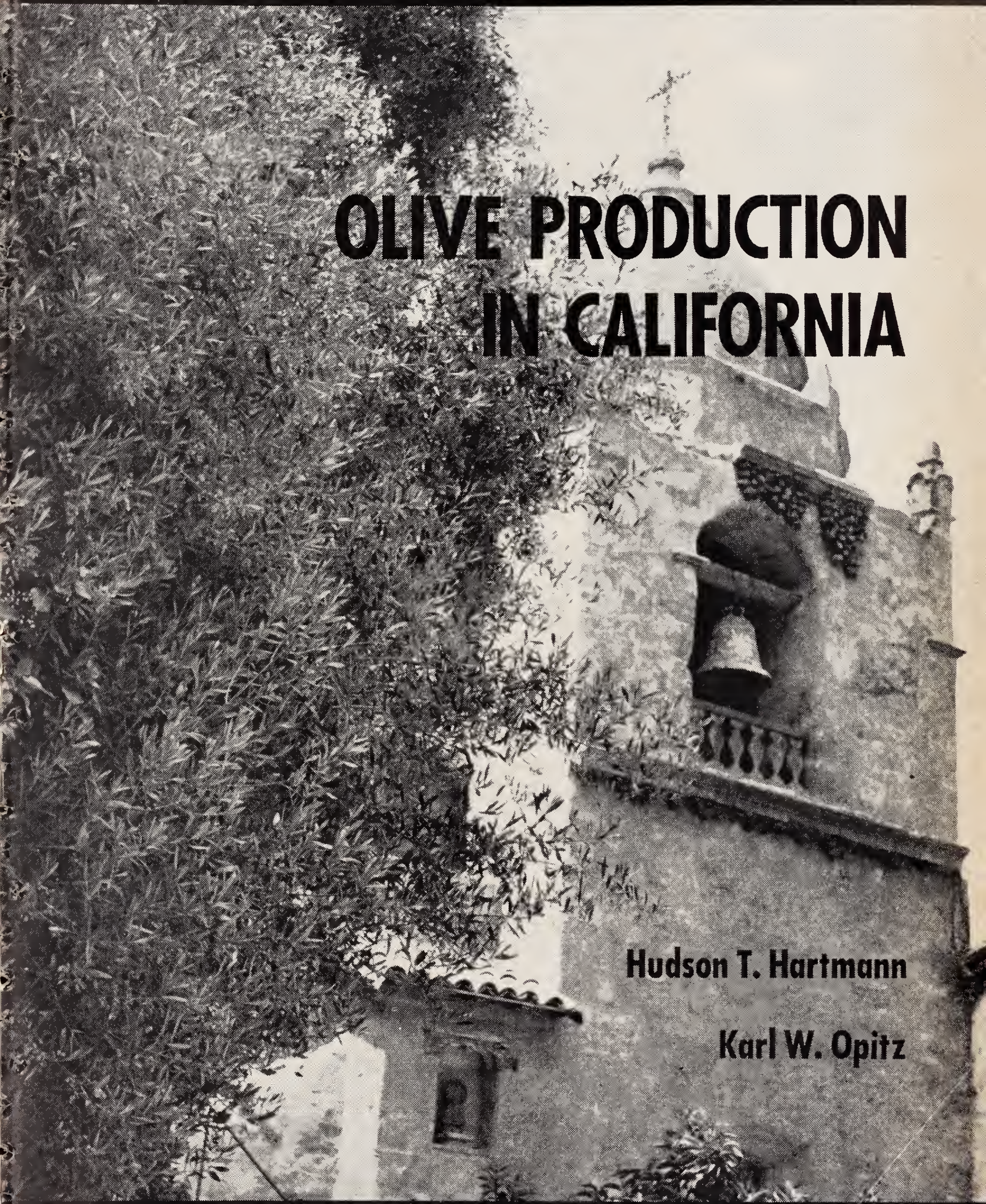
Division of Agricultural Sciences

UNIVERSITY OF CALIFORNIA

OLIVE PRODUCTION IN CALIFORNIA



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CALIFORNIA AGRICULTURAL
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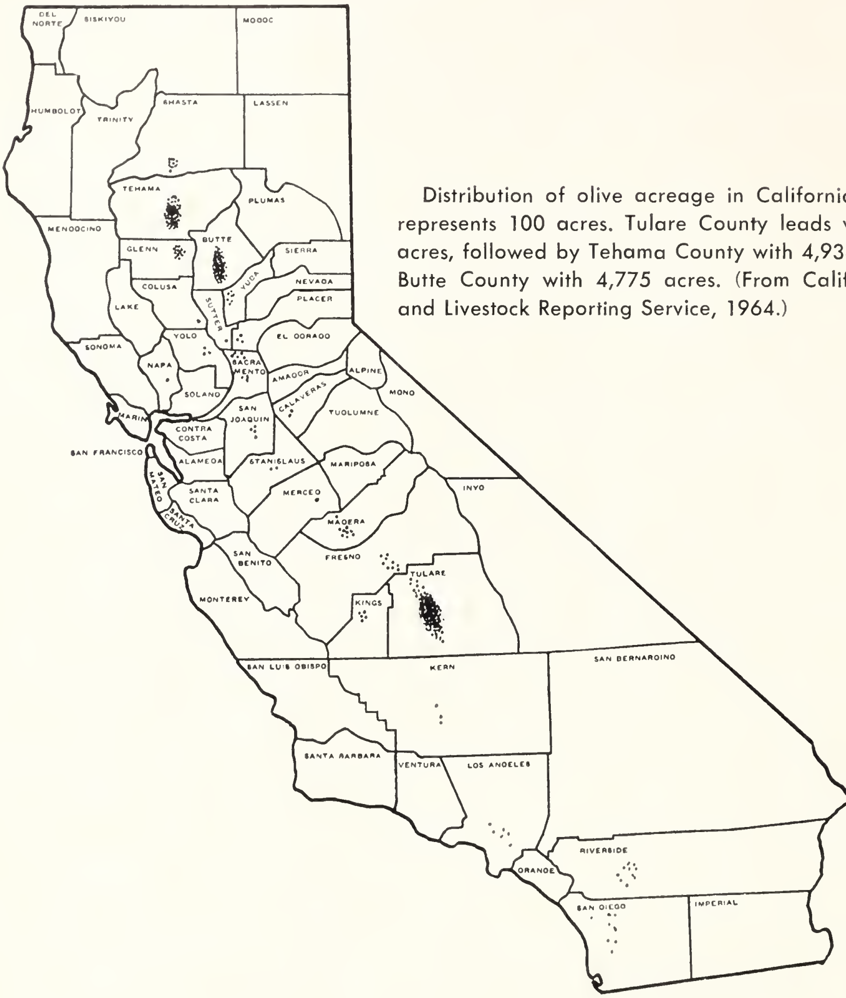
THIS CIRCULAR is intended for commercial growers interested in present or future olive production. All important aspects of such production are discussed, and references for more detailed information are given.

This publication replaces former Manual 7



Distribution of olive acreage in California. Each dot represents 100 acres. Tulare County leads with 11,730 acres, followed by Tehama County with 4,938 acres and Butte County with 4,775 acres. (From California Crop and Livestock Reporting Service, 1964.)

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OLIVE PRODUCTION IN CALIFORNIA

(Glossary of Terms starts on page 60.)

THE ECONOMIC BACKGROUND . . . A SHORT HISTORY OF OLIVE PRODUCTION . . . IMPORTANCE OF THE CROP . . . MAJOR VARIETIES

Olives are among the important tree fruits produced commercially in California. About 2500 growers farm 32,270 acres of olives, and the annual crop value for a 5-year period ending in 1964 was about $9,405,600. In bearing acreage, olives ranked ninth in 1964, above plums, apples, and avocados, and just below apricots and pears.

Commercial olive orchards are located mostly in the Sacramento and San Joaquin Valleys which, because of relatively cold winters and warm, fog-free summers, are more suitable for olive production than are the coastal regions or southern California. Yields are heavier and more regular, and insect control is less difficult than along the coast. Many olive plantings were made along the coast and in southern California in the past, but there are no new commercial plantings in this area. However, the olive will grow in all parts of California except where winter cold may kill the trees.

Beginnings of olive production in California

Olives are grown commercially between about 30° and 45° north and south latitudes. The trees will not survive temperatures below about 10°F (–12.2° C), and most varieties are injured at 15°F (–9.4°C). They will grow vegetatively nearer the equator than 30° north or south latitude but are usually unfruitful, probably because of insufficient winter chilling to induce flower formation.

Olives were originally taken to the Western Hemisphere from the Mediterranean area by Spanish explorers who brought cuttings or seeds to South America. Olive trees were first planted in California around 1800, when seeds or cuttings were brought to Mission San Diego from Mexico by the Franciscan padres. The variety resulting from this early planting at San Diego was named "Mission," and today it comprises about 30 per cent

Olive trees and production of olives, table olives, and olive oil in the leading olive-producing countries of the world.

Country	Total trees (1,000 trees)*	Average trees per acre*	Average total production per year (1,000 short tons) 1960–63†	Per cent of world production	Average quantity of olives crushed (1,000 short tons) 1960–63†	Average production for table use (1,000 short tons) 1960–63*	Average production of olive oil (1,000 short tons) 1960–63†
Spain	182,232	34	2478.7	30.6	2414.0	64.8	490.3
Italy	168,465	53	2468.6	30.4	2422.6	46.0	496.6
Greece	77,300	55	759.5	9.4	712.4	47.1	175.6
Turkey	57,153	55	557.8	6.9	486.7	71.1	98.4
Portugal	49,496	36	668.0‡	8.2	667.8	0.2	97.3
Tunisia	27,540	28	407.9	5.0	.....	....	88.5
Morocco	14,000	..	170.9§	2.1	.....	....	25.4
Syria	11,513	40	80.2	1.0	76.1¶	4.2	17.4
Algeria	11,258	30	154.9¶	1.9	120.2‡	34.7	17.4
France	11,000	50	8.0	0.1	7.2	0.9	1.4‖
Argentina	10,000	40	52.7	0.6	39.7	13.0	8.0
Jordan	5,767	40	48.8	0.6	42.4	6.4	9.1
Yugoslavia	5,000	50	35.8	0.4	.....	....	5.8
Lebanon	4,425	80	48.5	0.6	30.1‖	18.4	8.3
Libya	3,463	12	38.9§	0.5	.....	....	8.5
U. S. A. (Calif.)	2,326	75	54.9	0.7	6.1**	48.8	1.1
Cyprus	2,240	48	30.9‡	0.4	.....	....	4.4‡
Chile	1,745	..	.....	....	.....	....	....
Mexico	1,370	40	3.9	0.05	2.0	1.9	....
Israel	1,287	50	15.4§	0.2	9.4	6.1	1.4‖
Egypt	700	160	10.7§	0.1	.....	....	....
Peru	318	..	11.0§	0.1	.....	....	....
Uruguay	316	..	2.2‡	0.03	.....	....	1.1‡
Australia	285	45	1.4	0.02	.....	....	....
Brazil	253	40	.....	....	.....	....	....
Iran	250	..	.....	....	.....	....	....
Japan	124	120	.....	....	.....	....	....
Union of South Africa	120	..	.....	....	.....	....	....
Iraq	30	..	.....	....	.....	....	....
Malta	23	120	.....	....	.....	....	....
Colombia	6	..	.....	....	.....	....	....

* F. A. O. Government Surveys, 1957.
† F. A. O. Production Yearbook, 1963–64.
‡ 1960 only.
§ 1960, 1961, 1962 only.
¶ 1960, 1961 only.
‖ 1960, 1962, 1963 only.
** 1962, 1963 only.

of the acreage of olives in California. Other commercial varieties currently grown here were introduced about 1875 from Spain and Italy, where they still are cultivated as standard pickling varieties.

Numerous varieties were introduced between 1850 and 1900 from Mediterranean countries, and much effort was given to testing them, chiefly for oil production. By 1875 the industry showed promise of becoming important in California agriculture, with about 11,500 trees in bearing. In 1910 there were about 958,000 such trees, but emphasis then shifted from oil to table varieties, and many orchards were grafted to the more profitable pickling-type olives. Since about 1925 the bearing olive acreage in California has been fairly constant, fluctuating around 26,000 acres. Acreage has been gradually increasing since World War II, however, and in 1964 there were 28,606 bearing acres and 3,663 nonbearing acres.

The industry in California

California produces more than 99 per cent of the olives grown in the United States. (Arizona is the only other state having a commercial acreage, with production of 100 tons or less per year.) Olive production in the United States averaged 56,600

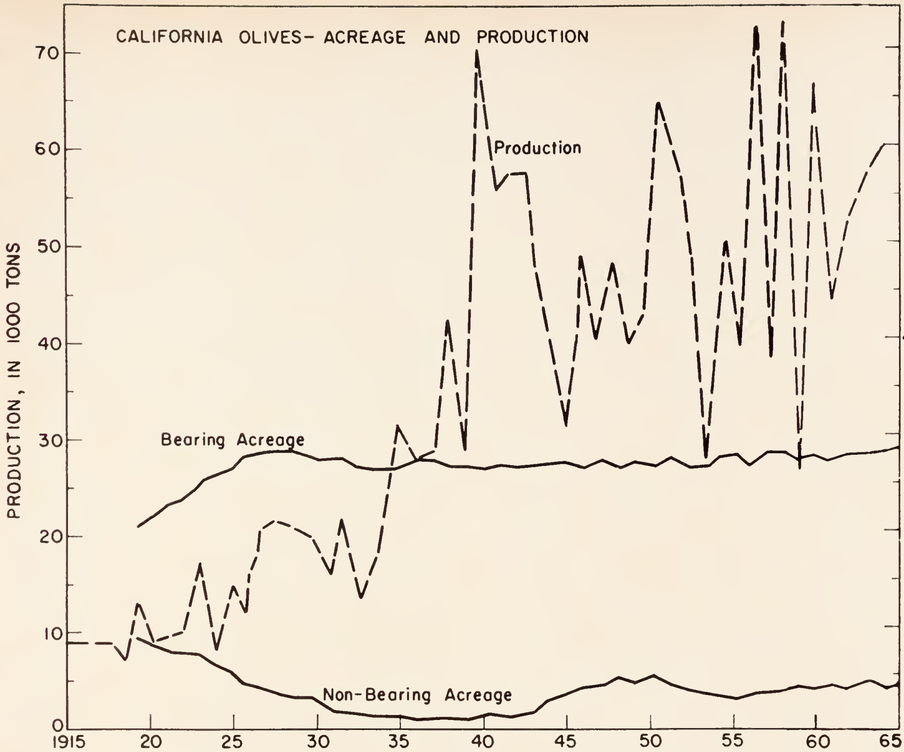


Fig. 1. Bearing and nonbearing acreage and production of California olives. (From California Crop and Livestock Reporting Service.)

tons per year from 1960 to 1964—less than 1 per cent of the total world production.

California supplies only about 6 per cent of the olive oil needed in the United States, and most of the remainder is imported from Spain and Italy. No orchards are planted for production of olives for oil only, because California cannot produce it as cheaply as can the Mediterranean countries. Thus, olive oil production in California is largely a salvage operation, utilizing small, cull, or frozen fruits. Imports of olive oil into the United States have remained fairly constant, averaging about 6,760,000 gallons annually for the period 1954–63.

Spanish-green olives produced in California accounted for only about 11 per cent of those consumed in the U. S. during 1959–1963; the remainder was imported, mostly from Spain. This type of olive was not processed commercially in California until about 1935, and the annual production has not changed much since 1940, chiefly because of competition from the imported product. A limited market exists in eastern cities for fresh, uncured olives purchased for processing at home.

Thus, California's olive industry is based on the production of canned ripe olives (black-ripe and green-ripe). The output of this product has increased from 2,300 tons in 1919 to 37,500 tons in 1964.

Yield per acre for olives varies considerably throughout the state, depending upon district, age of trees, variety, and cultural care. From 1954 to 1964 the average bearing acreage of all varieties was 28,260, and the average marketable crop was 52,100 tons—an average yield per acre of 1.84 tons; heaviest yields are generally in Tulare County.

With good care, California's olive trees start bearing during their third to fifth year, gradually reaching full production by the twelfth to twentieth year. Many groves decline in production after 40 to 50 years, usually because of overcrowding or poor fertilization, soil, and water man-

Table 1. Principal California bearing and nonbearing olive acreage (1964).

County	Bearing acreage	Non-bearing acreage	Total
Sacramento Valley:			
Butte	4,686	89	4,775
Glenn	1,092	169	1,261
Placer	315	4	319
Sacramento	841	0	841
Shasta	803	47	850
Tehama	4,357	581	4,938
Yolo	299	0	299
Yuba	711	4	715
Total	13,104	894	13,998
San Joaquin Valley:			
Calavaras	234	0	234
Fresno	912	43	955
Kern	171	75	246
Kings	327	99	426
Madera	513	353	866
Merced	137	2	139
San Joaquin	359	20	379
Stanislaus	230	13	243
Tulare	9,572	2,158	11,730
Total	12,455	2,763	15,218
Southern California:			
Los Angeles	568	0	568
Riverside	1,198	4	1,202
San Bernardino	47	0	47
San Diego	697	1	698
Total	2,510	5	2,515
All others	537	1	538
State total	28,606	3,663	32,269

SOURCE: California Crop and Livestock Reporting Service.

agement. Closeness of planting, which affects the ultimate size of the tree, is an important factor in such decline (see page 15).

Marketing olives

California processor-canners (of whom there are about 14) handle the marketing of olives. Their output is chiefly canned ripe olives, but most processors also pack Spanish-green, chopped olives, and other types, and some also manufacture olive oil. A few grower-owned cooperatives market about half of the olives produced. There are several olive oil plants in California, although some do not operate every year. Processing olives and olive oil requires considerable capital and technical knowledge

The California Olive Association (with headquarters in San Francisco) was organized in 1920 to promote the interests of the ripe olive industry, largely through collecting and pooling information. It is a trade association of ripe-olive canners but does no marketing of olive products.

Five varieties are commercially important

The Manzanillo variety is grown on about 37 per cent of the bearing acreage in California (10,533 acres in 1964). Next in importance are Mission (9,356 acres), Sevillano (7,095 acres), Ascolano (833 acres), and Barouni (339 acres). In nonbearing acres in 1964, Manzanillo led with 2,119 acres (about 58 per cent of the total) followed by Sevillano, Ascolano, Mission, and Barouni.

In past years the value per ton of olives has increased considerably as fruit size increased. Therefore, varieties producing large fruits (such as the Sevillano and Ascolano) have been favored in new plantings, but the increased production of these varieties has caused a narrowing of the price differential favoring them. Most large processors now favor Manzanillo because it processes with the least difficulty, and because its fruit sizes sell more readily and are preferred by most consumers.

In Tehama County, Sevillano is preferred for new plantings and for top-working other varieties. In Butte County, Mission is chiefly grown. The packers in that area favor this variety but there are small acreages of all the other varieties, with Manzanillo increasing. In Tulare County, Manzanillo is considered the most suitable, with Sevillano and Ascolano recommended for more limited plantings. Mission is not advised for new orchards in the Tulare district.

Each of the five commercial varieties will be discussed briefly below. (For a fuller discussion of varieties in California ask your Farm Advisor about University of California Agricultural Experiment Station Extension Service Bulletin 720,

Table 2. California production and imports of olive oil, Spanish-green olives, and canned ripe olives, 1944–1964.

Item	1944 to 1949	1949 to 1954	1954 to 1959	1959 to 1964
	Thousands of gallons*			
Olive oil:				
Average annual California production.......	774	549	461	249
Average annual U. S. imports...............	2,375	7,117	6,650	6,919
Per cent of U. S. consumption supplied by California............................	24.6	7.2	6.5	3.5
Spanish green olives:				
Average annual California production.......	1,324	1,098	1,796	1,709
Average annual U. S. imports.............	8,777	12,088	11,854	13,667
Per cent of U S. consumption supplied by California............................	13.1	8.3	13.2	11.1
Canned ripe olives: (black ripe, green ripe)				
Average annual California production.......	5,963 (16,400 tons)	8,720 (23,980 tons)	11,200 (30,800 tons)	12,189 (33,520 tons)
Average annual U. S. imports.............	None	None	None	None
Per cent of U. S. consumption supplied by California............................	100	100	100	100

* A gallon is approximately equal to 5.5 pounds of olives.
SOURCE: California Olive Association, "Statistics relating to the California Olive Industry," 1944–45 to 1963–64, April, 1965.

Olive Varieties in California, which is out of print but available in many libraries.)

Manzanillo. Trees are relatively low and spreading and fairly easy to harvest. Fruits process easily, are larger than those of Mission and have a much higher flesh-pit ratio. Oil content is high enough to warrant oil extraction of small size, frozen, or cull fruits. Fruit matures early enough in the fall to rarely be injured by frosts, but the trees are much more susceptible to low-temperature winter injury than are those of other major varieties. Manzanillo is not likely to become badly infected with peacock spot disease (see page 57), but it is very susceptible to olive

Table 3. Production, utilization, and average returns to growers for California olives, 1959–60 to 1964–65.

Crop year	Canned ripe		Crushed for oil		Shipped fresh		Other uses*		Total production	
	Tons	Average return per ton	Tons	Average return per ton	Tons	Average return per ton	Tons	Average return per ton	Tons	Average return per ton
1959–60...	20,400	$276	2,300	$65	200	$148	3,900	$86	26,800	$229
1960–61...	44,300	203	7,800	54	800	214	12,900	57	47,800	157
1961–62...	26,100	217	7,800	61	700	206	9,200	79	44,000	160
1962–63...	37,700	262	5,700	67	600	166	7,800	95	52,000	214
1963–64...	39,100	245	7,500	50	600	221	9,600	94	57,000	193
1964–65...	37,500	165	6,200	61	700	223	9,400	55	54,000	135
Six-year average.	34,200	$228	6,200	$60	600	$196	8,800	$78	46,900	$181
1945–46 to 1950–51 average.	......	$287	.....	$140	...	$249	.....	..	42,166	$227

* Other uses include California Spanish-green, Greek style, Sicilian style, chopped, sliced, and home cured.
SOURCE: California Crop and Livestock Reporting Service.

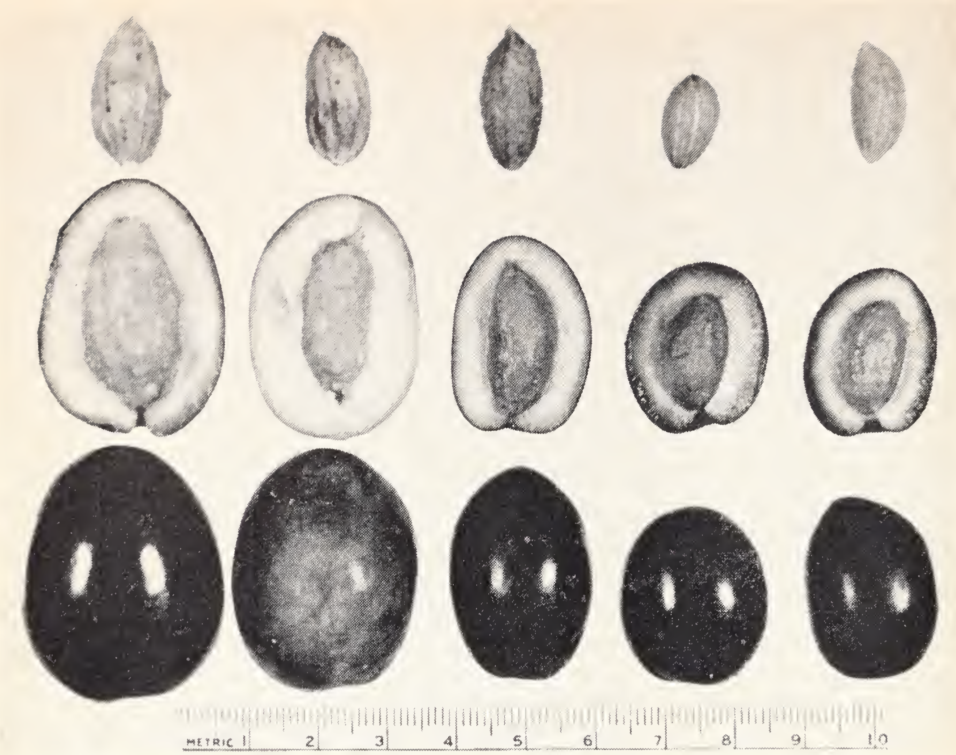


Fig. 2. California's major olive varieties. Left to right. Sevillano, Ascolano, Barouni, Manzanillo, and Mission.

knot (much more so than Mission); young trees or new grafts often become heavily infected with this disease, especially when planted in or adjacent to orchards where infection is present.

Mission. The fruit is fairly easy to process and its high oil content provides an alternative, though low-profit, product in years when oil production is necessary. Mission is most resistant to cold of any California commercial variety—some old trees survived temperatures as low as 8°F in the 1932 freeze—but its disadvantages tend to outweigh its advantages: the fruit is relatively small ("mammoth" or larger sizes are rare) and it has the lowest flesh-pit ratio of any commercial variety. Because demand is usually for larger fruits, this must be met with other varieties. The fruit matures for pickling during late October or November, when there is danger of freezing injury; if this occurs fruits shrivel and are no longer suitable for pickling, although they can still be used for oil.

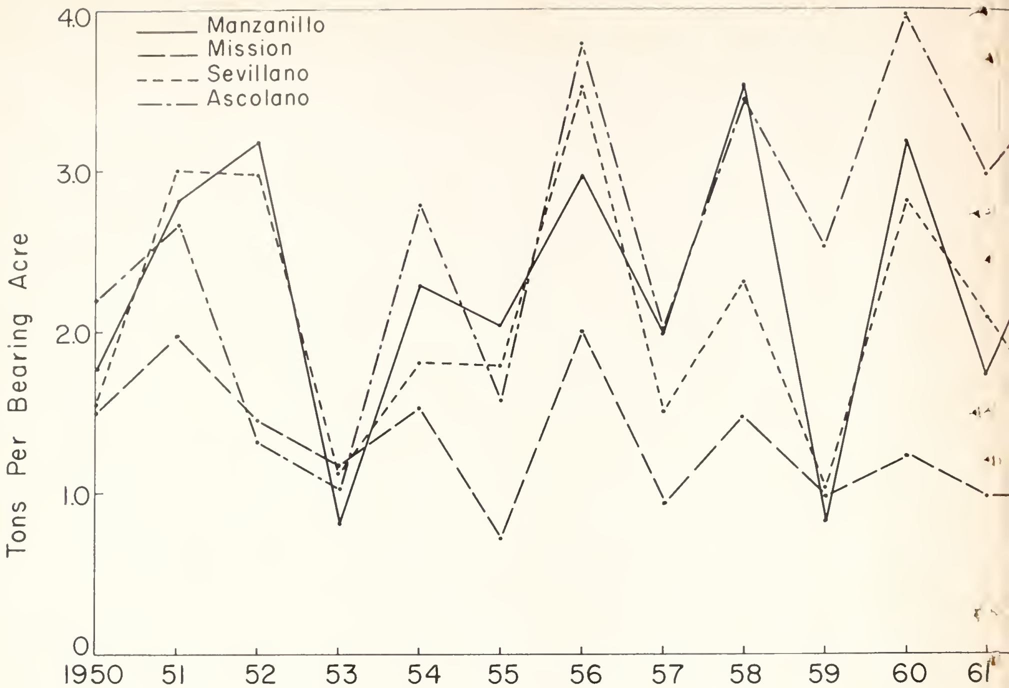
Mission trees tend to grow tall, and unless kept low by pruning they become difficult to harvest. While resistant to attacks of olive knot, Mission is quite susceptible to infections of peacock spot. There appear to be several distinct strains of Mission.

Sevillano. Chief advantage of the Sevillano is its large-size fruit, for which a premium is paid. Its flesh-pit ratio is above both Mission and Barouni, but below Manzanillo and Ascolano. Oil content is not high enough to justify oil extraction. Fruit is usually harvested before danger of early frosts. Because the trees are not upright growing, fruits are relatively easy to pick. Most packers consider this variety more difficult to process and its quality somewhat lower than Mission or Manzanillo, although with proper treatment a very satisfactory product can be obtained. Trees are susceptible to olive knot, but resistant to peacock spot. This variety is susceptible to three physiological disor-

Table 4. Production data on commercial California olive varieties.

Variety	State acreage				Reported average yield per acre		Average price received by growers per ton 1958–1963	Average fruit size, fresh weight	Per cent oil in fruit in winter-fresh weight	Flesh-pit ratio after canning	Uses of fruit	Time of harvest for pickling
	Bearing		Nonbearing		Tulare County*	State-wide						
	1950	1964	1950	1964	(tons)	(tons)	(dollars)	(grams)				
Mission....................	13,846	9,356	706	110	3.80	1.15	216	4.1	21.8	6 5 : 1	Black ripe Green ripe Greek style Oil extraction	Late October and early November
Manzanillo................	7,258	10,533	2,229	2,119	3.84	2.37	220	4.8	20.3	8.2 : 1	Black ripe Green ripe Spanish green Oil extraction	October
Sevillano..................	3,730	7,095	888	982	3.14	2.08	245	13.5	14.4	7.3 : 1	Black ripe Green ripe Spanish green Sicilian style Fresh fruit shipments	Mid- to late October
Ascolano..................	692	833	104	375	3.80	2.87	216	9.0	18.8	8.2 : 1	Black ripe Green ripe	Mid-September to early October
Barouni...................	297	339	11	32	....	....	...	7.4	16.5	6.8 : 1	Black ripe Green ripe Fresh fruit shipments	October

* Data mainly from Lindsay Ripe Olive Company.



ders: "shotberries," "split-pits," and "soft-nose" (page 56).

Ascolano. Since these fruits are tender at maturity, extra care must be taken to avoid bruising during harvest and processing (this is probably why Ascolano is not more widely planted). Fruit is almost as large as Sevillano and has a high flesh-pit ratio (8.2:1), which, with its good quality, makes this a fine table olive. Although canned ripe olives of this variety are generally considered excellent, the fruits are not suited to Spanish-green pickling because of "salt shrivel" during fermentation. Although its oil content is almost as high as Manzanillo, the fruit is not used for oil extraction. Ascolano fruits generally mature earlier than those of any other commercial variety, usually in late September or early October, so that frost damage is not a problem. Ascolano trees are relatively easy to harvest and are fairly resistant to peacock spot and olive knot. The trees are quite resistant to low-temperature winter injury.

Barouni. Fruits of this variety are difficult to process commercially and the resulting product not as good as some other varieties. Fruit is of good size, almost as large as Ascolano, but the flesh-pit ratio is relatively low (6.8:1); 200 to 600 tons of the crop are shipped fresh each year to eastern cities for home processing. In the northern part of the state, Barouni consistently bears very good crops, but in southern California it is reportedly a shy bearer. This variety, the last to be planted in commercial acreages in the state, was introduced in 1905 from Tunisia by the USDA Division of Plant Exploration and Introduction. It was widely planted throughout California from 1920 to 1925, particularly in Butte County, but practically no new plantings are now being made. Fruits mature for pickling during October or early November; trees are somewhat spreading and are easy to harvest. Barouni is more susceptible to olive knot than is Mission, and in the 1932 freeze showed greater tree injury.

Fig. 3 (opposite page). Fluctuation in yields of olives by variety, 1950 to 1962. Yields among varieties cannot be compared, as different varieties are grown largely in different areas of the state. (From California Crop and Livestock Reporting Service.)

Other varieties. A number of varieties, mostly from variety introductions in the early days of the industry, are found in scattered locations throughout California. Trees of strictly oil olives, such as the Nevadillo, Redding Picholine, Rubra, Pendulina, and Chemlali, have generally been top-worked to large-fruited table varieties. Pickling varieties still found occasionally include Cucco, Lucques, Macrocarpa, Obliza, Polymorpha, Rouget, St. Agostino, and Santa Catarina.

New introductions. Since 1900 the USDA Division of Plant Introduction and Exploration has imported some 50 olive varieties from all parts of the world, and since 1946 the Department of Pomology of the University of California has imported about 50 varieties principally from the Mediterranean region. They are all growing and being observed, along with selections from controlled crosses at the University's Wolfskill Experimental Orchards at Winters.

Table 5. Size grades and returns to growers for California's four leading olive varieties.

Size grades	Average number of fruits per pound*	Manzanillo		Mission		Sevillano		Ascolano	
		Average segregation of sizes (per cent)†	Average price per ton§	Average segregation of sizes (per cent)†	Average price per ton§	Average segregation of sizes (per cent)†	Average price per ton§	Average segregation of sizes (per cent)†	Average price per ton§
Super-colossal	32 or less	0.0	...	0.0	...	7.1	$318	0.9	$318
Colossal	36–40	0.0	...	0.0	...	20.6	277	5.4	277
Jumbo	46–50	0.0	...	0.0	...	26.8	248	22.6	248
Giant	53–60	2.5	$285	0.0	$276	13.9	218	19.4	218
Mammoth	70(65–75)	8.4	277	2.9	276	6.7‡	143	18.5	198
Extra large	82(76–88)	17.9	254	7.1	254	3.2	...	13.2‡	151
Large	98(91–105)	22.3	232	17.2	231	3.7	...	3.6	...
Medium	113(105–121)	16.8	210	21.5	209	0.3	...	0.0	...
Standard	135(128–140)	14.9‡	189	22.1‡	188	0.0	...	0.0	...
Sub-standard and culls	....	17.1	...	29.1	...	17.7	...	16.7	...

* Figures in parentheses indicate range permitted.
† Data from Lindsay Ripe Olive Company.
‡ Minimum-size grade that can be processed and sold as canned ripe olives according to the California Agricultural Code.
§ From California Crop and Livestock Reporting Service for 1958 to 1963, inclusive.

GETTING STARTED . . . CHOOSING A SITE . . . PREPARING THE LAND . . . PLANTING AND CARING FOR YOUNG TREES

Climate and yield

The best yields of Manzanillos are in Tulare, Fresno, Kings, and Madera counties, while good yields of Mission can be obtained in certain areas of Butte County. Sevillano has produced well in parts of Tehama County and is preferred by growers there.

There are some olive orchards south of the Tehachapi mountains, but these are rapidly being lost to subdivisions and other more profitable uses. Insufficient winter chilling, hot, dry winds during bloom, and mild summer weather along the coast limits production in most of southern California.

Because harvesting for pickling of most varieties occurs through October and well into November, it is important to avoid locations where early fall frosts prevail, as frost-damaged fruit is unsuitable for any processing other than oil extraction. Late spring frosts occasionally injure fruiting wood and inflorescences (see GLOSSARY OF TERMS at back of this publication), thereby reducing crops. Areas subject to poor air drainage, low winter temperatures, and late spring frosts, should be avoided.

Water supply

Commercial olive production in California depends upon irrigation; without it production is light and erratic. Also, fruit size and quality is generally inadequate on unirrigated land. Olives grown for pickling require nearly as much water as citrus or deciduous orchards growing on similar soils. The usual amount applied on most central California olive soils is a total of 2½ to 3 acre-feet per year applied when needed during the growing season.

Because olives have a higher boron tolerance than other tree crops and a relatively high requirement for this element, irrigation waters carrying up to 3 ppm (parts per million) of boron may be used with safety. Nitrates over 40 ppm in the irrigation water may cause excessively heavy vegetative growth and irregular production.

In general, olives tolerate more salinity than do most other tree crops. Waters too salty for general use may be safely applied to olives provided salts do not accumulate in large amounts. Irrigation water high in sodium must be treated with gypsum to prevent structural changes in the soil that would interfere with adequate water penetration.

Soils

Olives grow well in a wide range of soil types. In central California, groves planted on soils rather high in clay, or underlain with hardpan, often yield better crops than those grown on deep fertile soil where vegetative growth may become excessive. Olives tolerate soils where many other tree crops fail, but prolonged wet soils or soils with a pH of 8.5 or more will cause poor tree growth. Thus it is desirable to avoid poorly drained or alkali soils. Olive trees grow well in soils relatively high in calcium and in boron.

Transportation and marketing facilities

Many olive growers sell their fruit to commercial packers or to buyers who in turn sell to canners, and many growers belong to cooperative canning organizations which process, pack and sell the olives. Canneries, or receiving stations operated by packers, are mostly located in the principal olive-producing areas (around Lindsay, Oroville and Corning) but some delivery points are found in other parts of the state. Raw olives can be trucked at comparatively little cost for long distances and therefore it is not necessary to be close to processing centers—but it is important to be reasonably close to an adequate harvest labor supply.

Fig. 4. Effect of poor drainage on growth of olive trees. Center trees are in a low, poorly drained spot. Trees behind and to the left are in better-drained areas.

Establishing the orchard

For furrow or flood irrigation, properly graded and leveled land is essential. Land preparation will help determine the kind of irrigation system to install. Hardpan soil requires 36- to 48-inch-deep chiseling before planting; on rocky soils, or soils requiring extensive dirt moving, this should be done before leveling and planting.

Grading and leveling. For furrow irrigation on hardpan soils, 0.2- to 0.6-foot fall per 100 feet of irrigation run is commonly employed. If soil is of fairly uniform texture and the furrows properly constructed, the ground can be leveled (without regard to moderate side-fall) to a good even grade for satisfactory water handling. Adobe soil may be more steeply graded, as long as the grade is uniform. Sandy soils are subject to erosion when graded to more than 0.3 foot per 100 feet of fall. If leaching is considerable, irrigation runs must be short; for medium-textured soils, 400 feet is about right.

Rolling land with variable slopes is difficult to furrow irrigate, but improved sprinkler design has made possible more satisfactory water application without costly land moving, such as is involved in terracing. Application rates are determined by the slope and the soil type.

Installing the irrigation system. Careful planning and installation of the irrigation system, which is normally in and functioning before the first tree is planted, pays off with trouble-free water management.

With furrow systems, a return-flow arrangement is often used. This permits more uniform water application, helps avoid over-irrigation, conserves moisture, and works well with the system of non-tillage commonly employed in central California.

Tilled (cultivated) groves use the furrow, the contour check, the check, and the square basin systems of irrigation, although sprinklers are occasionally employed. The best use of sprinklers, however, is in non-tilled (permanent sod or weed-free, chemically treated) orchards. With sod, or on coarse-textured soils, Sample costs per acre to establish a Manzanillo olive orchard in Tulare County, California—1964.

Item	1st year	2nd year	3rd year	4th year	5th year
Yield (tons)	.....	0.2	0.4	0.8	1.2
Pre-harvest cash, labor and field power:					
Land preparation	$ 10.00	.....	.....	.....	.....
Layout and plant	11.00	.....	.....	.....	.....
Trees: 40 at $1.25	50.00	.....	.....	.....	.....
Irrigate	12.50	$15.00	$15.00	$15.00	$15.00
Water at $6 per ac. ft.	3.00	4.50	6.00	9.00	12.00
Weed control	12.00	12.00	12.00	12.00	12.00
Fertilize: ½ and ¾ man and tractor hrs.	1.35	1.35	1.35	2.03	2.03
Fertilizer: N at 12¢/lb.	.30	1.20	2.40	3.60	4.80
Pest control application—contract	.....	.....	.....	4.50	6.00
Pest control material	.....	.....	.....	2.60	3.50
Misc. labor: sucker, stake, rodents, etc.	3.75	3.75	3.75	6.25	7.50
Misc. material	2.50	1.50	1.50	1.50	1.50
County taxes	9.00	9.00	9.00	9.00	19.00
Office, car, operating capital, etc.	5.90	3.50	4.50	7.00	9.80
Repairs: irrig. system, equip. except tractor	2.50	3.00	3.50	4.50	5.00
Total pre-harvest cash and labor cost	$123.80	$54.80	$59.00	$76.98	$98.13
Harvesting cost:					
Picking at $85 per ton	.....	$17.00	$34.00	$68.00	$102.00
Hauling at $4.50 per ton	.....	.90	1.80	3.60	5.40
Total harvesting	.....	$17.90	$35.80	$71.60	$107.40
Total cash and labor cost	$123.80	$72.70	$ 94.80	$148.58	$205.53
Depreciation costs:					
Irrigation system ($200 cost)	$ 12.00	$ 12.00	$ 12.00	$ 12.00	$ 12.00
Buildings and equipment, except tractor ($100 cost)	7.50	7.50	7.50	7.50	7.50
Tractor	4.95	2.75	2.75	2.90	2.90
Total depreciation cost	$ 24.45	$ 22.25	$ 22.25	$ 22.40	$ 22.40
Total cash and depreciation cost	$148.25	$ 94.95	$117.05	$170.98	$227.93
Interest on investment at 6%:					
Irrig. facilities at ½ cost ($100)	$ 6.00	$ 6.00	$ 6.00	$ 6.00	$ 6.00
Buldings and equipment, except tractor on ½ cost ($50)	3.00	3.00	3.00	3.00	3.00
Tractor	2.25	1.25	1.25	1.30	1.30
Land at $800	48.00	48.00	48.00	48.00	48.00
Interest on accumulated costs	.....	12.45	19.99	26.90	32.68
Total interest on investment	$ 59.25	$ 70.70	$ 78.24	$ 85.20	$ 90.98
Total cost for year	$207.50	$165.65	$195.29	$256.18	$318.91
Credit for fruit at $200 per ton	.....	$ 40.00	$ 80.00	$160.00	$240.00
Net cost for year	$207.50	$125.65	$115.29	$ 96.18	$ 78.91
Total accumulated cost	$207.50	$333.15	$448.44	$544.62	$623.53

SOURCE: Karl W. Opitz and Burt B. Burlingame. Mimeo. sheet, May, 1964.

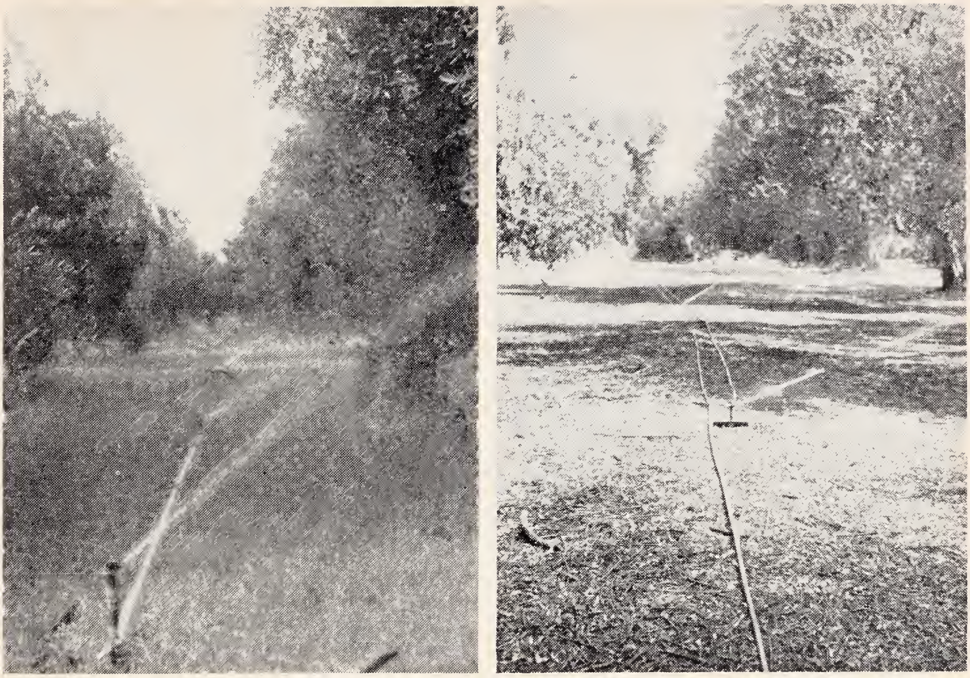


Fig. 5. Left: orchard in permanent sod, using high-volume sprinkler heads. Right: non-tilled orchard under chemical weed control with low volume, movable, drag hose lines.

large volume sprinklers can be used; on non-tilled, fine-textured soils, low-volume sprinklers are required. Orchards planted on steep or uneven terrain are best sprinkled with movable drag hose lines. Except in very porous soil, permanent over-the-tree sprinklers are generally unsuitable because their fixed pattern of precipitation leads to under- or over-irrigated spots in the grove.

If it is necessary to establish the orchard before the irrigation system is installed, trees may be basin-irrigated for a year or two, although the cost of hauling water is often more expensive than conventional furrows. When a drag hose system is employed, "spits" or "spitters" (small, fixed sprinkler heads) rather than rotating sprinklers are used the first year or two.

Laying out the orchard. Most California olive orchards are planted on the square. Many recently planted groves are double set with the intention of cutting back and eventually removing the interset or "filler" trees. (If filler trees are not removed, production will drop considerably after tree crowding commences). Standard permanent planting distances vary from 30×30 up to 40×40 feet. Manzanillo trees on shallow, infertile soil are planted closest together—Sevillanos, Missions and Ascolanos fartherest apart. Some of the earlier-planted groves were set with 20×20 foot spacing, but this is much too close: yields from closely planted trees quickly decline, due to shading out of bearing surfaces and to root competition.

Planting the trees. Nursery trees are available in gallon containers or as field-grown, bare-root stock. With the latter, leaves are usually stripped off and the tree cut back to a single trunk without branches. If the bare-root tree is large, the primary scaffold limbs may be selected and cut back to stubs. Strongly cut-back trees suffer less shock, become more quickly adjusted to root loss, and start vigorous growth quicker in the spring than do trees not cut back heavily. Exposed roots require careful handling; they should be covered and kept moist at all times. It is best to set out bare-root trees in December, January or February when

Sample costs for producing Manzanillo olives in Tulare County, 1964.

Based on a yield of 4 tons per acre. Man-labor at $1.30 and $1.50 per hour. Light wheel-tractor: cash cost $1.20 per hour; depreciation 55 cents; interest 25 cents.

	Sample costs	
	Per acre	Per ton
Pre-harvest cash costs:		
Pruning: 40 trees at $1.30	$ 52.00	
Brush disposal: contract	3.50	
Fertilize: 1-man and tractor hr.	2.70	
Fertilizer: 40 lbs. N at 12¢	4.80	
Irrigate: 7 times, 12 man hrs.	15.60	
Water: power to pump 3 acre-ft. at 6¢	18.00	
Cultivate and furrow: 7-man and tractor hrs.	18.90	
Spray: 1½ times, contract 2000 gal. at 1½¢	30.00	
Spray material: Parathion + oil + ½ Bordeaux	18.00	
Miscellaneous labor: 4 man and 1 tractor hrs.	6.60	
Miscellaneous material	4.00	
County taxes	25.00	
Office, car, operating capital, etc.	27.40	
Repairs, irrigation system, equipment (except tractor)	5.00	
Total pre-harvest cash and labor cost	$212.60	$ 53.15
Harvesting cost:		
Picking at $85 per ton	$340.00	$ 85.00
Hauling at $4.50 per ton	18.00	4.50
Miscellaneous harvest 2 man and 1 tractor hrs.	4.00	1.00
Total harvesting costs	$362.00	$ 90.50
Total cash and labor	$574.60	$143.65
Depreciation costs:		
Trees ($624 cost—50 years)	12.48	
Irrigation facilities: ($200 cost)	12.00	
Tractor: 10 hrs. at 55¢	5.50	
Buildings and equipment ($100 cost)	7.50	
Total depreciation cost	$ 37.48	$ 9.37
Total cash and depreciation cost	$612.08	$153.02
Interest on investment at 6%:		
Trees: on ½ original cost ($312)	$ 18.72	
Irrigation facilities: on ½ cost ($100)	6.00	
Tractor: 10 hrs. at 25¢	2.50	
Buildings and equipment on ½ cost ($50)	3.00	
Land at $800	48.00	
Total interest on investment	$ 78.22	$ 19.56
Total cost of production	$690.30	$172.58

Cost per ton at varying yields.

Yields, tons per acre	2	3	4	5	6	7
Cash and depreciation costs	$216.54	$174.19	$153.02	$140.32	$131.85	$125.80
Total cost per ton	$255.65	$200.27	$172.58	$155.96	$144.88	$136.97

SOURCE: Karl W. Opitz and Burt B. Burlingame, Mimeo sheet, May, 1964.

soil can be worked, but in heavy, wet, clay soils it may be necessary to delay bare-root planting until early March. Trees can be kept heeled-in, in trenches, until the soil works well. Container-grown trees may be planted anytime.

Planting holes need only be large enough to accommodate the roots in a natural position—extra long roots can be pruned, and broken ones cut off. Trees should be set at the same depth they grew in the nursery. For a good start it is important to firm the soil around roots as the hole is filled in, and to thoroughly soak soil around the newly planted tree. *Never allow the newly planted tree to suffer from lack of moisture.* A mulch of sawdust, straw, or sand helps prevent surface drying and reduces necessity for frequent irrigation the first year after planting. Good weed control also helps the tree make a quick start by eliminating competition for water and nutrients.

Newly planted trees are protected with a coating of whitewash on the trunk or with impervious white paper wraps. Newspaper or printers' mats also serve to protect the trunk from sunburn. (See p. 27 for whitewash formulations.)

Care of young trees. Good weed control, fertilization as necessary, and ample irrigation provides conditions favorable for rapid growth and early bearing. Young trees are sometimes attacked by insects not normally considered olive pests, such as the false chinch bug and the soldier bug; these must be controlled, or growth suffers. The more serious insect pests on olives do not usually appear until the trees are of bearing age. (See p. 28 for methods of training young trees.)

Intercropping the young orchard. If intercrops are grown, they must not be allowed to compete with the olives. Most vegetable crops, particularly tomatoes, potatoes, melons and strawberries are subject to Verticillium wilt; cotton is also a host for Verticillium. Obviously these Verticillium-susceptible plants are unsatisfactory as intercrops. Soil previously planted to such crops should not be used for olives unless Verticillium-resistant rootstocks are employed. Of annual crops, corn, milo and other grains make the best use of the unused areas between tree rows. Citrus, or plums and peaches, or deciduous trees other than pomegranates conflict with olive cultural requirements and are not satisfactory as companion crops. Pomegranates tolerate conditions under which olives are grown, except that they are sensitive to the soil sterilants, Karmex® and simazine, which are used for weed control in non-tilled olive orchards.

BOTANY, PROPAGATION, TRAINING, AND PRUNING

Botany of the olive

The olive is a broad-leaved evergreen tree capable of living more than a thousand years. The wood is resistant to decay, and if the top dies a new trunk will often arise from the roots. Trees are quite shallow-rooted even on deep soils. The thick, leathery leaves adhere to the tree for 2 to 3 years, dropping mostly in spring.

Cultivated varieties of the olive of commerce belong to the species, *Olea europaea* L. of the genus *Olea*. About 20 species of this genus are found in tropical and subtropical areas, but other than *Olea europaea* L. none of them produces edible fruit. The genus *Olea* is a member of the family, Oleaceae, which also contains the following well-known genera: *Fraxinus* (ash), *Syringa* (lilac), *Ligustrum* (privet), *Forsythia* (Golden Bell), *Jasminium* (the jasmines), and *Forestiera* (*Forestiera neomexicana* — the California "wild olive").

Flowers of *Olea europaea* L. are borne on a paniculate inflorescence (see Glossary of Terms) arising in the axils of the oppositely arranged leaves; they are usually produced on branches formed the previous season, but may arise from dormant buds 1 or 2 years old. Flowers are small and yellowish-white, with a

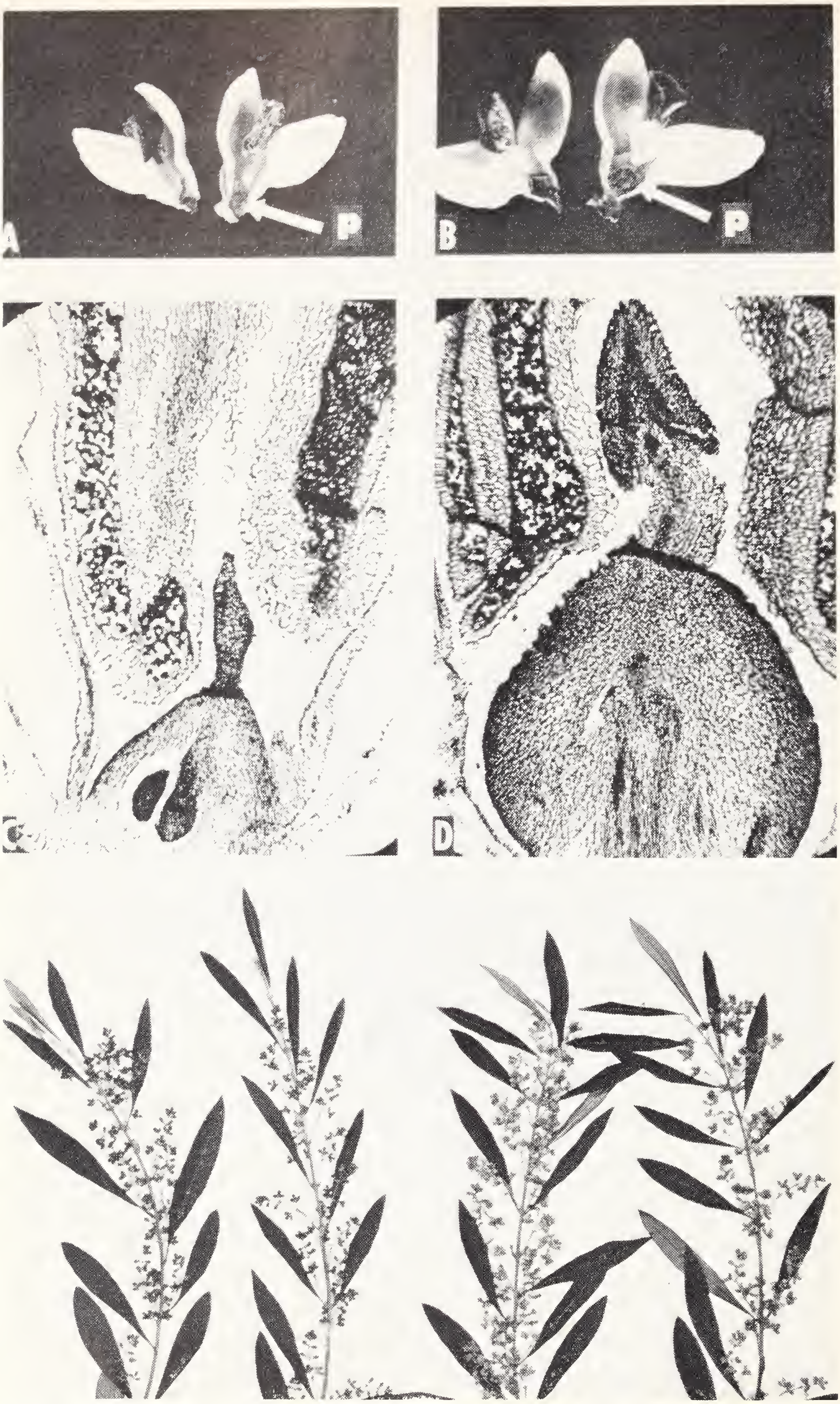


Fig. 6. Top: enlarged views of olive flowers at full bloom: A: staminate (male) flower; B: perfect (male and female) flower; p: pistil. Center: photomicrographs of olive pistils (female part that develops into fruit) shortly before bloom. C: aborted pistil in staminate flower; D: developed pistil in perfect flower. Bottom: inflorescences (flower clusters) shortly before and during bloom.

short, 4-toothed calyx, and a short-tubed corolla with four lobes. There are two stamens and a 2-loculed ovary, bearing a short style and capitate stigma.

Flowers are of two types: (1) *perfect,* containing both stamens and pistil; and (2) *staminate,* containing only stamens, the pistils being abortive and nonfunctioning. The relative proportion of perfect and staminate flowers varies with varieties and with the particular year. No purely pistillate flowers occur. In the perfect flower the pistil is large, almost filling the entire space within the floral tube; it is light green in the bud, and deep green at full bloom. In the staminate flower the pistil is rudimentary, barely raised above the floor of the floral tube, while the style is small and either brown, greenish-white, or white; the stigma is not large and plumose as it is with functioning pistils. The reason for the abortion of the pistil in staminate flowers is not clearly understood, but it is probably associated with water or nutritive deficiencies during the developmental period. Bud removal in early spring causes a decrease in the percentage of pistil abortion in the remaining buds. Leaf removal up to within a month before full bloom causes pistil abortion; after this, defoliation no longer exerts an influence, the flower type apparently already being determined.

The normal pistil in the olive flower has two carpels originally, each containing two mature normal ovules capable of fertilization and development. However, in the subsequent fruit only one carpel is found, usually having only one seed.

The olive fruit is a drupe (like the peach, apricot, and plum). It consists entirely of carpel tissue, the wall of the ovary having both fleshy and dry portions, the skin being the exocarp, the flesh the mesocarp, and the stone or pit, the endocarp. The seed is within the endocarp.

The mature seed is made up of a thin seed coat, enclosing the starch-filled endosperm, which surrounds the tapering, flat, leaflike cotyledons and short radicle (root) and plumule (stem).

The first evidence of flower formation in olive buds is found about 8 weeks before bloom, with a subsequent rapid development of floral parts. Full bloom in California occurs from about May 1 to June 1, depending upon the variety, season, and location; blooming is generally 1 or 2 weeks earlier in the southern than in the northern sections.

Grafting affinities and rootstocks

Varieties of *Olea europaea* apparently can be intergrafted without difficulty, and can be successfully grafted on seedlings of other varieties. In grafting varieties of *Olea europaea* on seedlings of certain other *Olea* species—*Olea ferruginea, Olea verrucosa,* and *Olea chrysophylla*—the results have not generally been good: trees may show considerable overgrowth at the graft union, produce excessive numbers of shotberry fruits, or may develop large numbers of yellow leaves; in many cases, the trees finally die. One combination among those tested—Sevillano on *Olea chrysophylla*—seems to produce normal, healthy trees, with adequate crops of fruit. However, Mission and Manzanillo varieties on this same rootstock produce trees with obvious incompatibility symptoms.

Of five trees each of Mission, Manzanillo, and Sevillano propagated on seedlings of *Forestiera neo-mexicana,* only one tree was still alive after 10 years. This tree was quite dwarfed, with about half the fruit produced being of the shotberry type.

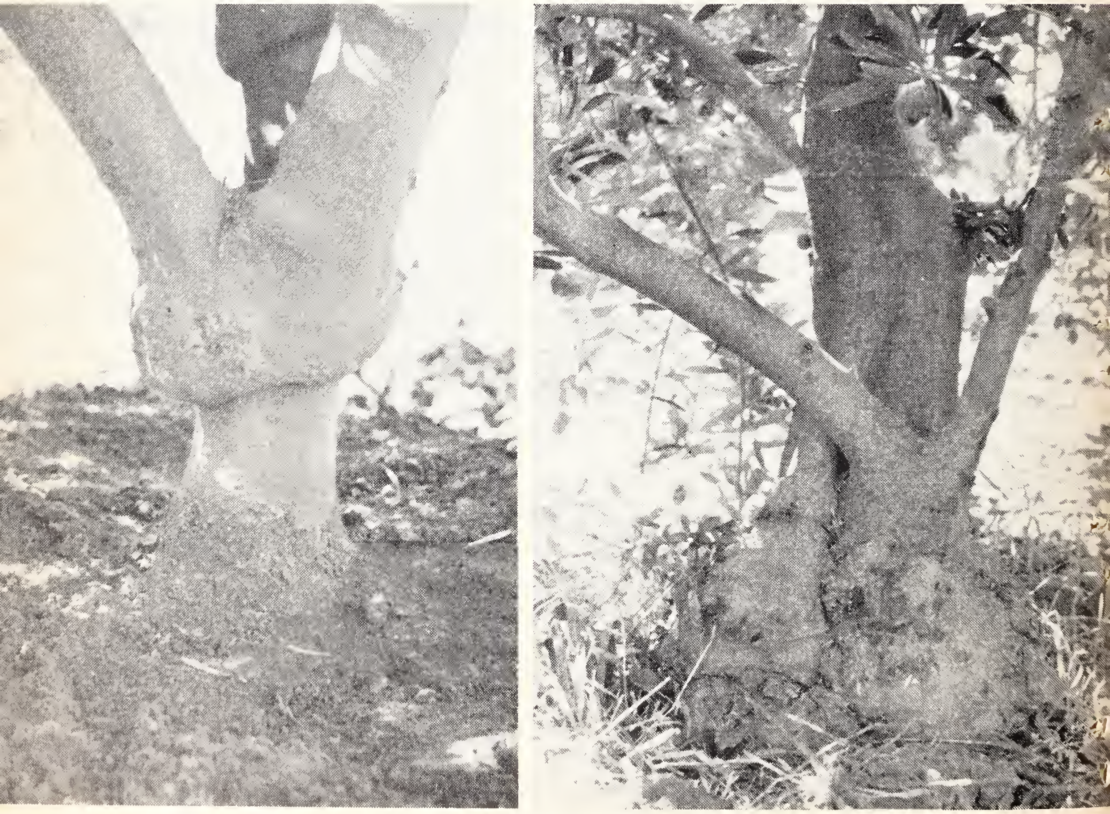
Attempts to graft varieties of *Olea europaea* on the ash (*Fraxinus*) and on the lilac (*Syringa*) produced plants which lived for several years, but with little new annual growth. The plants finally died.

Studies at Winters, California, using three scion varieties and twelve different rootstocks over a 16-year period ending in 1965, gave results as follows:

- The principal rootstock effect on the scion variety was in tree vigor. Rootstock influence noted in a given scion-rootstock combination did not necessarily hold true for a different scion variety on the same rootstock.
- In two scion varieties, Mission and Manzanillo, own-rooted trees were more vigorous and yielded more fruit than did trees grafted on any of the rootstocks tested. In the Sevillano variety, however, this was not the case. Trees on certain

Fig. 7 (above). Dwarfing effect due to a seedling rootstock. Left: own-rooted Mission tree. Right: Mission grafted on an Ascolano seedling rootstock. Both trees are 9 years old; measuring stick is 10 feet long.

Fig. 8 (below). Left: Sevillano on *Olea verrucosa* rootstock. This type of overgrowth is usually found when *O. verrucosa* or *O. ferruginea* is used as rootstock. Points of swelling mark position of inserted scion buds. Right: Mission on Ascolano seedling rootstock. Scion portion of the tree was markedly dwarfed but the rootstock was making a strong growth, as evidenced by enlarged portion below graft union.



rootstocks were more vigorous than own-rooted trees.

- Considerable variation in individual tree vigor was noted with different seedling rootstocks. Various degrees of dwarfing or invigoration of the scion variety occurred. Obtaining suckers from such rootstocks, and making cuttings from them, provides clonal rootstocks for a given variety which would allow some vegetative growth control.
- Generally, no observable rootstock effect on fruit characteristics appeared, although trees on *Olea ferruginea* and *O. verrucosa* produced fruit with a reduced length-width ratio and with an increased percentage of fruit developing as shot-berries.

Many instances of unexplainable tree behavior observed in California olive orchards could be due to rootstock effects resulting from the variable influence of seedling stocks. For uniform, strong-growing, and high-yielding trees of the Mission and Manzanillo varieties, own-rooted trees started from cuttings would seem to be the most suitable. Ascolano on its own roots, started from cuttings, develops into strong-growing, productive trees. Where reduced tree growth is acceptable for Sevillano, own-rooted trees would be satisfactory; Sevillano cuttings root with difficulty. To obtain vigorous-growing uniform Sevillano trees, cuttings of a strong-growing variety such as the Mission could be suitable for the rootstock. When seedlings are used as a rootstock for any variety, variable tree performance can be expected.

Propagation

Olives do not produce the true variety from seed, hence they must be propagated by budding or grafting the desired variety onto a rootstock (seedlings, suckers, or cuttings) or by some other vegetative method such as cuttings or suckers.

A full discussion of propagation will be found in *Propagation of Temperate-zone Fruit Plants,* Univ. of Calif. Agr. Exp. Sta. Cir. 471 (revised).

Nursery stock. The first four methods listed below are the most important for starting olive trees.

1. Making hardwood cuttings of wood several years old; these should be 1 to 3 inches in diameter

Fig. 9. Mission olive nursery stock after 2 years in nursery propagated in two ways: Left: suckers with piece of old root or stem attached. Right: leafy cuttings.

2. Making leafy cuttings of 1- or 2-year-old growth.

3. Removing suckers with a root piece attached from the base of old trees and transplanting them to the nursery or orchard.

4. Grafting or budding seedlings in the nursery.

5. Removing and planting knobby-type growth (ovuli) from the trunk of old trees.

6. Planting truncheons (large pieces of wood) horizontally 3 to 6 inches under soil surface.

Propagation by hardwood cuttings. This requires no special equipment but results are not always successful. It has the further disadvantage of requiring relatively large branches; if numerous cuttings are wanted it involves removal of much fruiting wood. (If you can find an orchard being pruned heavily in late winter or early spring, you can use pruning wood from it, if wood is prepared immediately after cutting.)

Do not use wood infected with olive knot, or new trees will have this disease. Do not try to start Sevillano trees by this method, as the cuttings are very difficult to root. Root-promoting chemicals, such as indoleacetic acid or indolebutyric acid, increase the rooting percentage and promotes more root formation.

Directions. Prepare cuttings in late January or early February from wood 3 or 4 years old, and from 1 to 2 inches in diameter. Cut into 1-foot lengths and remove all leaves. Use care not to get the polarity of the cuttings reversed—they must be planted right side up.

Soak the basal few inches of the cuttings for 24 hours in a fresh solution of indoleacetic or indolebutyric acid (root-promoting chemicals) at a strength of about 13 ppm (1/20 gram in 1 gallon water, or a level ¼ teaspoon in 8 gallons of water). Dissolve the chemical in a small amount of alcohol (isopropyl, methyl, or ethyl) before adding to the water. Next, bury cuttings in slightly damp (not wet) sawdust for about 30 days in a building where the temperature will be from 60° to 70° F; during this time root initials develop at the base of the cuttings. After the 30-day moist storage period, plant cuttings in a well-prepared nursery soil, with about one-eighth of the cutting above ground. Frequent irrigations during summer are essential.

Propagation by leafy cuttings. Many cuttings can be prepared by this method without removing an excessive amount of fruiting wood from trees. However, it has the disadvantage of requiring glass- or plastic-covered beds or greenhouse mist propagation facilities—and, preferably, provision for maintaining bottom heat.

To obtain a high percentage of well-rooted cuttings they should be treated with a root-promoting chemical, preferably indolebutyric acid. This type of cutting must be handled under greenhouse conditions after having rooted or losses will be heavy. After cuttings are properly hardened-off they can be lined out in the

Fig. 10. Hardwood olive cuttings after 1-year's growth in nursery. Mission variety. Left: check (no treatment). Right: cuttings soaked 24 hours in indoleacetic acid at 13 ppm, followed by storing in moist sawdust at 65° F for 30 days before planting.

Fig. 11. Effect of concentration of indolebutyric acid on rooting of Ascolano olive cuttings after 8 weeks under intermittent mist in a perlite and peat moss rooting medium. Upper, left to right: control, 500 ppm, 2000 ppm. Lower, left to right: 4000 ppm, 7000 ppm, 10,000 ppm.

nursery row. Some nurserymen prefer to transplant rooted cuttings into gallon cans and grow them 1 to 2 years until they are large enough to plant in the orchard.

Directions. Make the cuttings in June or July from wood of the previous summer's growth, using fairly vigorous shoots growing in full sun in the tree's upper portions. Discard the succulent terminal few inches of each shoot.

Cuttings should be about 4 or 5 inches long, with the basal cut just below a node. If rooted under mist, retain 4 to 6 leaves at the top of the cutting (in a closed frame two leaves are sufficient). Keep cutting-wood and cuttings damp at all times.

Dip the basal ends of the cuttings for 5 seconds in a 50 per cent alcohol solution of indolebutyric acid at about 4,000 ppm. (Add an equal amount of water to 95 per cent alcohol to obtain approximately a 50 per cent alcohol solution. Dissolve a level ¼ teaspoon of the crystals in 3⅓ fluid ounces of the 50 per cent alcohol solution. This will be enough to treat several thousand cuttings. Isopropyl, methyl, or ethyl alcohol may be used).

Place cuttings in flats containing a rooting medium of perlite and peat moss 1 : 1, sand and peat moss 1 : 1 or, preferably vermiculite and perlite, 1 : 1. If intermittent mist propagation facilities are available the cuttings should be rooted under these conditions. Even difficult-to-root Sevillano cuttings can be started by this method if they are taken in midsummer. If mist-propagation facilities are not available, keep cuttings covered with glass at all times and water them frequently (but not excessively) to maintain high humidity. Protect them from the full sun. Provision for bottom heat under the cuttings, using electric soil cables, is desirable but not essential.

Cuttings usually root in 8 to 12 weeks, and can then be transferred to pots or gallon cans. Keep them under high humidity for a time to allow plants to become adjusted to the new environment. Cuttings well rooted by midwinter can be hardened-off in the flats in which they were rooted, and then transplanted to the nursery row by mid-March. If they are well irrigated and lightly fertilized with nitrogen through the summer, nursery trees large enough to set out in the orchard may be obtained by late fall.

Fig. 12. Typical Manzanillo olive nursery trees 1 year after being started as leafy cuttings under mist. Cuttings started on November 28 and transplanted to the nursery on March 23; trees dug the following December 3.

Propagation by the use of detached suckers. This simple method of starting new trees requires no special equipment—all that is necessary is a source of large trees originally propagated on their own roots, which produce an abundance of suckers from the base. The suckers are sometimes planted directly in the orchard, but it is preferable to grow them for a year in the nursery. One hazard here is that the suckers coming from the mother tree may be from the rootstock of a grafted tree, in which case the new trees must later be budded or grafted to the variety desired.

Directions. In February or March remove suckers from the old tree, using an ax or sharpened heavy shovel to take a piece of the old root about 3 inches in diameter with the sucker. Cut back to about 18 inches and remove all leaves. Plant immediately in the nursery with the root piece about 6 inches deep. Irrigate when necessary through the summer. After 1 year in the nursery, trees are usually large enough to set out in the orchard.

Propagation by grafting or budding seedlings. It is said that olive trees on seedling roots are longer-lived and less likely to blow over in heavy winds than are trees started from cuttings. No formal experimental evidence supports this belief, however, and in California excellent orchards have been propagated by both methods. Starting trees from seedlings is generally slower than using cuttings.

Directions: germination of seeds. Secure seeds in October from fruits of Mission, or preferably Frantojo or Chemlali variety. The seeds are planted about ½-inch deep in a seedbed; when seedlings are several inches high they are transplanted to nursery rows and grown until they are large enough to bud or graft (this usually requires 2 years).

To facilitate germination, the pits are cracked, or the tip ends are clipped. Germination can also be hastened by soaking uncracked pits in concentrated sulfuric acid—this causes partial disintegration of the pit and allows the seedling to emerge more readily. Pits of the Redding Picholine variety are soaked in acid for 24 hours, then washed thoroughly in running water for 2 hours and planted. The acid-soaking period may be different for different varieties. Treated seeds germinate in about 6 weeks; untreated seeds require 5 to 6 months. A cold-storage stratification period does not seem necessary for germination of olive seeds.

EXTREME CAUTION should be taken to avoid contact with skin or eyes when using concentrated sulfuric acid.

Some nurserymen have as sources of seedlings large Chemali, Mission, or Manzanillo trees, under which volunteer seedlings can be pulled up each year after rainy periods during the winter, thus saving the trouble of germinating seeds. Such seedlings are usually grown another year in the nursery before grafting or budding.

Grafting or budding seedlings. Seedlings may be grafted in the nursery, using the side graft method shown (fig. 13), in late February or early March. The tops above the graft should be cut back about a month after grafting. In Italy, olive seedlings are successfully grafted in great quantities using a miniature form of the bark graft. (See circular 471 referred to on page 21, or Cal. Ag. Ext. Service OSA number 65, *Grafting Olive Trees.* See these also for information on bark grafting.)

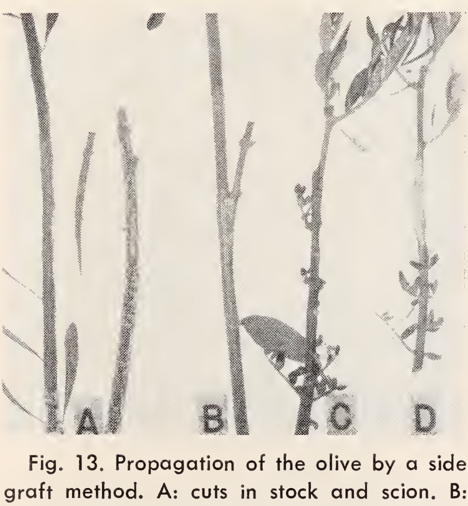


Fig. 13. Propagation of the olive by a side graft method. A: cuts in stock and scion. B: scion inserted into stock, and graft union tied with plastic tape. C: graft after 1-year's growth. D: section cut through graft union.

The seedlings may be budded in March, after the bark starts "slipping," using the T or shield-bud method. The disadvantage of budding as compared with grafting is the possibility of losing the bud "eye." If the bud eye, or shoot, dies the stock must be rebudded. A graft, however, has several growing points and loss of a single bud from the scion will not be serious. It is essential to cut back the seedling to the bud 2 to 3 weeks after budding. If the soil is somewhat dry, an irrigation shortly before budding is helpful in getting the buds to "take." Grafted or budded seedlings are usually grown in the nursery for 1 or 2 years before the trees are large enough to set out in the orchard.

Top-grafting

In many cases it is desired to change the variety of an olive tree or orchard. This can easily be done by bark grafting.

Directions. Top-grafting can be done at any time from early March to late April. Select three to five well-spaced primary scaffold branches, cutting them off near the trunk but leaving a smooth place to graft. Cutting the branches low eliminates considerable water-sprout growth and starts the tree at a desirably low height. With large branches it is necessary to use enough scions (spaced 3 or 4 inches apart around the trunk) to obtain satisfactory healing of the stub. One to three branches should be retained as "nurse" or "safety" branches to be removed during the following year or two; other non-grafted branches can be removed at the trunk, at grafting time or a year later.

Stubs should be grafted not more than 3 or 4 hours after the limbs are cut back, using the bark-graft method with three or four scions in each stub; if branches are quite large more scions are necessary. Use scion wood of the desired variety, collected at the time of grafting from trees with good fruit and bearing characteristics. Scions should be ¼- to ½-inch diameter, obtained from wood 1 or 2 years old. Remove leaves immediately and keep scion sticks continually moist and cool in

Fig. 14 (above). Twig-bud method of budding olives, using the T, or shield-bud technique: A: bud stick with desirable twig-bud. B: twig-bud removed. C: stock cut and prepared for insertion of bud piece. D: bud in place and tied wtih budding rubber. Ordinary dormant buds may be used, rather than twig-buds. It may be necessary to notch or girdle the seedling just above the inserted bud to force it into growth.

Fig. 15 (below). Bark graft for top-working olives. A: side of scion resting against wood of the stock; B: side view of scion. C: opposite side from A. Right: scions in place, held by two flat-headed wire nails (¾-inch, 20-gauge) driven through the scion. After grafting, all cut surfaces are thoroughly covered with grafting wax. Sometimes a longer more slanting cut can be made on the scion, which can then be inserted between the bark and wood of the stub without cutting bark.

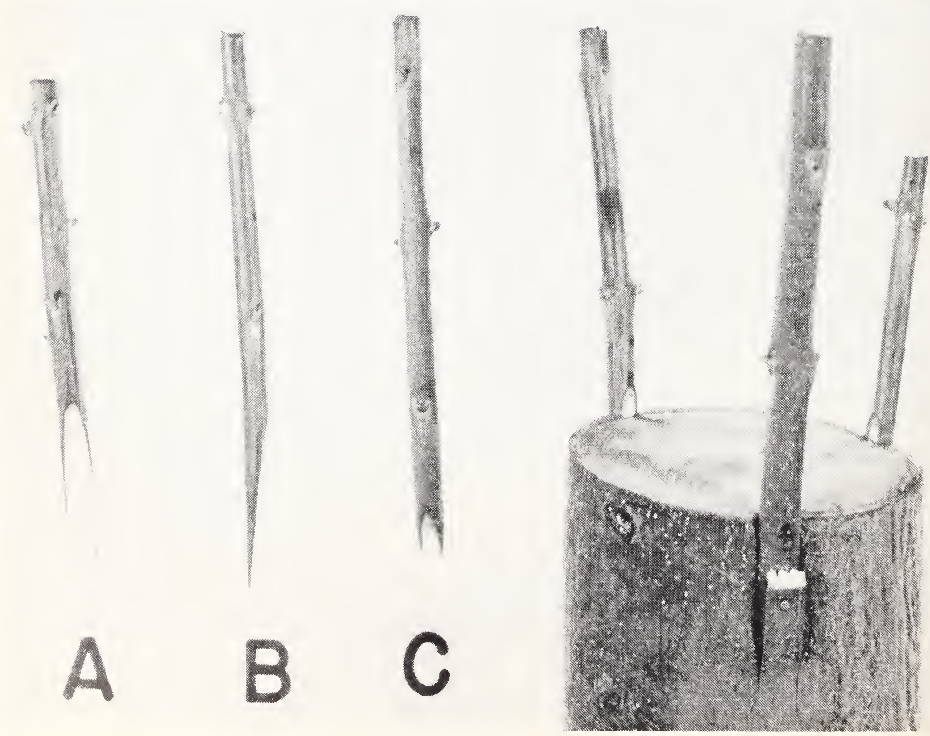


Fig. 16. Mature olive tree top-grafted to a different variety by the bark-graft method. Branches whitewashed to prevent sunburn. Nurse branches will be removed after 1 or 2 years.

Fig. 17. After large olive trees have been top-grafted, black polyethylene sheeting or heavy brown wrapping paper can be wrapped and tied around base of trunk to prevent sucker growth.

damp burlap or peat moss. Scions ready for insertion should be about 5 inches long, with 2 nodes (4 buds) above the stub.

A formal comparison was made between the bark-graft and the cleft-graft methods for top-working olives. Of 152 scions inserted by the bark-graft method, 55 per cent grew vigorously, 30 per cent were weak, and 15 per cent failed to grow. With the cleft-graft method (using 70 scions) 26 per cent were vigorous, 41 per cent were weak, and 33 per cent died.

It is important that all exposed cut surfaces be thoroughly covered with grafting wax immediately after grafting, using hot wax or a commercial asphalt-emulsion grafting preparation. (The latter will wash off if rains occur before it dries.) Grafting wax often cracks after application; if this happens, graft unions should be rewaxed immediately. After waxing, whitewash scions, branches, and trunk of each tree. This facilitates healing of the graft union by reducing temperature, and prevents death of exposed wood from sunburning.

Commercial, prepared, whitewash compounds, such as Tre-Co-White or Tree-Trunk-White are available. A good, ready-to-use whitewash spray formula consists of 10 pounds of zinc sulfate, 50 pounds of lime, and 1 pound of casein or Z-1 spreader per 100 gallons of water. A longer-lasting formulation, which requires several days advance preparation, is quicklime (CaO), 5 pounds; salt, ½ pound; wettable sulfur, ¼ pound. Add salt and sulfur while lime is slacking. Age whitewash mixture for several days before using, and dilute to a consistency easy to apply with a brush.

If grafts grow vigorously and become top-heavy by midsummer, especially in areas where strong winds may occur, tie them to stakes or prune them back to prevent their breaking off.

Vigorous sucker and water-sprout growth usually follows top-working. These

shoots should be removed from around the scions but can be left on the trunk for a time during the summer to nourish the tree and to protect the bark from the sun. Head them back, however, to prevent excessive growth. Withhold nitrogenous fertilizers from newly grafted trees for 2 or 3 years, but continue irrigation, although the water requirements are considerably less because of the reduced leaf area.

During the year or two after grafting, remove the nurse branches and prune the grafts lightly and judiciously to select the limbs that are to be retained permanently. Cut back the other grafts gradually to permit the stub to heal over. When the grafting wound heals, the excess grafts are removed. The grafted branches usually bear fruit the third season after grafting.

Moving large trees

In mature orchards where the trees have been planted too closely together (e.g., $20' \times 20'$), considerable benefits in increased yields may be obtained by removal of about half the trees—as alternate trees in each row. In such cases, the trees can be pulled out, moved to a new location, and replanted, and can be in bearing again by 3 or 4 years. For such an operation to be a success the primary scaffold branches should be pruned back heavily to reduce leaf area; the digging and moving should be done during winter months, preferably during cloudy weather. After replanting, the trees must be thoroughly watered and irrigations continued through the summer.

Training and pruning olive trees[1]

Young olive trees are pruned to:

- develop a good structure without an unnecessary delay in production
- provide a mechanically strong trunk and scaffold framework for sustaining heavy crops and resisting strong

Fig. 18. Transplanting mature olive trees. Above: trees shortly after being moved to a new location. Below: trees cut back and ready to be replanted. (Photographs courtesy B. E. Glick & Sons, Corning, California.)

[1] See: University of Calif. Ag. Expt. Sta. Cir. 537, *Pruning Olive Trees in California.*

Fig. 19. Left: well-trained, 3-year-old Mission olive tree pruned to a single trunk, with three well-spaced primary scaffold branches. Right: the same tree 2 years later. A strong trunk and a low-headed scaffold system not likely to break as the tree grows older has been developed.

winds without limb breakage throughout the tree's lifetime.

Bearing olive trees are pruned to:

- help obtain satisfactory yields of good quality fruit for many years
- facilitate harvesting and spraying operations for insect and disease control
- prevent deterioration of the trees and reduction in yields as they grow older.

Young trees. Olive nursery stock in gallon cans, or balled and burlapped, can be planted with no pruning other than removal of suckers or badly placed branches. Bare-rooted trees should be cut back to 24–30 inches from the ground.

During the first growing season, three laterals, well distributed around a single trunk and spaced within 12 to 24 inches from the ground, are retained and the remaining branches, especially suckers from the base, kept removed. By going over the young orchard several times during the summer much can be done at little expense to create a desirable framework and eliminate unwanted branches before they make much growth.

During the second, third, and fourth growing seasons, pruning should consist of removal of suckers and watersprouts from the base of the tree, as well as broken branches or those crossing over in unwanted positions. Pruning should be kept at a minimum, although an attempt should be made to develop a satisfactory system of scaffold branches—excessive cutting increases the age at which young olive trees come into bearing.

During the first few years, little or no wood should be removed from the upper portion of the tree. After trees come into bearing (from 3 to 5 years of age) another phase of pruning is required to develop a secondary scaffold system. This consists of about three permanent branches arising from each of the three primary scaffolds spaced around the tree so as to form a strong supporting framework for the fruiting top and side branches. It is best to develop this secondary scaffold system, and to thin out unwanted branches over a period of several years. Heavy thinning out of branches in any one year causes trees to become so strongly vegetative that they stop bearing until fruiting wood again develops.

Bearing trees. Olive fruits are usually borne laterally along shoots of the previous season's growth, the bearing area being a more or less hemispherical "shell" 2 to 3 feet deep around the tree's periphery. Few fruits are borne inside this shell—that is, closer to the trunk. For maximum

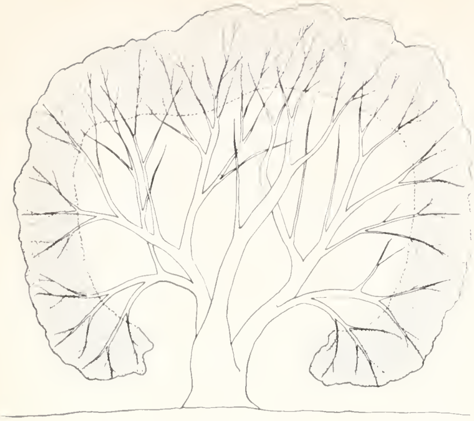


Fig. 20. The natural fruit-bearing area of the olive is a shell (shaded area) around the tree's periphery. Highest yields can be expected if this shell is kept as large as possible and close to the ground for easy harvesting.

crops, pruning should be designed to promote a continuing supply of new fruiting wood and to keep this bearing region vigorous and with a maximum leaf area. This is impossible if the trees are planted too close together, in which case excessive shading reduces the bearing surface to the top, the south half, and perhaps the upper sides of the east and west halves of the tree—and this reduces yields. Cutting out the top in order to let light into the center and north portion of the tree will not solve the problem, as this merely eliminates fruiting wood from one portion in an attempt to produce it in another.

Moderate annual pruning is necessary in mature, bearing olive trees for the following reasons. (1) Stimulation of pruning helps to maintain growth of new fruiting shoots. (2) There is a continuing production of dead or dying unfruitful twigs caused by shading out in the fruit-bearing shell; these twigs should be thinned out to admit more light, facilitate harvesting and spraying, and reduce the chance for insect or disease infestation. (3) After the tree occupies all the space allotted to it (with allowance for good light conditions on all sides) moderate pruning is necessary to hold it to the desired size.

High harvesting costs require that trees be kept relatively low to facilitate picking. After the tree's fruiting top has reached about 15 to 18 feet, judicious pruning can hold it at that level. During annual pruning a special effort is made to remove or cut back upright growing branches in the center of the tree which tend to raise the height of the top fruiting surface.

Continuing unchecked growth, especially where trees are planted fairly close together, gradually results in the shading out and death of fruiting wood on the sides and confines the bearing surface to the tops. These factors cause decreased yields.

If trees have been planted too close together ($20' \times 20'$, for example) pruning does little for obtaining satisfactory yields. Removing some trees to provide ample sunlight will improve production.

Severe pruning is sometimes required. Older trees (especially Mission) may grow to such heights that it is impossible to harvest fruit in the tops. In such cases a severe heading back of upright branches is required, followed by an annual cutting back of branches tending to grow out of reach.

Neglected orchards having had little or

Fig. 21. Well-shaped and well-spaced olive trees capable of bearing heavy, easily harvested crops.

no pruning for many years sometimes require a rejuvenation type of pruning. In addition to removing dead wood and broken or crossing branches, upright and laterally growing main scaffold branches are cut back to about half their length 8 to 10 feet from the ground; these cuts should be made just above smaller lateral branches if possible. Excessive scaffold branches should be removed. New growth forced out by this heavy pruning needs to be thinned out during the following few years to space new branches properly. When such heavy cutting is practiced, nitrogen fertilizers should be withheld for a year or two to reduce excessive sucker and water-sprout growth. If much bark area is opened to direct sunlight, whitewash should be applied to avoid sunburning and death of the tissues.

When well-spaced scaffold branches have been established and all unnecessary branches eliminated, severe pruning should be avoided, as continued heavy pruning of irrigated olive trees reduces production markedly without a sufficient increase in fruit size to offset reduced yields. Instead, a maximum fruit-bearing shell, reaching almost to the ground around the entire tree, should be encouraged.

When olive knot is present, pruning should be done in summer to guard against spreading the disease. If pruning must be done in winter, tools should be disinfected frequently. A satisfactory solution for this consists of Clorox (1 part to 10 parts of water) plus a small amount of household detergent to facilitate wetting the surfaces of the pruning tools when they are dipped.

In orchards having a definite alternate bearing pattern some benefits may be obtained by doing a portion of the pruning just after fruit set of the "on" year. When it becomes apparent that the tree is going to bear too much fruit, some of the small branches and twigs carrying large numbers of fruit can be cut off, using care to avoid removing branches bearing only a few fruits. The objective is to remove as much fruit as possible while removing a minimum number of leaves.

Brush from pruning should be shredded or hauled out of the orchard. Brush should not be burned in the orchard because this injures the trees.

Pruning of frost-damaged olive trees

After cold winter weather (15° to 17° F) excessive leaf fall, bark cracking, and occasionally death of limbs occurs. Heavily pruned trees are more susceptible to cold damage than are lightly pruned (or unpruned) trees. The effect of foliage loss from freezing injury is similar to that of severe pruning. New growth from uninjured buds appears in abundance during late spring. If trees are cut back too soon following a damaging freeze, it is likely that some limbs will be removed that may have recovered and become fruitful the following season.

Experience and experimental evidence show that the best treatment for frost-damaged olive trees is to leave them unpruned until the following June or July, by which time the necessary corrective cuts can be readily determined. At the same time, trees suffering from olive knot may also be pruned with safety (the chief pruning then to be done is cutting out dead and diseased limbs).

Young trees are more sensitive to cold than are older trees. If temperatures are likely to drop to 23°F or below, the trunks may be wrapped with an insulating covering for protection.

Fruit growth

Olive fruit exhibits a cyclic growth pattern, the first stage being one of rapid growth followed by a second stage in August and September when size increase is slower. The third stage, in autumn, is again one of rapid growth and coincides with the color changes—from green to straw to red to black. Because the value of olive fruits increases markedly with size, it is best to delay the harvest of canning olives to take advantage of this rapid increase in fruit size. But it is unwise to delay harvest to the point where the processing qualities of the fruit are affected, or where damage from early frosts is likely. Recommended harvest maturity standards developed for the industry are given on page 48.

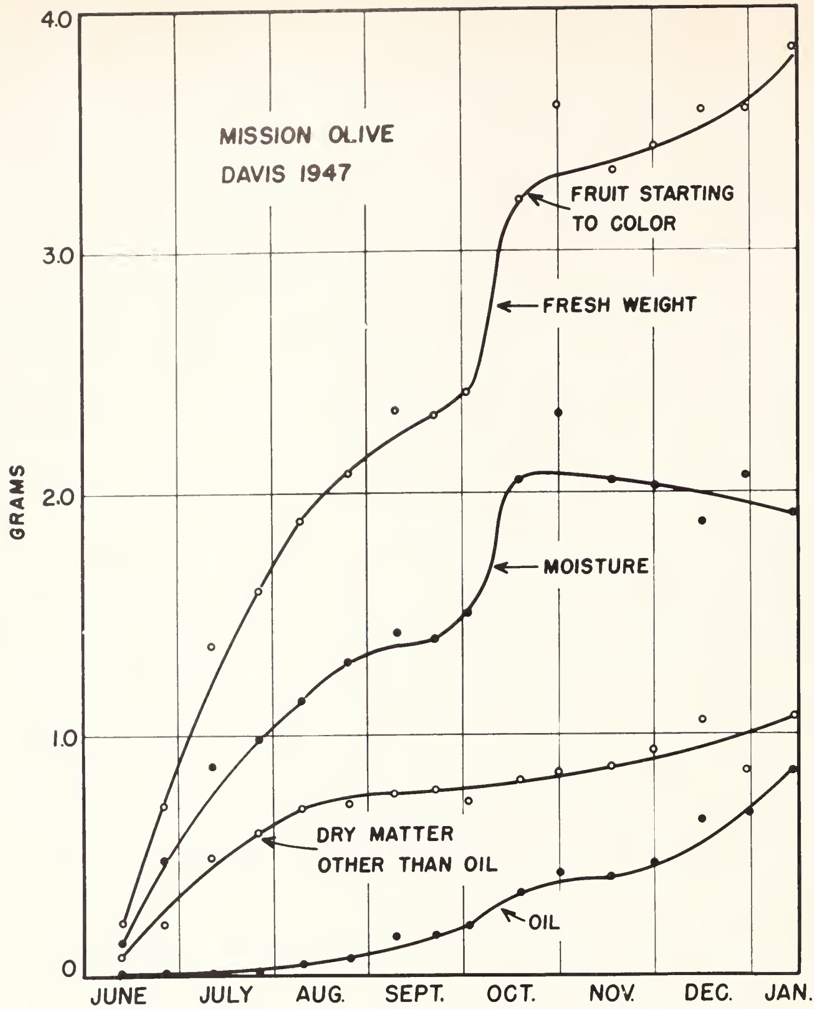


Fig. 22. Fresh weight, moisture, oil, and dry matter other than oil of Mission olives. (Based on an average of 100 fruits.)

Fruit size increase in autumn comes mainly from increased moisture content of the fruit, so if the trees lack soil moisture during this period the expected increase in fruit size cannot occur. If there is high transpiration and low soil moisture the leaves withdraw water from the fruits, causing them to shrivel. Therefore it is important that the trees are amply (but not excessively) supplied with water for several weeks just before harvest.

About August 1 accumulation of oil in the fruit begins; this increases gradually through fall and winter and reaches its maximum in late December or January as fruits become completely black.

Vegetative growth

Vegetative shoot-growth in the olive commences about the first of April in California and continues until about the middle of October. Growth rate is fairly uniform, with no abrupt flushes of growth as in citrus. Vegetative growth starts when an appreciable number of hours over 70°F are experienced daily, and ceases when there are no hours above this temperature.

SETTING A SATISFACTORY CROP . . . EFFECTS OF CONTROLLABLE AND NONCONTROLLABLE INFLUENCES ON FRUIT SET

Olive trees often fail to set a satisfactory crop even though they are well cared for and make excellent vegetative growth. Part of the problem is that of alternate-bearing; the trees exhaust their nutrient reserves with a heavy crop and are unable to produce the year following.

It is also quite common for some orchards to set little or no fruit each year for several years, although causes for such nonbearing are not clear. The influence of cultural methods on yields is probably secondary to influences of climate in the long run, and thus weather conditions are probably the most fundamental forces affecting yields.

An important time in the setting of an olive crop is from about February 1 to July 1. From March 1 to 15 the first microscopic evidence of flower formation in the buds may be observed. Following this is a rapid development of the floral parts, with extension of flower clusters; full bloom occurs about 8 weeks after initiation of the floral parts. Coinciding with this is the beginning of vegetative growth (about April 1). Obviously, a heavy drain on the tree's food reserves occurs during this period, and trees in top condition are therefore more apt to produce good crops.

One of the causes for poor fruit set in some orchards in certain years is the lack of enough perfect flowers—orchards have been observed where practically the entire bloom was composed of staminate flowers. These result from an abortion of the pistil, occurring sometime during the development of the floral parts, which may be caused by a deficiency of water, mineral nutrients, carbohydrates, or by some imbalance of hormones during floral development (March, April). Other factors that may influence fruitfulness in the olive are discussed below.

Temperature

Olive trees in California are unfruitful unless they are exposed to a certain amount of cold during the winter period. In experiments at Davis, half of a group of young, bearing Mission trees growing in large containers were kept in a warm greenhouse throughout the winter, while the other half remained out-of-doors. None of the greenhouse trees bloomed or fruited, but the outdoor trees bloomed and fruited normally.

Effect of duration of exposure to natural winter chilling temperatures on inflorescence production of Manzanillo olives.

Treatment*	Buds forming inflorescences†	Lateral buds growing vegetatively‡
	Per cent	
Greenhouse control: 2 hours below 45°F......	0.0	0.0
Partial chilling: 1240 hours below 45°F...	6.1	1.6
Out-of-doors all winter: 1852 hours below 45°F...	73.4	0.4

* Treated plants were 4-year-old trees in containers.
† L.S.D. at 5% level = 19.5; at 1% level = 29.5.
‡ Differences not significant at 5% level.

Some olive varieties seem to require more winter-chilling than others for good flower production. At Davis, Ascolano and Sevillano required from 1700 to 2000 hours below 45°F during the winter to produce a normal set of inflorescences. Mission, Barouni, and Manzanillo produced a few inflorescences with less chilling (about 1300 hours below 45°F). Azapa and Rubra produced some inflorescences with only about 600 hours below 45°F. However. all varieties produced the maximum number of inflorescences with the maximum amount of winter chilling provided. In microscopic examinations of the buds no flower parts were observed until late winter. (Chilling is not essential for vegetative growth to take place).

Along with winter-chilling the presence of leaves on fruiting shoots is necessary for inflorescence formation. This is shown in the following table and it emphasizes the importance of preventing tree defoliation.

Effect of defoliation at beginning of chilling period on percentages of buds forming inflorescences, and of buds growing vegetatively, on 3-year-old Manzanillo olive trees grown in containers.

Treatment	Buds forming inflorescences*	Buds growing vegetatively†
	Per cent	
Out-of-door trees, completely defoliated	0.0	65.0
Out-of-door trees, half defoliated:		
Defoliated half	1.7	24.0
Foliated half	83.4	1.0
Greenhouse trees, intact control	0.0	0.0
Out-of-doors trees, intact control	84.3	1.0

* L.S.D. at 1% level = 30.0.
† L.S.D. at 1% level = 16.7.
SOURCES: Hackett, W. P. and H. T. Hartmann, "Morphological development of buds of olive as related to low temperature requirement for inflorescence formation." Bot. Gaz. **124**: 383–87. 1963.
Hackett, W. P. and H. T. Hartmann. "Inflorescence formation in the olive as influenced by low temperature, photoperiod and leaf area." Bot. Gaz. **125**: 65–72. 1964.

Olives in California usually bloom from about May 1 to June 1, depending upon season, variety, and location. Damage to the crop from spring frosts is rare during bloom—average dates for the last killing frost are: Oroville, March 17; Corning, March 8; Orland, March 4; and Lindsay, March 19. (But there have been years when unopened buds were damaged by cold spells in late March or early April.)

The occasional occurrence of hot, dry winds during the blooming period has been associated with poor sets of fruit. Winds occurring during June, when there is a period of natural drop of the young fruit, may increase the amount of fruit dropping. In California, fruits still on the tree by July 1 will as a rule continue on to maturity.

In a statistical study of yields of Sevillano olives in Tehama County in relation to temperatures during certain periods in the winter (1951 through 1960), the following conclusions were drawn:

> Years with January mean temperatures approaching the 50°F level are likely to be years of poor olive production unless the temperatures in the immediate post-January period are cool enough for flower-bud development. Intermediate yields can be expected in years with only moderately low January temperatures and moderate to high temperatures in February and early March. Highest olive yields are most likely when both January and February temperatures are cool. In Tehama County, where in most years January temperatures are cold enough to favor some flower bud initiation in olives, the temperatures of February and early March are also critical in relation to the number of flowers formed and the ultimate yield.

Soil moisture

The fact that practically the entire olive acreage in California is irrigated is argument for the benefits of this practice. Irrigation results in increased yields because it helps produce new fruiting wood, increases fruit set as well as fruit size, and prevents shrivelled fruits.

If normal winter rainfall has been insufficient so that trees may be suffering from a lack of moisture during the critical spring period, one or two pre-bloom irrigations are advisable. Experiments show that insufficient soil moisture during the spring floral development period not only causes abortion of the pistils in the flower, but also causes a reduction in the number of inflorescences and flowers formed.

This effect of low soil moisture on fruit set and yields is further borne out by an irrigation experiment conducted in the spring of 1951 in a Sevillano orchard at Corning. In that year, March and April were extremely dry, with only 0.2 inch of rain falling from about the first of March until April 28 (the normal amount of rainfall expected then is about 5 inches). Three adjacent experimental plots were

Fig. 23. Typical inflorescences from experimental olive trees grown in containers and exposed to different soil moisture conditions in early spring. A: continuous ample soil moisture during floral development period. B: soil moisture deficiency during a 1-week period at an early stage of flower development. C: moisture deficiency for 1 week during an intermediate stage. D: moisture deficiency for 1 week at a late stage. E: soil moisture deficiency during entire period of floral development.

established. No. 1 had one irrigation on April 1; No. 2 had one on April 14; No. 3 had no irrigation until after bloom.

All three plots had about 1.9 inches of rain from April 28 to May 7. The unirrigated plot was thus without water during most of the time the flower buds were forming, from March 1 to April 28. The effect of the three different irrigation treatments on the crop was determined by making counts of the number of fruits per 100 inflorescences, and by obtaining yield records per tree at harvest.

Showers occasionally fall during olive-blooming, and the question arises as to how this may affect the set of fruit. Experiments were conducted at Davis in 1950 in which one tree was kept wet 8 hours a day during the blooming period by a sprinkler placed in the top of the tree, while an adjacent tree received the same amount of water on the ground under the tree. Fruit-set counts made on both trees showed no significant differences. The sprinkling seemed to have no adverse effects under the conditions of this test.

Effect of pre-bloom irrigation on fruit set and yields of olives with low spring rainfall, Sevillano variety, Corning (thirty trees per plot)*.

	Date of first irrigation	Fruits per 100 inflorescences	Yields per tree (lb.)
Plot 1....	April 1	2.7	101
Plot 2....	April 14	2.3	113
Plot 3....	After bloom	1.4	65

* Rainfall was 0.2 inch from March 1 to April 28; normal is 5 inches.

Mineral nutrients

Nitrogen. Nitrogen fertilizers should be applied early enough so that they will be absorbed by the tree by March 1. Applications of commercial fertilizers are usually made in late December or January, and manures applied the previous fall. Nitrogen applications are essential to sustained production. This is due, in part, to the necessity of stimulating growth of fruiting wood. There also is evidence that nitrogen applied several months prior to bloom results in increased fruit set, especially in the shallow soils of Butte County. In fact, some growers in that area are cautious about applying too much nitrogen for fear of causing excessive fruit set and developing an alternate-bearing condition. Olive trees in deeper and more fertile soils are not so responsive to changes in the nitrogen fertilization practices.

Boron. One of the symptoms of boron deficiency in olives in Butte County was unfruitful trees. Some trees appeared to blossom and set fruit normally, but most of the immature fruit dropped during July and August. Such trees would be expected to have a boron content of 14 to 15 ppm in the leaves. However, severely affected trees (having a boron leaf content of 7 to 13 ppm) produced few if any blooms.

Potassium. Potassium deficiency in olives causes marked reduction in yields due to resultant lack of new vegetative growth, failure to produce a satisfactory bloom, and reduction in fruit size.

Other than the mineral nutrients mentioned above, there is no evidence of mineral deficiency in California soils sufficient to result in reduced friut set and yield in olives.

Carbohydrates

Little can be done to increase the carbohydrate level in the tree other than to maintain a heavy, vigorous leaf area. This can be accomplished by irrigation, nitrogen fertilization, wide spacing of the trees, minimum pruning and control of the fungus disease, peacock spot, which infects leaves and causes them to drop.

Increasing the carbohydrate level in the tops of trees during the flower-forming period of March and April has been done experimentally by girdling the branches in mid-February. This has sometimes resulted in definite increases in the percentage of perfect flowers, fruit set, and yields. In girdling, a strip of bark about ¼-inch wide is removed from most of the primary scaffold branches on the tree (a grape-girdling knife does this very rapidly), and the girdled area is covered immediately with a grafting compound. This is most effective when performed on young, vigorous trees, but it has several disadvantages and is advisable only as a last resort in getting trees to set a crop. In orchards infected with olive knot it is quite likely that the bacteria will become established in the girdling cuts unless cuts are immediately covered with hot grafting wax, then with a Bordeaux-mixture paste, and finally with an asphalt-emulsion grafting compound. Bordeaux paste applied directly to the girdling cut causes considerable injury to the tissues and is not advised.

Alternate bearing

The physiological basis for this condition is the fact that flowering and fruiting "exhausts" the tree considerably. A heavy crop removes much of the various carbohydrate materials, organic nitrogenous substances, and other essential nutrients from the tree so that adequate stored-food reserves are not available for production of a crop the following year.

The best method for preventing alternate bearing is the prevention of excessively large crops. Because the olive has an erratic bearing behavior it is difficult to predict excessive fruit set, which cannot be determined until about the first to the middle of June. Therefore the only practical way to prevent an excessively heavy crop is to thin out some of the young fruits after they have set. This must be done early, preferably in June. Such thinning is done only with heavy crop sets; once a regular bearing pattern is established thinning can be discontinued, perhaps for several years.

There is no clear-cut evidence that alternate bearing can be overcome by pruning, but it is possible that if pruning can be delayed until late June of the "on" year, it may lessen the alternate-bearing tendency. Pruning is not as effective as fruit thinning in overcoming alternate bearing, however, because leaves as well as fruit are removed. This type of pruning should be "detailed" rather than simply the removal of large branches. Efforts should be made to cut off shoots heavily laden with fruits, and to ignore shoots bearing only a few fruits: the object is to remove as many fruits as possible while removing only a minimum number of leaves.

No fertilizer practice can be relied upon to eliminate alternate bearing in olives, although nitrogen fertilization may increase production without greatly changing the long-term patterns of fluctuating yields—patterns which are similar to those of unfertilized orchards. On the other hand, excessive applications of nitrogen in winter or early spring may cause a heavy fruit set and initiate an alternate-bearing pattern. (This is especially true in Butte County.)

Fruit thinning

Apart from possible alleviation of alternate bearing, the benefits of thinning excessive sets of fruit are: (1) increased fruit size, (2) earlier fruit maturity with less chance for frost-damage and shrivelling at harvest, (3) higher oil content, (4) greater flesh-pit ratio, (5) reduction in harvesting cost, (6) less limb breakage, (7) production of more fruiting wood for the next season's crop, and (8) increased yields over the years.

The disadvantages of thinning are the cost of the thinning operation and the reduction in total yield the year thinning is done. Increased fruit size will not offset the reduced number of fruits, therefore the premium paid for larger fruits must be enough to overcome decreased yields.

In general, thinning will not pay unless trees are definitely overloaded. With excessive fruit set, however, thinning may be profitable because it increases to canning size fruit that otherwise would have to be sold for oil.

Spray thinning. Experiments and grower experience since about 1954 have shown that spray thinning of olives with naphthaleneacetic acid (NAA) is a useful tool for regulating the size and quality of the crop. Naphthaleneacetic acid has been registered by the USDA as a fruit thinner on olives when used at the rate of 150 ppm and applied ½ to 2½ weeks after full bloom. This approval was given on the basis of no tolerance at time of harvest.

Best results from NAA are obtained if sprays are applied when fruits are about

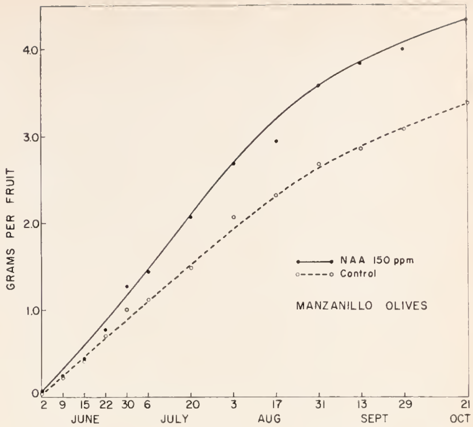


Fig. 24. Fruit growth of olives during the summer on unsprayed control trees (dotted line) and on trees spray-thinned with NAA (naphthaleneacetic acid). Final fruit size on thinned trees was about 30 per cent greater than from unthinned trees.

⅛-inch to $^{3}/_{16}$-inch in cross diameter, which is generally from about May 27 to June 5. Timing is critical: spraying too early may remove too much fruit; spraying too late will not take off enough. A concentration of 150 ppm of NAA, plus enough household detergent to cause good wetting of the leaves, has given the best results. (NAA at 100 ppm plus 1½ per cent light summer oil may also be used).

High air temperatures (above 100°F) during and just after spray application have tended to accentuate the thinning effect. Addition of oil has also resulted in increased removal of the fruits. A combination of oil additive plus high air temperatures may cause excessive thinning, especially if the orchard's soil moisture is low.

Fruits of all the commercially grown varieties of olives except Sevillano have been thinned by applications of NAA. The thinning action is greater on heavily loaded trees than on trees bearing a light set of fruit. NAA seems to accentuate the naturally occurring June drop of young olive fruit. The chief effect in spray thinning is to remove a portion of the fruit, with remaining fruit reaching a greater size than that attained by fruit on similar unthinned trees. The size increase of the remaining fruit is directly proportional to the amount of fruit removed. There is some evidence that trees showing a substantial thinning effect will, during the next year, produce a heavier crop than will unthinned trees.

When olive trees are used as ornamentals it is often undesirable to have them fruit at all. Sprays of naphthaleneacetic acid at the same concentration used for fruit thinning (100 to 150 ppm) if applied at full bloom will usually prevent fruit setting. If the bloom is prolonged—over 7 days—two sprays, one toward the beginning of bloom and one near the end, may be necessary to prevent fruiting. Tender ornamentals growing under or near sprayed trees should be covered during spraying to prevent injury to them; drift of the spray onto nearby properties should also be avoided.

Hand thinning. Trees should not be thinned unless they are overloaded. Experienced growers know the maximum fruit set their trees can carry while still maintaining satisfactory fruit size at maturity: this is approximately three to five fruits per foot of twig, depending on such factors as age and vigor of trees.

Thinning should be done as early as possible for maximum benefits; mid-June to July 10 is the preferable time; reduction of alternate bearing is obtained only with such early thinning. Later thinning (late July or August) causes increased fruit size for the remaining fruits, but total reduction in yield is proportionately increased. The following points should be observed:

Wear heavy rubber gloves or tape the fingers. Use both hands, stripping fruit from several twigs at once.

Thin only those twigs where at least five or six olives can be removed at one pull. Try to leave an average of three to five olives per foot of twig. Unless enough fruits are removed, thinning will not be useful.

To check results, leave overloaded unthinned trees near the thinned ones, at least for the first trials.

Pollination

The need for cross-pollination in olives has long been debated here and in other olive-producing countries. Experimental work in Italy showed that most varieties examined were self-sterile, a few were self-fertile, and some were partially self-fertile, and so the planting of pollinizer varieties was recommended. In Portugal, however, hundreds of acres of isolated olive orchards of one variety sometimes produce excessive crops. In California many large orchards of a single variety have produced satisfactory crops, although some of the highest and most consistent yields are in orchards where two varieties are interplanted.

Investigations with Ascolano, Manzanillo, and Sevillano olive varieties showed that chances of fertilization and fruit set are much greater after cross-pollination than after self-pollination. Pollen-tube growth usually is faster following cross-pollination than after self-pollination, and more pollen tubes can reach embryo sacs before the sacs degenerate.

Despite long-standing contradictory views regarding the benefits of mixed varieties in olive orchards, studies at Davis and Winters have shown that cross-pollination of varieties does increase fruit set in some years. In parts of California the olive crop is poor in some years, even when conditions seem favorable for pollination and fruit set. Temperature is a possible factor in olive fruit set, because individual varieties have particular temperature requirements and temperatures affect pollen-tube growth.

Generally higher temperatures are more favorable than low. However, in cross-pollinations with Sevillano pollen, cool conditions were better. Higher temperatures increase the incompatibility reactions of Sevillano, and pollen tubes more frequently become blocked somewhere between the stigmas and embryo sacs.

Of the three varieties tested, Sevillano appeared to be the most self-incompatible and Ascolano the least so.

Growers contemplating planting of new orchards of two varieties may find it profitable to interplant them, especially if orchards of other varieties are not nearby. It facilitates harvesting operations to plant varieties in groups of four rows each.

Delayed harvest

Olive trees excessively loaded with fruits often fail to produce fruit of sufficient size by October to justify harvesting them for canning olives. Consequently fruits are allowed to remain on the trees until January or February and are then harvested for oil. Such late-harvested trees produce little if any fruit the following year. Trees with a light to moderate crop, however, produce fruits large enough to be harvested in October for canning. These early-harvested trees have usually been observed to return a satisfactory crop the following year. It was thought from this that late harvesting itself was detrimental to the set of a subsequent crop, but experiments in two Mission orchards in Butte County failed to bear out this conclusion. Adjacent groups of trees in the same orchard, and bearing approximately the same amount of fruit, were harvested early (October), medium (December), and late (February); yields the following year were practically the same in each of the three plots, and similar results were obtained yearly for 4 years. The lack of a subsequent crop with heavily-loaded, late-harvested trees is perhaps due simply to alternate bearing: such trees probably exhausted their stored foods maturing the heavy crop, and would not have set a crop the following year even if they had been harvested early.

PRODUCTION OF THE CROP . . . CULTURAL PRACTICES THAT WILL CONTRIBUTE TO SATISFACTORY LONG-TERM YIELDS

Fertilizers

Nitrogen. This is the main fertilizer with which olive growers need be concerned. It has been so beneficial in increasing yields that most growers annually apply about ½ to 2 pounds of actual nitrogen per tree.

Nitrogen can be applied as animal manures, or as one of the chemical fertilizers listed in table on page 43. Fertilizers should be chosen on the basis of which of them will supply a pound of nitrogen at the lowest cost. When manures are used as a source of nitrogen they should be applied in the fall, as the nitrogen in them is slowly available to the trees. Commercial fertilizers are best applied in late December or January, because fruit bud differentiation, floral development, and fruit setting occur in the olive from March 1 to June 15, and the fertilizers should be applied early enough so that they will be available to the trees during this time.

Concentrated organic nitrogen (urea) fertilizers have been applied experimentally to olives at the rate of 12 pounds per 100 gallons as foliage sprays during floral development (March 1 to April 15). Leaf analyses showed that the olive absorbs nitrogen in this form through the leaves. In some experiments fruit set has been increased over that of non-fertilized trees, but benefits have not usually been sufficient to justify the increased cost of this method of application.

Nitrogen fertilizers have been applied to large olive trees experimentally as high as 30 pounds of ammonium nitrate per tree (10 pounds of actual nitrogen) on clay soils in Tulare County without causing injury. However, it is uneconomical to practice continued heavy applications of nitrogen fertilizers to olives, because nitrogen in the tree, as determined by leaf analysis, never exceeds about 2 per cent of the dry weight of the leaves—thus indicating that there is a maximum amount the tree will absorb (additional nitrogen may be leached out of the soil and wasted). Conversely, the nitrogen level of olive trees apparently seldom or never goes below about 0.9 per cent of the dry weight of the leaves. Average orchards in good condition have a nitrogen content in leaves of about 1.5 to 1.8 per cent.

If leaves are dark green and the new shoot growth is 8 to 20 inches a year, the trees are probably adequately supplied with nitrogen. If leaves are a medium to light green and are not making a shoot growth of at least 8 inches per year, it is likely that trees are deficient in nitrogen and would respond to fertilizer applications. Chemical soil analyses are not a reliable means of judging the fertilizer requirements of trees, because they do not allow for the tree's ability to absorb the elements from the soil—nor is it possible to get a soil sample representative of the entire orchard. Leaf analysis is a much better method, although fertilizer requirements probably can best be judged by the trees' response to test applications.

Some growers believe that applications of nitrogen during the summer cause increased fruit size, but experimental work with nitrogen fertilization of olives and other fruit crops has not substantiated this.

Two 4-year nitrogen fertilization experiments were conducted with Manzanillo olives in Tulare County from 1937 through 1940. One was in an orchard in poor condition with trees 24 × 24 feet apart; the other in an orchard in fair condition with trees 30 × 30 feet apart. In addition to the "control" of no nitrogen, two different amounts were added as shown immediately below. Yield of fruit per tree for the 4-year period is also shown in the text table below.

The main responses to fertilization in these experiments were increased tree growth, with a large increase in bearing surface, and setting of more fruit. Fruit size was not increased; with some heavy sets, size decreased proportionately as set increased. No particular difference in time of fruit maturity was reported.

In orchards having a high level of nitrogen fertilization, marked responses such as obtained with nitrogen-deficient trees would not be experienced by further increases in nitrogen applications.

In similar tests in Tehama County with Sevillano olives the following conclusions were drawn: yield and income tended to increase with each year of nitrogen application; fertilizers induced better bud development and additional growth, so that the effect of annual applications was cumulative.

Sizes (expressed on a percentage basis) were reduced by nitrogen fertilizers, but the greater total yield resulted in greater production of larger sizes.

Percentages of culls in fertilized olives were higher than in non-fertilized, and this seemed to be associated with a vigorous, rank type of growth. No marked difference in pickling quality or flavor was apparent in olives from trees with or without nitrogen fertilization.

Experiments with nitrogen fertilizers in Butte County (1952 through 1956) led to the following conclusions: Under the low-fertility conditions of the foothill soils, Mission olives responded markedly to nitrogen applications by increased fruit set and yields. Reduced fruit size accompanied increased nitrogen levels because of increased numbers of fruits per tree. Increased levels of nitrogen retarded fruit maturity. Oil content of fruit was not associated with nitrogen level of the tree. Unfertilized trees had significantly smaller leaves than did those receiving nitrogen.

In the Corning district, Sevillano trees having more fertile soil conditions and less subject to leaching rainfall showed much less response to added nitrogen; after withholding nitrogen fertilizers for 3 years, leaf analyses showed the nitrogen level to be still within the normal range. No consistent immediate response in fruit set or yields was generally found. Table 7 gives the results obtained from this study.

Orchard	No fertilizer	One pound of nitrogen per tree per year	Two pounds of nitrogen per tree per year
		Yield	
Orchard I (24′ × 24′) (poor condition)	18 pounds	141 pounds	186 pounds
Orchard II (30′ × 30′) (fair condition)	161 pounds	323 pounds	367 pounds

Table 6. Effect of nitrogen fertilizer applications on yields per tree and leaf nitrogen. Mission olives at Palermo.

Treatment	Pounds of fruit per tree and per cent leaf nitrogen					
	1955		1956		1957	
	lb.	per cent	lb.	per cent	lb.	per cent
Control	1.3	(1.23)	48.8	(1.23)	60.8	(1.06)
½ lb. nitrogen per tree in February and ½ lb. nitrogen per tree in June	9.3	(1.52)	171.6	(1.42)	98.4	(1.49)
1 lb. nitrogen per tree in February	21.2	(1.43)	196.2	(1.62)	106.2	(1.53)
3 lb. nitrogen per tree in February	19.5	(1.48)	225.7	(1.60)	105.4	(1.71)
Difference required for significance at:						
5% level	13.8	......	54.5	......	30.5	......
1% level	18.5	......	72.9	......	40.9	......

Response of olive trees to nitrogen fertilizers is likely to be rapid and pronounced when the nitrogen level in the trees is low (1.2 per cent or less in leaves). In gravelly, shallow hillside soils low in organic matter and subject to heavy, leaching rains the natural nitrogen content is low and added nitrogen soon disappears. Under such conditions, a pronounced response of olive trees to nitrogen fertilizers would be expected. This would be the case year after year, because added fertilizers tend to be lost by leaching, and the low level of organic matter in the soil would not be conducive to a natural build-up of soil nitrogen. However, in heavier and deeper clay soils on level ground, nitrogen would tend to be more stable because of higher organic content and less leaching. Even with no added nitrogen the level in the trees tends to remain adequate for some years; hence, lack of immediate response to one nitrogen application, or to withholding of one application, is not surprising.

Maintaining olive trees at an optimum nitrogen level under the soil conditions found in the Tulare and Tehama valley floor olive districts is relatively simple. Soil nitrogen there does not fluctuate appreciably, and the only problem is that of occasionally adding nitrogen to maintain trees at an optimum nitrogen level. Even at initially high nitrogen levels, however, trees will gradually lose nitrogen after several years and should receive applications before leaf nitrogen drops below approximately 1.5 per cent.

Maintaining proper nitrogen level under conditions such as those in Butte County is more difficult and is likely to be a major problem of the olive grower. Shallow, gravelly soil with low organic matter and fertility, coupled with heavy leaching due to the rolling topography and high rainfall, causes a rapid loss of soil nitrogen and a need for annual additions of nitrogen fertilizer.

Potassium. The paragraphs on potassium and boron deficiencies apply mainly to Butte County; except in isolated instances there is no record of deficiency of these elements in the other olive-producing areas in California.

In 1947, olive trees in the Wyandotte area of Butte County showed leaf symptoms later identified as being caused by potassium deficiency. Analysis of these leaves showed them to contain 0.1 per cent potassium on a dry-weight basis. Previous extensive work by Lilleland and Brown in orchards in different parts of California had established the average potassium level for olives as ranging from 0.8 to 1.0 per cent.

In experiments in a potassium-deficient olive orchard in Butte County, single massive applications of potassium sulfate (25 to 50 pounds per tree) increased potassium content in leaves the following year, eliminated the development of dead areas in leaves, and caused a leaf color change

Table 7. Effect of N (nitrogen) fertilizer treatments on leaf nitrogen, fruit set, yields, fruit size, flesh-pit ratio, and shotberry production. Sevillano olives at Corning (initial treatments: January, 1955).

Treatment	Leaf nitrogen (per cent dry weight)		Fruit set (fruits per 100 inflorescences)	Yields per tree (pounds)		Fruit size index		Weight per fruit (grams)		Flesh-pit ratio		Shotberry development (per cent)	
	Dec. 1956	April 1958	1955	1955	1956	1955	1956	1955	1956	1955	1956	1955	1956
Control	1.60	1.38	3.0	105	236	6.86	5.53	10.6	7.8	6.6 : 1	5.7 : 1	16.0	3.8
¾ lb. N in January and ¾ lb. in June	1.70	1.47	6.4	133	248	6.10	4.97	10.1	7.0	6.3 : 1	5.1 : 1	13.0	1.5
1½ lb. N in January	1.69	1.42	4.8	121	250	6.66	5.16	10.1	7.1	6.2 : 1	5.3 : 1	12.0	1.8
3 lb. N in January	1.76	1.57	6.1	151	250	6.40	5.06	9.4	7.3	6.0 : 1	5.5 : 1	9.5	2.0
Difference required for significance at:													
5% level	0.12	0.12	5.9	32	62	0.78	0.94	0.9	1.0	1.5 : 1	0.2 : 1	6.9	2.3
1% level	0.18	0.18	7.8	42	83	1.12	1.36	1.3	1.4	2.1 : 1	0.4 : 1	9.9	3.3

from light green to normal dark green. The response from this single application continued to be evident for several years. Fertilized trees showed increased shoot growth, fruit size, and yields in comparison with unfertilized trees. Yields per tree for the unfertilized olives over a 4-year period averaged 36 pounds per year, while trees receiving 50 pounds of potassium sulfate at the beginning of the trial produced 152 pounds of fruit per year. Potassium-deficient, unfertilized trees produced 20 per cent canning size fruits (standard grade or larger) in the first year, 19 per cent the second year, and 5 per cent the third year. Trees receiving potassium fertilizer produced 78 per cent canning size fruit the first year, 62 per cent the second year, and 33 per cent the third.

Boron. For a number of years olive trees in the Wyandotte area of Butte County exhibited the following symptoms, diagnosed as being caused by boron deficiency: (1) Short, branched growth in contrast to the long, straight shoots of normal trees. This branching is apparently caused by the death of the terminal bud, which forces growth out from lateral buds; the new terminal buds die and additional branching occurs. (2) Limb dieback in severe cases, sometimes dying back to main trunk. (3) Small leaves with brown, scorched tips, and with an intermediate golden-yellow area between dead tips and green basal portion. There are no dead areas along lateral margins, as with potassium-deficient leaves. (4) Thickened and corky bark, sometimes having a rough, blister-like appearance. (5) Mission trees affected have a high percentage of defective fruits, locally termed "monkey-faced." (6) Reduced yields due to early dropping of fruits before harvest.

For differences in the leaf symptoms of potassium- and boron-deficient trees see page 51.

Experimental injections of copper, manganese, boron, and zinc salts directly into limbs of affected trees were made in the spring of 1941, but response was obtained only with boron. Later tests showed that

Table 8. Comparison of some common forms of nitrogen-containing fertilizers.

Fertilizers	Nitrogen	Phosphate	Potash	Approximate amount required to supply 1 pound of nitrogen
	per cent			lb.
Inorganic concentrated fertilizers:				
Ammonium sulfate	20.5	....	....	5.0
Calcium nitrate	16.0	....	....	6.3
Sodium nitrate	16.0	....	....	6.3
Ammonium nitrate	33.0	....	....	3.0
Ammonium phosphate (16–20)	16.0	20.0	....	6.3
Anhydrous ammonia	81.0+	....	....	1.2
Organic concentrated fertilizers:				
Nu Green (urea)	44.0	....	....	2.3
Fish meal*	10.0	6.0	2.4	10.0
Tankage*	8.0	10.0	12.0	12.0
Dried blood*	12.0	....	8.0	8.0
Cottonseed meal*	7.0	3.0	2.0	14.3
Bulky organic fertilizers:				
Dairy manure (wet)*	0.5	0.3	0.7	200
Dairy manure (dry)*	1.0	0.5	1.8	100
Lot-fed steer manure*	2.0	0.6	1.9	50
Poultry manure (wet)*	1.6	1.3	0.9	63
Poultry manure (dry)*	2.5	2.3	1.2	40
Rabbit manure*	2.0	1.3	1.2	50
Sheep manure*	1.6	1.0	3.0	63
Olive pomace*	1.0	0.3	0.7	100

* These organic materials vary widely in analysis between lots. Figures are averages and useful only for estimates.

the same response was obtainable by applying borax to the soil under the trees at 1 pound per tree.

There is a correlation between the severity of the symptoms and the boron content of the leaves. Trees showing severe deficiency symptoms have a boron content of 7 to 13 ppm; mild symptoms, 14 to 15 ppm; doubtful range, 16 to 18 ppm; normal boron content, 19 ppm and over.

Olives are semi-tolerant to excess boron and are not likely to be injured by borax applications continued for several years at the recommended rate of ½ to 1 pound per tree. With the exception of a few isolated cases, definite response of olives to boron applications has been found to occur only in the Butte County olive district. Leaf analyses from trees in well-maintained orchards in other commercial areas have shown they are in the normal range for boron, but it is possible for deficiencies to develop in the future.

There is no evidence that olive trees in California will respond to fertilizers other than nitrogen and (in Butte County only) potassium and boron. Orchards do not respond to fertilizers containing these elements if trees already have enough.

Irrigation

Most of the world's olive trees grow in the Mediterranean basin and receive virtually no irrigation. In California, however, all commercial olive orchards are irrigated.

Olives tolerate considerable drought and high temperatures because their leaves are relatively small and leathery and have a protective cuticle on the upper surface that tends to reduce water loss; the hairy undersurface also slows transpiration. Stomata, while numerous on the lower surface, are sunken and have small openings. For good crops of canning-sized olives, irrigation comparable to that required by most other tree crops is essential.

Experimental work in California shows that olives react to a lack of readily available soil moisture just as other trees do: growth rate of the fruit declines when soil

Fig. 25. Boron deficiency symptoms in Mission olives. Upper: defective fruits (commonly termed "monkey-face" fruits). Lower: twig dieback; the death of the terminal growing point with subsequent branching is characteristic of this trouble.

moisture is deficient, and insufficient moisture during blooming and fruit setting causes crop failure. Insufficient water in the growing season any time after the crop sets may result in shriveled fruit. Growers are particularly concerned with providing ample moisture as harvest approaches in order to gain the maximum fruit size; however, excessive water sometimes results in a soggy, poorly aerated soil which causes root losses, interferes with adequate water uptake, and contributes to fruit shrivel. If too much water is applied during the growing season, withholding water until soil moisture approaches the permanent wilting percentage helps restore normal root activity. After cold, wet winters it is important not to aggravate high-moisture conditions by applying water too early in the spring. Alternate middle irrigation will help to prevent overwet conditions. Trees suffering from drought do not tolerate winter cold as well as do trees having an adequate moisture supply to the roots.

There is no optimum nor best soil moisture content for fruit-tree growth. Experiments with many kinds of tree crops show that water is used with equal ease throughout the entire range of soil moisture—that is, between field capacity and permanent wilting percentage.

Water taken by trees from the soil is almost entirely given off through the leaves by transpiration, the rate of which is affected by soil moisture, sunlight, temperature, humidity, and wind. Large, healthy trees use more water than small ones, because of greater leaf area. The amount of fruit does not materially affect the amount of water used, as the main water demand is from leaves. Because the olive is an evergreen it uses water throughout the year, although much less in winter than in summer.

Total water used by comparable trees will not be greater on a sandy than on a clay soil, if both soils are fertile and have readily available water at all times—although on sandy soils water must be applied more frequently and in smaller amounts than on clay soils. On shallow, hardpan soils, trees require more frequent irrigation (in smaller amounts) than they do on deeper soils.

Moisture-measuring devices (such as tensiometers and gypsum blocks) are a help in deciding when to irrigate. In orchards with a cover crop of some deep-rooted, broad-leaved plants such as *Malva* or *Melilotus*, the appearance of the plants helps determine the soil moisture conditions: when they wilt, the trees need more water. Soil moisture conditions can be determined accurately after a little experience by means of a soil auger or tube. To be certain that soil has sufficient moisture, it is best to irrigate before all the trees need water—if some get too much water while the majority of them are being correctly irrigated, cut water away from those over-irrigated.

Benefits derived from good irrigation practices are cumulative and may take two or three seasons to appear, but an irrigation procedure that provides ample, though not excessive, soil moisture at all times will help produce and maintain healthy trees. Poor irrigation practices cause low yields, small fruit, poor fruit quality, and stunted trees. To avoid shriveled fruit, considerably more water (by means of more frequent irrigations) should be applied during the hot periods normally experienced in July, August and September. Shriveled fruits regain their turgor after irrigation, but may shrivel again during processing and make a poor-quality product.

Poor drainage

Olives do not grow well where surface or subsurface drainage is poor. Trees in such locations are stunted, with numerous dead twigs, small yellowish-green leaves, poor yields, and prematurely ripe fruit. Eventually, adverse root conditions may cause the trees to die. Olives cannot be successfully grown with such poor drainage, and the best way to avoid it is to carefully determine the drainage characteristics of the orchard site prior to planting.

Soil management

Cover crops will help to maintain or improve soil structure, increase water penetration, and prevent erosion. Good soil structure helps speed the infiltration of water applied to the soil and provides conditions favorable to tree-root penetration. Root channels formed by the cover crop provide a means for rapid movement of water into the soil, but cover crops do not provide a substitute for careful soil handling. Cultivation when soil is too wet puddles many soils so badly that it takes years of good care to repair the damage—and working too dry a soil may have a similar effect. The use of any kind of heavy equipment on moist soils also results in compaction and lowered infiltration rates.

In California's interior valleys, cover cropping does not increase the moisture-holding capacity of soil as it may in cool, humid climates. (In experiments at Davis, moisture-holding capacity of the soil remained unchanged after 25 years of cover crops.)

Cover crops may have great value on slopes subject to erosion: a plant cover reduces the puddling effect of rain drops beating on the soil, and acts as a sponge to collect and distribute water so that the soil can absorb it more easily. The cover also tends to hold the soil in place and to reduce the amount of washing by the part that does flow away.

Although soil nitrogen may be increased in cool, humid regions by leguminous crops, experiments carried out in California's hot, dry interior valley failed to show any measurable nitrogen increase with summer or winter legumes. Commercial fertilizers still must be relied upon to achieve and maintain the desired nitrogen level in the soil of California's olive-growing areas.

Some of the benefits of cover crops can be obtained by working organic material—sawdust, straw, or manures—into the soil. With sandy or medium-textured soil, straw causes a decrease in soil nitrates because bacteria needed for cellulose breakdown utilize available nitrates, which thus become unavailable to the trees. (Clay soils are more apt to be well-supplied with nitrates and putting strawy materials into them is less likely to affect tree growth.) Extra amounts of nitrates applied with organic matter help alleviate nitrogen deficiency.

Cover crops utilize nitrogen while growing, particularly after being incorporated into the soil by disking, and extra amounts of nitrogenous fertilizers may then be necessary for adequate growth and fruitfulness of the trees. Cover crops also use much soil moisture. If they grow in summer, additional irrigation water is needed.

A few of the annual cover crops used are (1) the winter legumes—yellow clover (*Melilotus indica*), the vetch and bur clovers; (2) the summer legumes—cowpeas, soybeans; (3) the winter non-legumes—mustard (*Brassica nigra*), rye, barley and volunteer weeds; and (4) the summer non-legumes—orchard grass, Sudan grass and annual weeds.

Perennial weeds such as Bermudagrass, Johnson grass, nut grass and morning glory rob the trees of needed nutrients and moisture and tend to choke out more desirable cover. They should be eliminated—and this requires persistent efforts.

Sod culture

Many olive growers in the Sacramento Valley utilize permanent sod culture, adjusting fertilization and irrigation to satisfy the needs of trees and sod. Well-constructed, permanent furrows are established before planting. If sprinklers are to be used, the orchard is leveled sufficiently to eliminate pockets where water might collect, and then grasses are sown. Grass is kept low by mowing or (occasionally) letting livestock graze it. If animals are used, it is important that water and salt be properly placed to avoid injury to trees when the animals move around. If the animals start to browse the olive trees they should be taken out of the orchard.

With sod culture cultivation expense is nil, the root system undisturbed, erosion controlled, and orchard operations may be carried on soon after irrigation or rains. However, sod culture is inadvisable if water or nitrogen is limited. Perennial rye grass or native grasses and weeds make satisfactory sod.

Tillage

Conventional cultivation practice is to disk-in volunteer weeds before they use much moisture and nutrients. This usually involves disking, floating or harrowing, and furrowing out after every second or third irrigation during the summer; weed cover is allowed to grow in winter. The soil is disked and floated prior to spraying or harvesting if the weed cover interferes with these operations.

Because most of the olive tree's roots are in the first 2 or 3 feet of the soil, even in deep soils, deep cultivation or subsoiling can destroy much of the root system. Frequent cultivation compacts the soil and reduces movement of water and air into it. Where olive trees grow on shallow or rocky soil, eliminating tillage allows tree roots to completely penetrate the available soil mass.

Non-tillage

Because of water costs and disadvantages inherent with tillage, many growers in central California eliminate weeds with weed oils, such as Karmex® or simazine. The costs of a weed-spray rig and preparation of soil prior to chemical herbicide applications make the first year's costs higher than with tillage, but after weeds are controlled, costs are generally less—sometimes only half as much as with conventional tillage. These herbicides are safe if proper dosages are used and materials carefully applied, but *it is essential that weed oil be kept off the fruit.* If spray mist gets on the fruit, it will impart an unremovable off-flavor to the canned product.

> Check with your local Farm Advisor or Agricultural Commissioner if you plan to use any herbicide other than those mentioned above. Many herbicides cannot be safely used in or near olive orchards.

Harvesting the crop

Harvesting olives represents 50 to 70 per cent of the total production labor cost, and 30 to 40 per cent of the gross returns from the crop. In general, the bigger the trees and the smaller the yield, the greater the expense of picking the fruit. Excessive amounts of brushy growth, dead limbs, large weed growth, smut from black scale infestations, and rough ground add to the picking expense.

Picked fruit begins to lose moisture immediately. When picked during hot, sunny weather, boxed fruit should be set in the shade while waiting to be hauled away. Unshaded picked fruit sunburns and will be graded as culls. Rough handling causes bruises and loss of grade.

A few growers harvest their fruit mechanically, using oscillating tree shakers and catching frames. More developments may be expected in this field.

Canning olives

Olives are harvested for pickling in California from mid-September to mid-November depending on variety, local conditions, and needs of the canneries. Optimum harvesting time is determined by the color and texture of the olive. In order to get the greatest amount of large fruit, harvesting should be delayed until olives reach maximum size. When the crop is large, it may be necessary to spot-pick—first the ripest fruit, and then the remainder; some growers pick over the grove several times, taking only the large, mature fruit each time. Some overloaded trees may be left until the latest possible time to pick for canning or (in the case of Manzanillos and Missions) to harvest substandard fruit for oil.

Over-mature or badly bruised fruit frequently develop spoilage during processing. To get the best returns from harvested fruit, it should be delivered to the cannery as soon as possible. Olives kept too long in boxes or bins after harvesting start "sweating"; this may cause deterioration during processing. Maximum time between picking and brine storage should be not more than 14 hours, therefore long-distance hauling presents an important problem. Some processors do their long-distance hauling at night, while others provide brine storage close to supply centers.

Low temperature injury to canning fruit. To avoid freeze damage to fruit, the pickling-olive harvest is usually concluded before November 10. Fruit from overloaded trees may not attain maturity

HARVESTING AND HANDLING OLIVES FOR CANNING

An olive is considered immature if it will not yield a characteristic white juice under moderate pressure between thumb and finger.

Manzanillo olives should be picked when an even pale green color with a minimum of whitish spots visible, to and including a straw color. During the first half of the season the olives may show a light red blush covering not more than half of any olive; blush is undesirable during the second half of the season.

Mission olives should be picked when an even, pale green color with a minimum of whitish spots visible, to and including a dark red color; during late season dark red olives are undesirable.

Sevillano olives should generally be picked when straw colored. During the first half of the season the olives may show a slight blush if confined to the shoulder on the stem end; no blush is permissible during the second half of the season.

Ascolano olives should be picked when an even, pale green with a minimum of whitish spots to and including a straw color.

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The break between early and late season is considered to occur (on the average):

	Mission	*Manzanillo*	*Sevillano*	*Ascolano*
Sacramento Valley	Nov. 5–10	Oct. 20–25	Oct. 20–25	
San Joaquin Valley	Nov. 5–10	Oct. 16–21	Oct. 22–27	Oct. 15–25

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Growers should be permitted to start picking when no more than about the following per cent of the first fruit delivered will be immature:

Mission and Manzanillo	20 per cent
Sevillano and Ascolano	15 per cent

The grower should be stopped from making further deliveries of any variety when more than 10 per cent of the fruit delivered is overripe.

Olives should be of good color, shape and quality, and in good condition for pickling.

Olives should be free from

- damage by bruises, hail, frost or wind
- spray residues
- scale or scab (scars)
- clusters, leaves, dirt and other foreign substances.

After harvest, olives should be placed in the shade and protected against direct sunlight.

All canning olives should be delivered to the processor on the day harvested.

(Prepared by Industry Harvest Standards Committee sponsored by the California Olive Association.)

TO LOWER HARVEST COSTS

Prune and space trees to encourage the natural spreading tendency of most olive varieties. Remove dead and interfering branches to facilitate picking and encourage the production of higher-quality fruit.

Adopt cultural methods to permit tree skirts to come within a foot or two of the ground. Use weed-control implements designed to avoid contact with tree or fruit.

Teach pickers to use both hands, and to pick toward the container. Moving the hands together rather than independently results in more rapid, careful picking. Ascolanos require careful picking lest they bruise. Manzanillos may be "milked" off if the picker learns to avoid stripping the leaves and twigs along with the fruit.

Have pickers climb to the highest point for the fruit with each new set of the ladder, and then pick coming down.

Greater picker efficiency may be obtained if the grower manages the picking crew himself, or has an experienced foreman do so.

by this time. This condition may be avoided by spray-thinning such trees in late May or early June, or by hand-thinning them before the last of June.

The average date of the first killing frost is November 14 at Lindsay, November 26 at Oroville, and December 3 at Corning. Freezing temperatures of 25° to 28°F (–3.9° to –2.2°C) for an hour can cause fruit damage consisting of shrivelling, softening, or pitted flesh. Injury is much more likely to occur if moisture is present on the fruits than if they are dry. If the temperature has dropped below 27° to 28°F during a still night, the fruits should be allowed to warm up gradually before they are touched. Fruit temperatures can drop considerably below their freezing point without ice crystals forming, but if the fruits are shaken or jarred at this time they may freeze immediately.

Frost damage varies among orchards and may not become apparent until after processing, when the olives become mealy and soft. There seems to be no difference among varieties in regard to the freezing point of their fruits, although small fruits freeze more quickly than large ones. Green fruits are more susceptible to freezing injury than are the red or black. Olives that have been frozen are permanently injured; they become shrivelled, and will not regain their normal turgor even with added irrigation water or rainfall—such fruits cannot be used for canning but can be harvested for oil later in the winter.

Temperatures of 32° to 36°F can cause "chilling injury" to olive fruits, resulting particularly in the development of darkened tissues around the pit, with poor flavor after processing. All fruits subjected to these temperatures should be examined carefully for evidence of such damage.

During the latter part of the harvesting period, another type of fruit shrivelling

Size grades of canning olives

Fruits must reach a certain minimum size at harvest, depending upon variety, or they cannot legally be used for canning. Minimum sizes are:

Mission and **Manzanillo**	Standard
Obliza	Medium
Ascolano, Barouni, and **St. Agostino**	Extra large
Sevillano	Mammoth

often occurs in which fruit cells are not injured and canning quality is usually unimpaired. Such shrivelling may develop when there are low night temperatures and strong, drying winds; then, loss of water from leaves exceeds uptake of water by the roots, with the consequent withdrawal of water from the olives, shrivelling them. However, if this is followed by low transpiration conditions (such as cloudy, rainy, or foggy weather) with higher temperatures, fruit regains normal turgor and is apparently uninjured. This type of shrivelling is more likely to occur with heavy than with light crops, probably because of the relative immaturity of fruit on heavily loaded trees.

Oil olives. If fruits in October and November are not large enough for canning, they can remain on the tree until mid-December or mid-February, by which time they are usually black and have maximum oil content. Although the fruits will probably be shrivelled and perhaps frozen this does not impair their value for oil extraction. (In California, returns from oil olives are much lower than from canning fruit.)

Oil olives may be harvested by handpicking or by spreading canvas sheets under trees and beating limbs with poles to cause the fruit to drop—but this is not desirable as it tends to break off fruiting twigs and causes openings in the bark through which olive-knot bacteria can enter. Beating poles may also cause the spread of olive knot through the orchard. Mechanical devices, such as tree shakers, are used to some extent in California to facilitate the harvesting of oil olives. In some countries small rakes are used to strip fruit from the branches.

PESTS AND DISEASES . . . HOW TO IDENTIFY THEM

(This section on insect pests was prepared by E. M. Stafford, Professor of Entomology, except for the discussion of nematodes prepared by M. W. Allen, Professor of Nematology, and the discussion of biological control of olive scale, prepared by C. B. Huffaker, Professor of Entomology.)

Insect pests

The three principal pests which confront olive growers are olive scale, oleander or ivy scale, and black scale. In some parts of California, growers use the term "olive scale" to designate oleander or black scale. However, the term can properly be applied only to the olive parlatoria scale, which is found from San Diego County to Tehama County, with occasionally heavy infestations in the San Joaquin Valley from Bakersfield to Modesto. Oleander and black scales are commonly found in all olive-growing regions of California.

> See *Pest and Disease Control Program for Olives* (available from the University of California Agricultural Extension Service, or your Farm Advisor) for all chemical control measures.

Olive scale (*Parlatoria oleae* [Colvee]). Often a grower finds olive scale for the first time during harvest. The sharply outlined dark purple spots caused by the scale appear in marked contrast with the yellow-green background of the ripening fruit (page 51).

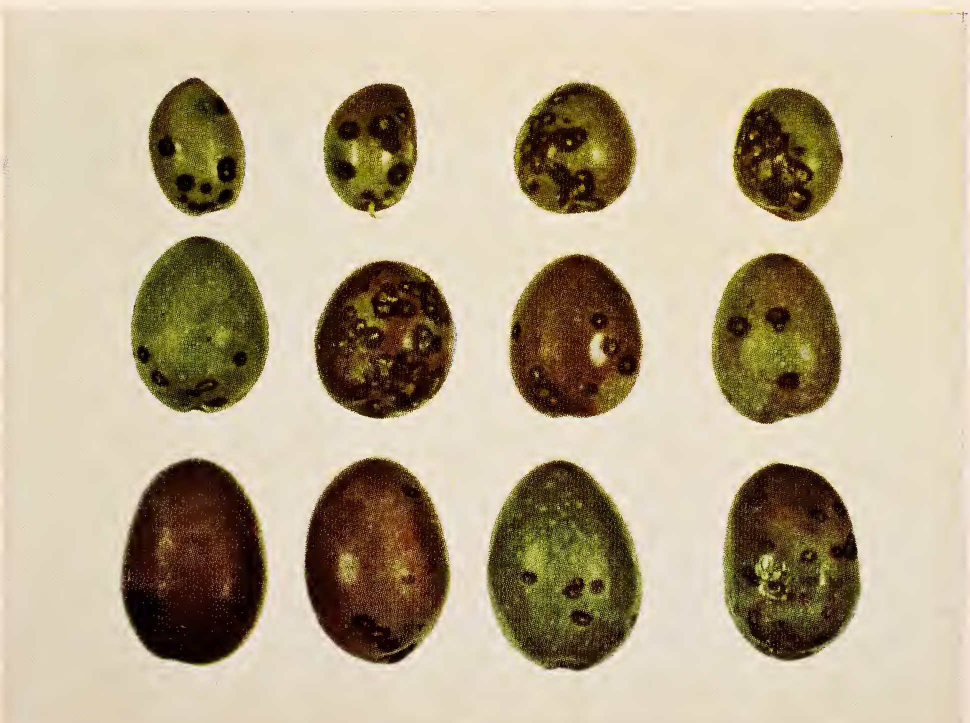
What to look for. The adult female scale has a small gray covering somewhat less than 1/16-inch long. The cover is circular or oval with a small black spot near the edge.

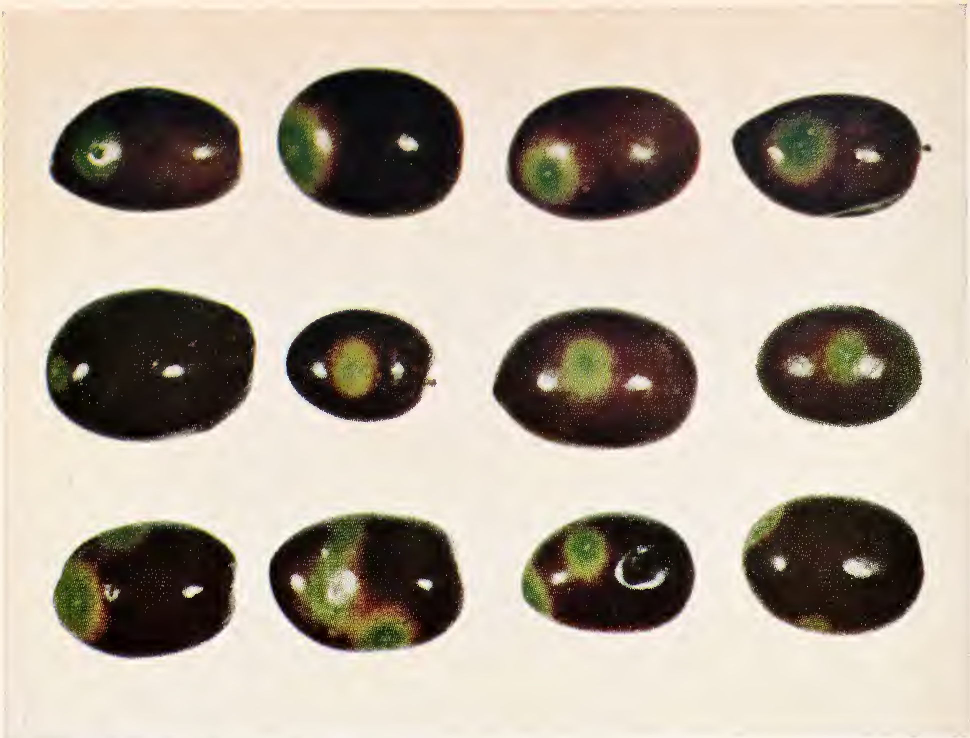
The male scale has a narrow elongate cover, with a smaller black spot at one end. Beneath the coverings the bodies of male and female scales are reddish purple. Both male and female may live on any part of the tree above ground. On leaves they may cause a slight chlorosis, and on small twigs the wood is often a little deformed and darkened.

When infestation is heavy the scales

Potassium-deficient leaves (left) show dead areas at tip and along lateral margins. Boron-deficient leaves (right) have dead areas only at tip, together with a yellow transition zone. (See pages 41–42

Olive parlatoria scale. Purple spots appear on green and red fruits at harvest. (See page 50.)





Oleander scale. Green spots remaining on the dark, ripening fruit are caused by this insect. (See page 54.)

Peacock spot. Black spots first appear on the green leaves causing them to turn yellow and drop. (See page 57.)

Fig. 26. Olive fruits at harvest severely damaged by olive (Parlatoria) scale.

settle on the fruit as soon as it is formed in the spring, and this commonly results in a badly deformed olive at harvest. In early June the scales make their characteristic dark purple spots on the small fruit; these tend to fade as the fruit grows rapidly, so that a grower cannot survey his orchard for the presence of olive scale by looking for purple-spotted fruit in midseason. By mid-August the young, small (and difficult to see) scales may be on the fruit without causing any change in color.

What to do. The best control of olive scale is obtained from thorough spray treatments to control eggs and young scale of the first brood (late May to July 1). Experience has shown that best control has resulted from thorough drenching of the tree. This has been true when spraying with hand-operated guns, oscillating-nozzle boom sprayers, or blower-sprayers.

If spraying is not completed by July 1 the remainder of the application should be delayed until July 15 to August 1, at which time another brood of eggs and young will be present. (In early July the scales are adults and therefore are more difficult to kill.)

To avoid possible injury to trees, spray oils should not be used when the temperature is over 90°F. Oil-spray injury (especially when an excessive amount of oil is used) appears on the fruit as small dark spots, or raised corky tissues, where oil has penetrated the lenticels of the fruit. Lenticels of fruit sprayed with oil in July or August are usually a little darker and more noticeable than those on unsprayed fruit. This cannot be seen on black ripe olives—it is most easily seen on olives pickled by the green-ripe process, although it does not affect the quality of the canned olives. Olives to be used for green or green-ripe processing should not be sprayed with oil after about August 20.

Biological control of olive scale. Two species of insect parasites of olive scale introduced here in recent years have become well established. The Persian *Aphytis, Aphytis maculicornis* (Masi), introduced in 1952, now occurs throughout the range of olive scale in California. A more recent introduction, *Coccophagoides utilis* Doutt, has not spread as rapidly but is now (1965) well established in all major olive-growing districts of California although not in all groves.

Orchard trials employing *Aphytis* to control olive scale met with varying success during the period 1953–1960. In certain olive orchards *Aphytis* held olive scale below economic levels year after year; in others it failed to exert satisfactory control.

Limited colonization of *Coccophagoides* in 1957 and 1958 resulted in its establishment in two olive orchards in Madera and Fresno Counties. With both parasite species working together, olive scale was brought under excellent control within two years in these two orchards. Additional orchards subsequently colonized with *Coccophagoides* and already having *Aphytis,* have also exhibited consistently excellent control. Increased colonization of *Coccophagoides* (4,500,000) since 1961 has resulted in a marked increase in the number of growers employing this method of olive scale control. Commercial olive acreage now under biological control in the San Joaquin Valley is approximately 1,500 acres (1965). Portions of large acreages in the Sacramento Valley are also under biological control, and the parasites have also undoubtedly reduced the rate of invasion into uninfested acreages.

As *Coccophagoides* continues to spread throughout the olive districts of the state the achievement of fully reliable biological control of olive scale (as good as is obtained by use of chemicals) should greatly reduce the necessity for using chemicals. It is reasonable to expect that a much greater proportion of the total acreage could be placed under this control program, with large savings to the industry. It is not as easy to establish *Coccophagoides* in the groves as it was to establish *Aphytis,* but with time, patience, and proper techniques this transition can be made with little risk of substantial economic losses.

Oleander scale. (*Aspidiotus hederae* [Vallot]). In sharp contrast to symptoms of the olive scale, that part of the olive beneath and near an oleander scale is delayed in maturing. This results in green spots on dark, ripe fruit (page 52).

What to look for. The whitish covering of the adult female oleander scale may be slightly larger than 1/16-inch in diameter. It is circular, with a yellow or light brown spot near the center. Male scales are somewhat elongate. The female scale body beneath the shell is yellow, but that of the male is a brownish yellow. These scales often appear in greatest numbers on the leaves of the lower inside part of the tree. Oleander scales have the ability to deform the fruit greatly. Extremely heavy infestations may reduce the oil content as much as 25 per cent.

What to do. Natural enemies of the oleander scale may keep this insect at a low level for many years. In some regions and in certain years chemical control becomes necessary.

Black scale (*Saissetia oleae* [Bern.]). Trees infested with black scale often have black sooty-appearing leaves which are very sticky (pickers do not like to harvest the black, sticky fruit). Black scale may greatly reduce vigor and productivity of the trees.

What to look for. Black-scale adult females are from 3/32- to about 3/16-inch long, and are dark brown or black with a very tough outer skin. Ridges on their backs form a characteristic "H" shape. Dead scales may remain attached to the twigs for 2 or 3 years. The young, found on the leaves, are yellow to orange in color. These scales secrete a sticky liquid ("honeydew") which supports the growth of a black fungus. The scale's feeding often so weakens the trees that many leaves drop and the next season's crop is reduced. Before reaching maturity, most of the scales move to the twigs to complete their growth.

Fig. 27. Black scale on olives showing various stages of development. Younger scales on the leaves with "rubber," and adult stages on the twig. (Photo by E. M. Stafford.)

What to do. Well-pruned trees are less apt to harbor black scale; sunlight, high temperatures, and prolonged hot weather may greatly reduce infestations. In the northern part of the interior valley of California black scale is often held in check by natural enemies. This is especially true where sprays for other olive insects and diseases are not necessary or are not regularly applied. In this area chemical control of low infestations of black scale may not be advisable—control chemicals kill both the black scale and its insect parasites and predators, and once started the grower may thereafter have to depend on chemical control. However, it is usually not necessary to spray olives more than two consecutive years for control of black scale anywhere in the interior valley.

Greedy scale (*Aspidiotus camelliae* Sign.). This insect may easily be mistaken for oleander or olive scale. The shell covering is more conical, however, and there is a small black spot to one side of the center; the body is yellow. Control measures as for olive scale are used.

Red scale (*Aoinidiella aurantii* [Mask.]). This important citrus pest is often found on olives in southern California. The female adult has a thin, circular shell about 1/16-inch in diameter. The body color is reddish and shows through the scale shell. Control measures as for olive scale are used.

Thrips. Western flower thrips *Frankliniella occidentalis* (Perg.), and *Chirothrips aculeatus* (Hal.) occasionally damage olives in California, and the damage is sometimes severe enough to require treatment. Parathion treatment for scale controls thrips if applied during bloom, but special permission from the local County Agricultural Commissioner is required, as this treatment destroys bees that might be working during bloom.

Grasshoppers. These insects cause severe damage to olive fruit, but the amount of fruit attacked does not usually warrant control.

Branch and twig borer (*Polycaon confertus* Lec.). This beetle bores a small, round hole at the base of a bud or in the fork of a small branch and as a result the twigs may break at these holes. The beetles normally breed in dead wood, chiefly madrone, oak, and old grape canes, and elimination of such wood is probably all that is necessary to prevent severe attacks.

Olive bark beetle (*Leperisinus californicus* Swaine). Growers may notice small dead twigs on olive trees near piles of olive prunings. Often this is due to the work of the olive bark beetle, which bores holes in small twigs in much the same manner as the branch and twig borer. The olive-bark beetle is about 1/8-inch long and black with a whitish pattern on the back. It breeds on unhealthy trees or olive prunings. In areas where this insect is a pest, cut olive wood should be burned.

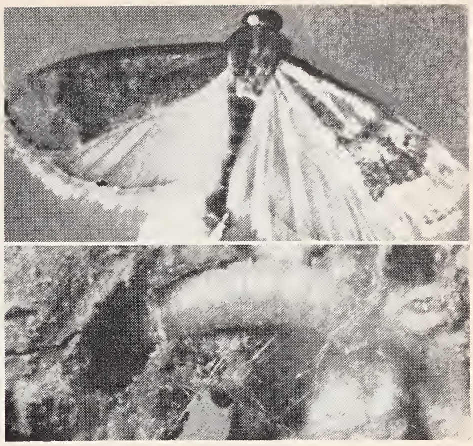


Fig. 28. American plum borer. Above: adult moth. Below: larval stage which causes the injury. (Photos by R. M. Hoffman.)

American plum borer (*Euzophera semifuneralis* [Wlkr.]). The moths are pale gray with reddish brown and black markings. Full-grown larvae are about 1 inch in length. Larvae of the moth attack soft, spongy tissue such as that of tree wounds, grafts, and olive-knot tissue; from such tissue larvae may continue feeding into healthy tissue and thus girdle fairly large limbs.

Nematodes. The root-lesion nematode, *Pratylenchus vulnus* Allen and Jensen, attacks the roots of olive trees in several areas of California. Infested trees may be characterized by poor growth and dieback of small branches; young trees planted in infested soil frequently fail to make satisfactory growth and are dwarfed or stunted. Larger roots of infested trees have symptoms of longitudinal cracking of the root cortex, and the area underneath these cracks is darkened and necrotic—the necrotic lesions are typical of the attack of the root-lesion nematode, and nematodes are normally present in

Fig. 29. Left: longitudinal cracking on olive roots typical of injury due to the root-lesion nematode, Pratylenchus vulnus. Right: uninjured roots.

root tissue immediately adjacent to the dead area. Nematodes also attack and frequently kill small feeder roots.

The citrus nematode, *Tylenchulus semipenetrans* Cobb, has attacked olive roots in a few localities in California where the trees were adjacent to, or planted on, land previously occupied by citrus. Information about the effect of citrus nematode infestations on olives is not available, but infested trees sometimes lack vigor, and their root systems are characterized by considerable disintegration of small feeder roots.

Root-knot nematodes, *Meloidogyne* spp., sometimes attack olive roots, causing the formation of galls or knots on the roots; heavily infested roots cannot carry on their normal functions. Infested trees may have reduced vigor and show symptoms of decline. There are no known methods of controlling nematode infestations on the roots of established olive trees. Pre-planting soil fumigation, and use of nematode-free planting stock, are the best known methods for avoiding nematode injury to young trees.

Non-parasitic defects

Shotberries. This trouble is most prevalent with Sevillano and Manzanillo. Shotberries are undersized, round-shaped fruits which occur more frequently in some years than in others. The fruits develop to varying sizes, and while some of the larger ones have been used in pickling they are generally too small to be of much value. There is no seed within the pits of such fruits. This is possibly a form of parthenocarpy, with enough stimulus present at the post-bloom stage to cause fruits to set. The seed fails to develop normally, however, and without it the fruit also fails to grow to its normal size. Many of the undersized fruit drop early, but some adhere until maturity. No method of bringing such fruits to normal size is known.

Soft-nose. Sevillano variety is particularly susceptible to this non-parasitic trouble, which does not appear until late in the season, during or at the end of the harvesting period. The fruit colors first at the apex end; this is followed by a shrivelling and softening. This trouble (which is more prevalent in years of heavy crops) varies in intensity from one orchard to another, and some growers think that it may be correlated with heavy nitrogen fertilization practices, especially when nitrogen is applied as manure. In 1950, a light crop year, tests were made using heavy applications of poultry manure (500 pounds per tree) and amounts of ammonium nitrate equivalent in nitrogen, on different groups of Sevillano trees. Soft-nose failed to appear either in the trees treated with manure or with ammonium nitrate. In 1951, a heavy crop year, soft-nose appeared in the entire orchard, but was especially noticeable in trees which had heavy applications of nitrogen in 1950 both as manure and ammonium nitrate.

Split-pit. This trouble occurs largely with Sevillano variety and is a serious problem in some years. The pits split gradually along the suture during fruit growth, resulting in a bluntly flattened type of fruit. Although the fruit is of normal size and seems to process satisfactorily, it makes a poor product because the pit comes apart when the fruit is eaten. The cause is not clear, but probably lies in environmental conditions occurring at a certain stage in fruit growth. Some growers believe it appears when the orchard soil is allowed to become dry before

Fig. 30. Olive knot galls on olive shoots caused by infection with the bacterial organism, Bacterium savastanoi, E.F.S.

pit hardening and the trees are then heavily irrigated.

Parasitic diseases

Three diseases of commercial importance affect olives in California. Two are fungus diseases, *Cycloconium oleaginum* Cast. (peacock spot), and *Verticillium alboatrum* R. and B. The third is a bacterial disease, *Bacterium savastanoi* E.F.S., known generally in California as "olive knot." These diseases are found in all the olive-producing areas of the state, but orchards can be found where one or more of the diseases does not occur.

Peacock spot. This disease has been observed in California for over 60 years. It is commonly found on Mission, and to a lesser extent on Sevillano, Barouni, Ascolano, Nevadillo, and Manzanillo, in the order named.

Outbreaks are associated with years of above-average rainfall. Infection is most prevalent on leaves in the lower parts of the tree and in the interior parts of the orchard, where exposure to sunlight and air movement is at a minimum. Peacock spot was of little commercial importance before 1940 in California, but since then the productiveness of some trees has been considerably reduced due to partial defoliation from the disease.

Infection and development of the disease in healthy leaves occurs during the rainy season (November through May), with symptoms appearing from 2 weeks to 3 months after infection. Moderate temperatures and abundant moisture in the form of rain or fogs are favorable to this organism, whose activity is low in hot, dry summer months; during this period it exists in diseased leaves on the tree.

What to look for. Typical leaf symptoms are found mostly on the leaf blade (page 52) but may also occur on the leaf petiole. Lesions develop on the upper surface of the leaf, first as inconspicuous, sooty blotches and then developing into dark green to black circular spots from ⅛- to ⅜-inch in diameter. A faint yellow area is sometimes found in the leaf tissues around the spot; as lesions expand the rest of the leaf becomes yellow and finally it drops from the tree.

What to do. Successful prevention of infection depends largely upon spraying. Orchards already seriously affected should be sprayed as soon as possible after fruit is harvested for pickling. Pruning to admit sunlight helps somewhat to reduce peacock spot.

Olive knot. This disease, first observed in California in 1893, is now widespread in olive orchards throughout the Sacramento and San Joaquin valleys. Mission is most resistant to this, followed by Ascolano, Sevillano, and Manzanillo, in the order named.

Olive knot bacteria are abundant in knots with live tissue; they move to the surface of the galls and then spread downward on the branches by rains. New infections occur largely during long midwinter rains, but galls do not appear until spring. Wounds of some sort are apparently necessary for infection—these may be freezing cracks, pruning wounds, scars from dropped leaves or flower clusters, and injuries from ladders or other equipment. Spread of the disease about the tree is due to dissemination of bacteria over the surface of branches, and not to internal translocation of bacteria through conducting tissues. Infection may be spread to adjacent trees by wind-borne rain; spread over longer distances is believed due to infected pruning tools or diseased nursery stock.

What to look for. The disease is marked by rough, roundish galls or swellings, sometimes 2 inches or more in diameter, on twigs, branches, trunks, roots, or even on leaf petioles and fruit stalks. Galls are likely to develop on fruiting shoots in the spring following winters in which low temperature caused defoliation and injury to twigs. The disease may kill much of the tree's fruit-bearing area.

What to do. No adequate control for this disease is known. Two approaches are possible, however: removal or killing of galls to reduce sources of infection, or preventive sprays to reduce new infections. For badly infected trees, removal of all knots would be impractical as it would mean removing all the branches. Where only a few galls have appeared in an orchard, their treatment is especially important to prevent further spread of the disease.

Since one of the chief methods of spreading olive knot is by pruning during the rainy winter months when active bacteria are present, all pruning in an infected orchard should be done during the dry summer months, when there is little likelihood of spreading the disease.

Verticillium. This fungus disease has appeared in olive groves in California since about 1942, although it has been observed since about 1900 in peach, apricot, and almond orchards, where it is commonly known as "blackheart." Verticillium wilt, which has become the most serious disease affecting olives in central California, is caused by a soil-borne fungus infecting trees through their roots. It is likely to be found in soil that is, or has been, planted to potatoes, tomatoes, cotton, or other truck crops. Trees of all ages are killed or rendered worthless by this disease. Due to the large increase in cotton acreage and consequent rise in soil inoculum it is not safe to set out new groves in much of Tulare County unless they are on resistant rootstocks (the same is true of replants in established orchards). The University of California is screening many hundreds of seedlings and has found some highly resistant to this fungus, and eventually recommendations will be made on rootstocks best suited for Verticillium-infested soils.

What to look for. The disease may attack the entire tree, or it may be confined sharply to one side or even to only one branch. Usual symptoms are the sudden collapse of one or a few branches, and this may be followed within a few weeks by collapse of other branches. Small trees often wilt and die all at once. Symptoms usually appear in May or June but sometimes do not occur until midsummer or later. The most striking evidence of Verticillium wilt in olives is the persistence of dead leaves and flowers, which usually remain on the tree throughout the summer. In olives the typical internal symp-

Fig. 31. Common fruit defects found in olives. Upper left: soft-nose. Upper right: split-pit. Lower left: shotberries. Lower right: spray injury due to summer oil applications.

toms are not present and there is no brown discoloration of the wood such as is characteristic of Verticillium in other plants.

What to do. Avoid planting young olive trees in soil that has recently been planted to such susceptible crops as tomatoes, potatoes, or cotton; avoid also interplanting such crops in young olive orchards. Since infection takes place underground in the root system, it is impossible to control the disease with fungicidal sprays. Branches killed by this disease should be pruned out after midsummer.

GLOSSARY OF TERMS

Alternate middle irrigation—watering every other middle between the tree rows, reversing the pattern at each subsequent irrigation.

Axil—the upper angle between a twig or petiole and the stem from which it grows.

Bud-eye—the growing bud occurring on the shield piece used in propagation by budding.

Calyx—outermost flower whorl.

Cambium—a layer of dividing cells between the phloem and xylem which causes growth in diameter.

Capitate—abruptly enlarged; forming a head.

Carpel—a floral leaf, bearing ovules, frequently along the margins of the leaf.

Chlorosis—loss of chlorophyll in leaves or parts of leaves.

Corolla—petals, collectively; the conspicuous flower whorl.

Cortex—primary tissue of stems or roots, bounded on the inside by the phloem and the outside by the epidermis.

Cotyledon—seed leaf—a part of the embryo.

Cuticle—a waxy layer on the outside of epidermal cells.

Detailed pruning—type of pruning in which many small cuts are made rather than the removal of a few large branches.

Drupe—a simple fleshy fruit, derived from a single carpel, in which the exocarp is thin, the mesocarp fleshy, and the endocarp stony.

Embryo sac—a structure inside the ovule in which the embryo originates.

Endocarp—inner layer of fruit wall (pericarp).

Endosperm—a nutritive tissue in the ovule, formed within the embryo sac of seed plants.

Exocarp—outermost layer of the fruit wall (pericarp).

Field capacity—all the water a soil will hold after it is drained.

Indolebutyric acid—an organic acid, having growth-promoting properties, which is quite active in stimulating development of adventitious roots on stem cuttings.

Inflorescence—flower cluster.

Inoculum—source of infection by organisms.

Lenticels—structures in the outer layer of the bark and fruit through which gases may pass.

Lesions—areas of dead tissues on stems or roots.

Locule—cavity of the ovary of the flower in which the ovules occur.

Mesocarp—middle layer of fruit wall (pericarp).

Milked-off—picking fruit in groups, using both hands, rather than removing them individually.

Necrotic—dead plant tissue.

Node—slightly enlarged portion of the stem where leaves and buds arise.

Ovary—enlarged basal portion of the pistil (in the center of the flower) which becomes the fruit.

Ovule—a rudimentary seed, developing in the ovary.

Own-rooted trees—those propagated by rooting cuttings; having no graft union.

Paniculate—referring to a panicle; an inflorescence, the main axis of which is branched, and whose branches bear loose flower clusters.

Parthenocarpy—the development of fruit without the union of sperm and egg cell in the embryo sac.

Perfect flower—a flower having both stamens and pistils. An hermaphroditic flower.

Perlite—a gray-white material of volcanic origin; it is crushed and screened to small particle sizes, then expanded by heating to high temperatures. It is widely used as a rooting medium for cuttings.

Permanent wilting percentage—the soil moisture content at which plants cannot obtain water readily.

Phloem—conducting tissue in stems and roots just outward from the cambium layer, through which organic nutrients move downward.

Pistil—central organ of a flower consisting of an ovary, style, and stigma.

Pistillate flower—a flower having a pistil but no stamens; a female flower.

Plumule—the first bud or shoot of an embryo.

Polarity—the exhibition of different characteristics at opposite ends of an axis.

Pollen tube—a structure arising from a germinated pollen grain which grows from the stigma through the style to the embryo sac in the ovule.

Puddle—harmful alteration of soil structure due to cultivation when wet.

Radicle—that portion of the plant embryo which develops into the seed root.

Salt shrivel—olive fruits shrivelling when stored in salt brine.

Scion—piece of stem used in grafting from which the upper portion of the new grafted plant will arise.

Stamen—the flower structure consisting of the anther (pollen-bearing organ) and the stalk or filament.

Staminate flower—a flower having stamens but no pistil. A male flower.

Stigma—receptive portion of the style to which the pollen adheres.

Stomata—small openings in the epidermis of leaves and stems through which gases may pass.

Style—slender column of tissue which arises from the top of the ovary through which the pollen tube grows downward to the ovary.

Suture—the junction, or line of junction, of contiguous parts.

Sweating—moisture developing on fruit surfaces when they are stored in boxes.

Vermiculite—a micaceous mineral which has been exposed to very high temperatures giving it a fluffy characteristic. When graded to small particle size it is useful as a rooting medium for cuttings.

Xylem—a conducting tissue in stems and roots just inside the cambium through which water and inorganic nutrients move upward.

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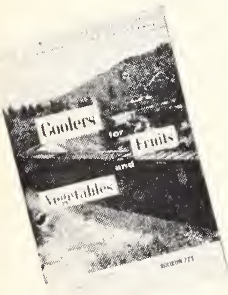

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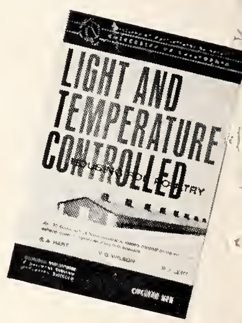

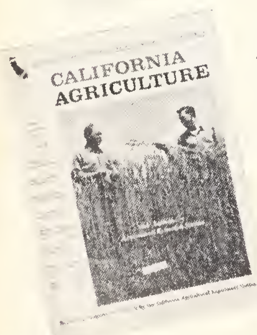

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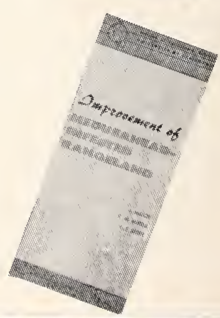

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