Pistachios:
An Economic Assessment of the Feasibility of Providing Multiple-Peril Crop Insurance

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Executive Summary

The pistachio tree, *Pistacia vera*, belongs to the same family as cashews, mangoes, poison ivy, poison oak, and sumac. The fruit produced by pistachio trees is a semi-dry drupe, similar to the fruit of an almond tree. Pistachio nuts are small (less than an inch long) and uniform in size with relatively thin shells. Most pistachios are roasted and marketed in their partially-open shells as a snack food.

The Census of Agriculture reported 1,051 farms growing pistachios in the United States in 1992, with 69,345 acres in orchards. California accounted for 96 percent of U.S. pistachio acreage in that year, and most of the industry's expansion has occurred in that state. The combined acreage of Arizona, New Mexico, Nevada, and Texas accounted for about 4 percent of all U.S. pistachio acreage reported in the 1992 Census of Agriculture.

The bulk of California's production is located in Kern and Madera counties in the San Joaquin Valley. Kern County accounted for 40 percent of the state's 1992 pistachio acreage, and Madera County, about 30 percent. Tulare, Fresno, Merced, and Kings counties (also in the San Joaquin Valley) each reported 2,000 to 5,000 acres. Butte and Glenn counties (in the Sacramento Valley) reported nearly 650 acres each.

Although there are more small farms than large farms producing pistachios, the bulk of production is from large, diversified operations. Nearly a dozen growers have more than a thousand acres and one company (Paramount Farms) has about 15,000 acres of pistachios in western Kern County. Homa Company and Keenan Farms, Inc. are also large operations. However, most pistachio orchards range from 40 to 80 acres in size.

In Kern, Tulare, and Fresno counties, farms with pistachios frequently also grow almonds and citrus fruit. Madera County growers often have a similar number of acres in pistachios and almonds. Other crops produced by pistachio growers throughout the San Joaquin Valley include cotton, wheat, onions, olives, garlic, and lettuce.

Pistachio production fluctuates widely from year to year, mainly due to the natural tendency of trees to be alternate bearing. However, pistachio nuts can be stored from one season to the next so carryover stocks, and to a lesser extent imports, act to stabilize supplies and prices.

U.S. consumption of pistachios, mainly as a snack food, has nearly doubled since the early 1980's. While U.S. imports have shrunk and California production has grown, important export markets have developed in the Far East, notably Japan and Hong Kong, as well as in Germany.

Pistachio trees are either male or female, and the trees that produce nuts, consequently, do not produce pollen. Cultivars used as pollinators are called male (or "nonbearing") and those used for nut production are referred to as female (or "bearing"). Pistachio trees produce nuts about six years after planting and reach full-bearing potential in twelve to fifteen years.

Mature pistachio trees have a pronounced tendency to alternately produce heavy crops (an "on" year) and light crops (an "off" year). This characteristic is referred to as an "alternate bearing" tendency. The aggregate effect of the alternate-bearing pattern is reflected in state-level yields. However, county-average yields reveal additional variations that probably are related to the age of the trees. In Kern County, where some of the first orchards were planted, average yields are 2-4 times higher in "on-years" than in "off-years." Annual yield changes in Madera and Glenn counties are less marked, but follow the same pattern as in Kern County.

The major production perils to pistachio production are excessive rain and humidity, late frosts and hard freezes, warm winters, drought, and various diseases and insect pests. Rain and humidity promote fungal diseases which have probably contributed more to yield reductions than any other peril. Late-spring frosts, unusually warm winters, and drought may also reduce yields.

Most of the pistachio crop is mechanically harvested in September. The highest-quality nuts are harvested within ten days after maturity. Pistachios are hulled, dried, and sorted soon after harvest, but may be roasted, salted, colored, and shelled later. There is no marketing order establishing minimum quality standards, but voluntary inspection and grading is widespread. The pistachio industry is well organized, with a state marketing agreement administered by the California Pistachio Commission.

Disaster assistance payments for pistachio losses totalled $387,748 during the 1988-93 period. Payments were relatively high following the California freeze, at $211,136 in 1991, and at $160,265 in 1992. Payments were less than $10,000 annually in other years. California accounted for nearly 96 percent of the disaster payments made between 1988 and 1993, while Arizona accounted for 4 percent, and Texas accounted for 0.2 percent.

Our assessment is that there would not likely be significant interest in crop insurance for pistachios, beyond the basic coverage contained in the catastrophic insurance plan. The most significant loss in the 15-year history of the commercial industry was due to a hard freeze in December 1990 that killed a large number of trees. Insurance on pistachio nut production would not have provided very much help to growers in that year because the crop had already been harvested. If a multi-year pistachio nut policy had been in effect, however, producers would likely have collected sizeable indemnities in the following year.

We believe that California pistachio growers are likely to be more interested in tree insurance than pistachio nut insurance. The loss of pistachio trees causes greater economic injury than the loss of the nut crop. A tree constitutes a long-term capital investment and its loss entails multiple years of foregone production, as well as the expense of establishing a replacement. The development period for a new tree is at least 5-6 years, with 7-8 years needed before an economically significant crop can be harvested. About 12 years are required before the tree attains its mature production potential.

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Introduction

Pistachios were brought to the Mediterranean Basin near the beginning of the Christian era (Crane and Maranto). They are believed to have originated in Central Asia. Although the pistachio was introduced into California in 1854, there was little interest in its commercial possibilities until after the development of mechanical harvesting and processing equipment. Substantial acreage was planted in California in the early 1970's and additional acreage was planted during the early 1980's. Commercial production of pistachios began in 1976 and grew to 152 million pounds by 1993 (USDA, NASS).

The pistachio tree, *Pistacia vera*, belongs to the same family as cashews, mangoes, poison ivy, poison oak, and sumac (Crane and Maranto). There are dozens of pistachio varieties in the world. Most countries produce two or three different varieties. California, however, produces mainly one variety, "Kerman," which was developed from seed brought from Persia (now Iran) by William Whitehouse in about 1930.

The fruit produced by pistachio trees is a semi-dry drupe, similar to the fruit of an almond tree. Pistachio nuts are small (less than an inch long) and uniform in size with relatively thin shells. Most pistachios are roasted and marketed in their partially-open shells as a snack food.

The Census of Agriculture reported 1,051 farms growing pistachios in the United States in 1992, with 69,345 acres in orchards (Table 1). The farm value of pistachio production was $118 million in 1994 (USDA, NASS).

This report examines those aspects of the pistachio industry that relate to the demand for crop insurance and the feasibility of developing a pistachio insurance policy.

The U.S. Pistachio Industry

Location

California accounted for 96 percent of U.S. pistachio acreage in 1992, and most of the industry's expansion has occurred in that state. California's pistachio area increased by 16,673 acres between 1987 and 1992, while area in all other states rose by only 712 acres. The combined acreage of Arizona, New Mexico, Nevada, and Texas accounted for about 4 percent of all U.S. pistachio acreage reported in the 1992 Census of Agriculture.

The bulk of California's production is located in Kern and Madera counties in the San Joaquin Valley (Appendix table 1). Kern County accounted for 40 percent of the state's 1992 pistachio acreage, and Madera County, about 30 percent. Tulare, Fresno, Merced, and Kings counties (also in the San Joaquin

Table 1--States reporting pistachio production, 1992 and 1987

States	1992			1987		
	Farms	Acres	Trees	Farms	Acres	Trees
Arizona	69	1,863	231,698	56	1,485	174,505
California	920	66,847	8,838,978	733	50,174	6,038,819
Nevada	10	167	21,950	7	71	5,924
New Mexico	46	449	47,711	24	193	18,385
T exas	6	19	2,417	10	37	5,257
United States	1,051	69,345	9,142,754	830	51,960	6,242,890

Source: U.S. Department of Commerce, Census of Agriculture.

Valley) each reported 2,000 to 5,000 acres. Butte and Glenn counties (in the Sacramento Valley) reported nearly 650 acres each.

Farm Characteristics[1]

The largest number of farms with pistachios are relatively small operations. Sixty-one percent reported less than $25,000 in sales of all crops in 1987. Only 6 percent reported $500,000 or more in sales, although nearly 20 percent reported sales of $100,000 or more (Table 2).

Most farms with pistachios are privately owned. Sixty-two percent were owned by individuals or families in 1987 and 30 percent were partnerships (Appendix table 2). Fewer than 7 percent were owned by corporations (including family-held) or had any other forms of legal ownership.

Although there are more small farms than large farms producing pistachios, the bulk of production is from large, diversified operations. Nearly a dozen growers have more than a thousand acres and one company (Paramount Farms) has about 15,000 acres of pistachios in western Kern County. Homa Company and Keenan Farms, Inc. are also large operations. However, most pistachio orchards range from 40 to 80 acres in size (Nichols). Smaller orchards are more numerous in Madera County, although there are two large operations with 3,000-4,000 acres of pistachios, S&J Ranch and Agri-World (Holtz).

Absentee ownership is fairly common. Orchard owners frequently have full-time, non-farm careers, and hire orchard management companies to run their operations (Kallsen).

According to the Census, the majority of pistachio producers were part-time farmers. Just 36 percent considered farming their main occupation in 1987 (Appendix table 3). Seventy-two percent of the operators reported working off the farm at least 1 day during the year. More than half (52 percent) worked off the farm 200 days or more.

In addition to off-farm employment, growers supplement their pistachio income with substantial sales of other agricultural commodities, especially other fruits and tree nuts. Pistachios accounted for only about 20 percent of agricultural sales on California farms in 1987, while fruits and tree nuts accounted for more than three-fourths of sales (Table 3). Since pistachio bearing acreage has risen considerably since 1987 (USDA, NASS), the value of pistachio production has likely increased as a share of farm sales.

In Kern, Tulare, and Fresno counties, farms with pistachios frequently also grow almonds and citrus fruit (Kallsen). Madera County growers often have a similar number of acres in pistachios and almonds. Other crops produced by

[1] The statistical description provided in this section is based on a special tabulation of pistachio-producing farms from the 1987 Census of Agriculture. No comparable tabulation from the 1992 Census was completed at the time this report was prepared.

Table 2--Size distribution of farms producing pistachios, 1987

State	All farms	Total value of crop sales: $500,000 or more	$100,000 to $499,999	$50,000 to $99,999	$25,000 to $49,999	Less than $25,000
	Number	Percent of farms				
California	733	7	14	10	12	57
Other	97	3	5	1	3	88
U.S.	830	6	13	9	11	61

Source: U.S. Department of Commerce, Census of Agriculture.

Table 3--Market value of sales from farms producing pistachios, 1987

State	All products	All crops	Fruit & nuts	Pistachios	Pistachios, % of all products
	Million dollars				Percent
California	240	234	184	47	20
Other	69	15	1	NA	NA
U.S.	309	249	185	47 1/	15 1/

NA = Not available.
1/ California only.

Note: The category "other" is computed as the U.S. total minus listed states.

Source: U.S. Department of Commerce, Census of Agriculture, and USDA, NASS.

pistachio growers throughout the San Joaquin Valley include cotton, wheat, onions, olives, garlic, and lettuce.

The Pistachio Market

Pistachio production fluctuates widely from year to year, mainly due to the natural tendency of trees to be alternate bearing. However, pistachio nuts can be stored from one season to the next so carryover stocks, and to a lesser extent imports, act to stabilize supplies and prices. U.S. consumption of pistachios, mainly as a snack food, has nearly doubled since the early 1980's. While U.S. imports have shrunk and California production has grown, important export markets have developed in the Far East, notably Japan and Hong Kong, as well as in Germany.

Supply

U.S. pistachio production was negligible until about fifteen years ago, but since 1980, output has grown at an average annual rate of 25 percent.[2] The long-term trend in California pistachio output is illustrated by the steady rise in the four-year moving-average of production between 1980 and 1994. "Off-year" output (see more on the alternate-bearing tendency below) rose from 14.5 million pounds (in-shell weight) in 1981 to 128 million pounds in 1994, while "on-year" output jumped from 26.9 million pounds in 1980 to 152 million pounds in 1993.

Production is quite variable[3] because pistachio trees have a marked tendency to alternate between very large and very small crops in consecutive years (Table 4). Declines in state-average production of 50 percent or more are not uncommon after a large crop. However, the 1993 and 1994 pistachio crops broke the alternating bearing pattern apparent since 1980. Total output increased for two consecutive years because of the rising yields of many young trees. Yields rise rapidly after trees begin to produce nuts, which occurs about five to six years after planting.

Because pistachio output varies considerably from year to year, carryover stocks play a major role in balancing supplies with consumption. During the 1990-1993 seasons, beginning stocks averaged about 20 percent of total supplies. During some "off-year" seasons, however, such as in 1981 and 1991, beginning stocks accounted for as much as 40 percent of supplies (Table 5). But, in 1992, following an "off-year" season, beginning stocks were less than 10 percent of supplies.

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[2] USDA only reports California production. Since California accounts for the bulk of U.S. output, the USDA estimate for California is treated as a U.S. estimate in this report.

[3] The standard deviation of California pistachio production between 1980 and 1994 was about 45 million pounds and amounted to 64 percent of the average output (coefficient of variation = 0.64).

Table 4--California pistachio acreage, production, prices, and values, 1980-94

Year	Bearing acreage	Yield per acre 1/	Production	Grower price	Value
	Acres	Pounds	1,000 pounds	$/pound	$1,000
1980	27,000	996	26,900	2.050	55,145
1981	28,100	516	14,500	1.360	19,759
1982	29,900	1,470	44,000	1.490	5,560
1983	31,100	849	26,400	1.410	37,224
1984	30,800	2,050	63,100	0.976	61,586
1985	32,300	839	27,100	1.370	37,127
1986	34,200	2,190	74,900	1.120	83,888
1987	41,000	807	33,100	1.370	45,347
1988	47,200	1,990	94,000	1.220	114,680
1989	50,900	766	39,000	1.630	63,570
1990	50,500	2,380	120,000	1.020	122,400
1991	52,300	1,470	77,000	1.250	96,250
1992	52,400	2,810	147,000	1.030	151,410
1993	53,700	2,830	152,000	1.070	162,640
1994	57,500	2,230	128,000	0.922	118,016

P: Preliminary.

1/ Dry weight, in-shell basis.

Source: USDA, National Agricultural Statistics Service.

Table 5--Pistachios: Supply and utilization (shelled basis), 1970/71 to 1993/94

Season 1/	Domestic consumption: Marketable production 2/	Imports	Beginning stocks 3/	Total supply	Ending stocks 3/	Exports	Domestic consumption: Total	Domestic consumption: Per capita
			1,000 pounds					Pounds
1970/71	NA	7,489	NA	7,489	NA	NA	7,489	0.036
1971/72	NA	10,003	NA	10,003	NA	NA	10,003	0.048
1972/73	NA	7,025	NA	7,025	NA	NA	7,025	0.033
1973/74	NA	13,433	NA	13,433	NA	NA	13,433	0.063
1974/75	NA	10,072	NA	10,072	NA	NA	10,072	0.047
1975/76	NA	7,574	NA	7,574	NA	NA	7,574	0.035
1976/77	NA	7,771	NA	7,771	NA	NA	7,771	0.035
1977/78	1,520	9,528	0	11,048	2,080	320	8,648	0.039
1978/79	840	6,863	2,080	9,783	1,080	160	8,543	0.038
1979/80	5,240	9,219	1,080	15,539	5,000	1,400	9,139	0.040
1980/81	11,672	1,175	5,000	17,847	5,135	1,840	10,872	0.047
1981/82	5,888	1,817	5,135	12,840	2,061	1,480	9,298	0.040
1982/83	16,986	2,819	2,061	21,866	6,581	3,247	12,037	0.052
1983/84	11,115	6,683	6,581	24,378	4,977	1,815	17,587	0.075
1984/85	27,507	7,284	4,977	39,768	11,256	2,758	25,753	0.108
1985/86	11,518	14,875	11,256	37,649	7,362	1,658	28,628	0.119

1986/87	31,005	5,357	7,362	43,724	15,005	2,183	26,536	0.110
1987/88	14,579	2,166	15,005	31,750	5,487	3,469	22,794	0.093
1988/89	44,752	854	5,487	51,093	14,897	6,442	29,754	0.121
1989/90	18,029	2,124	14,897	35,051	10,045	5,164	19,842	0.080
1990/91	42,047	852	10,045	52,944	16,864	9,575	26,505	0.105
1991/92	25,477	250	16,864	42,590	6,072	16,407	20,111	0.079
1992/93	65,362	395	6,072	71,830	17,595	28,089	26,146	0.102
1993/94	61,911	493	17,595	79,999	25,672	21,944	32,383	0.125

NA = Not available.

1/ Season beginning September 1.

2/ Marketable production is NASS utilized production times NASS shellout ratio minus inedibles and noncommercial usage from the California Pistachio Commission.

3/ Beginning and ending stock estimates are from the California Pistachio Commission.

Source: USDA, Economic Research Service.

The role of imports in balancing supply and demand is, however, declining as U.S. production rises. During the 1990's, pistachio imports averaged less than 1 percent of total U.S. supplies, compared to 14 percent in the 1980's. In 1985, pistachio imports were at an all time high, and accounted for 40 percent of U.S. supplies.

Although Iran is the world's leading pistachio producer, Turkey provided more than three-fourths of U.S. pistachio imports in 1993 and 1994. Turkey's important role in the U.S. import market is because of the U.S. imposition of countervailing and anti-dumping duties on Iranian pistachios in 1985, and an import embargo in 1987.

The California Pistachio Commission estimated Iranian pistachio output at 132 million pounds in 1994, and 220 million pounds in 1993. During those years, the U.S. ranked second in pistachio production and Turkey ranked third, producing 110 million pounds in 1994 and 55 million pounds in 1993.

Demand

Pistachios are mostly roasted and sold in a partially-open shell as a snack food. Most pistachio shells open naturally as the nut matures, but those that remain closed can be split artificially. The red color of some packaged pistachios is not natural. Mature pistachios have ivory-colored shells and greenish kernels, with a thin, rosy-red skin.

Consumers became accustomed to red pistachios from the Middle East when most of the U.S. supply was imported, and some consumers still prefer the red color. About 75 percent of California-grown pistachios are sold in the shell. Most are roasted, and very few are dyed (California Pistachio Commission).

U.S. consumers used an average of 0.103 pounds of pistachios per person per year during the 1990's, nearly twice as much as during the early 1980's. Consumption rises and falls with changes in the size of the current crop and carryover stocks. During the 1993 marketing season, for example, consumption rose to a record-high 0.125 pounds per person due to a large 1993 crop and substantial carryover from the 1992 marketing season. In contrast, per capita consumption was only 0.079 pounds for the 1991 marketing season following the small 1991 crop.

Although U.S. pistachios are mainly consumed domestically, exports have risen markedly since 1990. Exports averaged 31 percent of U.S. supplies in the 1990's, compared with less than 10 percent in the 1980's. The Far East, including Hong Kong, Japan, and China, and western Europe (mainly Germany) are the top export markets. In 1994, Hong Kong accounted for more than one-third of U.S. exports, while China and Japan each accounted for 10 percent, and the European Union purchased somewhat less than 10 percent (USDA, ERS).

Prices

The prices that growers receive for pistachios fluctuate from year to year, depending on supplies. In most years, prices move in the opposite direction from yields and production. Thus, prices typically rise during low-yield years, and decline during high-yield years, although the relationship is not as strong as for certain other crops.

Higher prices can help support grower revenues when output falls. However, pistachios can be stored from season to season, and carryover stocks, as well as foreign trade, help moderate annual price fluctuations. Because of relatively mild year-to-year swings in prices,[4] pistachio revenues usually decrease when output decreases, and rise when production rises.

Nut quality is also a determinant of pistachio prices. Prices are discounted for excess moisture and defects of the shell or kernel. An excessive number of blank nuts, or nuts with non-split shells, will also lower grower prices. Growers are likely to receive only 30 cents a pound for closed-shell pistachios, compared to $1.50 for nuts with naturally-opened shells (Brown).

Growers who have processing and storage facilities can store pistachios from one season to another and are more able to sell pistachios when prices are higher. Smaller growers, however, tend to sell their pistachios shortly after harvest and accept prices that reflect the current supply-demand balance.

Buyers base their early price offers on carryover stocks and the projected crop size. If the quantity actually harvested differs substantially from what was initially expected, prices may not accurately reflect the actual supply-demand balance. Prices for the 1993 crop, for example, did not decline despite very high production because most of the crop had been harvested and sold before its size became apparent.

Cultivation and Management Practices[5]

Pistachios trees are deciduous, dropping their leaves in November. The trees require a dormant period between bearing cycles. Pollination occurs during April and harvest is in September.

Pistachio trees are either male or female, and the trees that produce nuts, consequently, do not produce pollen. Cultivars used as pollinators are called male (or "nonbearing") and those used for nut production are referred to as

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[4] The standard deviation of 1980-94 pistachio prices was 22 percent of the mean value (coefficient of variation = 0.22). During the same period, the coefficient of variation for production was 0.64.

[5] Technical information in this section is from *Pistachio Production*, by Julian Crane and Joseph Maranto, unless otherwise noted.

female (or "bearing"). Pistachio trees produce nuts about six years after planting and reach full-bearing potential in twelve to fifteen years.

The fruit of pistachio trees are nuts that grow in clusters along the distal portions of branches produced the previous season. The nuts are composed of an outer skin (epicarp), a hull (mesocarp), and a shell (endocarp) that encloses a kernel (embryo). As the nut matures, the outer skin changes from translucent to opaque in color, and the hull softens and loosens from the shell. The shell then opens and the hull dries and shrivels, but remains closed, protecting the nut and the partially-opened shell from the weather, insects, and diseases.

Physiological Characteristics

Pistachio trees have several noteworthy physiological characteristics that affect annual crop yields and the quality of the crop. These characteristics include an alternate-bearing tendency, the production of blank nuts, the production of "non-splits," and early splitting.

Alternate Bearing

Mature pistachio trees have a pronounced tendency to alternately produce heavy crops (an "on" year) and light crops (an "off" year). This characteristic is referred to as an "alternate bearing" tendency, and is common for many tree fruits, including apples, olives, oranges, pears, pecans, and plums.

In pistachios, alternate bearing occurs when the tree sheds an unusually large number of flower buds. Flower buds develop on the pistachio tree during the spring prior to the year of blossoming and fruiting. Each year some flower buds are shed during the spring. However, in an "on-year," flower-bud drop continues into the summer and is probably triggered by the formation of nut kernels. During the summer of a heavy-crop season, the tree sheds flower buds in such numbers that few remain to produce a crop the following season.

The aggregate effect of the alternate-bearing pattern is reflected in state-level yields. However, county-average yields reveal additional variations that probably are related to the age of the trees. In Kern County, where some of the first orchards were planted, average yields are 2-4 times higher in "on-years" than in "off-years" (Table 6). Annual yield changes in Madera and Glenn counties are less marked, but follow the same pattern as in Kern County. An alternating pattern is harder to distinguish in Tulare, Kings, and Fresno counties, where a larger share of the orchards were planted in the 1980's.

The effects of the alternate bearing pattern on individual tree yields are quite dramatic. In research plots, "off-year" yields averaged from 8 to 34 percent of "on-year" yields. It is not unusual for an orchard's yield to range from 4,500 pounds an acre in an "on-year" to 400 pounds the following season (Ferguson).

Table 6--California pistachio yields, selected counties, 1986-94

County	1986	1987	1988	1989	1990	1991	1992	1993	1994
	Pounds per bearing acre								
Butte	956	968	1,123	526	1,165	918	1,973	1,611	1,809
Colusa	0	0	0	150	975	1,337	2,427	3,409	1,932
Contra Costa	581	575	501	293	83	287	303	736	482
Fresno	1,690	2,437	2,515	1,464	2,459	2,322	2,520	2,542	1,269
Glenn	640	803	1,454	862	1,271	932	2,080	1,332	1,656
Kern	3,096	1,096	3,308	1,092	4,282	2,261	4,386	3,833	3,153
Kings	3,710	1,182	2,272	442	950	956	815	1,322	2,208
Madera	1,639	842	1,596	598	1,867	1,034	2,662	2,194	2,101
Merced	1,807	968	769	373	1,403	588	1,803	1,507	1,379
Placer	808	593	642	306	1,665	645	2,106	700	1,156
Sacramento	0	853	995	313	2,928	394	1,630	2,389	2,982
San Bernadino	101	36	91	11	4	3	26	85	52
San Joaquin	1,029	1,524	1,306	555	1,275	710	2,016	1,819	2,012
San Luis Obispo	0	284	113	148	196	516	331	280	425
Santa Barbara	--	--	--	0	0	231	0	1,120	792
Stanislaus	958	477	1,779	536	1,264	363	985	591	1,540
Sutter	234	1,064	610	670	0	2,142	2,859	514	1,365

Tehama	82	132	343	131	166	52	193	276	301
Tulare	1,308	1,214	1,043	1,301	1,354	1,173	1,604	3,047	1,509
Yolo	380	1,475	884	1,137	1,646	1,632	2,341	1,749	1,207

--: Not reported.

Source: California Pistachio Commission.

Alternate bearing tends to become more pronounced and coordinated as the trees mature. Most of the pistachio trees in a 12-year-old plot are likely to have the same bearing cycle (Nichols). In addition, management practices that raise yields in one year, such as fertilization, or exceptionally-good weather, can lower yields the next year.

Pruning can also change the cycle. Trees pruned after an "off-year" crop will produce a second small crop the following summer. Management practices can reinforce or alter the alternate-bearing pattern, but growers have not yet been able to eliminate it.

Blank Nuts

All pistachio trees produce blank nuts, or shells that have no kernels inside. The percentage of blanks is correlated with the alternate-bearing pattern, rising during off-yield years and falling during years of higher yields. Research indicates that the actual crop load on the tree has less of an influence on the percentage of blanks than the alternate bearing pattern. In one sample, individual trees averaged 3-12 percent blanks during "on-years," and 8-17 percent blanks during "off-years" (Ferguson).

In addition to the alternating pattern, blank nut production appears to be related to boron deficiencies and insufficient irrigation. A late-dormant spray application of boron was found to reduce the percentage of blanks.

Shell Splitting

Pistachio shells open naturally (split) as the kernel matures. Shell splitting before harvest is a desirable characteristic because it facilitates consumers' removal of nuts from the shells. Although the exact mechanism causing shell-splitting is unknown, research has shown that it progresses simultaneously with the maturing of the kernel (Ferguson). Shell splitting usually begins at the end of July, at least a month before nut maturity, and continues through mid-September. The hull normally remains closed while the shell is opening.

As with blank nut production, the percentage of "non-splits" (nuts with closed shells) is correlated with alternate bearing. More non-splits occur during an "on-year" than during an "off-year." Samples from individual trees show non-splits as low as 3 percent during an "off-year," and as high as nearly 30 percent in an "on-year" (Ferguson).

Harvest timing, irrigation, and micronutrient levels all can affect shell splitting (Ferguson). Growers who delay harvest until the maximum number of nuts are mature will have a higher shell-split percentage than those who harvest earlier. Insufficient irrigation from mid-August through early September will increase the percentage of non-splits. A late-dormant spray application of boron has been found to increase the percentage of splits.

Early Hull Splitting

Early splits are abnormal nuts that have both the hull and shell split at the same time, along the shell suture, prior to harvest (Doster). This early opening of the hull (between late July and early September) allows the shell and kernel to be damaged. The earlier the hull splits, the more likely the kernel is to be infested with navel orangeworm or contaminated with mold.

Since the hull is removed before the pistachios are dried and sorted, processors depend on the shell to show signs of early hull opening. Some signs that may signal moldy kernels include: extensive dark-brown shell discoloration, stains only along the shell suture, and oily, crinkled, or small shells.

Early splits normally make up 1-4 percent of nut production, with the percentage varying among trees in an orchard. Insufficient water during shell formation (mid-April to mid-May) and excess water during kernel formation (after mid-June) increase the incidence of early-splits.

Propagation and Planting

Pistachio trees are propagated by grafting a bud of the selected cultivar to a chosen rootstock. The choice of cultivar and rootstock can influence the tree's resistance to diseases, cold hardiness, nut yield, the incidence of non-splits, the extent of blank nut production, and the alternate-bearing tendency. There are two dominant pistachio cultivars and two rootstocks that comprise most commercial pistachio orchards in California.

Rootstock

The most common rootstocks used in California pistachio orchards are *Pistacia atlantica* and *Pistacia integerrima* (also known as Pioneer Gold I). During the first decade of commercial planting, *P. atlantica* and *Pistacia terebinthus* were used exclusively. Both, however, were found to be susceptible to verticillium wilt and many trees in the southern San Joaquin Valley were lost. Pioneer Gold I was subsequently adopted because it is less susceptible to verticillium wilt, although it is less cold tolerant than *P. atlantica*. A newer hybrid, Pioneer Gold II, combines verticillium resistance and cold hardiness. According to a 1994 survey, Pioneer Gold I rootstock accounts for 48 percent of all pistachio acreage in California; *P. atlantica* accounts for 42 percent; Pioneer Gold II, 3 percent; and *P. terebinthus*, less than 1 percent (California Agricultural Statistics Service).

Establishing an Orchard

Rootstock seedlings are grown in containers for about a year until they are large enough to be transplanted to an orchard. Transplanting is usually done in mid-June. A cultivar is budded to the rootstock in the orchard the following April or May, although some rootstock seedlings are ready for budding in the fall. Fall budding is usually done in August.

Seedlings are usually spaced 11 to 12 feet apart within a row, with 22 to 24 feet between rows. The trees are planted close within the row initially to boost production during the early years of the planting, and then are thinned out when crowding occurs. However, crowding is usually not a problem for at least ten years because the trees grow slowly.

Mature pistachio trees are usually 20-25 feet tall and 25-30 feet wide. They begin producing nuts 4-5 years after budding (5-6 years after planting), but an economically significant crop is not usually harvested for 7-8 years.

Varieties

A given pistachio tree produces either male or female flowers, but not both. Cultivars tend to be identified as female or male because all of the trees of that cultivar have been propagated with buds from trees of the same sex. Kerman and Joley are the preferred female (nut-bearing) cultivars, while Peters and Gazvin are the main male (pollinator) cultivars.

Kerman

USDA began evaluating various pistachio cultivars from the Mediterranean in 1904 at the Plant Introduction Station in Chico, California, as a potential new crop. However, a suitable variety for California growing conditions was not found until 1957 when "Kerman" was introduced for trial purposes. Kerman was selected from a group of seedlings grown from seeds imported from Iran.

In 1994, Kerman comprised 92.5 percent of California pistachio acreage (CASS). Kerman produces exceptionally large nuts with excellent kernel quality. However, the trees have a pronounced alternate-bearing tendency and, despite relatively high yields, produce a high percentage of blank nuts and nuts with non-split shells.

Joley

Joley is a new pistachio cultivar grown in California and New Mexico. It comprised less than 0.1 percent of California acreage in 1994 (CASS). Joley was developed at the USDA Station in Chico, originating as an open-pollinated seedling from seed imported from Iran. It was named in 1980 after a former station director. Joley trees blossom and bear nuts earlier in the season than Kerman. Experience with limited plantings of Joley indicates it produces more nuts with split shells and fewer blanks than Kerman.

Peters

The Peters cultivar was developed in Fresno and named in the early 1900's. It remains the dominant pollinator, accounting for 6 percent of California's 1994 pistachio acreage. It is considered a universal pollinator because it sheds pollen while many female cultivars are receptive.

Gazvin

Recently introduced from Israel, the Gazvin variety may be able to provide more pollen to Kerman than Peters because Gazvin has an earlier peak-bloom date. Although Peters has been an effective pollinator of Kerman, its average peak-bloom date occurs before Kerman bloom begins. The peak-bloom date of Gazvin coincides more closely with the early bloom of Kerman.

Production Requirements

Soil

Although pistachios can adapt to many kinds of soils, they grow best on deep, light, sandy loams that have a high lime content. Well-drained soils are required in order for the tree to flourish and bear well, since the root system will not tolerate prolonged wet conditions. Pistachio trees are more tolerant of alkaline and saline soil conditions than are many other trees.

Temperature

Pistachios thrive in areas with hot, dry, summer weather and moderately cold winters. Optimum temperatures for pistachio production in the United States can be found in California's central valleys at elevations of 500 to 600 feet. Pistachios should not be planted above an elevation of 3,000 feet because cool summer temperatures do not promote good kernel development. Pistachio trees grow well in some areas of southern California, including the desert areas, but produce very few nuts if the winter is too warm. From 700 to 1,000 hours of winter temperatures at or below 45^{o} F are needed in order for pistachio trees to fruit normally.

Pruning

Young pistachio trees require training during the first 4-5 years to develop a recommended structure. Training begins the second year after the rootstock is planted in the orchard. A strong trunk that extends 36 to 40 inches from the ground to the first scaffold branch is developed to facilitate mechanical harvesting. Each year new growth should be headed back to 30 inches while the framework of the tree is being established.

Trees are pruned as the orchard matures to keep the centers open so that all branches receive sunlight. Trees tend to naturally spread as they grow and branches will eventually be pulled down by the weight of the foliage and nuts. Drooping branches tend to sunburn and to shade the branches below. Older wood must occasionally be removed to prevent spreading and to stimulate renewal growth from the scaffold branches. Topping and hedging machines are often used on 3-5 year old wood. Pruning is done during the winter.

Pollination

Pistachios trees are dioecious, which means that they do not produce male (staminate) and female (pistillate) flowers on the same tree. Wind carries the pollen from the male to female flowers. Female flowers do not produce nectar nor do they have colorful petals to attract bees. Consequently, bees are not effective pollen carriers.

For maximum fruiting, abundant pollen should be available during the first 2 to 3 days of the female bloom period. The Kerman variety has a bloom period of about 11 days, from the first to the third week of April. Since the Peters and Gazvin varieties bloom from the end of March through mid-April, both can provide adequate pollen to Kerman trees. Male pistachio trees are prolific pollen producers so that one male tree provides enough pollen for 10 to 12 female trees.

Fertilization

The most likely plant nutrients to be deficient in pistachio orchards are nitrogen, boron, zinc, and copper. Although precise nutritional needs are still being researched, the ranges of recommended mineral weights for healthy leaves have been established. Foliar analysis is recommended to determine plant nutrient needs before applying fertilizer because excess levels of some minerals can be as harmful as shortages.

The normal range of nitrogen in pistachio leaves appears to be 2.5 to 2.9 percent dry weight in August (Beede, 1994). Levels below 2.3 percent are likely to be associated with symptoms of nitrogen deficiency, including: delayed bud break; short, thin shoots, with reddish bark; small, pale-green leaves with reddish veins and petioles; leaves that turn reddish to yellow with time; and early leaf drop.

Nitrogen is typically applied to the soil of pistachio orchards four times from March through July. A recommended application rate is one pound of nitrogen per tree per year, which is approximately the amount removed by a moderate-sized (1,500 pound per acre) nut crop. Insufficient nitrogen replacement lowers potential yields.

Boron deficiency is associated with "crinkle leaf," which is characterized by deformed leaves that are twisted, cupped, crinkled, and irregular in shape. In addition, irregular, blister-like areas develop on the bark and shoot tips die back. Boron deficiencies are likely if the leaf tissue level is below 90 parts-per-million (ppm) in August and below 50 ppm in the spring. Soil applications will correct deficiencies, but repeated applications can result in leaf necrosis caused by boron toxicity.

Research has indicated a link between boron nutrition and fruit set. Applying boron in foliar sprays in April and May (just prior to bud swell and through 20 percent bud break) during the "on year" was found to raise yields by increasing pollen germination, as well as by reducing blanking and non-splits (Ferguson). Foliar boron sprays are more effective at raising yields than are

soil applications. However, excess boron can also be a problem with foliar applications, causing reduced fruit set.

A zinc deficiency can cause "little leaf," which is characterized first by delayed growth of floral and vegetative buds in the spring, and then by dwarfed leaves on shoots that have very short internodes. Zinc deficiency has been associated with leaf tissue values below 7 ppm, based on foliar analysis in August (Beede, 1994). Fall (mid-October) and late-dormant soil applications of zinc chelate or zinc sulfate will correct deficiencies, as will foliar applications in early-to-mid April.

Shoot die-back in late July and August is a sign of copper deficiency. Normal pistachio leaves contain 6 to 10 ppm of copper. Values at less than 4 ppm probably signal a deficiency (Beede, 1994). Copper compounds are often added to insecticide sprays that are applied after bloom in April.

Pesticides and Fungicides

Pistachios usually receive two sulfur applications for control of mites in July and August. Permethrin insecticides are commonly used after fruit set in mid- to late-April to combat navel orangeworms and other pests.

Fungicides may be applied at any time between April and October, whenever climatic conditions make infection by air-borne fungi a problem. Fewer applications are made in August or September because many pesticides are prohibited within specific pre-harvest intervals.

Spray applications of chemicals currently registered for use on pistachios--benomyl at full bloom, followed by three copper hydroxide sprays--provide partial control of fungal disease. The most effective fungicides (iprodione and chlorothalonil) are not yet available for growers to use on pistachios.

Irrigation

Although pistachio trees are relatively drought tolerant, successful commercial production requires adequate soil moisture, particularly during the summer. Insufficient soil moisture reduces tree growth and yields, causes the nuts to be lighter and smaller, and increases the number of blanks and non-splits.

Mature pistachio trees with canopies covering about 60 percent of the orchard floor use approximately 40 inches of water during an average summer in the southern San Joaquin Valley. Trees use 7-10 inches of water per month during June, July, and August. Somewhat less irrigation is required in the Sacramento Valley, where winter rainfall is higher (typically 16-20 inches). Virtually all California pistachio orchards are irrigated. Originally, most were irrigated with furrow (flood) or drag-line sprinkler systems. However, a higher incidence of fungal infection associated with those systems prompted growers to change to low-volume (drip, fan-jet, and microsprinkler) systems (Kallsen). Flood and sprinkler irrigation systems were found to promote

fungal infection by raising the relative humidity in the orchards. In addition, the splashing water from high volume sprinklers spreads fungus spores. Nearly all irrigation systems in Kern County orchards are low-volume, but flood irrigation is still used in some areas of Madera County.

Production Perils

The major production perils to pistachio production are excessive rain and humidity, late frosts and hard freezes, warm winters, drought, and various diseases and insect pests. Rain and humidity promote fungal diseases which have probably contributed more to yield reductions than any other peril. Late-spring frosts, unusually warm winters, and drought may also reduce yields.

Rain and Humidity

High relative humidity associated with excessive rain provides ideal growing conditions for several types of air-borne fungi that cause pistachio diseases. Rain drops initiate spore release and help spread fungal diseases by carrying spores to uninfected leaves and nuts. Yield losses have been reported as high as 40-70 percent due to fungal-disease damage.

The incidence of two common fungal diseases, botryosphaeria and botrytis, are increased by wet conditions. Spores of botryosphaeria are released from tree bark when struck by rain drops in the spring. Prolonged rainfall in the spring also favors botrytis shoot blight. (See further discussion below.)

Frosts and Freezes

Pistachio trees can generally tolerate relatively low winter temperatures, with some having survived a winter temperature of 6° F without injury. However, the "100-year freeze" in December 1990, which caused widespread damage to most fruit and nut trees in southern California, provided one of the few weather-related set-backs to pistachio production. Trees were killed in Kern and Madera counties, prompting the only significant disaster payments made to pistachio growers between 1988 and 1993.

Pistachio trees begin to blossom in late March and may be damaged by a late-spring frost. However, pistachio blossoms in California's central valleys have never been subjected to a late-spring frost (Ferguson). In Madera County, early-fall freezes can damage late-harvested pistachio (Holtz).

Cold damage can be minimized by choosing an orchard site with good air flow and planting trees with cold-hardy rootstock. *Pistacia atlantica* is the most cold tolerant rootstock, followed by Pioneer Gold II and Pioneer Gold I.

Warm Winter Temperatures

Warm winter temperatures can reduce pistachio yields (Ferguson). Pistachios require from 700 to 1,000 hours of winter temperatures at or below 45° F in order to fruit normally the following summer. Nut production may be reduced in a season following a winter that provides inadequate chilling.

Hail

In Arizona, the hail that often accompanies late-season thunderstorms has caused extensive damage to pistachio crops just before or during harvest (Nichols).

Drought

Pistachios are fairly drought resistant, but drought stress during critical stages of the growing season can decrease yields by reducing nut size, by interfering with shell splitting, and by diminishing vegetative growth. Lack of water during shell formation (mid-April through mid-May) is associated with a higher number of early-split nuts. The percentage of nuts with non-split shells rises with insufficient water late in the season (mid-August to mid-September). Although most pistachio orchards are irrigated, drought may be a production threat if insufficient water is applied.

Diseases[6]

Botryosphaeria Blight

Botryosphaeria blight is caused by *Botryosphaeria dothidea*, an air-borne fungus that damages pistachio buds, flowers, young shoots, leaves, and fruit clusters. When infected, the entire cluster usually dies. The fungus overwinters on tree bark. The spores are released when struck by rain or irrigation water. High temperatures (80° F - 86° F) and wet conditions favor this disease. Until 1989, Botryosphaeria blight was largely confined to the Sacramento Valley, where rain in April fostered outbreaks resulting in yield reductions of up to 40 percent (Michailides). However, in 1994, growers in the San Joaquin Valley reported losses as high as 70 percent. Orchards with sprinkler irrigation are more susceptible than those with low-volume systems.

No fully-effective fungicide has been registered for use on pistachios to combat Botryosphaeria blight. Using registered pesticides--an application of benomyl at full bloom, followed by three copper hydroxide sprays--provides partial control. Combining fungicide applications with the pruning of infected shoots and the removal of infected clusters can keep the disease level low.

The incidence of Botryosphaeria blight can be greatly reduced by using low-angle sprinklers and by removing overwintering fruit stems and leaf petioles.

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[6] Unless other sources are identified, information about diseases is based on *Pistachio Production*, by Crane and Maranto.

Botrytis Shoot Blight

Botrytis cinerea is an air-borne fungus that initially infects flower clusters and then spreads to new shoots. Botrytis shoot blight girdles and kills new growth. This disease is favored by prolonged rainfall in the spring and relatively low temperatures, which occur more often in the northern Sacramento Valley than in the San Joaquin Valley, where most pistachio orchards are located.

The same fungicides used to control Botryosphaeria blight are recommended to control Botrytis shoot blight. Removal of infected foliage will destroy the source of the spores, and lower the incidence of infection.

Alternaria Late Blight

The fungus *Alternaria alternata* can cause severe defoliation of pistachio trees and result in fruit deterioration during harvest (Michailides). Yield losses are due to moldy kernels, nut shell staining, and early defoliation. Alternaria late blight usually develops from late July to October, when dense tree canopies, heavy morning dew, and high temperatures can combine to create the high-humidity climate favorable for fungal growth.

Alternaria infection generally occurs earlier and does more damage in orchards with flood or sprinkler irrigation than in orchards with low-volume systems. However, in recent years, periods of high relative humidity near harvest-time and delayed harvesting have made late blight more of a problem, even in orchards with low-volume irrigation.

Although difficult to control because the most effective fungicides (iprodione and chlorothalonil) have not been registered for use on pistachios, infection can be reduced significantly by omitting one irrigation in late-July or early-August. Growers have used several spray applications of approved fungicides (benomyl and copper hydroxide) with mixed results.

Verticillium Wilt

Verticillium wilt is caused by a soil-borne fungus, *Verticillium dahliae*, and is the most serious disease of pistachio trees in California, particularly in the southern San Joaquin Valley (Ferguson). The fungus can live in the soil for many years. It invades the plant through the roots and moves up through the water-conducting tissues. When the tree is affected, the leaves wilt, and turn yellow and then brown. Eventually, the tree dies. Pre-plant soil fumigation with methyl bromide and chloropicrin is recommended. The use of resistant rootstock is the best way to control this disease.

The two most common rootstocks used in early California pistachio orchards, *Pistacia atlantica* and *Pistacia terebinthus*, were found to be susceptible to verticillium wilt. During the late 1970's and early 1980's, many pistachio orchards in the southern San Joaquin Valley were planted where cotton had been grown and the soil was infected with verticillium. Thousands of pistachio

trees planted in Kern County died and were replaced with trees on new rootstock. *Pistacia integerrima* (Pioneer Gold I) rootstock is tolerant of the disease and has been used successfully in infected areas.

Crown and Root Rot

Crown and root rot is due to infection by several species of Phytophthora, a soil-borne fungus. Pistachio trees in poorly-drained areas are the most likely to be infected. However, the fungus is widespread. Symptoms of Phytophthora rot are similar to verticillium wilt. Less vigorous trees are the most likely to succumb to Phytophthora infection and die quickly. The incidence of crown and root rot is expected to increase as pistachio trees increase in age and decline in vigor.

Trunk and Branch Canker

Three species of Phytophthora, *P. parasitica, P. cryptogea*, and *P. capsici*, have been associated with trunk and branch cankers (MacDonald). Symptoms of the disease include the development of dark, sunken areas of bark from which resin exudes. These cankers can enlarge over time, girdling and eventually killing entire branches or trees.

Fungicides are not an effective treatment. The best control is to minimize tree injury during the growing season because spores enter through wounds such as those from pruning cuts or limb breakage. Using irrigation systems that do not splash water onto branches or trunks will also reduce infection, since surface waters may be contaminated with pathogenic species of Phytophthora.

Aflatoxin

Aflatoxin, a very toxic mold that infects many types of nuts and seeds, is produced by *Aspergillus falvus* and *A. parasiticus* fungi (Doster). Early splitting of pistachio hulls can allow entry of these fungi and the development of aflatoxin on the kernel. Early splits normally make up 1-4 percent of nut production, with the percentage increasing with either too much or too little water at different stages of development. If good quality standards are being enforced by the processor, nuts with stained shells or other signs of mold will not be packed, thus reducing the risk of marketing contaminated nuts.

Nut-importing countries, particularly the European Union and Japan, are demanding that more restrictive aflatoxin standards be met by exporting countries. Although California pistachios have been free of aflatoxin, the Western Pistachio Association created a committee several years ago to make recommendations about upgrading U.S. sampling and testing methods (Brown).

Insects[7]

[7] Technical information in this section is from *Insect and Mite Pests of Pistachios in California*, by R.E. Rice, W.J. Bentley, and R.H. Beede, unless

Navel orangeworms were the first reported pest of pistachios and remain a source of serious kernel damage. Several types of sucking bugs cause epicarp lesions (shell discoloration) and kernel necrosis. Unlike navel orangeworms that do the greatest damage in August, most insects that cause epicarp lesions are a threat all season. Mite and scale damage to pistachios has increased with the use of insecticides to combat other pests. Insecticides, predaceous insects, and good orchard sanitation practices help control insect populations.

Navel Orangeworms

Mature pistachio nut meats are primary hosts of the navel orangeworm (*Amyelois transitella*), along with almonds and walnuts. Adults lay their eggs within split hulls or shells, on the nut surface, or on nearby twigs and stems. Four generations of navel orangeworms can be produced in a pistachio orchard between late March and October, but most egg-laying takes place when nut shells are beginning to split, in late July or early August.

Damage by navel orangeworm larvae to pistachio nuts varies from pin-hole entry points to total destruction of the kernel. Late-harvested nuts usually have the most damage, with potentially 10 percent or more of the nuts infested, while nuts harvested earlier will have a lower infestation rate.

In addition to early harvest, good orchard sanitation helps control navel orangeworm populations. Navel orangeworms overwinter in the larval stage or as pupae in mummy nuts on the tree or the ground. The host fruit (pistachio, almond, or walnut kernels) is the only known food source for the larvae. Thus, thorough harvesting of new-crop nuts and the removal and destruction of mummy nuts prevent the survival and development of larvae.

Several insecticides are registered for the control of navel orangeworms on pistachios. The best time for applying chemicals is in August. However, there are restrictions on chemical application within certain pre-harvest intervals. Orchard sanitation is the most satisfactory way to prevent navel orangeworm infestation.

Leaffooted Bugs, Stinkbugs, and Similar Pests

Epicarp lesions can lead to substantial yield loss, and may be caused by leaffooted bugs (*Leptoglossus clypealis*), stinkbugs (especially *Thyanta pallidovirens*, or the red-shouldered plant bug), and small insects of the Miridae family (*Phytocoris relativus, Lygus hesperus* and *Calocoris norvegicus*). Epicarp lesions cause brown-to-almost-black spots on the hull and shell. The spots may be the diameter of a pea, or may cover most of the nut's exterior surface. Since most pistachios are sold in the shell, darkened shells are usually rejected by processors, lowering grower yields and causing economic losses.

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otherwise noted.

Nuts attacked early in the season (before shell hardening in late May or early June) shrivel and drop from the tree. Infestations later in the season result in poorly developed, discolored kernels and shells. Leaffooted bugs and stinkbugs lay eggs on pistachios from April through September, but mirids do little damage after shell hardening.

Most of these bugs are general feeders, and pistachios are not the main host. Leaffooted bugs overwinter in evergreen hosts and in orchards where protection is provided by leaf litter and debris. Stinkbugs and mirids migrate from native legumes and grasses in uncultivated areas and from commercial crops (such as cereal grains, alfalfa, cotton, and safflower) to pistachio orchards.

Frequently, the damage to pistachios is reduced by controlling insect populations in adjacent areas. Permethrin insecticides applied to pistachio orchards after fruit set in mid-to-late April can prevent extensive damage. Some egg parasites and predator insects have been identified, although biological control is not yet widespread.

Mites

Citrus flat mites (*Brevipalpus lewisi*) feed on the leaves, petioles, stems, and fruit of pistachio trees and form dark, scablike blotches on surface tissues. Continued feeding causes nut clusters, petioles, and hulls to wither and dry. Pacific mites (*Tetranychus pacificus*) colonize on both the upper and lower leaf surfaces of pistachio trees. Damage first appears as small, brown spots along the mid-rib of the leaf, and then expands until much of the leaf is brown and dead. Mites can cause severe defoliation.

Infestations of citrus flat mites can be controlled by applying sulfur-based compounds. Several predaceous mites have been isolated that could provide effective biological control. However, the heavy use of insecticides to control other pests of pistachios may preclude the development of biological control. Increased populations of citrus flat mites and pacific mites typically follow heavy insecticide use.

Scale

Two species of scale have been the most troublesome in pistachio orchards: European fruit lecanium (*Parthenolecanium corni*) and frosted scale (*Parthenolecanium pruinosum*). Scale insects are very small, with body diameters usually less than 5 millimeters. Adults vary from light to dark brown and may be covered with a light-white wax, while immature scale is dark and shiny. Black scale (*Saissetia oleae*) may attack pistachios, but its primary hosts are citrus and olives.

The damage to pistachios from scale arises from the large amounts of honeydew produced during the early spring. The honeydew contaminates the foliage and fruit, and provides a substrate for growth of sooty mold. Heavy populations of scale reduce tree vigor. Sooty mold interferes with photosynthesis and may

raise the proportion of non-splits (Beede). Nut clusters covered with honeydew and sooty mold are difficult to harvest and process.

Frosted scale and fruit lecanium scale have been kept under control by several species of wasp parasites and other general predators, including ladybugs. However, the widespread use of pesticides to control insects that produce epicarp lesions has disrupted the biological control of scale. Application of dormant oil can help prevent the survival of scale (Beede).

Birds

Birds can remove entire nuts and puncture hulls, creating an entry point for fungi and insects. Damage can result in substantial losses, particularly in smaller, isolated orchards, where bird depredation affects a larger share of the crop. Crows, scrub jays, and ravens are the primary bird pests of pistachios. Of lesser importance are magpies, black birds, and starlings. No effective control measures exist except temporary deterrents, such as noisemakers.

Marketing Pistachios

Most of the pistachio crop is mechanically harvested in September. The highest-quality nuts are harvested within ten days after maturity. Pistachios are hulled, dried, and sorted soon after harvest, but may be roasted, salted, colored, and shelled later. There is no marketing order establishing minimum quality standards, but voluntary inspection and grading is widespread. The pistachio industry is well organized, with a state marketing agreement administered by the California Pistachio Commission.

Harvesting

California pistachios are harvested from late August through mid-December, but the bulk of the crop is harvested during September. Nut maturity is signaled by the skin changing from translucent to opaque, and taking on a rosy hue. In addition, a softening and loosening of the skin and hull from the shell occurs, which is sometimes described as "slipping." After loosening, the hull dries and shrinks over a period of several weeks. During that period, the hulls normally remain closed and the nuts do not fall from the tree.

Although pistachios can be harvested for up to a month after they mature, the highest-quality nuts are obtained by harvesting within 7 to 10 days of maturity. Crude fat accumulation, kernel dry weight, and the color of the kernel and shell are optimum when the hull first separates from the shell (Crane and Maranto). The inability to schedule custom harvesting at the optimal time is one common reason why growers delay picking.

Pistachios are harvested mechanically by prune-harvesting equipment, which is composed of two separate, self-propelled units. The shaker, which has a catching frame, and another catching frame (with a conveyor belt and blower),

are positioned on opposite sides of the tree. When the tree is shaken, the nuts fall into the canvas aprons of the catching frames and roll onto the conveyor belt. The nuts move past a blower, to remove leaves, on the way to large bins in which they are transported to processing plants. Two experienced workers can harvest about one acre of pistachio trees per hour (Crane and Maranto).

Packing, Storing, and Shipping

To determine nut quality, processors draw samples as loads are delivered from the field. Samples are used to determine the prices paid to growers. Loads from different growers are mixed together before processing. Processing consists of at least hulling and drying, and may entail roasting, salting, and coloring before nuts are packaged.

Pistachio hulls are removed mechanically. Abrasive vegetable peelers and walnut hullers modified with rubber discs have been used. However, the most common device used to hull pistachios consists of two rubberized belts that move in the same direction, with one belt moving faster than the other. The nuts are fed between the belts and the hulls are rubbed off. The nuts then move to a flotation tank for washing and blank removal. After washing, the pistachios are dried for 8 to 10 hours, at 150^{o} F to 160^{o} F, until the moisture content is reduced to about 5 percent (Crane and Maranto).

Pistachios should be hulled and dried within 24 hours of harvest in order to maintain high kernel quality and to prevent shell discoloration. The degree of shell staining increases with longer delays between harvesting and hulling. Excessively high drying temperatures, hull damage, and later harvest dates also increases shell staining. Nuts that cannot be hulled within two days of harvest are cooled and stored at 32^{o} F to deter deterioration of nut quality. Although harvest is completed within 3 months, pistachios are stored and marketed for more than a year. The marketing season extends from September 1 through the end of October the following year (USDA, NASS). Most pistachio stocks are held by processors. Only growers with the very largest operations do their own storing, packing, and shipping.

There are about two dozen pistachio processors, including Paramount Farms (the largest), Dole Dried Fruit and Nut Company, Homa Company, and Keenan Farms, Incorporated. There are two or three grower cooperatives that have processing facilities, including the Pistachio Producers of California and Cal-Pure Pistachio Cooperative (Brown). Most of the processors have growing operations, or subsidiary growing operations (Ferguson).

Grades and Standards

At the time this report was prepared, there were no federal or state marketing orders establishing minimum quality standards for pistachios. However, some industry members are interested in establishing compulsory grade standards. The Western Pistachio Association was instrumental in formulating voluntary

grade standards for pistachios that were issued by USDA in 1986 (Crane and Maranto).

Processors usually hire inspectors from USDA or the Dried Fruit Association of California (DFA) to grade the nuts (Brown). DFA is a trade organization that has been grading pistachios since 1980, and reportedly grades about half of the processed output.

Standards for the grades of in-shell pistachios list the maximum allowable percentages of non-split nuts, nuts not split on the sutures, shells with light and dark stains, nuts with adhering hull material, shell pieces, blanks, nuts with damaged kernels, and loose kernels. The highest grade is U.S. Fancy, followed by U.S. Number 1, U.S. Number 2, and U.S. Number 3. Standards also establish size ranges for in-shell pistachios: Extra Large (20 or fewer nuts per ounce), Large (21 to 25 per ounce), Medium (26 to 30 per ounce), and Small (31 or more nuts per ounce).

Quality standards are high for pistachios. In order to be graded U.S. Fancy, no more than 2 percent of the sample can have dark stains on the shell. The lot will not meet the lowest grade standard, Number 3, if more than 6 percent of the nut shells have dark stains. Non-splits must be no more than 4 percent of the sample to meet the standard for the lowest grade. By signing the voluntary marketing agreement, processors agree not to sell substandard pistachios or ungraded nuts.

Industry Organizations

The pistachio industry does not operate with a marketing order that regulates shipments or that establishes compulsory grade standards, but rather, has a state marketing agreement. California legislation authorized the industry to form an organization to collect grower assessments and to use the funds for market promotion and research activities.

The legislation resulted in the California Pistachio Commission, which was established in 1981 by producer referendum (Crane and Maranto). The Commission is composed of eight members and eight alternates, elected from among more than 500 pistachio growers throughout the state. The 1994/95 assessment rate was set at 1.5 cents per pound of pistachios sold (CPC).

Membership in the Western Pistachio Association is not limited to growers, and has grown to about 300 members since the organization was established in 1973. Prior to 1981, it was named the California Pistachio Association (Brown). The Association collects membership dues in order to conduct activities that the Commission is not authorized to undertake, such as the encouragement of the passage of federal regulations requiring imports to be labeled as to country of origin, and the imposition of duties on imports from Iran (Crane and Maranto).

Costs of Production

Production costs for pistachios in the southern San Joaquin Valley are estimated at about $2,100 an acre, regardless of the yield (Table 7). Harvest costs rise slightly with higher yield, but only slightly, ranging from $148 to $157 an acre for yields between 1,000 and 3,000 pounds. The added expenses for higher yields are due to added hauling costs. Harvesting accounts for about 25 percent of all cultural expenses, and about 7 percent of total costs. Appendix table 4 contains a detailed budget of production costs.

Table 7--Costs of producing pistachios, southern San Joaquin Valley, 1991

Item	Yield (Pounds per Acre)				
	1,000	1,500	2,000	1,500	3,000
	----------Dollars per acre----------				
Cultural cost	580	580	580	580	580
Harvest cost 1/	148	151	153	155	157
Total operating costs	728	731	733	735	737
Harvest percent of operating costs	20.3%	20.7%	20.9%	21.1%	21.3%
Cash overhead costs	221	221	221	221	221
Noncash overhead costs 2/	1,141	1,141	1,141	1,141	1,141
Total costs	2,090	2,093	2,095	2,097	2,099
Harvest percent of total costs	7.1%	7.2%	7.3%	7.4%	7.5%

1/ Based on a rate of $1.25 per tree and 115 trees planted per acre.

2/ Includes depreciation of trees representing recapture of establishment costs.

Source: Cooperative Extension Service, University of California, Davis.

Ad Hoc Disaster Assistance for Pistachios

Ad hoc disaster assistance legislation was made available for losses of commercially-grown crops in each of the years 1988-93. Ad hoc payments provide an indication of high-loss areas during that period, and may indicate states and counties that would be relatively high risk under a pistachio insurance program. Disaster data provide one indicator of the demand for a pistachio crop insurance policy.

Payments have been made under the categories of participating program crops, nonparticipating program crops, sugar, tobacco, peanuts, soybeans, sunflowers, nonprogram crops, ornamentals, and at times, aquaculture. Producers without crop insurance--the case for pistachios--were eligible for payments when losses exceeded 40 percent of expected production. If a producer had no individual yield data to use in calculating "expected production," county-level or other data were used as a proxy. Payment rates for pistachios were based on 65 percent of a 5-year average price, dropping the high and low years.

Disaster assistance payments for pistachio losses totalled $387,748 during the 1988-93 period (Table 8). Payments were relatively high following the California freeze, at $211,136 in 1991, and at $160,265 in 1992. Payments were less than $10,000 annually in other years.

California accounted for nearly 96 percent of the disaster payments made between 1988 and 1993, while Arizona accounted for 4 percent, and Texas accounted for 0.2 percent.

Ad hoc disaster payments for pistachios were concentrated in Kern and Madera counties in California, where most of the crop is produced. Disaster payments for California pistachios averaged to less than 0.1 percent of the value of crop production over the 1988-93 period (Table 9).

Insurance Implementation Issues

Adverse Selection

The alternate-bearing pattern of pistachio trees, and their susceptibility to soil-borne and air-borne fungi, create the potential for adverse selection in insuring pistachios. Pistachio yields in successive seasons tend to seesaw substantially above and below average (see section on "Alternate Bearing"). Because growers can anticipate low-yield seasons ("off-years" in the alternate bearing cycle), they could purchase insurance only during seasons following large crops. By insuring only during anticipated "off-years," indemnities would likely exceed, and insurance premiums fall short, of actuarially sound levels.

One method for dealing with the alternate bearing issue would be to require commitment on the part of the grower to buy insurance for several consecutive years. Such a multi-year commitment would generally avoid situations where

Table 8--Disaster assistance payments for pistachios, 1988-93

Year	Arizona	California	Texas	Total
		Dollars		
1988	0	8,785	0	8,785
1989	0	0	293	293
1990	5,723	0	0	5,723
1991	9,896	201,029	211	211,136
1992	0	159,861	404	160,265
1993	0	1,546	0	1,546
Total	15,619	371,221	908	387,748

Source: U.S. Department of Agriculture (CFSA) data files, compiled by the General Accounting Office.

Table 9--Pistachios: Cumulative crop value and disaster assistance in California, 1988-93

	Amount
Crop value 1/	$ 715,990,000
Disaster payments 2/	$371,000
Disaster payments, share of crop value	0.1%

1/ Crop values from USDA, NASS.

Source: CFSA data files, compiled by the General Accounting Office, and NASS.

growers purchased insurance only in years in which they expected below-average yields.

Diseases may also create the potential for adverse selection. Pistachio trees are highly susceptible to verticillium wilt, a soil-borne fungi which lowers the tree's vitality and yields, and may eventually kill the tree. Because growers know their orchard's disease history, they could insure high-risk sites where expected losses exceed premiums.

Some older rootstock varieties have much less resistance to verticillium wilt infection than the newer Pioneer Gold variety. In addition, some areas may present a higher risk of infection than others. Verticillium wilt has been a particular problem in the southern San Joaquin Valley, especially on land that had been planted to cotton.

The type of irrigation system creates a third adverse selection potential. Orchards with sprinkler or flood irrigation systems have a higher incidence of fungal infection than those with a low-angle or drip system because sprinkler water that comes into contact with the tree initiates production of blight spores. It may be desirable to limit coverage to resistant rootstock and fields with low-volume irrigation systems to avoid insuring orchards prone to fungal diseases.

Quality Loss

Various situations can lower quality and affect grower returns. Insufficient water, for example, can reduce the quality of the crop by increasing the proportion of non-splits and blank nuts. Delayed harvesting and/or hulling also can reduce quality by increasing the incidence of shell staining. Fungal diseases and insect-damaged kernels can also stain the shells. The phase of the alternate bearing cycle can also affect quality, as the proportion of nuts with non-split shells rises in heavy-crop years.

One way to take account of quality loss is to offer a value of production (or dollar) plan. In such a plan, growers insure based on a value-of-production guarantee. Since the value of production is determined by yields and prices, quality is factored into the value through its influence on price. Low-quality pistachios result in a lower price than higher-quality pistachios.

Setting Reference Prices

FCIC provides reference prices (price elections) for insured crops, which become the basis for calculating indemnity payments. Insured growers select a price election when they purchase insurance as the basis for valuing indemnity payments.

Despite the tendency for pistachios to alternate between above and below average output in successive seasons, prices have been relatively consistent. An average price for recent seasons, consequently, provides a fairly good

forecast of the following season's prices. The season average grower price reported by NASS provides an adequate estimate of farm-gate value.

Estimating "Appraised Production"

Appraised production for pistachios could be estimated by harvesting a sample of trees and inspecting the yield from the sample to determine the quantity and quality of the remaining production. This procedure would be comparable to the procedure used for tree fruits, such as peaches.

Market Prices and Moral Hazard

Moral hazard due to low market prices is not likely to be an issue in insuring pistachios. Pistachios are storable from season to season, and market prices, consequently, are relatively steady within and between seasons. Prices are not likely to be so low that intentionally causing a yield loss and collecting an indemnity is more profitable than harvesting and marketing a crop.

Growers are likely to harvest all pistachios regardless of low market prices since harvesting expenses are a relatively small share of total production costs. Moral hazard due to low prices, therefore, is not likely to be an issue in offering crop insurance for pistachios.

Availability of Individual Yield Data

Yield histories for plots within an orchard may vary because of differing ages of the trees (young trees require up to 12-15 years to reach their yield potential) and differences in micro-climate. In addition, some operations that produce pistachios have thousands of acres of orchards, located in different geographic areas.

Individual yield data will probably have to be supplied by the growers themselves. County-level production and yield data, as well as state-average prices, are published in the annual reports of the California Pistachio Commission. In addition, the Commission keeps records of planted and bearing acreage, while processors report individual grower's deliveries in the course of collecting assessments for the Commission. These data may supplement individual grower yield records.

The California Agricultural Statistics Service has conducted an annual Pistachio Acreage Survey since 1982 (except in 1993) under the sponsorship of the California Pistachio Commission. The survey is based on a random sample of 600 to 1,000 pistachio trees from all pistachio-growing regions in California. County-level data concerning the acreage, variety, and age of pistachio trees is published in the "California Pistachio Objective Measurement Survey Results."

Demand for Insurance

Our assessment is that there would not likely be significant interest in crop insurance for pistachios, beyond the basic coverage contained in the catastrophic insurance plan. The most significant loss in the 15-year history of the commercial industry was due to a hard freeze in December 1990 that killed a large number of trees. Insurance on pistachio nut production would not have provided very much help to growers in that year because the crop had already been harvested. If a multi-year pistachio nut policy had been in effect, however, producers would likely have collected sizeable indemnities in the following year.

Growers are able to deal with most of the production perils encountered in California. Pistachios are moderately drought resistant and most orchards are irrigated, so that drought is not a serious production peril. However, fungal disease problems have recently become widespread in pistachio-growing areas, and can be difficult to control with approved fungicides. Production practices can help prevent mold damage in some cases.

Insuring Trees vs. Insuring Nuts

The loss of pistachio trees causes greater economic injury than the loss of the nut crop. A tree constitutes a long-term capital investment and its loss entails multiple years of foregone production, as well as the expense of establishing a replacement. The development period for a new tree is at least 5-6 years, with 7-8 years needed before an economically significant crop can be harvested. About 12 years are required before the tree attains its mature production potential.

We believe that California pistachio growers are likely to be more interested in tree insurance than pistachio nut insurance. The only substantial losses that the California industry has experienced arose from freeze-damaged and verticillium-infected trees that had to be removed and replanted.

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Appendix Table 1--States reporting pistachio production: Agricultural Census, 1987 and 1992

State and major counties	1992						1987		
				Total	Harvested				Total
	Farms	Acres	Trees	Trees 1/	Farms	Pounds	Farms	Acres	Trees
Arizona	69	1,863	231,698	198,729	52	1,032,336	56	1,485	174,505
Cochise	32	1,089	125,592	102,160	24	522,110	23	719	84,514
Pinal	5	194	25,398	(N)	3	(N)	8	(N)	42,177
Other	32	580	80,708	96,569	25	510,226	25	766	47,814
California	920	66,847	8,838,978	7,656,771	715	143,301,741	733	50,174	6,038,819
Kern	92	26,727	4,199,538	3,642,834	63	75,578,564	58	16,869	2,276,239
Madera	276	20,672	2,365,346	2,235,572	265	36,549,444	252	16,238	1,854,494
Tulare	86	4,747	538,413	363,026	73	5,179,276	65	3,428	351,787
Fresno	74	4,273	486,261	375,529	45	6,400,361	45	1,884	223,508
Merced	61	3,611	423,099	411,465	56	10,360,924	43	4,639	520,386
Kings	14	2,143	235,579	179,820	11	3,092,997	14	3,754	439,765
Butte	27	648	77,896	73,234	21	1,161,635	23	532	65,963
Glenn	16	637	93,515	92,353	14	1,428,095	13	591	82,938
San Bernadino	82	577	64,853	40,706	51	437,458	56	327	37,131
San Luis Obispo	14	504	69,587	41,156	10	303,607	13	162	16,091
Santa Barbara	6	394	51,694	46,442	4	(N)	8	435	36,267
San Joaquin	12	106	13,182	(N)	8	122,105	10	145	18,274
Other	160	1,808	220,015	154,634	94	2,687,275	133	1,170	115,976
Nevada	10	167	21,950	5,000	2	(N)	7	71	5,924
New Mexico	46	449	47,711	17,093	17	64,072	24	193	18,385
Texas	6	19	2,417	(N)	1	(N)	10	37	5,257
United States	1,051	69,345	9,142,754	(N)	787	144,399,899	830	51,960	6,242,890

1/ Trees of bearing age.

(N): Indicates "not available" or "not published" to avoid disclosure of individual operations.

Note: Counties sorted by 1992 total acres.

Source: U.S. Department of Commerce, Census of Agriculture.

Appendix table 2--Organizational type of farms growing pistachios, by sales class, 1987

Organizational type	All farms	Total value of crop sales: $500,000 or more	$100,000 to $499,999	$50,000 to $99,999	$25,000 to $49,999	Less than $25,000
	---Number of farms---					
Individual or family						
California	446	9	40	31	53	313
Other	66	0	1	1	2	62
U.S.	512	9	41	32	55	375
Partnership						
California	230	24	54	35	35	82
Other	21	0	3	0	1	17
U.S.	251	24	57	35	36	99
Corporation						
Family held						
California	40	11	7	5	0	17
Other	4	1	0	0	0	3

U.S.	44	12	7	5	0
20					
Other than family held					
California	9	5	1	0	0
3					
Other	2	0	1	0	0
1					
U.S.	11	5	2	0	0
4					
Other					
California	8	0	1	0	1
6					
Other	4	2	0	0	0
2					
U.S.	12	2	1	0	1
8					

Source: U.S. Department of Commerce, Census of Agriculture.

Appendix table 3--Principal occupation and number of days worked off-farm by operators of farms growing pistachios, 1987

Item	All farms	Total value of crop sales			
		$500,000 or more	$100,000 to $499,999	$50,000 to $99,999	$25,000 to $49,999
Less than $25,000					
	Number of farms				
Farming is main occupation:					
California	258	40	56	24	26
112					
Other	38	3	5	1	2
27					
U.S.	296	43	61	25	28
139					
	Percent of all farms				
California	35.2	5.5	7.6	3.3	3.5
15.3					

Other	39.2	3.1	5.2	1.0	2.1	27.8
U.S.	35.6	5.2	7.3	3.0	3.4	16.7
	----------Number of farms----------					
Operator days off-farm:						
None						
California	169	27	34	11	15	82
Other	31	3	4	1	2	21
U.S.	200	30	38	12	17	103
Any						
California	532	20	64	53	72	323
Other	65	0	1	0	1	63
U.S.	597	20	65	53	73	386
1 to 99 days						
California	74	5	15	1	13	40
Other	6	0	1	0	0	5
U.S.	80	5	16	1	13	45
100 to 199 days						
California	73	6	10	6	7	44
Other	12	0	0	0	0	12
U.S.	85	6	10	6	7	56
200 days or more						
California	385	9	39	46	52	239
Other	47	0	0	0	1	46
U.S.	432	9	39	46	53	285
Not reported						
California	32	2	5	7	2	16
Other States	1	0	0	0	0	1
U.S.	33	2	5	7	2	17

Source: U.S. Department of Commerce, Census of Agriculture.

Appendix Table 4

Sample Costs for Producing Pistachios

Southern San Joaquin Valley