Crop Profile for Olives in California

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General Production Information

- Over 99% of the olives grown in the United States are grown in California. There is a small percentage of the acreage in Arizona.
- Approximately 1,000 growers farm 35,300 bearing acres of olives in California (1).
- California is primarily a table olive industry producing the "California black ripe" table olive. This is a product unique to California and is unlike the Mediterranean styles.
- In 1998 the crop totaled 99,663 tons valued at approximately $23,834,925 (1).
- California grows almost 11.2 % of the total world production of table olives and 0.1% of the olive oil.
- The cash costs required to produce an acre of table olives (5 tons) is approximately $2,400, including harvest (3).

Production Regions

The majority of olive acreage in California (65%) is located in the San Joaquin Valley, primarily in Tulare County (53% of the total). The other production area is the Sacramento Valley, primarily Glenn and Tehama counties (1). There is small but developing acreage in the coastal areas of California to exclusively produce gourmet olive oil.

Cultural Practices

The table olive industry includes 4 commercially grown olive (*Olea europea* L.) cultivars (CVs): Manzanillo (the most common), Sevillano, Ascolano, and Mission which account for over 99% of the total olive acreage in the State (1). In the southern districts, Manzanillo is by far the dominant CV. In Northern California, Manzanillo, Sevillano, Ascolano, and Mission are commonly grown. Recently some foreign CVs have been introduced for the olive oil market (6). Most of these olive CVs are grown from cuttings and are thus on their own root. The Sevillano is the exception and has to be grafted onto another CV because of rooting difficulty. These CVs can vary somewhat in susceptibility to diseases and

insect pests (2,4).

Olives can grow and be productively grown on a wide range of soils and soil quality. Very productive groves occur on hardpan soils and those higher in salts and Boron than would be suitable for other crops. Deep, well-drained fertile soils are less productive than more marginal soils because the trees tend to vegetation rather than production. Olives, although they are extremely draught tolerant, will not produce commercial crops without irrigation. Approximately 38-39 acre inches of water per acre per year are required for optimal production in the Sacramento and San Joaquin Valley respectively (4). Drip and micro-sprinkler irrigation are the most popular methods of irrigation, used by approximately 70% of the acreage. Furrow irrigation is used by most of the remaining acreage.

Most olives in California receive annual applications of nitrogen (N). Olive does not require a high dosage with about one pound of actual N applied per tree per year. Usually N is applied as commercial fertilizer, although manure and leguminous covercrops are used in a few cases. Potassium (K) and Boron (B) deficiencies occur in some locations, especially in the Sacramento Valley. Potassium Sulfate or Potassium Chloride are soil applied to correct K deficiency. Agricultural Borax or "Solubor" correct B deficiency. Deficiency of Zinc and other micronutrients is very rare in California olive production.

Due to the cold sensitivity of olive, non-cultivation is the most popular method of orchard floor management. Weeds are usually controlled over the entire orchard floor with herbicides. In some cases herbicides are applied to the tree row and the middles mowed but this is not as common as complete weed control. With the change to low-volume irrigation, few growers still cultivate.

About 99% all of the olives are currently hand harvested. Hand harvest is costly, approximately $300/ ton, which amounts to approximately ½ of the growers' production costs. Machine harvest is a high priority for California olive growers and new equipment is being developed and tested in field conditions. Trees suitable for contemporary machine harvest must be configured into a hedgerow arrangement for optimal fruit removal.

All olives destined for the "California Black Ripe" process, the most popular process in California, are picked green and immature. Following harvest, the fruit are soaked in an aerated lye solution that eliminates the bitterness contained in the fresh fruit and turns the fruit black. Following the washing process used to remove any trace of lye, Ferrous Gluconate is added to promote uniformity and stability of color. If air is not added to the lye, a green style (but not Spanish) olive evolves. The Spanish style, often pimento stuffed, olive is produced to a minor extent in California. This process requires lactic acid fermentation of the fruit (4).

Recently, a market for olive oil has developed. This component of the industry is targeting gourmet markets and the tourist trade with extra virgin oils. Currently, about 2% of the industry are involved in producing high quality olive oil (6).

Aside from CV distribution, there are few regional differences in olive culture.

OVERVIEW OF OLIVE PEST COMPLEX

Several insect, disease, nematode and weed pests attack California grown olives. The most severe pests include Black Scale, *Saisettia oleae,* Armored scales (Olive scale, *Parletoria oleae* [Colvee]; Oleander scale, *Aspidiotus nerii* [Bouche]; California red scale, *Aonidiella aurantii* [Maskell], Verticillium Wilt fungus *Verticillium dahliae* (Kleb.), Olive leaf spot, *Spilocea oleaginea* (Cast), and Olive knot bacteria, *Pseudomonas syringae pv savastanoi* (Smith) (4). Severity of damage is dependent upon year, culture, and region. Other minor pest problems (e.g. phytophthora disease or bud mites) occur on a very sporadic and site specific basis.

Insect Pests

Major Insect Pests

Black Scale, *Saisettia oleae*

Black Scale is a key pest for California olives. Although it is present in all olive growing districts, it most commonly requires control in the San Joaquin Valley (4).

In the hot interior valleys where most olives are grown, black scale has one generation per year. In the coastal districts 2-3 generations can occur per year. Where one generation occurs, the scale overwinters as an immature female scale on small shoots and branches. In March, the scale matures, lays eggs which are retained under her female body that begin to hatch in June. The crawlers emerge in June, July and August and move to the new leaves where they spend the remainder of the summer and fall. They then move to the shoots where they overwinter.

Black scale damages olive trees by direct feeding and secreting honeydew that inhibits photosynthesis. Research has shown that black scale populations allowed to develop into the late summer months reduce the following years bloom. Also, olive pickers do not like to pick fruit with honeydew on them.
Monitoring: No quantitative method of monitoring black scale is currently available. Need for treatment is determined by grove inspection.

Controls:

Biological and cultural:
Biological control of black scale is not currently effective in the central valleys of California. Weather conditions are unsuited to natural and introduced parasite survival from one year to the next.

Black scale prefers dense trees and humid, cool conditions. Annual pruning to eliminate dense conditions and "open up" the trees has proven effective in maintaining control of black scale while not influencing production (2,4).

Chemical:

- **Narrow Range oils** – 0 day PHI. Oils are applied at a rate of 1 – 1.5% (VV) from August through March. Used alone they provide modest control of black scale with thorough coverage. Most often, they are most combined with conventional insecticides to improve control (2).

- **Carbaryl** (Sevin 80S) – 14 day PHI. Applied at a rate of 4 - 5 lb per acre. Carbaryl is not applied alone for black scale but in combination with 1-1.5% VV spray oil. It is the most popular insecticide for scale control and is applied to approximately 15% of the acreage annually (2).

- **Methidathion** (Supracide 2E**)** – Applied at a rate of 1 gallon per acre. No treatment allowed pre-harvest. Methidathion effectively kills black scale but can only be applied post harvest, often after damage has occurred. This restriction has reduced its popularity and it is used on approximately 8% of the acreage. The new WP formulation requires the addition of a narrow range oil to be effective (2).

Armored scales

Olive scale, *Parletoria oleae* (Colvee)

Oleander scale, *Aspidiotus nerii* (Bouche)

Olive and Oleander scale can be serious pests. They infest the vegetative and reproductive growth. Vegetative growth, shoots and branches, can be killed when heavily infested. Fruit are un-marketable if armored scales are present (4).

Controls:

Biological Control:
Olive scale is effectively controlled biologically. The parasites *Aphytis maculicornis* (De Back and

Rosen) and *Coccophagoides utilis* (Doutt) have essentially eliminated need for chemical treatment of olive scale in California. Oleander scale is also usually controlled biologically (2,4)

Chemical:
When biological control has been upset, Methidathion (Supracide 2E) at a rate of one gallon per acre or Carbaryl (Sevin 80S) at a rate of 4 - 5 lb per acre plus oil applied during the growing season when immature crawlers are present effectively control armored scales (2). Less than 1 percent of the acreage requires chemical control.

Black vine weevil, *Otiorhynchus sulcatus* (Fabricus)

There is one generation of Black vine weevil per year. Adults emerge from the soil and feed on young leaf tissue close to the ground. Most damage occurs to younger trees where extensive leaf injury can occur.

Controls:

Biological and chemical control are not effective in controlling Black vine weevil. Best control is achieved by pruning "tree skirts" up, off the ground to prevent access to the foliage. Trunk protectors can also prevent access to the treetop.

Minor Insect And Mite Pests (4):

California red scale, *Aonidiella aurantii* (Maskell)

Greedy scale, *Hemiberlesia rapax* (Comstock)

Latania scale, *Hemiberlisia lataniae* (Signoret)

Western flower thrips, *Frankliliella occidentalis* (Pergande)

Branch and twig borer, *Polycaon confertus* (Le Conte)

American plum borer, *Euzophera semifuneralis*

Olive bud mite, *Oxyenus maxwelli* (K)

These insects and one eriophyid mite rarely occur and are not usually considered economic pests of olive. Their presence is usually the product of an insecticide upset or cultural condition favoring infestation. Loss of registered organophosphates and carbamate insecticides would limit access to chemical control of the scale pests (if needed). Western flower thrips, branch and twig borer, and American plum borer do not have registered pesticides available for their control. Sulfur, either 8 lb of wettable or 70 lb of dusting per acre, can be used to control olive bud mite.

Diseases

Several diseases may cause serious problems in olives; Verticillium wilt, olive leaf spot, olive knot. Their severity depends on weather conditions, location, and cultural practice (4).

Foliage diseases and diseases effecting shoots and branches are caused by pathogens that are spread by wind, splashing water or insects. Injuries such as frost cracks provide entry points for infection.

Soil-borne diseases are caused by soil-inhibiting pathogens that infect roots. Root and pathogens are spread by wind, in surface water, and soil contaminated equipment.

Foliage Diseases

Olive Leaf Spot, *Spilocea oleaginea*

Olive leaf spot, a fungus disease, is one of the most common and damaging diseases of olive. This fungus disease infects leaves with the first fall rains. The fungal spots enlarge and become colored resembling the "eye spot" of a peacock's tail; thus often referred to as "peacock spot". In spring, infected leaves defoliate, reducing bloom and subsequent crop. In years of high winter rainfall, untreated trees can lose fifty percent of the canopy due to olive leaf spot infection (4).

Controls:

Cultural Control:

Dense trees and humid conditions encourage optimal olive leaf spot infection. Pruning, to eliminate dense clumps of foliage, mitigates infection and enhances coverage of protective fungicides.

Chemicals:

Coppers (Bordeaux mix, and proprietary "fixed" coppers) - Applied at a rate of 4 lb of metallic copper per acre. Copper containing fungicides are applied following harvest as protectant sprays, preferably before the onset of fall rains. Additional applications are often put on in January if winter rains are above normal. Chemical control of established infections is ineffective (2).

Olive knot, *Pseudomonas syringae* pv *savastanoi*

Olive knot, a bacterial disease, requires an opening for infection. Pruning wounds, leaf scars and frost cracks are the most common wounds of olives that become infected with Olive Knot. Rainfall disseminates the bacteria into these openings. Once infected, tissue grows uncontrolled forming a gall ("knot") that girdles and kills shoots and branches. Severe infections, usually resulting from freezing temperatures that result in a profusion of wounds, can result in considerable fruit wood death.

The Manzanillo CV is the most susceptible to infection, as it is the most frost sensitive of the olive CVs grown in California. Sevillano, Mission, and Ascolano are more resistant to Olive Knot. Olive knot is most serious in Northern California growing districts where probability of cold damage is high (4).

Controls:

Growers prune olives in spring to reduce the hazard of opening pruning wounds for infection from rainfall. Pruning out established knots is recommended in summer to eliminate inoculum from the grove.

Grove floors are managed free of weeds for optimal protection against radiation and advective freezes.

Chemical:
Coppers (Bordeaux mix, and proprietary "fixed" coppers) - Applied at a rate of 4 lb of metallic copper per acre. Copper containing fungicides are applied following harvest as protectant sprays, preferably before the onset of fall rains and dissemination of the bacteria. Additional copper applications are required following hard freezing weather to protect frost cracks from infection (2).

Although chemical control of established infections is effective by topical treatment with Gallex ^{R}, this is expensive and time consuming and is only done where infection of trunks and major limbs occurs.

Verticillium Wilt, *Verticillium dahliae* (Kleb.)

Verticillium Wilt is a very serious disease of olive. It is also a common disease of cotton, tomatoes, melons and many broadleaf weed species. Strains of the Verticillium Wilt fungus exist and vary in virulence. The cotton strain is most damaging. Severe damage to olive occurs in the San Joaquin Valley growing district where the crop is often grown in close proximity to cotton. Commercial olive culture does not exist on the west side of the San Joaquin Valley due to Verticillium Wilt.

The fungus is soil borne and resides in the soil as a long-lived microsclerotia. It infects the root system directly in spring, fall, and cool periods of summer where it grows into the vascular system clogging the water conducting tissue. When hot weather occurs following infection, portions of the tree wilt and suddenly die due to lack of water. Leaves on infected portions of the tree remain attached to the tree and do not defoliate. Depending on the particular strain of *Verticillium dahliae*, damage can range from death of occasional small shoots to the entire tree (4).

The Sevillano CV is the most sensitive to Verticillium Wilt. Mission and Manzanillo are sensitive and Ascolano is highly resistant.

Controls:

There are no effective chemical controls for Verticillium Wilt in established groves. Pre-plant fumigation with materials such as Methyl Bromide has not provided acceptable control of the fungus (2). Solarization, covering infested soil with plastic to raise the soil temperature and kill the fungus inoculum has been inconsistent in effectiveness (4).

Some growers plant a winter grass cover crop (e.g. Barley) to flood the soil profile with non-host roots of the fungus. Such a practice has been observed to mitigate infection in some situations. Such practices are not popular however because of the increased frost hazard and additional management of a standing cover crop.

It is best to plant olives in areas where the Verticillium hazard is low. Laboratory techniques can determine the level of Verticillium inoculum in acreage's proposed to be planted to olives.

Phytophthora Root and Crown Rot, *Phytophthora* spp.

Phytophthora species attack olive trees in California but the disease is not considered a major problem. The pathogen enters the tree either at the crown near the soil line, at the major roots or at the feeder roots, depending on the species. Trees affected with *Phytophthora* first show small leaves, sparse foliage, and lack of terminal growth. Infected trees may decline for several years or die within the same

growing season in which the foliage symptoms first appear. Phytophthora can survive in the soil for many years and spreads and infects the trees during moist cool to moderate temperatures and some infection may occur in the summer depending on species (4).

Controls:

Cultural:
Control of Phytophthora and crown rot is based on site selection and preparation, proper irrigation management, and improvement of soil drainage.

Chemical:
No chemical controls for Phytophthora exist in California.

Armillaria Root Rot, *Armillaria mellea*(Vahl.)

Armillaria occasionally infects olives in California. The fungus prefers soils that are often wet (e.g. along river drainages) which are not popular olive locations. Many strains of the fungus exist, ranging from non-virulent or weakly virulent to extremely virulent that kill trees shortly after infection occurs. The pathogen invades the roots, crown and basal trunk, eventually girdling the crown region and destroying the entire root system causing death of the tree. It can survive for many years in dead roots of many different species of tree (4).

Controls:

Cultural:
One of the best methods of managing *A. mellea* is careful selection of orchard ground before planting an orchard. Avoid planting where forest or oak woodland has been cleared recently or on a site with a history of Armillaria root rot.

Chemical:
Methyl bromide has shown some promise for control of *A. mellea* at the rate of 300-600 lb. per acre applied by injection with tarping.

Nematodes

Citrus Nematode, *Tylenchulus semipenitrans*

Root Knot Nematodes, *Meloidogyne* spp.

Root lesion nematode spp. *Pratylenchus vulnus; Pratylenchus penetrans*

Root lesion, citrus and root knot nematodes

Plant parasitic nematodes are microscopic roundworms that feed on plant roots of most plants including prunes. They live in soil or within the cortical tissues of the roots. The extent of the damage caused by nematodes in olives depends largely on the density of the nematode population and soil conditions. Symptoms of a nematode infestation include lack of vigor, small leaves, and a sparse root system, particularly the lack of small feeder roots. Necrotic lesions on roots are symptomatic of root lesion nematode. Root galls are an indication of citrus and root knot nematode (one study has shown production loss due to Citrus Nematode). Root knot nematodes take up a single feeding site within a root where they remain for their entire life. Some legumes grown for covercrop on the orchard floor provide an excellent habitat and food source for nematodes (4).

Of the root lesion species, *Pratylenchus vulnus* is more common in the Southern California olive district and *Pratylenchus penetrans* in the Northern districts (4).

Controls:

Biological:
There are no known biological agents that are deliverable to soil or the surfaces of roots, which will provide relief from endoparasites such as root lesion nematode.

Cultural:
If possible, new olive groves should be planted on land where non-woody plants have grown for several years. However this is not a viable option for most growers. No rootstocks are known to be resistant to Citrus or Root Knot nematodes. Nematode numbers are greatly reduced for as long as 6 years by fallowing 1 or 2 years and then fumigating prior to replanting. Few growers can afford to idle their land for the 4 to 5 years necessary to achieve adequate nematode reductions.

Chemical:
Methyl Bromide can be used as a preplant treatment when replanting into soils previously in orchard crops. However, due to its expense, fumigation is rarely used in pre-plant treatment of California olive groves.

Weeds

Orchard floor management in olives is a challenge.

Weeds can cause a multitude of problems in olive orchards. They reduce the growth of young trees because they compete for water, nutrients, and space. Weeds also increase water use, increase vertebrate and invertebrate and other pest problems, and may enhance the potential for disease. Frost hazard is greatly increased when weeds are present on the orchard floor. The increasing use of more efficient low-volume irrigation systems has increased the need for selective preemergence herbicide use in drip, micro-sprinkler, and sprinkler-irrigated orchards. The most popular system is herbicide treatment of the entire orchard floor to eliminate weeds (4).

Herbicides can also be used in the tree row. This reduces the total amount of herbicides and prevents the surface roots in the tree row from being damaged by cultivation equipment. This is not popular in California olive culture.

Preemergence, postemergence, or a combination of pre- and postemergent herbicide controls weed species. Soil characteristics have an effect on the broad weed spectrum (often 15-30 species per orchard), and the residual activity of herbicides. Irrigation methods and the amount of irrigation or rainfall affects herbicide selection and the residual control achieved (4).

Treatment decisions and herbicide selections are based on dormant and early summer weed surveys and history of weeds in particular blocks.

Controls:

Cultural:
Complete tillage is an option in olives and was the only weed control technique available until the advent of herbicides. It has a number of drawbacks and is decreasing in use. Tilling requires a large expenditure for machinery, and is expensive. Machinery used for tilling depends on the use of non-renewable fossil fuels, contributes to air pollution, destroys soil structure and causes compacted layers in the orchard, hindering water penetration. Tillage can contribute to pest buildups by causing dust on trees, which increase scale problems, and injuring trees allowing disease organisms to invade trees (2,4).

Hand hoeing can be used to remove weeds from around trees and sprinkler heads but is not used extensively because of the expense involved.

Chemical:

- **Glyphosate** (Roundup, etc.) – 14 day PHI. Applied during the dormant, pre-and/or post-bloom

by ground one or more times per season to 95% of the olive acreage at an average rate of 0.67 lb. a.i. per acre (5). Nonselective systemic used for a broad range of weed species. Effective anytime on emerged, irrigated, rapidly growing, non-stressed weeds, but activity is slower in lower temperatures. Not effective on some broad-leaf weeds at older stages of growth (malva and filaree). Continued use of this material leads to a shift of species and selection of tolerant species.

- **Simazine** (Princep 4L, Princep Caliber 90, etc.) – Typically 300 day PHI. Simazine is usually applied during fall but can be applied pre-bloom. Applied to bare soil or in combination with glyphosate by ground one time during the season to 26.5% of the acreage at an average application rate of 2.2 lbs a.i. per acre (5). Simazine is effective as a pre-emergence herbicide for many broadleaf and grass weeds. Effective when combined with translocated herbicide such as glyphosate or the contact herbicide paraquat, and a broad leaf pre-emergence herbicide such as Oxyfluorfen. Used for "border to border" treatment to maintain a weed free orchard floor. Simazine is the only material effective on fleabane and horseweed. Simazine is weak on grasses.

- **Diuron** (Karmex, Direx) – Applied in spring before bud growth to approximately 34% of the acreage at an average rate of 1.6 – 3.2 lb ai per acre (5). Diuron is a pre-emergence herbicide most effective when targeting grasses. Does not control spurge or bristly oxtongue.

- **Oxyfluorfen** (Goal) – 0 day PHI. Applied by ground one time per season on 16% of the olive acreage at an average rate of 0.37 lb. a.i. per acre (5). Oxyflorfen is a selective broadleaf herbicide that is effective as a pre and post-emergent material. Particularly useful when combined with Glyphosate to increase efficacy on various broadleaf weed species and to prevent broadleaf species shifts with glyphosate.

- **Paraquat** (Gramoxone Extra) – 13 day PHI. Applied pre or postbloom by ground one or more times per season on 19% of the olive acreage at an average rate of 1.2 lb. a.i. per acre (5). Nonselective post-emergence material used for quick "burndown" of most weed species. Less effective against perennials that will regrow with vigor, e.g. bermudagrass, dallasgrass, Johnsongrass and bindweed. Most effective when used on early spring or winter growth of annual weed species in combination with preemergence herbicides.

- **Oryzalin** (Surflan AS) – no specific PHI. Applied preemergence by ground one time per season on 3% of the acreage at the average rate of 2 – 6 lb. a.i. per acre (5). Oryzalin is a pre-emergence selective herbicide most effective on annual grass species and numerous broadleaf annuals. Very safe for young or newly planted trees and on sandy or sandy-loam soils. It is used to maintain control in strips down the row. Often used in combination with other preemergence herbicides.

Fruit Thinning

Olives are valued based on fruit size. Heavy crops have preponderance of small fruit that are expensive to pick and of little value. Further, olives are alternate bearing; light crops invariably follow heavy crops. Fruit thinning has been shown to reduce crop load, improving size of the remaining fruit and to minimize alternate bearing (4).

Hand thinning – Hand thinning is not practical for olives.

Chemical – Napthalene acetic acid (NAA) is an effective fruit thinner when applied 7 – 14 days following full bloom. Activity of the thinner is influenced by tree condition, air temperature, and NAA dose. If used improperly or under adverse conditions, over thinning results. In 1995 approximately 5% of the acreage (primarily Manzanillo CV) was chemically thinned (5).

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