format easily readable and informative about the intense management practices, quality, and care put into almond production.
References


1. Where did almonds originate from?
   a. Central and South East Asia
   b. Middle East
   c. Central and South Africa
   d. Eastern Europe

2. What percentage of total California commodity exports are made up of almonds?
   a. 10%
   b. 45%
   c. 30%
   d. 25%

3. What are the two techniques nurseries use to propagate almond rootstock?
   a. Seed and banding propagation
   b. Seed and vegetative propagation
   c. Seed and grafting propagation
   d. Seed and transferring propagation

4. Peach-almond hybrids offer an advantage of being 100% ____________.
   a. Blight resistance
   b. Canopy coverage
   c. Nematode resistance
   d. Band canker resistance

5. A typical orchard design is 24 x 24 feet spacing in ____________.
   a. Square design
   b. Block design
   c. Rectangular design
   d. Row design

6. A new orchard design being tested in production is?
   a. Square design
   b. High density hedgerow design
   c. High density rootstock design
   d. Mechanical row design

7. What are two factors a grower should consider when selection a variety to plant?
   a. Flower shape and nut size
   b. Pollen production and tree size
   c. Ease of nut removal and mummy removal
   d. Time of bloom and time of maturity
8. How long is the growing season in the Central Valley?
   a. 6 months
   b. 5 months
   c. **9 months**
   d. 8 months

9. How long is the almond tree reproduction cycle?
   a. 6 months
   b. 1 year
   c. **2 years**
   d. 3 years

10. What are the three ways growers use to monitor and diagnose nutrient problems?
    a. Scouting, soil analysis, and Mehlich 3 test
    b. Visual observations, nitrate test, and leaf analysis
    c. Visual observations, soil analysis, and foliar symptoms
    d. **Visual observations, soil analysis, and leaf analysis**

11. What is the most reliable way to determine nitrogen status?
    a. Soils analysis
    b. **Leaf sample analysis**
    c. Visual observations
    d. Soil survey

12. What nutrient deficiency is “Viking’s Prow” a symptom of?
    a. Potassium
    b. Nitrogen
    c. Zinc
    d. Boron

13. The water budget uses the crop ____________________ minus the effective rainfall plus system losses.
    a. Usage index
    b. Evaporation index
    c. **Evapotranspiration Index**
    d. Elevation index

14. ______________ is a safe depletion amount of total water percentage in the root zone guarding any yield reduction.
    a. Irrigation depletion
    b. Evaporation index
    c. Deficit depletion
    d. **Allowable depletion**
15. The typical root zone of an almond tree is around 3-5 feet and is called the ____________.
   a. Root zone
   b. **Root ball**
   c. Root round
   d. Root marble

16. Determining the amount of allowable water depletion will depend on the ____________, _____
    _____, and _______ at which the rate of total water percentage in the root zone is decreased.
    a. **Soil type, soil texture, weather demand**
    b. Soil type, soil texture, soil water
    c. Soil type, soil texture, precipitation
    d. Soil type, soil texture, temperature

17. How many critical times are there during the growing season that water stress should be avoided?
   a. One
   b. Two
   c. **Three**
   d. Four

18. What part of the growing season do the trees require the least amount of water?
   a. Post-harvest
   b. Nut development
   c. Bloom
   d. **Early spring**

19. The first pruning will determine the _________________ which will form the framework of the tree.
   a. Non-primary limbs
   b. **Primary scaffolds**
   c. Secondary limbs
   d. Cross Limbs

20. A balanced framework with three limbs oriented about _____________ apart will provide the best chance of reducing the chance of splitting branches, leaning trunks, and crossed limbs during the first heavy crop.
   a. 45 degrees
   b. 90 degrees
   c. 35 degrees
   d. **120 degrees**
21. The leftover nuts that remain either on the tree or on the orchard floor after harvest are called?
   a. Zombie nuts
   b. **Mummy nuts**
   c. Ghost nuts
   d. Moth nuts

22. What moth species is the primary insect pest in California almonds?
   a. **Navel orangeworm**
   b. Navel beetworm
   c. Peach twig borer
   d. San Jose scale

23. What are the names of the two stages of the San Jose scale?
   a. White cap stage and green cap stage
   b. White cap stage and dim cap stage
   c. **White cap stage and dark cap stage**
   d. White cap stage and down cap stage

24. What insect has 0.07-0.25 inches long with an amber head and thorax with black abdomen?
   a. Navel orangeworm
   b. Peach twig borer
   c. Mite
   d. **Southern fire ant**

25. A bearing almond orchard can remain productive for _________ to _________ years.
   a. 10, 15
   b. 1, 5
   c. **20, 25**
   d. 15, 20