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THE CHILEAN AVOCADO INDUSTRY: AN OVERVIEW

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In recent years the presence of Chilean avocados in U.S. markets has become a familiar sight. Most California avocado growers' knowledge of the Chilean avocado industry is limited, although they are familiar with its impact on the U.S. market and on personal harvesting strategies. Inventory reports by the California Avocado Commission and packinghouse faxes are the primary sources of information on the flow of Chilean avocados into the marketplace. This overview is an effort to answer the questions interested growers may have about different aspects of the Chilean avocado industry.

Chilean avocado groves are located in a range of latitudes similar to those in California, but in the Southern Hemisphere. La Serena, the northern limit of the Chilean industry is located at 29°53'S, while the southern limit at Melipilla is at 33°41'S. Contrast this

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From The Editor

Guy Witney

California Avocado Commission Production Research Program Manager

There has been a lot of discussion in our industry about the impact of imported avocados on the domestic market. Our Education Committee believes that the more avocado growers are informed about their competition, the more likely they are to become involved in industry decision making, and shaping their future. The country emerging as perhaps the most important offshore supplier of avocados is Chile. To most of us, Chile has been somewhat of a mystery. We knew little about their production capacity, details of their costs of production, or how organized they were as an industry.

Following several months of research, Reuben Hofshi has written a comprehensive article on the Chilean avocado industry. This article follows the article on the Mexican avocado industry by Reuben in the last issue of AvoResearch. It is important to mention that the facts and figures presented here were compiled by Reuben working not only with the California Avocado Commission, but also directly with key industry individuals in Chile. These individuals also checked the article for accuracy prior to print.

Also in this issue, we have included two inserts to add to your collection. These cover our two most important disease organisms in the grove, namely root rot and collar rot, and were compiled by University of California Faculty: Lawrence Marais, John Menge, Ben Faber and Gary Bender.

RESEARCH UPDATE

- **Early results from growth regulator research by Garner and Lovatt have identified strategies that significantly retard the growth of the vegetative shoot apex of indeterminate floral shoots as opposed to purely vegetative shoots. This is encouraging, because these strategies may improve fruit set and assist in canopy management in the future.**

- **The latest avocado thrips research results were presented at grower meetings in February. Spray trials by Oevering, Morse, Hoddle, Faber, Phillips, Urena, and Anderson show that helicopter treatments of abamectin (Agri-Mek), well before fruit set, remained remarkably effective at thrips control. The researchers conclude that abamectin treatments, if applied properly, can suppress avocado thrips populations for 60-80 days. Look for a special edition of AvoResearch with a complete summary of these research results soon.**

Watch for meeting notices in the AvoGreensheet or log onto www.avocado.org/growers for more information.

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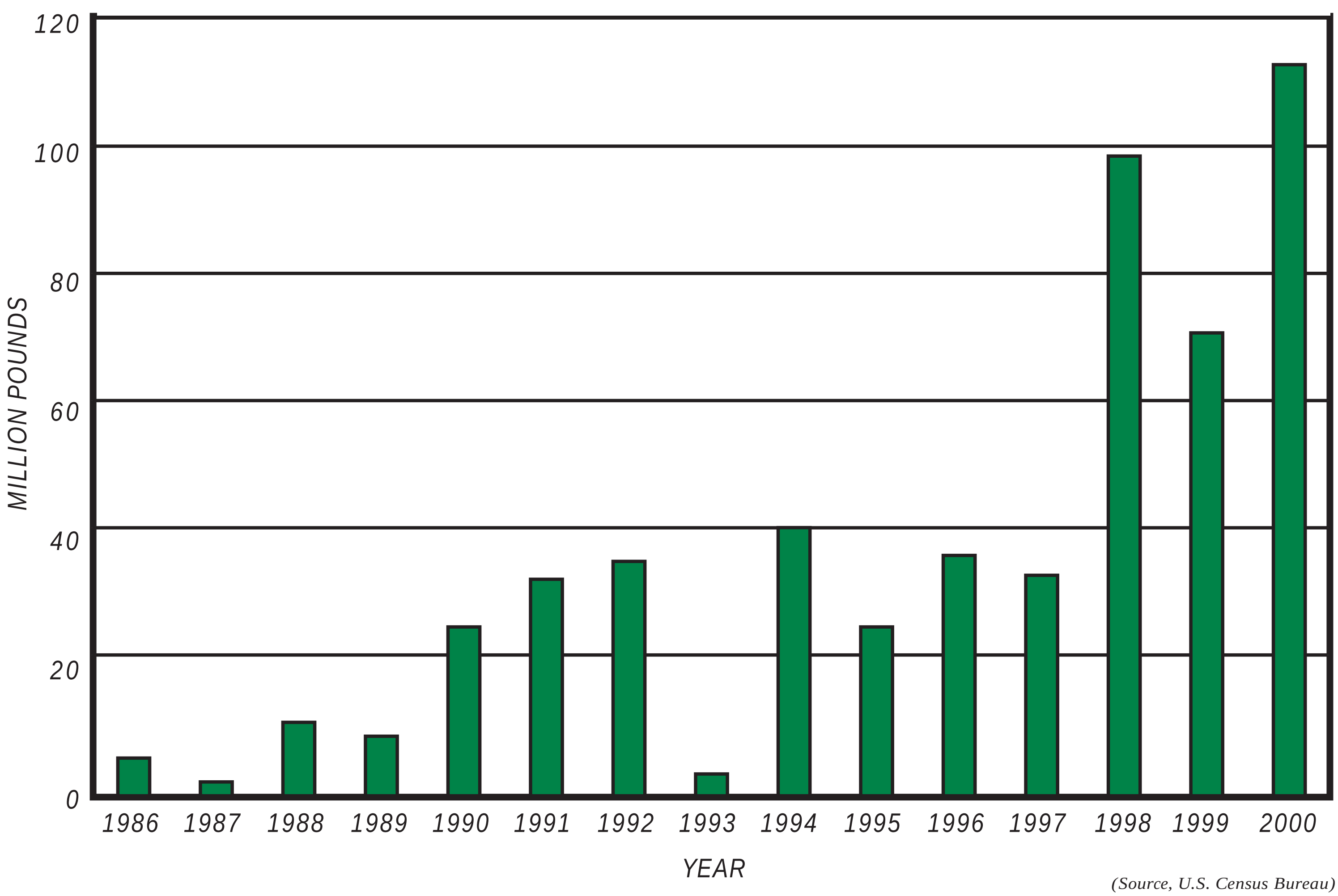
with San Diego, CA at 32°45'N and Cambria in San Luis Obispo county at 35°33'N. Chilean fruit is mature when California is at the transition between the late and early season, from August onward. This unique situation gives the Chilean industry a market well primed by the momentum of California avocado sales. Historically, during this time of the year, demand for California avocados would exceed supplies and prices would rise dramatically. The Chileans recognized this window of opportunity and turned the U.S. into the focus of their avocado exporting efforts.

The first significant shipment of 6 million lbs of Chilean avocados arrived in the U.S. in 1986 as the U.S. avocado market, thanks to the CAC merchandising efforts and demographic changes, was in a cycle of growth (Figure 1). After some initial attempts at exporting avocados to the U.S. through the usual produce channels, the Chilean industry quickly learned that the most efficient

Propagation of avocado trees at the Huerto California Nursery near Quillota, Chile.

Figure 1. Avocado Exports (all varieties) from Chile to the United States from 1986 to 2000.



(Source, U.S. Census Bureau)

distribution method was by the same organizations that market California avocados. This shift in marketing strategy provided the Chilean industry an infrastructure and a level of expertise that fostered the current expansion and success of that industry. The close relationship between California and Chilean marketers limited the flow of Chilean avocados to the months they were most needed, from mid-September through mid-December. Constraints of fruit maturity, on both ends of the spectrum, and a lack of dependable transportation have kept Chilean avocados out of the U.S. markets during the remainder of the year. The high returns for Chilean avocados in the U.S., in most years, have been phenomenal by any measure. This golden opportunity has generated a rush for continuous planting of new, predominantly Hass orchards in Chile. This season, the overall production of all varieties in Chile is estimated to be 264 million lbs, of which 176 million lbs will be Hass. The majority of this, 120 million lbs, is being exported to the U.S., amounting to about 95% of the total Chilean avocado exports. Most of these shipments are received and distributed by California handlers associated with one or more Chilean exporters. The exporting companies and their percentage of export volume for the 2001-2002 export season are: Agricom 26.2%, Propal 22.6%, Santa Cruz 17.1%, CabilFrut 13.6% and Safex 5.6%. The remaining 14.9% is distributed among 20-25 other exporters. Readers may recognize some of these names from the PLU stickers on Chilean fruit in supermarkets.

Comité de la Palta is the equivalent of the California Avocado Commission ('Palta' is the term for 'avocado' in Chile). It is a private organization formed in 1991 under the sponsorship of the National Federation of Fruit

Preparation of ridges prior to planting of new avocado grove in Chile.

Producers (Fedefruta). It has a Board of Directors composed of 7 producers, 5 marketers and 2 alternates. Ninety-five percent of Chilean avocado exports are made under the umbrella of this organization. In the last few years the Comité de la Palta has been assessing growers approximately 1 cent per lb for all avocados exported to the U.S. by its members. There have been several attempts at joint promotion efforts between CAC and the Comité de la Palta. The voluntary agreement between the two organizations to promote avocados during Fall 2001 demonstrates that alliances between competitors are possible. All producers benefit from a full calendar year perspective, as opposed to fragmented, country specific, seasonal campaigns for promotion programs. Overall, both industries recognize that the existence of the other is a fact of life. An issue that concerns the Chilean industry is the import duty of $1.50 per 25 lb carton levied by the U.S. Government on Chilean avocados entering the U.S. (These funds, over $7 million this season alone, are put in the general government fund and do not help promote avocado sales). They hope that the new trade negotiations between both countries will result in the removal of such duties or at least direct some of these funds towards

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Newly planted avocado trees on ridges in Chile.

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avocado promotion. Relations are likely to improve as both industries learn to understand each other, and recognize their mutual needs and apprehensions. With closer ties and the similarity of the growing conditions of both countries, closer cooperation on research, technical management, variety development and other mutual interests, could produce a positive synergy between both industries.

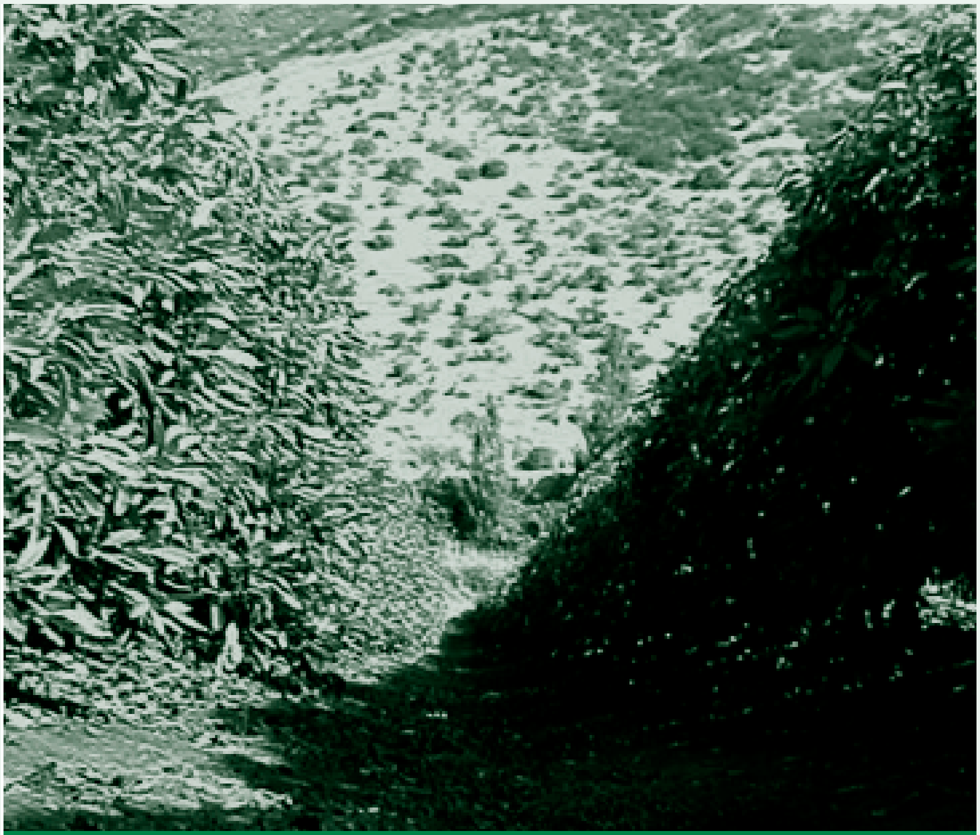
The current planted acreage of approximately 48,000 acres is comprised of 30% newly planted, non-bearing trees, 40% not yet fully mature with increasing production, 26% mature trees in full production, and 3% older trees with declining production. New trees are being planted at a rate of 2,500 acres per year. It is expected that plantings of new orchards will slow once the industry reaches 50,000 acres of Hass. California currently has 58,227 producing acres and 739 non-bearing acres, with a high percentage of trees over 15 years old and Hass accounts for 95% of the total production.

Chile has the second highest per capita consumption of avocados in the world at 8.5 lbs per person. Chile's population of 15.5 million will consume approximately 130 million lbs of the current year production of all varieties. Due to increased production and the proliferation of exporting companies, there is pressure to expand the shipping period into January, February and even into March. This could be facilitated by the adoption of faster and more efficient transportation, and better postharvest handling techniques. (It usually takes 10-15 days for the 5,435 mile voyage from Valparaiso, Chile to San Diego, California.) One solution for increasing shelf life, and thus the shipping season, is the use of controlled atmosphere (CA) containers where fruit is kept in a controlled environment of reduced oxygen and increased carbon dioxide, similar to long-term apple storage. This may add $0.80 - $1.00 per carton in transportation costs but without CA it would be risky to ship late-season avocados. February - March in Chile is equivalent to August - September in California, a period which, due to maturity and shelf life limitations, is not conducive to long-distance shipping of avocados. Other options are being studied to improve shipping and storage quality. One material that is likely to be used in the future is the simple organic compound, 1-MCP, which is already registered for use on floral and edible products in some countries. Registration for the United States food crop sector is expected in Summer 2002; however, rigorous detailed studies are still required before this material can be commercially applied to avocado. 1-MCP, in quantities of less than 100 parts per billion and under regular refrigeration, can extend avocado shelf life. The compound attaches itself to the ethylene receptors in the avocado fruit and blocks ethylene action, thus delaying fruit ripening.

Chile is not the only country that exports avocados to the U.S. during this time of the year. Chile, Mexico and New Zealand all have avocados at basically the same time, and the day when supplies may exceed demand is lurking on the horizon. The Chileans are industrious, learn from both success and failure and adapt quickly.

Avocado production regions of Chile.

They are continually looking for new markets to help dampen the inevitable competition for the market window on which they have focused their efforts. The lack of available alternative markets is a major concern for the Comité de la Palta and all Chilean marketers. One option is the development of the European market by the Chilean industry. Europe has been neglected mainly due to the higher prices that can be obtained in the U.S.. Peru, which cannot export avocados to the U.S. due to the Mediterranean fruit fly, is also targeting the European avocado market. In 1999 it exported close to 2 million lbs of quality Hass avocados to Europe. Not withstanding the Peruvian competition, which could become significant if increased domestic and imported U.S. volume causes prices to decline, Europe could become a viable, alternative market. Another alternative could be Japan, but it is a small market and Chile would face competition from New Zealand and Mexico. These two markets are marginal options for Chile since the transit time to Europe and Japan is approximately 30 days. Such long transit would require optimum pre- and post-harvest management and the use of expensive CA containers. It is possible, but very risky and costly. The major foreign competition for Chile, particularly in the U.S. during its traditional exporting months, is Mexico. With a high domestic consumption and a tendency for alternate bearing, Mexico is not always a consistent source of fruit. The Chileans, though watchful and concerned, no longer feel threatened by the Mexican presence. The reality is that Chile's natural export market is the U.S. and that it will likely remain the principal market in the future. In the meanwhile the Chilean avocado industry is experiencing a boom. Average FOB prices for the 2000-2001 season were $22 per lug. This season is likely to produce average FOB returns greater than $24.



Hass avocado trees planted on ridges sloping downhill in Chile.

Hass avocado trees planted on ridges going downhill in Chile.

In the long term, the Chilean Hass industry is hoping to find an important market alternative in South America, especially in Argentina. This option has been long contemplated, and test shipments have been made to that country. The high prices obtained in other markets, coupled with the economic problems and informal way of doing business in Argentina, have limited the development of this market. Compared with Chilean avocado consumption, Argentines consume a little more than 0.5 lb per capita. With the population of metropolitan Buenos Aires and suburbs approaching 13 million, it is obvious that the growth potential of this market is enormous. Although Argentina, Peru and South Africa are in the same hemisphere as Chile, their avocado harvest seasons are different from Chile's and thus they complement each other. The availability of fruit throughout the year is a critical component in developing a

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new market. If suppliers such as Peru, South Africa, the small Argentine avocado industry, and Chile could share the marketing and development effort, the potential exists for a strong market in Argentina.

Current returns to Chilean growers for domestic avocado sales range from \$0.36 to \$0.40 per lb for fruit over 6 ounces. The Chilean market, however, can absorb only a certain volume with the current per capita consumption rate and distribution system. The Comité de la Palta, which is currently only an exporting organization, is contemplating marketing Hass avocados in Chile. An important step for increasing consumption in Chile is price moderation for consumers. This could be achieved by making the supply chain more efficient with more rational margins for all the middlemen involved.

During April-June the demand for Hass avocados in Chile exceeds local supplies. California avocados were previously prohibited from Chile. Regulations have recently changed and export to Chile is now permitted. The fruit must meet certain phytosanitary requirements prior to embarkation.

GROWING REGIONS

Avocados have been grown in Chile since the mid 1800's with the initial seeds thought to have come from Peru. Roger Magdhal first brought the Hass avocado to Chile in 1935, three years after it was patented in California. The expansion of Chilean avocado plantings began, as in California, in areas where good soils, favorable climate and quality water were abundant. Today many new plantings are on marginal soils, often on hillsides, with poor water quality of limited availability, and the potential for occasional freezes. Prior to the initiation of exports to the U.S., the avocado varietal composition in Chile was diverse, with Hass, Fuerte, Negra de La Cruz, and Bacon as the dominant varieties. Today, 75% of the avocado trees in Chile are Hass. Edranol, Bacon and Zutano are used as pollinizers while Negra de La Cruz, which is a popular, late season Chilean selection, is grown for local consumption.

There are three major avocado growing regions in Chile, which are presented in order from north to south.

I. The river basins of the Petorca and La Ligua rivers.

This region is the area with the most significant new plantings and represents 35% of the total Hass plantings in Chile. Hass is the main variety grown in this region. Edranol is the main pollinizer variety although Zutano and Bacon are also used as pollinizers to a lesser extent. These river basins, which cross Chile from the Andes to the Pacific Ocean, vary in their climatic conditions as a function of their proximity to the coast. The areas of La Ligua and Longotoma, which have the greatest marine influence, have a dry, cloudy summer with an average relative humidity around 70% and average temperatures of 61°F. In the inland valleys, where the marine influence is reduced, the average temperatures are 72-74°F, and the average relative humidity is 45%. Average annual rainfall is 6-8 inches for the region.

Irrigation water comes from two rivers that flow above ground only intermittently. Water availability is a limiting factor since the mountains supplying these valleys are not as extensive and are not as high as other ranges that provide water for agriculture in Chile. Therefore, 95% of the groves are irrigated using either shallow or deep wells. Almost all growers irrigate via pressurized irrigation with a preference for microsprinklers. Water quality is good, with electrical conductivity (EC) of 0.4 decisiemens/meter (dS/m) (Colorado River water, in contrast, is 0.9 – 1.0

Hass avocado plantings near Quillota, Chile.

dS/m) with a pH slightly above neutral (7.2-7.5). Even though soil quality and climatic conditions can be outstanding for growing avocados, these areas are probably near their maximum potential for planting. In case of a drought in Chile, these valleys are likely to be the most affected since the water supply will deplete quickly.

There are 2 dominant soil types:

A) Light alluvial sandy alkaline soils (pH greater than 8) which are deep, poor in organic matter content and contain large quantities of rocks. The rocks help drainage and help maintain high soil temperatures.

B) Marine deposits are the dominant soils of the hillsides. They are not uniform, but are generally poor, thin, alkaline and often affected by high levels of carbonates. They are clay soils with low organic matter content. Generally, groves on hillsides are planted on ridges, sometimes running up and down the hill in a north-south direction when possible.

II. The Aconcagua Valley.

The Aconcagua River provides good quality irrigation water (EC 0.7 dS/m) with low sodium and chloride to this traditional capital of avocado and citrus growing. Like the Petorca – La Ligua basins, the Aconcagua basin represents 35% of the Chilean Hass plantings. Some of the well-known localities for avocado growing in Chile are Panquehue, Llay-Llay, Hijuelas, La Cruz and Quillota. Many of Chile's nurseries are located in this zone, including the Magdahl family's renowned Huerto California Nursery. This region has also experienced a large expansion of new plantings, mainly on hillsides since the flat land was already planted to avocado and other crops. Most of the old irrigation systems (flood or furrow) have been converted to pressurized systems, with microsprinklers as the preferred emitter. The valley soils are deep sedimentary of alluvial origin. Soil texture is light clay with clay substrate deeper in the profile. There are gravel and stones within the soil that has moderate permeability and organic matter content of 1 – 1.25%. Hillside soils are granitic in origin, are poor, with mild to heavy clay, and have an organic matter content of 0.5 – 0.75%. Average summer relative humidity is 55-60% and average annual rainfall is 16.9 inches. Average annual temperatures are 60°F with the maximum temperature around 80°F and minimum around 42°F.

III. The Maipo–Mapocho and Cachapoal river valleys.

This region is extensive and includes the metropolitan region of Chile's capital, Santiago, and the area south of Santiago. It represents approximately 15% of the total Chilean Hass plantings. Well-known localities are Mallarauco, Naltagua and Melipilla by the Maipo and Mapocho rivers and the localities of Peumo – Las Cabras by the Cachapoal River. New plantings in this zone are also extensive but more limited due to lower average temperatures and the high potential for freeze. As in California, growers minimize their risk by planting on hillsides where cold air can flow to lower elevations. This area has dry summers with warm temperatures (95°F maximum) and cold (as low as 23°F), wet winters with annual rainfall averaging 29–31 inches. Water quality of the Maipo and Mapocho rivers is poor. The water is hard, alkaline, with a pH near 8 and EC greater than 1.2 dS/m. There are many groves, especially in the vicinity of Mallarauco, with severe tip-burn and poor production. The region of the Cachapoal River is less affected by salinity (water EC is 0.6 dS/m). There is abundant water and drought rarely occurs. Many growers in this region still irrigate by flood irrigation although plantings, especially on hillsides, use pressurized systems. The soils are generally deep, consisting of light to moderate clay with about 1.5% organic matter content. Hillside soils are variable in quality, thin, poor, and shallow, with moderate to heavy clay content. Average summer relative humidity for both valleys is 76-77%. Average annual temperatures are 57°F.

IV. Other regions.

In the last few years, there have been limited new plantings in additional locations such as the interior portions of the 3 regions discussed above as well as the Ovalle and La Serena valleys, which are located 150 to 200 miles north of Santiago. These new and limited production zones, where summer fruit and grapes have traditionally been grown, have higher temperatures and fruit is harvested 1 to 2 months earlier than the in coastal areas. In La Serena there are dramatic temperature and humidity differences between the coastal area and the not too-distant interior valleys. All these marginal areas represent about 10% of the total Hass plantings in Chile.

PESTS AND DISEASES

Chile is blessed with having only a few pests and diseases. Red Spider mite *(Oligonychus yothersi)* is controlled by application of oil or wettable sulfur. Miticides are used only during severe infestations. Thrips *(Heliothrips haemorrhoidalis)* are left alone and are only controlled during severe infestations by mineral oils and Chlorpyrifos. A characteristic of the avocado production in Chile, which unfortunately was lost in California due to the introduction of the Persea mite *(Oligonychus perseae)*, and the avocado thrips *(Scirtothrips persea)*, is the limited use of chemical pesticides. Most of the products used are oils, soaps and sulfur. Growers often leave control of possible pests to natural

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Fruit packing and grading utilizing HACCP standards at Safex Packinghouse near Quillota, Chile.

predators and Integrated Pest Managment (IPM) strategies. Although Chile is geographically isolated, there have been several finds of Mediterranean fruit fly over the years. The source of the fruit fly infestation is thought to be either Argentina or Peru. These finds forced fruit to be quarantined in a manner similar to the event that took place in Ventura, CA in 1997 –1998.

The occurrence of root rot *(Phytophthora cinnamomi)* is limited and is much less severe than in California. The reason for this is thought to be the fungicidal effect of high copper content in the soils and, to a limited extent, in the irrigation water. This is one of the reasons clonal rootstocks are not used in Chile. Where root rot does exist, the use of low concentrations (less than 1%) of buffered phosphorus acid applied as a foliar and trunk spray is recommended.

There is little to no rain during the harvesting months in Chile and postharvest decays are substantially lower, and often almost non-existent, when compared to growing areas with high rainfall such as Australia and New Zealand.

THE CHILEAN AVOCADO GROVE AND CULTURAL PRACTICES

The following discussion represents the majority of the relatively young Chilean avocado orchards. Most of the trees in Chile are grown either on Mexícola seedling rootstock or, more recently in areas of poor water quality, on Nabal, which is thought to be salt tolerant. In the last few years, in response to pollination studies conducted by students at the Catholic University of Valparaiso, the variety Edranol has become the preferred ‘B’ type pollinizer variety. The Chilean advisors recommend 11% of the total planting to be planted to pollinizers. What is unusual about Edranol is that, although a well-liked fruit, it produces very little if any fruit but flowers profusely in Chile, every year; it is planted strictly for pollination purposes. There is a lesson to be learned by California avocado growers who have been struggling with which variety of ‘B’ flower trees to plant. The Chilean argument is that Edranol is such a good pollinizer that the increased production of the surrounding Hass trees more than compensates for the Edranol’s lack of productivity. In California, the search for replacement to the traditional pollinizer varieties by Hass-like varieties is somewhat misdirected. The foremost purpose of a pollinizer variety is to do the best job providing abundant quality pollen. Zutano, and to a lesser extent Bacon, are well suited to do the job!

To assist in pollination, honey bees are introduced to the groves at the recommended rate of 4 beehives per acre. A third of the colonies are brought prior to or at the initiation of bloom and the rest during peak bloom. Recently, a service providing bumblebees for pollination was introduced in Chile, but the cost-benefit remains questionable.

Planting, canopy management and production costs.

Land prices vary depending on the location and on the potential for future residential or commercial development. In well-suited avocado areas, land prices can range from $2,800 to $12,000 per acre. Hillsides, where generally mostly avocados are grown, can cost $400 to $1,800 per acre, depending on water availability and pumping requirements. An irrigation system with microsprinklers costs between $1,200 and $1,600 per acre. Non-clonal nursery grown trees cost about $4 each. The irrigation system and the trees normally constitute 50 to 70% of the total cost of planting a new orchard. By the fourth

Overview of fruit grading using HACCP guidelines at Safex Packinghouse near Quillota, Chile.

year, when commercial harvest commences, a grower with a 25-acre grove will have invested around $4,000 per acre.

The normal planting density for Hass is 20 x 20 ft with an additional tree on the diagonal, which is later removed. Other plantings are at 10 x 20 ft. Some progressive growers plant in a high density of 10 x 10 ft spacing and girdle 1-2 branches in the second year. Due to mild temperatures and appropriate fertilization regimes, trees don't grow as fast as in California and such densities can be maintained for a few years, especially when careful irrigation and well-monitored and balanced fertilizer regimes are practiced. Recent hillside plantings are mostly on ridges that are 20 ft apart, approximately 6 ft wide at the base, sloped to a height of 4-5 ft, and are about 2 ft wide at the top. The trees are planted either 13 ft or 20 ft apart. The ridges sometimes run down the hillside, preferably in a north-south orientation for better light interception, for better water and air drainage, and concentration of the thin topsoil, which is gathered at the top of the ridges. Pressure-compensating microsprinklers are used to maintain a high level of distribution uniformity for these unique irrigation systems.

The production costs per acre in Chile are between $500 and $850 per year. This includes water, energy, general labor, harvest, pruning, and all other direct costs. Two important factors affecting production costs are the size of the orchard and the slope of the terrain. Labor accounts for 50 to 60% of the costs, and fertilizers and energy, mainly for pumping water, account for 10% each. The harvest is performed by local farm labor hired by the grower. Harvest cost is $0.009 (0.9 cents per lb). The minimum wage in Chile, including associated costs and benefits, is $6 per day for basic labor. Chilean growing conditions are less stressful to the Hass avocado than the conditions in most growing areas in California. In general, good-quality mature orchards produce an average of 10-12,000 lbs per-acre, per-year. There are orchards, in areas with ideal climatic conditions during flowering and fruit set, with sustained average production exceeding 20,000 lbs per acre.

Tree pruning and canopy management.

This is a new concept with which Chilean growers are experimenting. One advantage they have over California growers is the availability of plant growth regulators (PGRs) such as Sunny, Cultar and NAA, which have proven to be extremely effective in Chile and elsewhere (Australia, Israel, South Africa) in improving productivity and the control of canopy size and shape. These materials are very expensive and are not used routinely in Chile. (The CAC Production Research Committee is currently funding Dr. Carol Lovatt to establish efficacy data on new PGRs such as Apogee, a likely candidate to be permitted for use on avocados.)

Irrigation.

Because of the Mediterranean climate and the lack of adequate rain between August and May, irrigation is a must. Many of the older commercial groves have converted from canal irrigation to pressurized systems. Modern irrigation is managed mainly through two systems: evaporation pans (or computerized weather stations that indicate evapotranspiration) and tensiometers. Tensiometers are used to control and monitor this program and to indicate the irrigation needs during winter. Ideally, growers try to use both systems. The Chilean grower prefers to vary the irrigation frequency and keep the duration of the irrigation event constant. It is common, when microsprinklers are used, to irrigate every 5 to 12 days during the dry summer. Drip irrigation is sometimes used during the first year after planting to provide better control of the amount of water and fertilizer each tree receives and for more efficient weed control. Normally by the second year the drip system is converted to microsprinklers. There are some plantings that use drip irrigation, based on the recommendation of foreign

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consultants (mainly from Israel), but prolonged use of drip irrigation is not common. The use of microjets, which have a more limited and focused throw, has increased due to higher density planting and the use of ridges for planting on hillsides. Currently, new research is being conducted utilizing pulse irrigation systems, which provide several pulses of irrigation water per day. Water requirements are monitored by dendrometers that measure the diurnal fluctuation of the girth of the trunk, limbs and leaves. One important difference between avocado production expenses of California and Chile is the cost of irrigation water. In the Quillota area (Aconcagua basin) for example, water cost is not higher than $50 per-acre, per-year. Water availability and water quality are much more important to the Chilean avocado grower. In California, although water quality has been an important issue, the cost of the irrigation water is the most critical. In areas with salinity problems the irrigation volumes are increased by 20 to 30% to provide leaching and to prevent the accumulation of salts in the soil. Soil variability and the availability of reliable weather data are important issues for growers, especially when marginal soils and poor-quality water are used. Francisco Gardiazabal has been conducting a study to establish new crop coefficients (Kc) for Chile. Table 1 lists the currently used crop coefficients (as compared to those we use in California) and his proposed new values.

Table 1.

MONTH SOUTH — NORTH	CURRENT Kc CROP coefficient Values CHILE— CALIFORNIA	PROPOSED Kc VALUES CHILE
JANUARY — JULY	0.72 — 0.65	0.72 — 0.75
FEBRUARY — AUGUST	0.65 — 0.65	0.72 — 0.75
MARCH — SEPTEMBER	0.58 — 0.60	0.72 — 0.75
APRIL — OCTOBER	0.58 — 0.55	0.72
MAY — NOVEMBER	0.58 — 0.55	0.72
JUNE — DECEMBER	0.52 — 0.50	0.72
JULY — JANUARY	0.52 — 0.40	0.72
AUGUST — FEBRUARY	0.52 — 0.50	0.72
SEPTEMBER — MARCH	0.58 — 0.55	0.72
OCTOBER — APRIL	0.58 — 0.55	0.72
NOVEMBER — MAY	0.65 — 0.60	0.72 — 0.75
DECEMBER — JUNE	0.72 — 0.65	0.72 — 0.75

Fertilization.

Fertilizer application is primarily limited to nitrogen (N) and potassium (K), although minor amounts of boron and zinc are also applied. The general rate of application is 100-175 lbs of actual N per acre. The use of K is controversial. Some advisors, influenced by Spanish researchers, do not recommend the addition of any K, while others recommend 35-53 lbs/acre in the form of potassium nitrate. Zinc, in the form of zinc sulfate, is applied at the rate of 18-22 lbs/acre and boron in the form of boric acid is applied at the rate of 35-70 lbs/acre. Often, especially in alkaline soils, the total application of these micronutrients is buried in shallow holes at the four corners of the tree or in a band along the drip line. Most Chilean avocado growers have leaf analyses performed annually, while soils are analyzed less frequently.

Organic production.

Organic production has been slow to take hold and is constrained by certain limitations. Even though the pest pressure in avocado orchards in Chile is low and the use of pesticides is limited, the main limiting factor is the availability of a good and reliable source of organic nitrogen. The cost of organic fertilizers, which are always in high demand for use in avocado orchards and in other crops, in addition to the transportation and handling costs of large volumes of manures and other bulk organic products, limit the adoption of organic farming.

The Chilean educational system.

The Chilean educational system is superb, producing many professionals with an uncanny determination to work hard, learn, and excel. The Catholic University of Valparaiso is where the majority of the subtropical fruit research is conducted. Under the watchful eyes of Francisco Gardiazabal, their major professor, students are required to produce after graduating from college a significant, albeit one year in length, research project, and a final report in order to receive their degree in Agronomy. These works are well designed and executed, and include a comprehensive literature review of the subject and statistical analysis. In the last 10 years the research, which is very pragmatic in nature, has been concentrated on subjects such as avocado phenology under Chilean conditions, nutrition and fertilization, irrigation, pruning, tree manipulation with growth regulators and girdling, the use of honey bees and other insects, fruit set and the selection and use of pollinizers, and the evaluations of new varieties from local and international sources. This practical approach to research is enhanced by the participation of technical people and advisors who are close to the grower community and to the industry. The research activities are not funded by the industry and financial support is available mainly through the initiative and vision of individuals within the industry. An unfortunate problem with the research performed in Chile is that the results are not published in any national publication. These valuable studies are only available in the library of the universities where the research was conducted. This author has requested those with access to these works to post summaries in Spanish or English on an accessible web page. Some representative summaries of the research these young agronomists conducted may be presented in future issues of AvoResearch.

Consulting and information dissemination.

In Chile, a system of technical consulting and advising has been established as part of the duties of the field personnel of the fruit exporting companies. The growers have accepted this service as an integral and important part of the service the exporting companies provide. These technical consultants are mostly agronomists who have specialized as field representatives and who also provide technical assistance for each type of exported fruit. This system is beneficial to the growers and also helps the exporters, at least in theory, predict and control the volume, size, and quality of fruit they ship. In addition, and often in place of company agronomists, many large growers use independent consultants/farm advisors, to help them with the technical aspects of their groves. These consultants are highly trained, well traveled, and have intimate knowledge of international avocado research and cultural practices. Some growers who employ private consultants believe that it is difficult for the field representatives, although well trained, to be up-to-date in the technical management aspects of their orchards. The crop is valuable and an educated opinion from a different perspective is good insurance. There is no extension service or government-sponsored farm advisor service in Chile. (In recent years, foreign advisers have begun consulting and setting up trial plots in Chile. These arrangements are expensive and are often limited only to growers associated with certain exporting companies. Sharing of experiences and specific information dissemination is more difficult under these circumstances.) The basic primer in Chile has been the book titled 'Cultivo del Palto' (Cultivating the Avocado), by F. Gardiazabal and G. Rosenberg, 1990. This book, even today, is a fine compilation of information gathered from around the world but with a Chilean perspective.

Growers under the umbrella of the Comité de la Palta are provided with one important meeting per year in which political, strategic, and technical issues are discussed. There are also seminars organized from time to time by various organizations, mainly concentrating on the technical aspects of growing avocados. Otherwise, there are very few organized industry-wide meetings such as those held in California. Some exporting companies have held growers meetings, inviting foreign experts for well-attended seminars, and some have taken important growers to visit other avocado industries. A large number of Chilean growers attend international avocado events, such as the World Avocado Congress. The Chilean industry is, for the most part, open and transparent, a trait learned from the openness and generosity of other industries such as Australia, Israel, South Africa, Spain and the U.S..

Quality assurance and food safety.

Walking into a modern avocado packinghouse in Chile is an experience in sanitary discipline we should all learn from. Most growers and exporters in Chile are getting involved in a program developed by the Chilean Export Association (ASOEX) known as "BPA" (Buenas Prácticas Agrícolas), which means Best Agricultural Practices. This program's objective is to assure sanitary quality of the fruit, environmental conservation, product traceability, and worker safety for both field workers and handling personnel. Additionally, most of the packinghouses have international inspectors to certify quality assurance practices. USDA-APHIS inspects the Chilean avocados before embarkation and issues a phytosanitary certificate. Upon arrival at destinations in the U.S., USDA will again inspect the fruit. The inspectors use the Florida Avocado Standards (a federal standard) to ascertain that the fruit meets minimum quality standards. California Department of Food and Agriculture (CDFA), during the early part of the export season, tests fruit arriving in California to insure that the fruit meets California's minimum maturity standards. Measuring dry matter content of the fruit 2 to 3 weeks after harvest is questionable. Implementing

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a standardized testing protocol that is easy to use, similar to the one being developed currently in California, could entice the Chilean industry to officially test fruit destined for export to the U.S. prior to shipment. The most popular food safety program is called HACCP (Hazard Analysis Critical Control Point), which is an internationally recognized food safety methodology that provides the framework for hazard identification and control. Some progressive companies have implemented this program and are contemplating the implementation of an ISO (International Organization for Standardization) protocol. ISO sets out the methods that can be implemented in an organization to assure that the customers' requirements are fully met. The organization's requirements will be met both internally and externally and at an optimum cost, resulting in efficient utilization of the resources available, including material, people, and technology. The Chilean avocado industry is export-oriented and is quick to implement requirements and standards requested by importers, especially those with strict standards such as Europe and Japan. Soon the California avocado industry will be called upon to do the same, and the sooner we begin working on this trek as an industry, the better it will be for all of us. Various packinghouses in California have been experimenting with different quality assurance programs. Initial steps were recently taken by CAC when it created a new Quality Task Force chaired by Roger Essick. The mission of this taskforce is to examine all aspects of fruit quality and fruit safety from the tree to the consumer.

One can only be amazed at the progress achieved by the Chilean avocado industry in the last 10 years, in the level of modernization, innovation, and rapid adaptability to new techniques. Everyone participates in the changes that benefit the industry as a whole although the industry is fragmented. The Chilean growers are capitalistic and are as secretive as any California grower, but they have a common denominator - they recognize and continually work on improving the industry in all its aspects for the benefit and profitability of the industry as a whole.

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AVOCADO STEM CANKER OR COLLAR ROT

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Three species of Phytophthora have been associated with trunk, collar and crown cankers on avocado trees viz. *P. cinnamomi* Rands, *P. citricola* Sawada and *P. heveae* A Thompson. The most devastating and abundant is *P. citricola*, especially in the cooler coastal production areas of California, where it was first described on avocado in 1974. *P. citricola* is apparently present in approximately 90% of the avocado orchards in California, while the disease itself occurs in only around 5% of these orchards. *P. cinnamomi*, the major causal organism of root rot, has infrequently been reported to cause cankers in California, South Africa, Brazil and Australia. The only report of *P. heveae* being associated with cankers on avocado was from a small nursery planting in Guatemala (Faber et al. 1995, Faber and Ohr 1999, Manicom 2001, Zentmyer et al. 1998).

SYMPTOMS

Trunk cankers caused by *P. citricola* are normally found at the base of the trunk extending to a height of approximately 18 in. The pathogen infects the crown, lower trunk and sometimes the main structural roots of avocados of all cultivars. The cankers usually originate at or below soil level, but can be found higher up in the tree if bark damage has occurred. This is because the pathogen can gain entrance through wounds caused by pruning tools, mechanical damage caused by pickers, or even limbs rubbing against each other during wind.

Canker lesions are discolored and the cankers give rise to copious amounts of a red resinous, water-soluble exudate through cracks in the bark. This exudate often dries to form a white crystalline deposit on bark. Cutting into a canker reveals an orange-tan to brown-pigmented outer layer of wood which has a fruity odor when exposed to air, instead of the normal white or cream-colored tissues. The cankers have distinct reddish-brown margins from which the fungus can readily be isolated (Bender 1999).

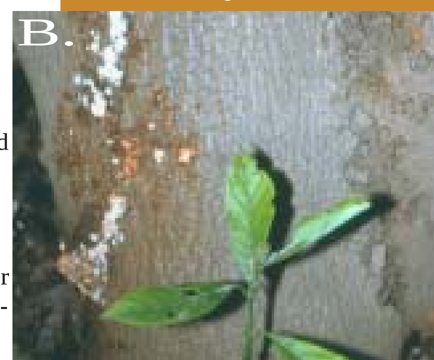
Foliar symptoms are similar to those caused by Phytophthora root rot (PRR). There always appears to be more leaf litter on the orchard floor than in the case of PRR, and there is usually an abundance of healthy, cream-colored feeder roots in the area of the root crown. The abundance of leaf litter is due to the fact that mildly canker affected trees develop a great deal more new flush during the growing season than do root rot affected trees. Moderately affected trees often appear quite healthy and may persist this way for several years until the canker progresses to a stage where it may start killing the cambium tissues around the trunk. Unless the trunk is inspected for lesions (and the tell-tale signs of white powdery exudates), the tree generally appears healthy. In some cases the disease can progress very rapidly, killing the tree in a few months by killing the cambium and effectually girdling the trunk. Sometimes trees have the disease without any above-ground signs of a canker. In these cases, cankers may girdle trees a few inches below the soil level before the disease is detected (Bender 1999, Faber and Ohr 1999, Zentmyer et al. 1965).

While of relatively minor importance in California, the disease may infect fruit under some conditions. During prolonged wet weather, particularly in northern growing regions, fruit still hanging on the tree may be infected with *P. citricola*. Affected fruit are often touching the soil or are hanging on the lower branches. Most damage occurs within 3 feet of the soil surface. Diseased fruit have a distinct circular black area that usually occurs at the lowest part of

California Avocado Commission

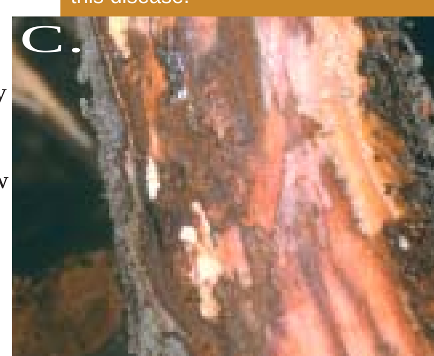
A.

Typical *P. citricola* canker on an avocado tree trunk. Often there is sugary exudate (bleeding) with a distinct pocket of wet dead tissue below the damaged bark.



B.

A typical *P. citricola* lesion on the trunk of this tree. Note the sucker growing from below the ground nearby. Mechanical damage to the tree resulting from pulling suckers is thought to be a major point of entry for this disease.



C.

Under the bark of a severely damaged tree. *P. citricola* will often girdle the tree, killing all living bark tissue resulting in eventual tree death.

Photos: H. Ohr

Photo: H. Ohr

Diseased fruit have a distinct circular black area that usually occurs at the lowest part of the fruit.

the fruit. While most infections occur at the bottom of the fruit, they can occur anywhere on the surface. Internally, the rot extends into the flesh, darkening it in the same pattern as the affected area on the surface (Faber and Ohr 1999).

Causal Organism and Epidemiology

The causal organism of this destructive disease in California is *P. citricola*. Previously uncommon, it has now become second to Phytophthora root rot in being limiting to avocado production. *P. citricola* has a wide host range and has been recorded on hosts such as walnut, cherry, cherimoya and fir trees. Phytophthora canker disease is favored by excess moisture, which is essential for the dissemination of the spores. Stress factors resulting from water deficit, salinity, excess fertilization and root disease caused by *P. cinnamomi*, are also conducive to infection by *P. citricola.* One of the primary ways in which the disease is spread is through infected nursery stock. Nurseries that do not take precautions to disinfect water used for irrigation purposes, sterilize potting media, and keep containers off the ground, may be responsible for disseminating the disease. Phytophthora canker differs from the root rot pathogen in that it infects through wounds created by gophers, sucker removal, wounds made during staking, and cold injury. It has been reported that severe pruning of canker infected trees increases the rate of demise of these trees. The pathogen can also be spread on contaminated pruning tools, harvesting equipment and vehicles, on the shoes of pickers climbing onto the trees, and by rodents which feed on the roots of the trees (Bender 1999, El-Hamalawi et al. 1995, El-Hamalawi and Menge 1994, Faber and Ohr 1999, Manicom 2001, Zentmyer et al. 1998).

Disease Management

The measures recommended for the control of Phytophthora canker diseases are similar to those described for Phytophthora root rot. The use of certified disease-free nursery stock cannot be over-emphasized. Unlike root rot infected trees which can be treated successfully to a state of total remission, it is very difficult to cure trees once they become infected with *P. citricola.* Some clonal rootstocks which are resistant to Phytophthora root rot, such as Thomas, may be susceptible to *P. citricola* (El-Hamalawi et al. 1994, Zentmyer et al. 1998). Current rootstock research in California now looks simultaneously for resistance to both diseases.

Chemical control of Phytophthora cankers caused by *P. citricola* has not been very successful in California. Field trials continue to test different chemicals and modes of application (Marais et al. 2001).

Greenhouse experiments at the University of California Riverside indicate that cutting away cankerous lesions on seedlings and applying Aliette® as a trunk paint, will arrest the infection (El-Hamalawi and Menge 1994). Scraping of cankerous tissues to remove active cankers and painting the area with copper Bordeaux has been employed by growers in the past, but some growers have reported an increase in the spread of the disease after this treatment. Preliminary research shows that if tree surgery is followed up by treatment with Aliette® or neutralized (buffered) phosphorous acid, disease spread is arrested. In much the same way, removing rootstock suckers in the field by cutting them above the ground and treating the cut surface with Aliette® or neutralized (buffered) phosphorous is likely to reduce potential infection.

Severely pruning canker affected trees should be avoided. Pruning tools should be disinfected before moving to the next tree. It is important to remove leaf litter from crotches of trees and from around the base of the trunk. Avoid sprinkler irrigation wetting the crotches of the trees and from spraying directly onto the trunks. Cankers frequently develop on the side of the trunk exposed to sprinklers (Faber and Ohr 1999).

In fruit, prevention of infection is challenging because it is likely caused by the splashing of Phytophthora spores from the soil surface to the fruit during rainy weather. Any practice that helps reduce splash, such as a layer of leaves or mulch, may help. Where *P. citricola* is a fruit problem, fruit lying on the ground should be removed because the fungus can grow and sporulate there, providing an abundant source of infection (Faber and Ohr 1999).

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PHYTOPHTHORA ROOT ROT

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Phytophthora root rot (PRR) is considered the most important and most widely distributed disease of avocados in countries where avocados are produced. From a production point of view PRR is the single most important disease of avocado. In California alone it has been estimated to affect between 60-75% of the orchards and causes a loss in excess of $40 million annually (Coffey 1992). The causal fungus, *Phytophthora cinnamomi* Rands, was first isolated from cinnamon trees in Sumatra in 1922 and has since been reported from over 70 countries. It has an extremely wide host range including 1000 varieties and species of plants. Major hosts include avocado, pineapple, chestnut, eucalyptus, several species of pine, sycamore, peach, pear, many ornamentals (including azalea, camellia and rhododendron) and many indigenous Australian and South African plants. The first published report on PRR was from Puerto Rico in 1927. A PRR-like decline was reported in California during 1920-1930, but it was only in 1942 that *P. cinnamomi* was isolated from avocado (Zentmyer 1980, Zentmyer et al. 1998).

Symptoms

The first signs of the disease are manifested in the tree canopy. The leaves are small, pale green, often wilted with brown tips, and drop readily. In contrast to Phytophthora stem canker, new growth is usually absent. Shoots die back from the tips, and eventually the tree is reduced to a bare framework of dying branches. Tree death may take

A. Healthy feeder roots growing near the soil surface are often cream colored.

B. The roots on the left have been attached by root rot fungus while those on the right may succumb to the disease soon. Note the difference in root color (dark brown) of the damaged roots.

from a few months to several years, depending on soil characteristics, cultural practices and environmental conditions. When declining trees flower, the trees may defoliate completely and may set a heavy crop of small fruit.

The small feeder roots on diseased trees may be absent in the advanced stages of decline. When present, they are usually black, brittle and decayed, in contrast to healthy trees which have an abundance of creamy-white feeder roots. Pencil sized and larger roots are seldom attacked by the fungus. (Faber and Ohr 1999, Manicom 2001, Pegg 1991, Zentmyer 1980 and 1984).

Causal Organism and Epidemiology

P. cinnamomi forms several different spore stages that are involved in infection, disease development and survival of the fungus; these include zoospores, chlamydospores and oospores. Fruiting structures on the fungus called sporangia give rise to motile (swimming) zoospores which are disseminated by flowing water on the surface of the soil or in films of water within the soil pores. The zoospores are attracted to the roots by root exudates. Zoospores then penetrate, germinate and infect tender root tissue. Root lesions appear within 24 hrs and mycelium (fungus tissue) can be found throughout the small absorbing roots within 72 hrs.

C. Root rot infected trees often produce an abundance of fruit while leaves on the tree are often pale, small and sparse.

D. Typical above-ground tree symptoms of root rot infection (foreground). Note the dead upper branches, sparse leaf cover and pale leaves.
Photos: G. Witney

Under dry soil conditions the fungus may produce chlamydospores which are survival structures that can survive for several years. These spores are formed within the roots and are released into the soil when the roots decay. Under low soil temperatures oospores, another type of survival spore, are produced by *P. cinnamomi*. Both chlamydospores and oospores can live for several years in orchard soils. When suitable moisture and temperature conditions arise, both can give rise to sporangia which produce infectious zoospores.

Soil moisture is the primary environmental factor influencing PRR development. High soil moisture stimulates the development of sporangia and improves conditions for zoospore release and movement in the soil. However, stress from low moisture and excess salt can also injure roots causing them to exude substances which attract zoospores and incite infection.

Where *P. cinnamomi* is not native to an area, the primary method of introduction of the disease into orchards is by infected nursery trees. Once in the orchard, PRR can be spread by infected soil on shoes, tools, vehicles, picking boxes, ladders and storm water (Faber and Ohr 1999, Manicom 2001, Menge and Marais 2000a, Zentmyer et al. 1965, Pegg 1991, Zentmyer 1980 and 1984, Zentmyer et al. 1998).

Disease Management

Since no definitive measures have yet been found to control PRR, an integrated approach to managing the disease has been found to be most effective. This approach includes prevention, cultural practices and chemical treatment. These aspects are discussed below:

Site selection and soil preparation: Planting an avocado orchard is a long-term investment and requires a high capital outlay in the initial stages. Soil should be prepared well in advance of planting. Severe PRR is associated with soils that have poor internal drainage, are less than 3 feet deep, have hard pans, clay pans and high clay content. These soils are conducive to inoculum build-up and infection of roots, and should be avoided. Less hazardous soils with a clay-loam texture and depth of 3-5 feet should be deep ripped and provision made for drainage. Saline soils and soils with high salinity potential should also be avoided since not only does salinity retard growth and reduce yield but it exacerbates avocado root rot (Borst 1970, Menge and Marais 2000a, Zentmyer and Ohr 1978).

On sloped land, the construction of interception and diversion drainage ditches, or provision of water tight drain pipes which drain rain water away from the orchard, will help prevent the introduction of *P. cinnamomi* into lower lying orchards. In heavy clay soils, trees can be planted on mounds or ridges. This practice has been found to increase the survival rate of young trees by as much as 180% because of improved drainage. Ridges and mounds improve top soil depth in poor or limiting soils since surrounding top soil is gathered and incorporated into the mounds and ridges.

Soil solarization, a practice of using clear polyethylene sheets on the soil surface to trap solar radiation and heat the soil, has been found to be effective in reducing Phytophthora inoculum following tree removal in infested soil in Israel (Erwin and Ribeiro 1996).

Soil amendments: Most soils in native habitats of avocados are high in organic matter, and the trees do best in soils with 8% or greater organic matter content. The application of amendments such as organic mulches and gypsum contribute to improving soil structure, thereby improving drainage, helping to remove salts from the soil, and have the added benefit of increasing the soil's suppressiveness to *P. cinnamomi*. The suppressive effect of calcium and organic matter was first discovered in Australia (Broadbent and Baker 1974). The beneficial effects of organic mulch are thought to be due to the development of high populations of micro-organisms in the soil which are antagonistic to *P. cinnamomi*. Also, avocado roots do best in soils with oxygen content greater than 25% and porous mulches contain high levels of oxygen. Mulches placed in layers 4 - 6 inches thick under the canopies of the trees has been shown to suppress PRR and be beneficial to avocado trees in California (Menge and Marais 2000a,b).

A study of the effects of calcium on PRR was conducted in California soils by Messenger-Routh (1996) who concluded that calcium primarily acted as a weak fungicide by reducing the size and number of sporangia produced by *P. cinnamomi*. Applications of 1500-3000 lbs/acre gypsum under the tree canopies, depending on the size of the trees, may be helpful in the prevention of the spread of PRR.

Disease-free nursery trees: Historically, diseased nursery stock was the major source of spread of PRR in California. Now, commercial nurseries have certification programs which ensure that growers can purchase PRR-free trees.

Irrigation and irrigation water: The avocado tree is extremely sensitive to water-logging due to the high oxygen requirement of its roots. Under such conditions, root growth ceases and the stage is set for large-scale destruction of feeder roots. The use of tensiometers or other tools to schedule irrigation is advised. Water from deep wells is unlikely to be contaminated with *P. cinnamomi*, while water from reservoirs and canals can be a source of infection and should be treated with chlorine to eliminate inoculum.

When an infection area is identified in an orchard, the diseased trees and the trees at the margins of the diseased area should be irrigated with caution, avoiding over-irrigation. Careful irrigation can retard the spread of the disease and often prolong the life of affected trees (Faber and Ohr 1999, Menge and Marais 2000a,b).

Orchard sanitation: Excluding *P. cinnamomi* from a clean avocado orchard is the most economical method of controlling the disease. Movement of soil and water from diseased orchards into healthy ones should be avoided at all costs. The fungus readily moves from orchard to orchard in moist soil on tools, vehicles, bins, ladders, shoes, domestic and wild animals, etc. Barriers in the form of fences and warning signs should be placed between uninfected and infected orchards. Boxes containing copper sulfate should be placed at the property entrance and all foot traffic should dust shoes before entering the grove. Shallow, chlorinated or copper sulfate-treated water baths may also be placed at the entrance to the property for vehicles to drive through when entering the premises. Shovels, soil augers and trowels should be dipped in 70% ethanol or rubbing alcohol before reuse. Always use disinfected equipment in healthy orchards after use in a diseased orchard. Severely affected trees should be removed (Menge and Marais 2000b, Faber and Ohr 1999, Zentmyer and Ohr, 1978).

Resistant rootstocks: A great deal of research has been conducted on detecting and developing resistant rootstocks, particularly in California, South Africa and Israel. Rootstocks such as Duke 7, Thomas, Barr Duke, Toro Canyon, and Merensky 2, exhibit a greater degree of tolerance to PRR than traditional Topa Topa seedling rootstocks. Not all of these rootstocks yield as well as the traditional PRR sensitive ones in non-infected groves. Trees on resistant rootstocks will survive under disease pressure when used in conjunction with the control measures mentioned above (Bijzet and Sippel 2001, Menge 2001, Menge et al. 1992, Menge and Marais 2000b). While disease-free clonal rootstocks have different levels of tolerance/resistance to PRR and may be expensive to purchase, they can provide a degree of insurance against devastation by PRR.

Crop replacement: When disease pressure and contributing environmental factors result in economic loss, it may be necessary to remove avocado trees. All varieties of citrus, many deciduous fruit tree crops, macadamia, persimmon, berries, all types of vegetables, and most annual flower crops are not susceptible to PRR and can be planted in old avocado orchard soils (Ohr et al. 1994, Faber and Ohr 1999).

Chemical control: In the 1970s and 1980s, systemic fungicides with specific activity against species of Phytophthora and related fungi revolutionized control of diseases such as PRR. The first of these compounds were metalaxyl (Ridomil®) and fosetyl Al (Aliette®) (Coffey 1987 and 1992, Erwin and Ribeiro 1996, Menge and Marais 2000b).

The phosphonates, including fosetyl Al and its active breakdown product phosphorous acid and potassium phosphite, have been effective when applied as foliar sprays, trunk paints, trunk injection, or soil application.

Trunk injection, first developed in South Africa, has given good results in several avocado producing countries (Darvas et al. 1984). In South Africa and Australia salts of phosphonic (phosphorous) acid, particularly potassium phosphonate (potassium phosphite) have been registered for foliar and trunk injection. A similar product has been registered for use in Israel. In most countries, trunk injection of these chemicals is the preferred method of application and is the best way to rejuvenate trees severely affected by PRR. Fosetyl Al injected into severely affected trees has resulted in complete recovery.

In South Africa 1 ml of a 50% neutralized (buffered) phosphonic acid (neutralized with potassium hydroxide) is injected per meter square (10 feet square) of tree drip area; this equates to 0.5 g (0.02 oz) active ingredient per meter square of tree drip area. Injections are applied twice annually, once following the hardening off of the spring flush, which occurs during and after flowering, and the second application following the hardening off of the summer flush. These two applications coincide with peak root flushes (Menge and Marais 2000b).

Metalaxyl (Ridomil®) has been applied as a granular, a drench, or injected into the irrigation water and has been found to be effective in some cases. However, Aliette® has been found to be more effective than metalaxyl in mature orchards in California (Coffey 1992).

Foliar and soil applications of Aliette® or phosphorous acid are made under certain conditions. The current recommended treatment for healthy and lightly infected trees in South Africa, New Zealand and Australia, is a foliar application of 0.8-1% buffered phosphorous acid 4-6 times annually.

Field trials continue in California, to test different chemicals and modes of application, for their efficacy in controlling PRR (Marais et al. 2001).

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