Good Agricultural Practices Manual

Guidelines for

California Pistachio Growers

2009 Edition

California Pistachio Research Board

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INTRODUCTION

The California pistachio industry first developed a Good Agricultural Practices (GAPs) manual in 2000. Most of the guidance was adapted from the United States Food and Drug Administration's Guide to Minimize Microbial Food Safety Hazards for Fresh Fruit and Vegetables because that was one of the few available references for food safety guidelines. Virtually all references were concerned with meat, eggs, and fresh fruit and vegetables. At that time, there had been no reports of microbial contamination in tree nuts and, due to their low moisture content, tree nuts were thought to be largely immune from microbial food safety concerns. However, human illnesses were traced to Salmonella contaminated almonds, first in Canada in 2001 and again in 2004 in the US. The pistachio industry considered microbial contamination highly unlikely due to its growing and harvesting practices and the common practice of roasting. Despite these mitigating factors, salmonella was detected in pistachios in 2009 and, although no illnesses were conclusively linked to pistachios, over 16 million pounds of pistachios were ultimately recalled. This event has forced a fundamental reassessment of food safety in the pistachio industry from the farm through the processing of pistachios for sale as a ready-to-eat food. This will include the revised GAPs contained in this manual prepared by the California Pistachio Research Board. The CPRB has also prepared a Pistachio Producer Self Audit to help the pistachio producer identify and mitigate potential food safety risks during pistachio production.

The pistachio industry has historically focused on fungal contaminants, the associated mycotoxins, and chronic food safety risks. These revised GAPs will retain the earlier sections on aflatoxin risk while adding greater emphasis on managing the more acute microbial contamination risks.

Food safety risks in minimally processed dry products like almonds, pistachios, and peanuts are different from high moisture foods. Yet, there are still many similarities among crop production practices in different commodities and, thus, these guidelines incorporate aspects of microbial control found to be practicable and valuable in other crops.

A brief description of the California pistachio industry follows. This description is intended to describe the environmental conditions under which pistachios are grown, the horticultural techniques used to raise a pistachio crop through harvest, and to allow the reader a better understanding of potential sources of food contaminants in the field.

THE CALIFORNIA PISTACHIO INDUSTRY

Pistachios have been grown in California at least since the turn of the 20th century but the pistachio industry really began in the late 1960s when an appropriate variety (Kerman), a suitable pollinator (Peters) and good rootstock (*Pistacia atlantica* and *P. integerrima*) all came together. The industry has grown from the first commercial harvest in 1976 of 1.5 million pounds from 4500 acres to the 2007 production of 416 million pounds from 103,000 acres. Planting of new orchards has continued and in 2009 there are 112,000 bearing acres and 80,000 nonbearing acres which will gradually come into bearing over the next 5 years.

The California pistachio industry is located primarily in the southern San Joaquin Valley. Merced, Madera, Fresno, Kings, Tulare and Kern counties accounted for 97% of the production in 2006-2008. Most of the remaining production occurs in the Sacramento Valley. The growing season is typically hot and dry; daytime temperatures commonly exceed 100 degrees F. and rainfall between May and October is virtually absent. The city of Fresno is centrally located and the average daily high in July is 98F and the 30 year average for July precipitation is trace. Due to the lack of precipitation, all pistachios are irrigated. The most common irrigation method uses micro-irrigation technology including drip and micro-sprinklers; this is used on about 97% of the pistachio acreage. Of the remaining 3%, some are flood irrigated and small amount are irrigated using solid-set low angle sprinklers to prevent irrigation water from contacting nuts and foliage.

Pistachio trees typically bloom in mid April. There are both male and female trees, planted in a ratio of about 1 male per 24 females. The pollen is airborne and the female flowers do not require insects for pollination. Flowers and nuts are borne in clusters. A mature nut consists of a fleshy hull surrounding the nut shell, which in turn encloses the nutmeat. Following pollination the hull increases in size from smaller than a BB to its maximum size of about 1 cm in diameter by 1.5 cm in length by early June. The nut shell then begins to differentiate and harden until it is completely sized and hardened by early July. Only after the shell has hardened does the nutmeat begin to grow. As the nutmeat grows, it fills the shell and, by virtue of its growth exceeding the shell size, cracks the shell open. This creates the naturally opened nuts characteristic of pistachios. With rare exceptions, the hull remains intact during this entire process, protecting the nutmeat from insects and pathogens. The rare exceptions are nuts commonly called “early splits” where the hull and shell both split along the same suture, exposing the nutmeat. These nuts commonly become infested with navel

orangeworm and can be infected with *Aspergillus* fungi, a fungus that can produce a mycotoxin called aflatoxin. The early split process begins in early August and continues until harvest. The earlier the hull splits, the more likely infestation and contamination becomes. The shells on early split nuts are, however, frequently stained and discolored. This allows them to be removed with great success during post harvest processing.

Harvest normally begins in early September and may continue through late October. California pistachios are mechanically harvested. The tree is vigorously shaken and the falling nuts are collected on canvas-covered catch frames. Due to the vigor of the shaking, nuts sometimes fly beyond the frames; these nuts are not recovered and nuts that fall to the ground are left. The frames are angled such that the nuts fall onto a conveyor which transports them to harvest bins or trailers. Harvest workers do not handle the nuts during this entire process. The nuts are transported in bottom dump trailers to the processing facility where they are dehulled and dried. When harvested, the nuts are commonly about 30% moisture. The harvest process through preliminary drying to about 9-10% moisture takes less than 24 hours and commonly less than 16 hours. Final drying to about 5-7% moisture takes place in silos and may take an additional 2-3 days. At this point, the pistachios are a stable raw agricultural commodity.

Creating a ready-to-eat food from the raw commodity requires additional activities which are the subject of a companion guide to these GAPs, Good Processing Practices for Pistachios.

SOURCES OF POTENTIAL FOOD BORNE PATHOGENS IN THE PISTACHIO ORCHARD ENVIRONMENT

Our understanding of the origins and persistence of microbes in the agricultural environment that ultimately may contaminate food has changed considerably over the past decade. Organisms such as *Salmonella* and *E. coli* are normally inhabitants/pathogens of animal gastrointestinal systems and were thought to be poorly adapted for survival in agricultural field environments. However, the almond experience with *Salmonella* has indicated that these organisms can survive in the orchard environment for years, not the weeks or months previously thought. Combine the greater environmental persistence with data that suggests the minimum number of bacteria necessary to cause human disease is much closer to 1 than 100 and it is easy to see how what was previously a negligible issue has assumed much greater importance. In the following discussion, *Salmonella* will be referred to frequently but the comments pertain to microbial pathogens in general.

Salmonella bacteria have wide host ranges (they infect many different animal species) and infections do not always cause observable disease. One study estimates that one in five Germans are symptomless carriers of *Salmonella*! Because they have wide host ranges and animals defecate, *Salmonella* should be considered ubiquitous. However, if the number of *Salmonella* increases, the risk of contamination increases. Thus, we should be aware of what conditions may increase the populations of potential food borne pathogens in the orchard.

Contamination of pistachios by human pathogens in the orchard has never been demonstrated but, as a result of the recent Salmonella contamination, we recognize that it might occur. Given the lack of detection, any discussion of potential sources is theoretical and relies on guesswork and the experience of other commodities.

The use of the orchard site prior to development as a pistachio orchard may influence the initial level of potential pathogens. If the orchard site was “virgin” ground prior to its development as an orchard, the potential pathogen level is generally considered low. If however, the land was previously used for a confined animal feeding operation, the risk could be considerably higher. If the land was reclaimed for agricultural use by application of animal waste or municipal biosolids, the risk could also be greater but this may also be dependent on the condition of the applied wastes. It is important to remember that this is not a

quantitative measure but something each grower should be aware of when assessing total risk.

Adjacent land uses may also be important. Potential pathogens may be airborne in dust, domestic animals may stray into the orchard and defecate, there may be pathogen-contaminated runoff from adjacent animal operations – again, nothing quantitative but these factors can contribute to total risk.

Water sources should be considered as possible sources of food borne pathogens. Surface waters may contain animal fecal matter and wells can become contaminated with bacteria.

Wild animals as well as domestic animals have been identified as a source of pathogens in some disease outbreaks.

In many cases, the most significant source of foodborne pathogens may be animal wastes, particularly manures, that have been added to improve soil texture as well as for nutrients. The "quality" of these amendments varies widely and, while our concern is primarily food safety, animal manure-based soil amendments are not currently regulated for food safety but nutrient content.

There is little human contact with pistachios prior to and during harvest due to the mechanized nature of pistachio cultivation and harvesting. However, field workers must be provided with adequate sanitary facilities to insure that human waste does not enter the orchard.

Many of the potential sources of food-borne pathogens would increase the population numbers on the orchard floor. Because pistachios are harvested using shakers equipped with catchframes and pistachios are not gleaned from the orchard floor, there is no contact between pistachios and the potentially pathogen-laden soil. Nevertheless, pathogens may be "aerosolized" by various orchard activities including pest scouting, cultivation, spraying, and harvest and be deposited on the pistachios. Thus, it is important to consider all the activities in an orchard that could potentially contribute to pathogen contamination of pistachios.

RANCH HISTORY and ADJACENT LAND USES

As mentioned earlier, land use prior to orchard establishment and use patterns of adjacent lands can have food safety impact. Whenever possible, historical and adjacent land uses should be considered when choosing an orchard site. Pistachio orchards are long-lived and adjacent land uses will certainly change during the productive life of the orchard. The grower may have little control over the changing land use but awareness of potential problems may help determine if mitigation is need and what control options are most feasible.

PRE-ESTABLISHMENT CONSIDERATIONS

Many potential human pathogens are associated with animal manure and feces. Consequently, prior use of the orchard site for a confined animal feeding operation (feedlot, dairy, poultry farm, etc), pasture, or for other animal husbandry purposes may create food safety concerns. Similarly, reclamation of marginal lands for agricultural purposes by application of manures and municipal biosolid waste may also create concerns. These concerns are, to a significant extent, mitigated by the 6-7 years of orchard establishment before the first commercial harvest.

Mine tailings and industrial wastes frequently contain high concentrations of heavy metals such as lead, mercury, and arsenic. Waste sites tend not to be a concern in the pistachio production areas and, because these pollutants are not usually mobile in plants, they are a greater concern for root crops than tree nuts. Indeed, in some locations root crops have become contaminated with arsenic due to the use of arsenic-based insecticides nearly 30 years earlier. Regardless, surface contamination of pistachios would likely be removed with the pistachio hull in the dehulling process but, depending on the particular circumstances, other mitigation measures may be needed.

Prior use of a particular site as a landfill may lead to bacterial food safety concerns and may have broader ecological concerns, especially if agronomic practices breach the landfill containment structures. In the pistachio producing areas of California, landfill sites are well documented and make unlikely orchard sites.

Agriculture in the San Joaquin and Sacramento Valleys of California dates back to the Gold Rush days of the 1850s but many early agricultural enterprises were primarily ranching and small grain production. Intensive agriculture is a more recent occurrence, frequently dating back 75 or fewer years. Nevertheless, compiling an accurate history of prior uses of any particular piece of land may be difficult due to the lack of records from earlier enterprises. Fortunately, the more recent the enterprise, the more effect it is likely to have on current food safety concerns. Thus, it is not necessary to document all land uses over the last century but it is valuable to determine the land uses prior to establishment as a pistachio orchard.

The geography of the orchard site should be considered as well. Precipitation in the pistachio producing areas tends to be low, especially during the growing season, but storm runoff can become concentrated and flooding may occur. Water drainage patterns should be determined.

POST-ESTABLISHMENT CONSIDERATIONS

The productive life of a pistachio orchard is not known. While orchards have been removed due to conversion to other uses (primarily housing), we are not aware of any orchard that has been removed due to declining production as a result of age. Many people estimate that the productive life is over 70 years. Because pistachios are one of the most long-lived perennial crops, adjacent land uses are certain to change during the life of the orchard.

Pre-existing situations have likely been addressed in the years since orchard establishment. Because food-borne pathogens can enter the orchard through wind-borne dust, storm runoff, animals, etc., it is important to consider these potential pathogen sources as adjacent land uses change. Some sources may be outside the pistachio growers control while mitigation may be possible with others. Pathogens and pollutants are frequently spread by water. Runoff from heavy rains may impact orchards adversely, particularly if confined animal operations have been established since orchard establishment. Diversion berms, runoff control structures, and vegetation buffers may help prevent polluted water form contaminating the orchard. Potential hazards may not be apparent and maps are a valuable tool to help identify and prioritize risks. Maps should be prepared for each pistachio orchard, indicating adjacent land uses, prevailing wind direction, topography indicating storm runoff flows, and adjacent riparian zones and wildlife habitat. How far the map should extend from the orchard is

difficult to say because the mechanisms of microbial "transferrance" from one location to another are not known. In pesticide reports, growers are commonly asked about adjacent uses and are expected to know if their pesticide use creates a potential concern. Growers could use the same standard for identifying food safety risks as well as mark their map to show how distant hazards without all intervening uses.

It may seem that advice growers receive is sometimes at cross purposes, particularly with regard to wildlife. On one hand, growers are encouraged to set aside land for wildlife and to create wildlife habitat on their ranches with corridors that encourage animals to move between different areas. On the other hand, growers are warned of the food safety risks associated with animal ingress into their orchard and are told to prevent animal ingress. Similarly, diversified agriculture is encouraged under sustainability advice but the conflict it creates within food safety is rarely mentioned. Regardless, it is not the purpose of these GAPs to resolve these conflicts and we recognize that a sustainable agricultural production system must first and foremost be safe.

IMPLICATIONS

While we do not anticipate a food safety incident that would necessitate tracing product back to individual (or a subset of) growers, we cannot see the future. If such an incident were to occur, the investigative authorities, be they federal or state, would ask for a ranch history and a map of adjacent land uses. It may seem daunting to develop these but a good faith effort should be made to document history and land uses. It may not all come together in one year but it would be entirely appropriate to set some benchmarks for document development and append these to your history and land use map. It creates a goal and, hopefully, due diligence on the part of the pistachio producer.

WATER USAGE

Water use in pistachio production may involve several field operations but especially includes irrigation and the application of pesticides and fertilizers. There is no use of water in field harvest operations but water is used during the hulling/drying process. Water use in these off-farm harvest operations will be covered in a later section. Regardless, water can be a direct source of microbial contamination and it can spread a localized contamination source. Its potential as a direct source of contamination is related to the source and its quality.

AGRICULTURAL WATER SOURCES

Growers obtain irrigation water from a variety of sources including wells located on the ranch, surface waters delivered through streams, ditches, canals, and reservoirs and, less frequently, from municipal wells and recycled water from other agricultural and municipal sources. A single orchard frequently uses water from more than one source. The potential for pathogen contamination varies with the source, as does the susceptibility of irrigation water to on-farm contamination. Regardless of the water source, growers should limit the exposure of the nut to irrigation water. It has been thought that the hull would protect the nut meat from contamination but this is untested and bacteria may be carried by the hull into later processing steps. For this reason, limiting contact is the most prudent course of action.

Municipal water is not widely used for irrigation. Potable municipal supplies have few food safety concerns but the irrigation system should be inspected for potential contamination sites. Pumps, holding tanks, canals, and reservoirs should be closely examined to ensure that animals do not have access to these areas and the water is not subject to animal fecal contamination.

Well water may be obtained from deep wells or from relatively shallow wells. The potential for water contamination may vary with the sources and are influenced by surface activities. Growers should have their water checked periodically for chemical and microbial contaminants. Chemical contaminants such as nitrates may indicate excess fertilizer is leaching into the water supply and the amounts applied to the crop should be accounted for in a nitrogen nutrition budget. Pesticide residues in the water may indicate that chemicals are leaching around well heads and casings into the supply and microbial contaminants may indicate

that animal access to the well should be restricted. The California Department of Water Resources has indicated that it will be inspecting well heads to insure that the well is situated correctly to reduce the risk of flow into the well. Examining the well and correcting discrepancies prior to inspection is prudent. Regardless, pesticides and foliar fertilizer sprays should be prepared in an area removed from the well and the well should be equipped with anti-siphon devices to eliminate siphoning as a means of well contamination.

Growers should assess the potential for contamination of surface water when these waters are used for irrigation. Surface waters may be subject to intermittent, temporary contamination from upstream livestock operations, either from unrestricted access to the water by livestock, discharge of waste into the water, or by polluted runoff from heavy rainfall.

Recycled water from municipal sewage treatment facilities should be carefully examined to insure its suitability for irrigation. Growers should require proof from the supplier that the water does not contain potential pathogens as well as proof of a routine and credible testing program.

NON IRRIGATION WATER USES

Water is commonly used in pesticide and fertilizer applications. Spray water will of course come in contact with the pistachio nuts and that is intended for efficient pest control. Growers should assess the quality of water used in these applications and whenever feasible use potable water for these purposes. The quality requirements for potable water may not be feasible under field conditions, especially in some areas of the San Joaquin Valley prone to arsenic levels above the new EPA tolerances. However, our focus has been on microbial contaminants and verifying that spray water meets microbial contaminant tolerances is prudent.

TESTING AND TREATING WATER FOR MICROBIAL CONTAMINATION

Pistachio growers routinely treat water to insure it's suitability for use in micro-irrigation systems. This may not be treatment for microbial contamination but water seldom arrives at the ranch in condition to be used directly and treating water to insure its suitability is an accepted concept. For food safety reasons, the concept is being expanded to include microbial contamination.

A decade ago, there was no scientifically valid water quality testing program for microbial contamination of agricultural waters. That is still true today because little is known about the transference mechanisms from water to the crop in the field. Thus, we cannot say whether a particular level of microbes in the water creates a food safety risk and testing may not be useful for all growers. However, we would not normally expect to see microbial contamination in deep wells. Finding microbial contaminants in well water obligates the grower to find the avenue of contamination and close it as well as to treat the well water to eliminate the contamination that is present. There are a number of guides for treating wells for microbial contamination and methods from North Dakota State and Oregon State Universities are posted on line.

When should testing and treatment be done? Clearly, wells are used for irrigation and testing should be done before water is needed for irrigation. It may also be appropriate to test when the well is at the greatest risk for contamination, particularly during the rainy season when contaminants can be leached into the well through cracked casing and improperly positioned well heads. This also allows time for appropriate corrective action before irrigation demands arrive. Checking the water quality at the end of the growing season would allow the maximum time for correcting the problem. Water quality frequently encompasses many materials. In the case of food safety, treating the well to insure that the water meets potable standards with respect to microbial contaminants should be adequate.

IMPLICATIONS

As with Ranch History and Adjacent Land Use, documentation is critical. Water sources were noted on the ranch map created earlier and growers should conduct at least annual testing of each water source. Results should be documented for each individual source as well as whether corrective actions were needed and when they were undertaken.

FERTILIZER, MANURE, and MUNICIPAL BIOSOLIDS

Adequate plant nutrition is essential for commercial pistachio production. Nutritional programs commonly use commercially prepared inorganic fertilizers applied to the soil by broadcast or through the irrigation system or by foliar sprays. Properly treated manure (animal excrement and/or plant remains) or biosolids (treated sewage plant waste, primarily human excrement) can also be effective and safe fertilizers. In addition, soil organic matter is critical to soil health, nutrient availability, and water penetration; manures can be effective sources of organic soil amendments. However, untreated or improperly treated manure or biosolids may contain pathogens that could contaminate pistachios and pose food safety concerns. Application of fertilizers, manures, biosolids, and soil amendments are subject to a number of different regulatory schemes. Fertilizer and manure nutrient contents should be documented. Biosolids must be tested for pathogens and treated to reduce or eliminate them but manures from animal feces do not. Pistachio processors may have additional requirements or exclusions for biosolids, manures, and fertilizers. Growers need to follow good agricultural practices for handling manure and biosolids to minimize microbial hazards.

Regardless of the reason for application, growers should prepare a fertilizer "budget" based on expected plant nutritional needs for each growing season and insure that their fertilizer and manure applications are within plant needs. Excessive application of nutrients is uneconomical, can lead to lush growth that is more susceptible to disease and pests, and can cause ground and surface water pollution. Due to water pollution, the State of California is considering how to regulate application of manures. Additionally, with the current concern about greenhouse gases and global warming, growers should be aware that nitrogen application can lead to nitrous oxide emissions. Nitrous oxide has 300 times the potential of carbon dioxide as a greenhouse gas and also contributes to ozone pollution.

MICROBIAL HAZARDS

Manure and feces are significant sources of human pathogens. E. coli 0157:H7 originates primarily from feces of cattle, sheep, deer, and wild pigs. Other pathogens originating from human or animal feces include *Salmonella, Cryptosporidium, Shigella,* and hepatitis B. The orchard environment selects

against many potential pathogens but others may persist for extended time periods. Thus, manure and biosolids must be closely managed to limit potential pathogen contamination and reduce the risk of pathogen persistence and proliferation in the orchard.

Growers should also be aware that human or animal fecal matter may be unwittingly introduced into the growing area. Potential sources include used of improperly treated manure, livestock or poultry operations, nearby manure or biosolids use, and high concentrations of wildlife in the orchard.

Following GAPs may reduce the potential for microbial contamination. These practices focus on reducing pathogen introduction into the orchard as well as measures to reduce the potential movement of pathogens onto pistachios.

MEASURES TO REDUCE PATHOGEN INTRODUCTION INTO THE ORCHARD

Pathogens may be introduced into the orchard through water, runoff, and air pollution or through animal and human manure and feces. In previous sections, we discussed risks associated with water and adjacent land uses and the importance of assessing and documenting these risks. In this section, only manure and feces will be discussed.

A variety of treatments may be used to reduce pathogens in manure, biosolids and other organic materials. The treatments may be performed by the grower using material produced on the farm or by a third party (supplier). Treatment choices will depend on the needs and resources of the grower or the supplier. In general, treatments are either passive or active.

Passive Treatments

Passive treatments generally rely on environmental factors such as temperature and moisture fluctuations along with time to reduce pathogen populations. Holding times will vary depending on regional and seasonal climatic variations and the type and source of material. Growers relying on passive treatment must ensure that manures are well aged and decomposed before applying to the orchard; this will reduce the risk of manure application but not as much as properly performed active treatments.

Active Treatments

Pasteurization, aerobic and anaerobic digestion, and heat drying are examples of active treatments used to reduce pathogen populations in raw manure and biosolids. Composting, a controlled and monitored process, is probably the most widely used active treatment.

Composting should not be confused with passive treatments. The United States Composting Council under a grant provided by the EPA has established a manual of test methods for evaluating composts as well as a Seal of Testing Approval for composts that meet the testing standards. The USCC has an informative web page at www.compostingcouncil.org.

ACTIONS TO REDUCE MICROBIAL HAZARDS FROM MANURE

- Apply only actively treated certified manures whenever possible
    - Obtain records and analyses from the supplier on treatment parameters, nutrient and pathogen tests, treatment dates, and other analytical tests
- If composting is performed on the farm:
    - Actively monitor the process to ensure that all materials receive adequate treatment
    - Consider barriers to secure storage and treatment areas
    - Segregate composting from orchard equipment and/or develop standard operating protocols for cleaning equipment. Document cleaning!
    - Limit traffic patterns that could carry raw manure into the orchard.
- The quality of treated materials will vary. Maximize the amount of time between application of material to the orchard and harvest, paying particular attention to quality. Target preharvest intervals for application of manure for registered organic producers range from 120 days for crops that have soil contact to 90 days for crops that do not have soil contact.
- Incorporate the manure/compost into the soil as soon after application as possible and within the above PHI.

- As harvest approaches, avoid field activities that would potentially deposit microbe-laden dust on the pistachios.

Dairy lagoon waste should never be applied to pistachio orchards. In addition to the food safety concerns, the salt content and other organic matter in the liquid waste adversely affects soil and tree health.

BIOSOLID APPLICATION TO AGRICULTURAL LANDS

Biosolids are organic wastes from municipal sewage plants. Before the invention of the Fritz-Haber process of converting nitrogen gas into nitrogen fertilizer, human waste was widely used as a fertilizer and remains in use in many countries. Biosolids are regulated by the EPA under 40 CFR 503 and their application to agricultural lands is controversial. Biosolids are classified by the level of active treatment they have undergone and analytical records of their composition must be provided to the landowner when they are applied. These records must be maintained for several years after application. The microbiological impact of biosolids, especially those not thoroughly treated, are obvious but the heavy metal and salt levels present in biosolids is often not appreciated or understood. Soils treated with biosolids will require extensive leaching to remove the salts before planting – the salts may contaminate ground or surface waters and growers should consult with appropriate authorities to determine if this could affect the legality of the biosolids application.

The phytotoxic salt levels preclude application of biosolids to existing orchards and biosolids can only be considered before planting. Even so, anyone thinking of remediating marginal lands with biosolid applications should consult pistachio processors to insure that there will be a market for their product when the trees are ready for harvest.

IMPLICATIONS

Growers must have documentation for materials applied to their orchards. Application of biosolids requires documentation and certificates of analysis. Nutrient content of the applied manure should be documented. While there are currently no restrictions on soil amendments, it would be prudent to keep the same records as required for other applications. These include the supplier of the

material, the nature of the material, relevant test data, dates of active/passive treatments, date of application to the orchard, date of other activities done to incorporate the material, and expected/actual dates of harvest (preharvest interval).

PESTS and PESTICIDE USE

Pesticides include fungicides, insecticides, acaricides, and herbicides. Pesticides must be registered with both the EPA and the California Department of Pesticide Regulation (CDPR) and have a current label with pistachios listed as a site of application for legal use of the pesticide in a pistachio orchard. Pesticides may be registered under different sections of federal law; these registration sections are commonly called Section 3 (full registration), Section 18 (emergency registration) and Section 24c (special local needs). Regardless, the pesticide must be registered in California for pistachios to allow legal use.

California has among the most restrictive pesticide laws in the world and California farmers are obligated to follow these laws. Not only are the registration requirements frequently more limiting, but pesticides must be formulated to limit the emissions of volatile organic compounds (VOCs) and growers must report pesticide applications to the their county agricultural commissioner's office. The county in turn reports these applications to CDPR who publishes summary statistics of pesticide use in the state and county by chemical and/or crop. These reports are available on the CDPR website as Pesticide Use Reports. Thus, we can determine which pesticides are being used and to what extent and can track use of different chemicals over the years. We know, for example, that Guthion (active ingredient – azinphos methyl) use declined well in advance of its registration loss and that use of phosmet is declining. The use of reduced risk insecticides has increased significantly.

CDPR also has a Pesticide Information Portal (PIP) where the public can request information about pesticide applications. For example, it is possible to determine the calendar date(s) of specific pesticides on pistachios down to township/range/section (TRS) or to determine which pesticides were sprayed on a particular crop at a particular TRS.

Pesticides can impact food safety in any of three ways: residues of unregistered materials, residues above the legal tolerance, and microbial contamination of spray water. Unregistered materials may occur on pistachios due to chemical drift from adjacent lands, soil contamination by unregistered persistent pesticides, mistaken application or by purposeful application of an unregistered material. There is little a grower can do about drift from adjacent farms. A significant amount of pesticide applied in the orchard ends up on the soil and movement of pesticide from contaminated soil to the pistachio fruit, while

possible, is unlikely. Mistaken application (wrong orchard, wrong crop) and purposeful application cannot be separated except in those cases where the pesticide has an activity spectrum not needed on the crop. Regardless, the crop may be considered adulterated if residues are found in violation of legal tolerances.

The development process of pesticide labels should preclude above tolerance residues when the pesticide is legally applied. However, if the sprayer has not been accurately calibrated and the pesticide is being used at high rates, over application could result. It is important to accurately calibrate sprayers.

The quality of spray water can vary and pesticide applicators should monitor the source and quality of the water used for pesticide application. If possible, potable water from municipal sources should be used but this is frequently not feasible. While potable water standards limit a number of compounds that do not have food safety impacts as spray water, water quality should be tested to insure that the water meets potable microbiological standards.

PEST MANAGEMENT DECISIONS

The pistachio grower must make pest management decisions based on a wide variety of inputs and expected outcomes. The inputs may range from qualitative to quantitative and the outcome may not be easily measured, depending on the pest.

Integrated Pest Management (IPM) is a pest management philosophy that combines pest population levels, the presence and numbers of pest parasites and predators, predicted economic losses if left uncontrolled, and the cost of control to determine whether control is justified and environmentally sound. Decisions based on IPM are thought to be better based than older control methods based on calendar dates. Because parasites and predators frequently attack insects and mites while they are virtually unknown for pathogens, IPM has historically been more associated with insect and mite control.

Pathogens frequently respond fairly specifically to environmental conditions and an accumulation of weather conditions (temperature, humidity, and/or precipitation) is commonly used to prescribe fungicide applications. The fungicide prescription may be for a single application or can call for repeated applications on a set schedule.

The sensitivity of weeds to herbicides may vary with the age of the weed as well as the specific herbicide. Because some weeds may be insensitive to common herbicides, cultivation is also used to control weed infestations. Disking is commonly used but repeated disking can damage surface roots, increase susceptibility to pathogens such as Verticillium fungi, accelerate the loss of soil organic matter, and lead to soil compaction. Consequently, a mixture of herbicides and cultivation is used to control weeds.

IMPLICATIONS

Pesticides are seemingly essential to pistachio production, from weed control for efficient water and fertilizer use to fungicides for maintaining tree health and insecticides for protecting the nuts from pests. Pesticides must be used responsibly to insure food safety and this includes using registered materials in a legal manner and using the appropriate technologies (sprayer calibration and water testing). Like so many other activities in farming today, documentation is essential. This includes reporting pesticide use to CDPR and maintaining your own records of applications as well as maintaining records of sprayer maintenance and calibration and water testing and treatment.

AFLATOXIN and NAVEL ORANGEWORM CONTROL

Aflatoxin is a potent carcinogen produced by the fungi *Aspergillus flavus* and *A. parasiticus*. These fungi and aflatoxin have been found in a wide variety of foods and agricultural commodities including tree nuts, peanuts, figs, corn, cottonseed meal, rice, and spices. When fed a diet contaminated with aflatoxin, poultry and other animals develop liver disorders and die of acute poisoning. In humans, aflatoxin consumption is rarely acutely toxic and it acts more as a chronic toxin. Thus, it is associated with liver cancer, especially in the presence of other predisposing factors including alcohol and tobacco use as well as hepatitis. Aflatoxin contamination in food and animal feed is tightly regulated in the United States and in many other countries. The United States has an action level (maximum allowable concentration) of 20 ppb for human food and the State of California extends that tolerance to pet and animal food. The federal marketing order for pistachios currently regulates domestic shipments of pistachios at 15 ppb, the European Union at 4 ppb and the international tolerance as set by the Codex Alimentarius Commission is 10 ppb.

Aflatoxin was discovered in the late 1960s and the potential for aflatoxin contamination in pistachios was recognized internationally in the early 1970s. Aflatoxin contamination was the subject of a report to the California Pistachio Commission in 1979 and, since then, the pistachio industry has conducted extensive research on aflatoxin contamination. Results have been published in the annual CPC reports.

Aspergillus is a weak pathogen and cannot normally infect hull tissue. As long as the hull is intact, the nutmeat within is safe from *Aspergillus* infection. *Aspergillus* consequently relies on indirect methods to gain access to the nutmeat, particularly early splits and navel orangeworm (NOW, *Amyelois transitella*). Nuts damaged by early splits and NOW account for over 90% of the aflatoxin present in the pistachio crop at the time of harvest. Growers should consider practices that reduce the amount of *Aspergillus flavus* inoculum in the orchard, increase hull integrity, and control NOW populations in the orchard. Together, these practices will lower the risk of aflatoxin contamination.

REDUCTION OF INOCULUM

Aspergillus flavus overwinters as a spore in relatively small numbers in the orchard. As the weather warms, spores germinate and colonize organic matter on the orchard floor. Measurable increases in spore numbers become detectable in late June or early July. It is thought that spores are moved from the orchard floor into the canopy and into split nuts by wind and orchard traffic, particularly traffic that raises dust. Incorporation of organic material into the soil may influence *Aspergillus* population increases and limiting orchard activities that raise dust may also reduce colonization of nuts. (Limiting dust-raising activities is also recommended to reduce the movement of bacteria from the orchard floor to the nuts).

The industry is currently conducting field evaluations of nontoxigenic *Aspergillus flavus* to determine if it can displace isolates that produce aflatoxin and thus limit the potential of aflatoxin contamination. Nuts could become infected with *Aspergillus* but the nontoxigenic *Aspergillus* would not be able to produce aflatoxin.

INCREASING HULL INTEGRITY

Hull integrity can be breached by early splitting and by the natural senescence that occurs as the crop matures. The exact causes of early splits are not known but some cultural practices have been associated with increased incidence. In particular, water stress has been shown to increase the incidence of early splitting. In drought years or when water is difficult to access due to political considerations, some growers have sought to conserve by practicing “deficit irrigation”. This practice is also implemented when growers attempt to overcome a history of low splitting percentages. Regardless of the reason, early split incidence also increases and with it, increased navel orangeworm incidence and increased aflatoxin contamination.

Diseases, particularly Alternaria blight, and inadequate nutrition can hasten hull senescence and degradation.

Pistachio growers are paid more for split nuts than nonsplits and many growers believe that the splitting percentage increases the longer the nuts stay on the tree. There is no data to support this belief during the time the hull has reached physiological maturity and if it happens, it is not likely to be significant. Delaying harvest may thus slightly increase the splitting percentage but the splitting

percentage increases very slowly while hull degradation increases relatively rapidly. Consequently, the increased number of clean split nuts may be decreased by increased staining and increased insect damage and the increase in economic return may be largely illusory. In addition, the grower may lose significant crop due to nut dehiscence in wind storms Especially from the viewpoint of food safety but also from product quality, a delayed harvest has more downside potential than upside. Growers are urged to harvest earlier rather than later, with the realization that due to limited harvest equipment and hulling capacity, early harvest is not possible for all.

Growers with large acreages are urged to consider split harvest where a light shake is done to remove the earliest maturing nuts and a second shake is done to remove the later maturing crop.

CONTROLLING NAVEL ORANGEWORM POPULATIONS

Navel orangeworm (NOW) is a difficult pest to control, in part because monitoring the populations is difficult and in part because the NOW larva is protected by the nut from contact insecticides. NOW can overwinter in the orchard in mummy nuts, both on the ground and in the tree. NOW in tree mummies have higher survival rates than those on the ground and whenever possible, nuts remaining on the tree after harvest should be knocked to the ground. Disking the ground mummies to bury them or mowing them to destroy them after removing as many nuts as possible from the berm by blowing or raking will also decrease NOW survival.

NOW populations can increase dramatically when the pest has access to current season nuts. Pesticide applications should be considered in consultation with your Farm Advisor or pest consultant. In general, pesticides need to be applied in a protectant manner because these pesticides are not systemic and once the worm is in the nut, pesticides cannot reach it. Fortunately, many of the pesticides currently registered for pistachios and navel orangeworm are fairly persistent (up to 3 weeks) and sprays do not need to be made on a shorter rotation.

As important as NOW is in the pistachio aflatoxin paradigm, there is little data to support an aggressive control program. Many growers practice sanitation (removal from the tree) with some disking combined with early harvest and experience few if any NOW problems.

Current research hopes to develop a pheromone technique for monitoring NOW populations as well as for disrupting mate location and breeding.

IMPLICATIONS

NOW and aflatoxin are problems that originate in the field and have little or no opportunity to increase after pistachios are delivered to the handler. It is incumbent on the grower to understand and control these problems. Growers should review their cultural practices to help maintain hull integrity and consider various means to reduce NOW infestation.

HARVEST SANITATION

Pistachios are harvested fresh and must be "processed" rapidly, generally within 24 hours, before natural chemical processes and the release of tannins from the fleshy hull results in shell staining that preclude their sale as an inshell product.

Pistachio harvest is not precisely defined but, for these purposes, will be considered as the activities preparing field equipment (shakers, bulk loaders, forklifts, etc) for use, field preparation activities to allow equipment safe and efficient operation, shaking the pistachios from the tree and transport to the hulling and drying facility, and the hulling and drying operations necessary to create a stable raw agricultural commodity. Thus, harvest activities are both on-farm and off-farm; many of on-farm activities are commonly under the control of the grower while the off-farm activities are commonly under the control of the pistachio processor. All these activities can have significant impacts on potential microbial contamination.

ON FARM ACTIVITIES

Most growers do not own their harvest machinery and instead use the services of custom harvesters. Regardless, the orchard floor must be prepared for harvest. Harvest equipment is large and heavy and irrigation system leaks that create soft and muddy spots in the equipment drive lanes should be repaired. Low branches that would impede equipment need to be removed or propped out of the path. Dips in the drive lanes should be leveled. All these activities will lead to an increase in worker activity in the field and sanitation and hygiene should be a special concern. Areas designated for off-loading bulk harvesters or bins into trucks should be cleaned and leveled.

Equipment under the control of the grower should be cleaned and, if harvesting involves bins, bins should be cleaned and stored to protect from animal infestations and contamination with animal feces. Harvest bins are precisely that – bins used for harvest and not transport of chemicals, fertilizers, toxic substances, or even hulled and dried pistachios. Equipment cleaning in the field is problematic – rarely is there access to high pressure washes and steam cleaning. If washing is done, be sure that waste water does not drain into the orchard or into the well head area.

Removal of pistachios by shaking is done with equipment equipped with catch frames that prevent the pistachios from falling to the ground. Nevertheless, some pistachios do fall on the ground because they fall outside the catch frame, the catch frame has coverage gaps (especially around the tree trunk), or in transferring the pistachios from bins and bulk loaders into transport trailers. It is generally not cost efficient to rake or glean these pistachios. Contact with the ground may also contaminate the nuts with bacteria present in the soil or with manure/compost/animal feces that are present on the soil. In effect, contact with the ground has made the soil a food contact surface if these nuts are gleaned. It borders on the ridiculous to carefully control field activities to reduce potentially microbe laden dust contaminating the nuts on the tree and then turn around and throw a shovel full of dirt (and nuts) into the bin or bulk loader while gleaning the fallen or spilled pistachios.

TRANSPORT TO HULLING MACHINERY

Pistachios are transported from the orchard to the hullers in tractor-trailer rigs. Each trailer contains up to about 60,000 pounds of fresh in-hull pistachios. In the early years of the industry, there was some experimentation with different types of trailers and trailer walls and the current arrangement grew out of these experiments.

Transport time to the huller varies with the huller and orchard locations. Almost all California hullers are located in the southern San Joaquin Valley and over 90% of the production is within a two-hour transport time of these hullers. The remaining production is no more than 6 hours from the huller.

As mentioned earlier, pistachios must be hulled and dried within about 24 hours of shaking to prevent shell staining and degradation of other quality parameters. It is incumbent on the grower to insure that the trucks can be loaded promptly and within a narrow timeframe so the first harvested pistachios do not exceed the 24 hour hulling “window”.

OFF FARM HARVEST SANITATION

It is not the intention of the GAP manual to cover the steps from handler receipt of raw pistachios to storage. Some steps however, particularly flotation tanks, wash lines, and dryers have microbiological implications.

Pistachios are dehulled in various types of machines and immediately after hulling, are put in flotation tanks. These tanks separate nuts which have less than about 50% nut meats (immature nuts, insect damaged nuts, and blanks) from those that have greater amounts of nut meat. Those nuts with less than 50% meat tend to float while the others sink. The floaters are removed and handled separately from the sinkers. Anytime water is involved, the risk for bacterial contamination and proliferation is increased. This risk may be mitigated by adding various antimicrobial chemicals to the floatation tank water, monitoring the activity of the chemicals, and changing the water. The most commonly used chemical is hypochlorous acid (bleach) and to maintain suitable activity, the tank pH must be monitored to insure that it remains below pH 7 and preferably below pH 6. The antimicrobial activity of bleach can also be compromised if organic material levels of the water become too great. Research is currently being conducted in a number of commodities on other chemicals that may be more robust.

Sinkers are conveyed to dryers and, during the conveying, are washed with water sprays to remove any organic matter that may have adhered to the nut. While not currently practiced, the rinse line offers an additional step where an antimicrobial can be used to reduce microbial contamination.

At harvest, fresh pistachios are approximately 30% moisture. To create a stable agricultural commodity, the nuts must be dried to 7% moisture or less. At these low moisture levels, fungi and bacteria may survive but they do not proliferate. Fresh pistachios are dried in commercial dryers supplemented by natural gas or propane fired heaters. The drying process takes 6-8 hours and reduces the moisture to about 9%. The temperature profiles within the dryers have not been measured and their utility as a control step for reducing microbial contamination requires additional research. Preliminary research measuring total aerobic bacteria indicated that microbial contamination is reduced by about 100-fold during drying. Additional drying with forced ambient air supplemented as needed with natural or propane gas-fired heaters is done in the silo to reduce the moisture levels to 7% or less.

IMPLICATIONS

Pistachios must be removed from the tree, transported, hulled, and dried in an efficient and timely manner to maintain or improve their quality and microbiological safety. While much of the harvest process is not controlled by the

grower, the grower can facilitate harvest by ensuring that the orchard and loading areas have been adequately prepared.

SANITATION AND HYGIENE

Good sanitation and hygiene practices are essential at every link of the food production chain to reduce the risk of food contamination. Workers can transmit many food-borne illnesses if they do not know and follow good hygienic principles. The risk of transmission of potential pathogens in the orchard by direct contact is low because there is limited or no human contact but poor sanitation practices can put the crop at risk. While pistachio processors use a variety of techniques to reduce the risk of contamination, this should not be regarded as a license to ignore basic hygienic principles. Indeed, the techniques used by processors presupposes due diligence on the part of the grower.

LEGAL REQUIREMENTS

The United States Code of Federal Regulations Title 21, Section 110.10 prescribes hygienic practices in food processing. While these are not legal requirements in the orchard, growers should consider the standards in an overall hygiene and sanitation program. There are established health standards in the Occupational Safety and Health Act that growers are required to follow.

WORKER TRAINING

Growers should be aware of the signs and symptoms of illnesses, especially those of infectious diseases that could contaminate food. When there is a question whether conditions exist that could compromise food safety, the worker should be reassigned to a job without potential food contact. Sometimes, simply covering a lesion may be adequate.

A personal hygiene training program should be considered. Good hygiene protects the worker from illness as well as reduces the potential for contamination. The importance of handwashing and handwashing technique should be stressed and employees should be encouraged to use the toilet facilities rather than relieving themselves in the orchard. Regardless, a training program need not be limited to sanitation but could also include proper use of protective clothing required during and following some pesticide applications. Regardless, the content of the program and a roster of the attendees should be documented.

TOILET FACILITIES

Training is inadequate if toilet facilities are not close enough to the work site or are not maintained in a condition that would encourage their use. Toilet facilities should be clean and well supplied as well as have handwashing provisions. A maintenance log should be kept to provide documentation of adequate toilet facilities. If a farm labor contractor is used and the contractor provides a portable latrine for worker use, it is still incumbent on the grower to insure that the facilities are adequate. After all, it is the grower who bears the risks associated with poor field hygiene! Regardless of who supplies the latrine, a plan for proper disposal of waste should be in place and contingency plans for containment and cleanup of leakage and spill should be made. Contamination of the orchard with human waste should be avoided. California agricultural field sanitation regulations are located in the California Code of Regulations, Title 8, Section 3457.

While farm labor contractors frequently provide portable latrines, growers should not neglect sanitary facilities for harvest crews. The duration of harvest is short but the effects of poor sanitation may linger for years.

IMPLICATIONS

As described earlier, humans in the orchard can be a significant source of potential food-borne pathogens. Because direct supervision of orchard workers is problematic, the grower should encourage good sanitation and hygiene by developing training materials and providing adequate facilities. The grower should demonstrate due diligence through documentation of training and facility maintenance.