Crop Profile for Artichokes in California

General Production Information

- California produces 100% of all commercially grown artichokes in the United States (NASS a).
- Commercial artichoke acreage in California was 9,300 acres in calendar year 1997 and 10,700 acres in 1998 (CASS, 1999).
- Artichoke production in California totaled 46,500 tons in 1997 and 45,500 tons in 1998 (CASS, 1999).
- Total value of California artichoke crop was $73,910,000 in 1997 and $62,899,000 in 1998 (CASS, 1999).
- Production costs range from $3,000 - $4,000/acre, depending on production method and the extent of pest control required.
- Approximately 75% of harvested artichokes are sold to the fresh market; the remaining 25% are processed as canned hearts and crowns or as frozen, quartered artichokes. (CAAB b)

Production Regions

The northern tip of the Central Coastal Region of California is the location of 84% of the state's artichoke acreage. Most of these plantings are in northern Monterey County, near the town of Castroville, where perennially grown *Green Globe* is

the dominant variety, but annual varieties are grown there as well. Other regions grow various annual varieties only, including *Imperial Star, Big Heart* and *Desert Globe*. In the South Eastern Region, these annual plantings, comprising 7.4% of the state's total acreage, are primarily in the desert counties of Riverside and Imperial. The third major district is the South Coastal region in the counties of Santa Barbara, Ventura and Orange, representing 6.8% of the total. The remaining artichoke acreage, less than 2% of the total, is located primarily in the San Joaquin Valley region counties of Fresno and San Joaquin (CAAB a).

Cultural Practices

Artichoke production systems are classified as either perennial or annual. Perennial artichokes are planted from root sections attached to basal stem segments (CAAB b). Depending on the vitality of the plants, artichokes are harvested for 5 to 10 seasons before replanting. Annual artichokes are direct seeded or transplanted from greenhouse-grown seedlings, harvested for one season, then normally rotated with another crop. The two systems differ in cultural practice as well as pest control issues.

Perennial Artichokes

Monterey Bay

The California commercial artichoke industry began in the late nineteenth century in San Mateo County with the vegetatively propagated perennial variety, *Green Globe*. Since then, the growing region for this "traditional" variety has expanded southward to include Santa Cruz County and the northern Salinas Valley region of Monterey County (Fig. 1). A total of approximately 5813 acres, or 62.5% of the total artichoke acreage in California, is planted in this variety. The epicenter of artichoke production within this region is the town of Castroville, near Monterey Bay. *Green Globe* grows best in well-drained heavy clay loam soil coupled with a cool, moist coastal climate, which is characteristic of this relatively small segment of the California coast. Currently, this is nearly the only area in the United States where perennially cropped *Green Globe* is commercially produced (less than 100 acres of perennials are grown in the South Coastal region).

Although research to develop *Green Globe* seed is ongoing, traditional Castroville growers report that this work has yet to produce seeded *Green Globe* that matches the quality of the vegetatively propagated variety (D. Huss, 1998, personal communication). As a result, *Green Globe* is still almost exclusively cultivated as a perennial with propagation achieved asexually through the replanting of root segments from mature plants.

The typical perennial row spacing is 9 ft to 10 ft, with plant spacing within rows set at 80 in. Most acreage is irrigated by overhead sprinkler, but some is irrigated through drip emitters and tape. During October, deep ditches are cut through the fields to drain winter rains from plant rows. In April, these ditches are filled-in through cultivation which aerates soil, reduces weed populations, and opens planting rows for additional agronomic activities.

If the initial planting takes place in the spring, a first-year crop can be harvested in late fall. Subsequent harvest intervals for most of the perennial acreage is controlled by the timing of "cut-back" or "stumping." This is the practice of cutting the artichoke plants at ground level at the conclusion of each production season. During cut-back, the above-ground part of the plants is shredded and incorporated into the soil. For approximately 75% of perennial artichoke acreage, this operation occurs in May, and precipitates a September - May harvest interval, or a "winter" crop. Approximately 15% - 20% of the acreage is cut-back in August or September, for a summer harvest period (Bari, 1998). Fields maintained by cutting back, may produce successfully for as long as 10 years before removal of the plants and replanting is necessary. A small percentage of the perennial fields are not cut-back at all, and are maintained by pruning only the dead stalks from

plants, which allows year-round harvesting. These fields usually need to be cleared and replanted after four years due to the build-up of pest populations (J. Giusti, 1999, personal communication).

Yield per season from a perennial field is typically 400 boxes/ac. Annual production cost is approximately $4000/ac, with about 15% ($600/ac) attributed to pest control.

Annual Artichokes

Monterey Bay

Although the majority of artichoke ground in the traditional Monterey Bay growing region remains in perennial cultivation, in the past decade, the development of seeded varieties has given rise to cultivation there of annuals such as *Imperial Star*. In 1997, approximately 25% of the acreage in this region, or 2000 ac, was annually planted.

Annual fields are planted February through May and harvested in the summer and early fall. Artichoke transplants are used exclusively (i.e., direct seeding is not practiced). Bed sizes of 40 in and 80 in are used. Irrigation regimes vary depending on climate and terrain, but drip is the primary method. Yield is typically 600 boxes/ac, which is significantly higher than perennially cropped yield.

Production costs for annuals are $3200 to $3600/year, with 5% being spent on pest control. Costs are lower than for perennials due to the shorter growing season (5 to 6 months), and the utilization of drip irrigation for annuals. Fields utilized for annual artichokes are either left fallow in between artichoke plantings, or are rotated with other crops such as celery and cole crops.

Seeded varieties have also allowed the geographical expansion of the commodity's growing area (CAAB b). This has developed in principally two regions: the Southern Coast and the Inland South Eastern Desert. Combined artichoke acreage in these two southern regions in 1997 was 1325 ac.

South Coastal Region

There are approximately 632 acres of artichoke along the southern coasts of Santa Barbara, Ventura, and Orange counties. The soil in that area is loamy sand and silica clay loam. Varieties grown include *Big Heart* and *Desert Globe*. Typical bed size is 40 in, with artichokes planted in a single line at a spacing of 30 in to 36 in apart. The average individual field size is 15 ac, planted during the period October - June. The planting timing for these fields is spread-out across several months to provide an extended harvest period from May through December.

In this annual coastal system, either direct seedling or transplant seedlings are utilized to establish new plantings. During wet seasons, transplants are favored since they require less care in establishment and are tolerant to wet soils. When transplants are used, a herbicide is sprayed on the beds, then overhead sprinkled to move the herbicide into the soil before planting. For direct-seeded fields, overhead sprinklers are used until thinning, after which the field is drip or furrow irrigated through plant maturity.

Approximately 4 to 6 weeks after harvest, southern coastal artichokes are chopped with a flailing type mower and tilled back into the soil. Annual artichokes are rotated with other crops, such as lettuce, broccoli, and cauliflower (Jordan, 1999, personal communication).

Annual production cost for southern coastal artichokes is approximately $3000/ac, with 5% to 10% spent on pest control.

South Eastern Desert Region

There are approximately 688 acres of annually cropped artichokes in the Inland Desert counties of Riverside and Imperial. The soil ranges from sandy clay loam to clay loam. Varieties grown there include *Emerald*, *Big Heart* and *Imperial Star*. The planting period is August through September, with harvest beginning as early as December in Riverside County. Hot weather, which tends to degrade the quality of the head, effectively ends the desert artichoke harvest season in mid-April.

The desert planting beds are commonly 72 in to 80 in wide. To compensate for the low percent germination that is characteristic of artichoke seed, growers will follow a strategy of overseeding and thinning to get a good stand at a spacing of approximately 2 ft to 3 ft within the row. However, direct seeding has fallen out of practice in the desert, and today the majority of desert artichokes are transplanted with greenhouse-grown seedlings. Due to the hot environmental conditions in August and September, overhead sprinklers are utilized to cool the seedlings and surrounding soil. When the weather cools, sprinkling is discontinued and drip irrigation is used (D. Jungers, 1999, personal communication).

Production costs in the desert are approximately $3000/acre, with 3% to 5% spent on pest control.

Various types of melons are compatible with artichokes in a rotational program. Watermelon, honeydew, and cantaloupe all share a common planting period, irrigation method, and row or bed spacing with artichokes. The crop rotation patterns vary among these crops; artichokes may be planted in alternate years, or there may be multiple years before their reintroduction into a particular field.

Other Growing Regions

There is also a small amount of artichoke acreage in the San Joaquin Valley and in Sutter County. The combined acreage of these growing areas is less than 2% of the total state acreage. Pesticide usage for these regions are included in Appendix Table A4, but discussion of regional pest control issues will focus on the Central Coastal (Monterey Bay), South Coastal, and South Eastern (desert) regions.

Insect Pests

Perennial Artichokes:

Artichoke Plume Moth, *Platyptila carduidactyla*

The artichoke plume moth (APM) is the most serious pest confronting growers of perennial artichokes. This insect is present in 100% of the 5813 acres of perennial *Green Globe* acreage in the Castroville area of northern Monterey County, as well as in the limited South Coastal perennial acreage. All stages of the pest are present in the fields year-round, although the infestation level drops somewhat during the period November - March. Economic damage occurs when APM larvae feed on the floral buds, rendering them unmarketable (Bari et al., 1996). If untreated, yield losses could reach 70% (Bari, 1998). The pest is monitored with pheromone traps to assess adult moth population levels, and by inspection of fields for worm infestation in the artichoke shoots.

Chemical Control:

- **Esfenvalerate**
  - **Trade Name & Formulation:** Asana XL, 0.66 emulsifiable concentrate
  - **Application Timing & Frequency:** Applied after shoot development, and continuing through harvest. Total number of applications ranges from 8 to 10 per season.
  - **Typical Application Rate & Method:** Typical rate ranges from 0.036 to 0.50 lb ai/ac, depending on pest pressure. These rates correspond to the upper limits of label indicated dosage. Tractor mounted spray booms are the preferred application method, but fields are not accessible to tractor sprayers after rainfall drainage ditches are cut in October, necessitating aerial applications in late fall and winter months.
  - **REI & PHI:** 12 hours restricted entry interval, 7 days pre-harvest interval.
  - 100% of perennial acreage is treated with this compound. It is considered by traditional Monterey Bay growers to be the key insecticide in their program to control APM, and it is the pest control chemical with the greatest number of applications and most aggregate treated artichoke acreage in Monterey Bay in 1997.
  - Esfenvalerate is effective against the adult and larval stages. Normally, it is tank-mixed with methidathion (Supracide) for two or three applications between shoot emergence and bud formation, then applied either alone or tank-mixed with diflubenzuron (Dimilin) for the remainder of the season. Sprays during the harvest period need to be carefully scheduled in accordance with the PHI restriction of seven days.
- **Diflubenzuron**
  - **Trade Name & Formulation:** Dimilin, 25 WP
  - **Application Timing & Frequency:** Soon after bud formation, 2 applications
  - **Typical Application Rate & Method:** 0.125 lb ai/ac, (low end of label dosage), usually applied by ground spray; occasionally applied by air.
  - **REI & PHI:** 12 hours restricted entry, 1 day pre-harvest interval
  - This product received a Special Local Needs registration in 1997. It is an insect growth regulator that is typically tank-mixed with esfenvalerate (Asana) for the first two applications after bud formation. It is moderately effective against eggs and exposed larvae, but does not kill adult APM (Bari, 1998).
  - 100% of traditional perennial acreage is treated with diflubenzuron. It ranks second to esfenvalerate in number of applications and aggregate acreage of artichoke treated in 1997.
- **Methidathion [OP]**
  - **Trade Name & Formulation:** Supracide 25 WP. There is a 2E formulation, but it is less commonly used.
  - **Application Timing & Frequency:** Applied 2 - 3 times per season, beginning after shoot emergence following cut-back, and ending before bud break. (The product label warns against applying after bud formation.) For the majority of perennials, which are cut-back in May, this would mean a June to July treatment period. In the Castroville area, application timing for most of the acreage is scheduled with input from degree-day modeling (insect forecasting system), based on recorded weather data and field counts of moths collected in pheromone traps.
  - **Typical Application Rate & Method:** 1 lb ai/acre, usually applied using a tractor-mounted spray boom. If the product is applied to a field that was cut-back in winter, applications would need to be made by air due to the deep

drainage ditches that are cut through the fields in October, rendering them impassable to tractors.

- **REI & PHI:** 48 hour restricted entry interval. Product may not be applied after bud formation.

- Except for a small amount of Monterey Bay perennial acreage that is harvested year-round, all of the perennial acreage is treated with methidathion. It ranks third behind esfenvalerate and diflubenzuron in total number of applications and aggregate acreage of artichoke covered in 1997.

- This compound is typically tank-mixed with esfenvalerate (Asana) before bud formation to augment early-season control of APM and to provide protection from aphid. It is effective against egg and larval stages of APM, and may also have efficacy against leafminer and *Proba* bug (a relatively new pest that was reported to have caused extensive damage to perennial artichokes in 1998) (Bari, 1998).

- Methidathion is a key insecticide for the management of APM resistance to esfenvalerate.

Alternative Chemical Controls:

- **Azinphos methyl** (Guthion) [OP] is a possible alternative to methidathion (Supracide) for control of APM larvae, but it is no longer registered for artichoke. A pre-harvest interval of 30 days severely restricted the allowable application period, and it was used on less than 10% of the perennial acreage in 1997.

- **Spinosad** (Success) and **bifenthrin** (Brigade) are possible alternative larvacides, pending registration for artichoke.

- **Permethrin** (Ambush, Pounce) products are somewhat more expensive and exhibit less efficacy against APM than esfenvalerate. With the same basic chemistry, they would not be advisable rotational products. However, due to permethrin's short REI, it is sometimes used for APM control during harvest.

- **Endosulfan** (Thiodan) was used against APM in the past, and is also a good aphicide, but the product label now specifically prohibits use of this chemical in the "Moss Landing" area of coastal California due to groundwater contamination concerns. (Moss Landing is on Monterey Bay, near Castroville.) This chemical has been shown to be extremely toxic to fish and marine life.

Biological Controls:
Bacillus thuringiensis products are not effective against APM when used alone, but experimental evidence suggests that APM control may be achieved by using *Bacillus thuringiensis* in combination with esfenvalerate (Bari, 1998).

Pheromone rope may provide additional control of APM through mating disruption when used with insecticides, although it is not considered to be a cost-effective approach (Bari, 1998).

Azadirachtin (Margosan-O), a botanical material, kills APM larvae. It, however, is not effective against adult APM and is more costly than conventional materials (Bari, 1998).

Parasitic wasps are natural enemies of APM, but are not currently effective at keeping APM populations below the economic threshold. (Bari et al., 1996) It has been speculated that predator populations have diminished over the years as a result of pesticide use (Knaster and Jarrell, 1997, quoting Debenedetti).

Trichogramma thalense is an egg parasite that may offer some APM control, but it has not yet been developed for commercial use (Bari et al., 1996)

Root cuttings for propagation may be dipped in beneficial nematode (*Steinernema carpocapsae*) to help suppress APM infestation during the first season of the planting. At present, the nematode suspension is not available in sufficient quantity for large scale commercial use. However, APM infestation in cuttings is not a major source of

pest infestation, and this process is not considered by growers to be cost effective (T. Shannon, 1999, personal communication).

Cultural Controls:
The most important cultural control is the practice of plant cut-back below the soil at the conclusion of harvest. This effectively clears the APM population from the field prior to the start of the following season.

Artichoke Aphid, *Capitophorus elaeagni*

Artichoke aphid is a common problem that causes significant loss of yield when present, but it is not as consistent and pervasive a pest problem as APM. The peak period for this pest is the summer months when the temperature and humidity are high. For the winter crop, which is cut-back in May, two to three applications of methidathion can be applied in the early summer weeks (before bud formation) to suppress aphid infestation. However, the summer crop, which is being harvested during peak infestation pressure, cannot similarly be treated and suffers an estimated 15% to 20% loss of the August to September harvest to damage from aphid (Bari, 1998).

Some of the crop damage is due to feeding injury, but the main deleterious effect of aphid infestation is related to a sugary secretion that the insect deposits on artichoke plants. Called "honeydew," this substance sticks to the plant, and serves as a host for mold. When this "sooty" mold forms, it interferes with the photosynthetic process and retards plant development, leading to undersized or poorly formed buds. If the mold forms on the buds themselves, it can turn them black. In addition to feeding and honeydew related damage, the presence of dead aphids in the buds at harvest may make the product unmarketable.

Fields are monitored by scouting and sampling the artichoke leaves. Treatment is recommended if the infestation reaches three aphids/leaflet. Currently, however, the material that would be recommended as an aphicide (methidathion) is also being applied for APM control, and the presence or absence of aphid would probably not alter the application schedule.

Chemical Control:

- **Methidathion** (Supracide) [OP] *See listing under Artichoke Plume Moth*

  This is currently the only pest control compound that has proven to be effective against artichoke aphid. It is tank-mixed with esfenvalerate (Asana) for 2 -3 applications before bud formation for control of the primary pest, APM, regardless of the level of aphid infestation. Due to the label restriction against applying this material after bud break, utility of methidathion for artichoke aphid is marginal for the summer crop. This is because bud formation begins in March for the summer artichokes, resulting in a situation where aphicidal efficacy of the pre-bud applications of methidathion will wear-off before the period of maximum aphid threat (Bari, 1998).

Alternative Chemical Controls:
There are currently no registered materials proven to be effective against artichoke aphid for the northern Monterey Bay growers. Endosulfan (Thiodan) was used for aphid on less than 11% of Monterey Bay artichoke acreage in 1997. It is an effective aphicide, but its use is problematic due to aforementioned label restrictions for the Moss Landing area, as well as the general reluctance of county officials to permit its use.

Imidacloprid (Admire, Provado) is a possible alternative, pending registration for artichoke.

Biological Controls:
Predaceous beetles native to the area may mitigate aphid infestation, but they have been ineffective at holding aphid population levels below the economic threshold. It is possible that the repeated usage of esfenvalerate (Asana) for control of the primary pest, APM, has had the effect of diminishing the population of beneficial parasites and predators. It is doubtful that the introduction of additional beetle populations into fields that are heavily sprayed for APM would result in sufficient survivorship of the beneficials to provide effective control of aphid (Bari, 1998).

Cultural Controls:
There are no known cultural control programs for management of this pest.

Cribrate Weevil, *Brachyrhnchus cibricollis*

Because adult weevils are unable to fly, the primary mode of introduction of this pest into an artichoke field is through root cuttings infested with eggs or weevil grubs during replanting. Adults emerge in July and feed on foliage for six to eight weeks. Larvae feed on root systems. This pest is present in 99% of the Monterey Bay region perennial acreage.

Damage to the artichoke plant is caused by both larval and adult stages. The larvae ("weevil grub") infest the root zone and stunt the growth of the plant, causing a drop in marketable yield at harvest. Plants with badly infested and weakened, shallow root systems will be unable to survive the stress of the cutback process. The force involved with cutting these plants at the soil level will lift the plant out of the bed, necessitating replacement of these infected plants. Approximately 5% to 10% of the artichoke plants are lost to weevil grub during this time. The adults feed on the buds and leaves; if the infestation level is severe, they can strip leaves down to the petioles. The peak period for adult feeding is mid-June through September, which makes the summer artichoke crop particularly vulnerable to yield loss from bud damage. It has been estimated that cribrate weevil causes an annual drop in yield of 25%. Untreated, it is estimated that the losses could reach as high as 70% (Bari, 1998).

Chemical Control:

- **Carbofuran** [CARB]
  - **Trade Name & Formulation:** Furadan 4 F
  - **Application Timing & Frequency:** July or August, one application
  - **Typical Application Rate & Method:** 1 lb ai/acre, ground spray, tank-mixed with esfenvalerate and methidathion.
  - **REI & PHI:** 48 hour restricted entry; 21-day pre-harvest interval, plus 30-day interval between successive applications.
  - 75% of the perennial acreage is treated with Carbofuran. It is effective against adult cribrate weevil, and is the only currently registered insecticide available to control this pest. The product label allows two applications per season, but the 30-day PHI does not allow a second application during a period of critical need for artichoke (i.e., during summer peak infestation period). This restriction prevents carbofuran from being applied with the necessary frequency to eradicate cribrate weevil from the fields.

Alternative Chemical Controls:
Registration for bifenthrin (Brigade) on artichoke is pending. Experimental evidence suggests that a treatment regime of one application of carbofuran followed by two applications of bifenthrin in successive years can eradicate cribrate weevil after three years (Bari, 1998).

Biological Controls:
Various species of entomopathic nematodes (*e.g., Steinernema carpocapse*) parasitize weevil grub, but it is not cost effective to dip root cuttings in nematode suspension (*see listing under Artichoke Plume Moth*). Soil applications have been tested experimentally, but results indicate that delivery of the nematode suspension at sufficient depth to provide effective control is problematic (Bari, 1998).

Cultural Controls:

The replanting period, which occurs every five to ten years, provides an opportunity for control of cribrate weevil through deep plowing. This process will kill the weevil grubs directly or expose them to predators. Remaining weevil grubs can be starved by leaving the field fallow for three to six months, although this is not considered by growers to be economically feasible.

It may also help to rotate the summer artichokes with the winter artichoke crop, because the latter will have a carbofuran spray "window" during the period of peak adult weevil infestation (Bari, 1998).

Beet Armyworm, *Spodoptera exigua*

Beet armyworm migrates into perennial and annual artichoke fields from adjacent row-crop fields during the summer months. By October and November, larvae will have begun to bore into the artichoke bud, or to feed on the exterior petals. Populations levels of this insect are sporadic from year to year. 1997 was a year of high infestation, followed by a light year in 1998. During seasons of light infestation the crop is not threatened, but larval feeding during periods of heavy infestation can cause losses in fall production from 3% to 5% (Bari, 1998).

Chemical Control:
Applications of esfenvalerate and permethrin for APM (*see listing under Artichoke Plume Moth*) may also provide some degree of worm control. However, these applications alone do not keep populations below the economic threshold during periods of high infestation.

Alternative Chemical Controls:
Spinosad (Success) and bifenthrin (Brigade) may be efficacious against beet army worm. Artichoke registrations for these two materials is being sought primarily for more serious pests (spinosad for APM and bifenthrin for cribrate weevil).

Biological Controls:

- *Bacillus thuringiensis*
  - **Trade Name & Formulation:** Agree Soluble Pouch, Cutlass 10 WP, MVP Bioinsecticide FC, Javelin 6.4 WG.
  - **Application Timing & Frequency:** Was applied once or twice in the fall in response to 1997 infestation.
  - **Typical Application Rate & Method:** Applied by air and by ground at an average rate of 0.21 lb ai/ac.
  - **REI & PHI:** 12 hour re-entry and pre harvest intervals.
  - *Bacillus thuringiensis* is the primary insecticide applied specifically for control of beet armyworm infestation. There are no known predators or natural controls for beet armyworm (M. Bari, 1999, personal communication).

Cultural Controls:
There are no known cultural control programs for management of this pest.

Annual Artichokes:

The ability to rotate annual artichokes with other crops virtually eliminates the build-up of artichoke plume moth and cribrate weevil. However, aphids and worms are significant pest control issues for growers of annuals in the Monterey Bay, Southern Coastal, and Southern Inland Desert areas. (Crop rotation for cultural control of these pests, therefore, has not been sufficient.)

Black Bean Aphid, *Aphis fabae*

Green Peach Aphid, *Myzus persicae*

Black Bean aphid has been reported as the dominant species in the Southern Coastal fields, where infestation levels peak in July and August. Nearly 100% of southern coastal acreage is populated by this pest, although infestation levels vary from year to year. Damage from black bean aphid occurs in the form of retarded plant growth due to feeding injury, which leads to undersized or poorly formed buds.

Green peach aphid is a minor pest on Monterey Bay annuals. Populations of this pest tend to peak in the spring and fall, but seldom reach treatment levels. It is probable that pest control programs targeted towards the major pests APM and artichoke aphid on perennial fields have the residual effect of controlling green peach aphid in proximate annual fields as well.

In the desert, all fields have some aphid present at all times, with infestations peaking in the winter. However, populations have only recently progressed to levels that require treatment, principally just before and during harvest.

Green peach aphid has less effect on plant growth than the southern coastal black bean aphid, but the presence of dead aphids of either species in artichoke buds at harvest may render the product unmarketable. The extent of potential "marketable" yield loss due to untreated aphid infestation depends heavily on consumer demand at the time of harvest.

Growers or Pest Control Advisors monitor aphid pressure by walking the fields. Infestations are also reported by harvest crews or quality assurance personnel.

Chemical Control:

- **Pyrethrins + Rotenone**
  - **Trade Name & Formulation:** Pyrellin EC
  - **Application Timing & Frequency:** Applied pre-bloom, once or twice per season on the southern coast, tank mixed with gibberellic acid (plant growth regulator). Applied late season in the desert.
  - **Typical Application Rate & Method:** Southern Coast and Desert both typically apply 0.01 lb ai/ac pyrethrins; 0.01 lb ai/ac rotenone, usually applied by ground spray rig.
  - **REI & PHI:** 12 hour restricted entry interval; 12 hour preharvest interval
  - On the South Coast, 100% of artichoke acreage is treated with Pyrellin for black bean aphid. Product efficacy is moderate (F. Lenser, 1999, personal communication).
  - Pyrellin is seldom used in the desert for green peach aphid.

Alternative Chemical Controls:

- Mevinphos (Phosdrin) [OP] was used on the coast in the past, and was very effective, but the registration for artichoke (as well as all other California crops) has been rescinded.
- Endosulfan is effective, but a PHI of 21 days is a serious limitation to commercial use of this product, and it is used very little for black bean aphid on the coast. In the desert, its usage has been limited by the requirement for a 150 ft buffer zone around open fishbearing waters, e.g., canals and reservoirs.

- Neem oil (Trilogy) has aphicidal properties, and was used on a limited amount of desert acreage in 1997. However, it is difficult to get the necessary plant coverage for control of green peach aphid and this material requires several weeks to take effect.

Biological Controls:
Desert growers are concerned with possible mite flare-ups that can be induced by some insecticides, because there is no proven miticide for use on desert artichokes. Fortunately, aphid populations in the desert are light enough to be controlled with ladybug and lacewing. These aphid predators are applied to artichoke fields in December, providing biological control of green peach aphid without stimulating the mite population. Strong winds and greater usage of insecticides inhibits adoption of this practice on coastal artichokes.

Cultural Controls:
There are no known cultural control programs for management of these pests.

Beet Armyworm, *Spodoptera exigua*

Cutworm, *Peridroma saucia*

Cabbage Looper, *Trichopplusiani*

Worms are a sporadic problem for the coastal artichoke growers. In 1997, the Monterey Bay fields had heavy populations of beet army worm (*cf. Perennials, Beet Armyworm*). Further south, cutworm incidence was high, affecting 100% of the South Coastal artichoke acreage. However, in 1998, worms were not a problem in either area.

Beet armyworm and cabbage looper are serious early season pests for the inland desert growers. They feed on the young, developing plants, causing loss of stand. Untreated, stand losses due to worm damage in the desert approach 100%. With conventional pest control, treating 100% of the desert acreage, the stand loss is reduced to less than 10%.

Chemical Control:

- **Permethrin**
  - **Trade Name & Formulation:** Ambush 25 W, Astro 25WP, Pounce 3.2 EC. (EC formulations are favored in the desert because the emulsifiers are less likely than other formulations to burn the usually dry foliage.)
  - **Application Timing & Frequency:** On the Southern Coast, permethrin is usually applied twice, pre-bloom. In the desert, it is applied once or twice early season for worms (plus 1 to 2 applications late season for aphid, see *Green Peach Aphid*, above).
  - **Typical Application Rate & Method:** On the coast, 0.25 lb ai/ac is commonly used, applied by tractor with high clearance spray booms. In the desert, 0.1 lb ai/ac to 0.2 lb ai/ac, applied aerially, or with ground spray rig, or through chemigation.
  - **REI & PHI:** 12 hrs restricted entry; buds may be harvested on day of application.
  - Of all pest control materials used on artichoke in the South Coastal region in 1997, permethrin was applied the most number of times and covered the greatest amount of aggregate acreage. In the desert, it is used for control of cabbage looper and beet armyworm , and also to control beetles, crickets, and grasshoppers.
  - Permethrin is typically tank mixed with *Bacillus thuringiensis*.

- **Esfenvalerate**
  - **Trade Name & Formulation:** Asana XL
  - **Application Timing & Frequency:** Early season on the southern coast and in the desert (late season applications for aphid.)
  - **Typical Application Rate & Method:** On the southern coast, 0.05 lb ai/ac. In the desert, 0.04 lb ai/ac; aerial, ground spray rig, or chemigation.
  - **REI & PHI:** 12 hour restricted entry; 7 day pre harvest interval.
  - Esfenvalerate is typically tank-mixed with *Bacillus thuringiensis*. On the southern coast and in the desert, it is sprayed in rotation with permethrin. (Commercially, esfenvalerate tends to be more efficacious than permethrin against cabbage looper.)
- **Piperonyl butoxide**
  - **Trade Name & Formulation:** Incite, Py-Rin
  - **Application Timing & Frequency:** early season, applied once or twice
  - **Typical Application Rate & Method:** 1.0 lb ai/ac, occasionally used in tank mix with permethrin (some product formulations also include a percentage of permethrin). Chemigation is not allowed.
  - **REI & PHI:** 12 hours restricted entry; no pre-harvest restriction
  - Piperonyl butoxide (Incite) is an insecticide synergist that is sometimes mixed with permethrin (Ambush). It was used minimally on the Southern Coast in 1997, and not at all in 1998. It is listed as an insecticide, but it would not be efficacious if applied alone.

Alternative Chemical Controls:
Chlorpyrifos (Lorsban) [OP] and spinosad (Success) are efficacious against worms, but are not currently registered for artichoke.

Biological Controls:

- **Bacillus thuringiensis**
  - **Trade Name & Formulation:** Agree Soluble Pouch, Cutlass 10 WP, MVP Bioinsecticide FC, Javelin 6.4 WG.
  - **Application Timing & Frequency:** 1 to 2 early season applications on the southern coast; in the desert, 1 to 2 early to mid season applications
  - **Typical Application Rate & Method:** 0.12 lb ai/ac by air or ground on the southern coast; 0.09 lb ai/ac in the desert
  - **REI & PHI:** 12 hour re-entry and pre harvest intervals.
  - *Bacillus thuringiensis* was the most often used and most widely applied insecticide in the desert in 1997. It was second only to permethrin for acreage covered on the southern coast.

Cultural Controls:
There are no known cultural control programs for management of these pests.

Diseases

Perennial Artichokes:

Powdery Mildew, *Leveillula taurica*

Powdery mildew is the most serious above-ground disease problem for the traditional perennial growers. It usually occurs in late August or September, and affects 75% to 100% of the acreage. It is monitored by walking the fields and examining the leaves for mildew mycelium. *L. taurica* is the predominant species involved with powdery mildew on artichoke. It can be found on the underside of older leaves which, if severely infected, will eventually die (Bari et al., 1996).This leaf stress slows production of the flower buds. Experimental evidence suggests that powdery mildew may reduce yield by 9% per year. More important than the loss of yield, however, is the economic loss to growers resulting from disruption of harvest timing caused by the disease. The delay in harvest due to powdery mildew tends to counteract the effects of gibberellic acid, a plant growth regulator that is applied by growers to accelerate harvest to coincide with the primary economic market for artichoke (Bari, 1998).

Chemical Control:
Yield losses are minimized through treatment with fungicidal compounds. In 1998, a Section 18 registration was obtained for the use of myclobutanil (Rally). (This product is currently in widespread use for control of mildew statewide.)

- **Myclobutanil**
  - **Trade Name & Formulation:** Eagle, Rally 40W
  - **Application Timing & Frequency:** Applied twice in the fall during bud formation.
  - **Typical Application Rate & Method:** 1.20 oz ai/ac. Tank mixed with insecticides, usually applied by ground 2 times per year.
  - **REI & PHI:** 48 hour restricted entry interval; 5 day pre-harvest interval.
  - This product was not registered for artichoke in 1997, the most recent year for which usage data is available. Section 18 registration, obtained in 1998, is due to expire August 17, 1999.

Alternative Chemical Controls:
Triademefon (Bayleton) was efficacious and widely used on Monterey Bay perennials until cancellation of artichoke registration for that product in 1997.

Sulfur is not used in the Monterey Bay growing region because the temperature is too cool for product activation.

Biological Controls:
There are no known biological controls for powdery mildew on artichoke. AQ10, a biofungicidal formulation of the fungus *Ampelomyces quisqualis*, may be efficacious, but data are lacking for this material on artichoke.

Cultural Controls:
Spores are transmitted from field to field through the air, which makes the spread of the disease difficult to control. No cultural practices have been identified to slow the development of powdery mildew on artichoke.

Annual Artichokes:

Ramularia Leaf Spot, *Ramularia cynarae*

Ramularia is present on nearly 100% of California artichoke acreage. It damages the leaf and sometimes the flower bud. Severe leaf damage and resultant loss of plant vigor will lead to smaller sizes of marketable buds. The best market is for the "#24" size (24 buds/carton). The marketability of the smaller sizes is not as strong. In weak markets, the smaller sizes may not sell at all; in stronger markets, the smaller sizes sell, but at significantly lower prices. Also, smaller buds results in lower carton units produced per acre. In addition to size reductions due to loss of plant vigor, *Ramularia* leaf spot also may infect the flower buds directly, rendering them unmarketable.

Due to the timing of disease symptoms (after the harvest period has peaked), leaf spot is not a serious economic problem for perennial growers. However, the disease is a serious issue for annual growers in the South Coast. It is estimated that the disease is responsible for yield losses of as much as one third in years of severe infection.

In the desert, *Ramularia* symptoms appear in late season foliage, but do not do economic damage to the crop.

Chemical Control:
In the past, benomyl (Benlate [CARB]) was used effectively, but disease resistance to this chemical compound became a concern, and it is no longer registered for artichoke.

Myclobutanil (Rally, *see listing under Perennial Artichokes, Powdery Mildew*) exhibits low efficacy against Ramularia. In addition, it has a "plant back" restriction that requires 120 days to elapse after last application before a new leafy vegetable crop may be planted in the treated field. This requirement is not compatible with the typical southern coastal rotational scheme of following artichoke with lettuce, cauliflower, or broccoli. Usage data for this product, which received a section 18 registration in 1998, is not available for this report. However, information from growers suggests that myclobutanil is utilized very little, if at all, for *Ramularia* control on artichoke.

Due to the scarcity of effective fungicides registered for artichoke, there are currently no effective chemical control programs being implemented for *Ramularia*.

Alternate Chemical Control:
The biorational material Azoxystrobin (Abound, Quadris) has exhibited potential for *Ramularia* control, but it is not currently registered for artichoke.

Biological Control:
There are no known biological controls for management of this disease.

Cultural Controls:
It is difficult to control the spread of *Ramularia*. It has been suspected that harvest machines may spread the fungus as they move from diseased sections of fields into healthy areas, or that that field personnel spread the disease through the fields as they cultivate and harvest. Results of informal testing to see if one harvest method is preferable over the other with respect to leaf spot abatement are inconclusive.

Incidence of Ramularia may be minimized by keeping the soil surface as dry as possible.

Root Pathogens,*Verticillium dahliae, Pythium spp*

Verticilluim and *Pythium* damage the vascular system of artichoke plants. The result of infection ranges from stunted growth and plant discoloration to the death of the plant. *Verticillium* infection in the field appears to encourage the development of *Pythuim* and bacterial problems. Occasionally, soil-sampling and lab testing will be performed to confirm the existence of *Verticillium* before planting, but this is not a routine practice. Grower knowledge of the disease history of the field plays a major role in planting and treatment decisions with respect to soil borne root pathogens.

Verticillium and *Pythium* are not problems for growers in the desert or Monterey Bay regions.

Chemical Control:

- **Metam-sodium [B1B2]**
  - **Trade Name & Formulation:** Vapam
  - **Application Timing & Frequency:** pre-plant, one application
  - **Typical Application Rate & Method:** 58 lb to 116 lb ai/ac (15 gal to 30 gal/ac), applied by shank or through buried drip tape.
  - **REI & PHI:** 48 hour restricted entry; (preplant application).
  - Approximately 40% to 60% of southern coastal acreage is treated with metam-sodium prior to planting for *Verticillium* and *Pythium*.

Alternative Chemical Control:
Dichloropropene (Telone [B1B2]) is somewhat efficacious against *Verticillium*, but usage is highly restricted and it is not used for artichoke.

Biological Control:
There are no known biological controls for management of these diseases.

Cultural Controls:
Disease control begins by exclusion of fields with a history of *Verticillium*. However, limitations of available acreage make it infeasible to completely avoid planting in fields with a history of the disease.

Broccoli may be a good rotational choice for Verticillium control due to its disease suppressive property when incorporated into the soil at the end of the season. Market considerations, however, make it economically impractical to rotate all artichoke acreage with broccoli.

Weeds

Weed management is a major problem. Not only do weeds steal nutrients from the intended crop, they also provide habitat for insect pests and can reduce the efficacy of spray-applied pest control materials.

Perennial Artichokes:
Monterey Bay perennial fields are hosts to a broad spectrum of weeds, including nettle, mustard, chickweed, and oxalis.

Chemical Control:

- **Pronamide [B1B2]**
  - **Trade Name & Formulation:** Kerb
  - **Application Timing & Frequency:** Applied once at replanting (i.e., every 5 to 10 years)
  - **Typical Application Rate & Method:** 2.0 lb ai/ac applied over newly planted crowns, then overhead sprinkled to work the herbicide into the beds.
  - **REI & PHI:** 12 hour restricted entry interval. Harvest may not occur within 60 days of application over crowns.
- **Simazine**
  - **Trade Name & Formulation:** Princep 4L, Drexel Simazine 4L
  - **Application Timing & Frequency:** Applied once after winter ditches are cut.
  - **Typical Application Rate & Method:** 0.64 lb ai/ac avg. rate, applied with ground spray rig to ditches.
  - **REI & PHI:** 12 hour restricted entry interval.
  - Registration for Simazine (Princep 4L) was recently rescinded. However, of all herbicide products applied to Monterey Bay artichokes in 1997, simazine was second only to oxyfluorfen (Goal) in aggregate acreage covered. It was an herbicide important for control of chickweed.
- **Oxyfluorfen**
  - **Trade Name & Formulation:** Goal 2XL
  - **Application Timing & Frequency:** Applied once, in October.
  - **Typical Application Rate & Method:** 0.7 lb to 2.0 lb ai/ac by spray boom mounted on ATV (All Terrain Vehicle). Applied to winter irrigation ditches only. Label restricts cumulative applications to 2 lb ai/ac total per season.
  - **REI & PHI:** 24 hour restricted interval, 5 day pre-harvest interval.
  - This product works well on most weeds, but is weak against chickweed.
- **Sethoxydim**
  - **Trade Name & Formulation:** Poast
  - **Application Timing & Frequency:** Applied once or twice in winter after opening of ditches.
  - **Typical Application Rate & Method:** Applied by helicopter at an average rate of 0.36 lb ai/ac. Label restricts cumulative applications to 0.94 lb ai/ac total per season.
  - **REI & PHI:** 12 hour restricted entry, 7 day pre harvest interval.
  - Sethoxydim was not used on as much acreage as oxyfluorfen, simazine, or pronamide in 1997. Its effectiveness is limited to grasses.

Alternative Chemical Control:
A possible replacement for pronamide (Kerb) is pendimethalin (Prowl), which is currently in the review process for registration on artichoke. However, no chemical alternatives for pronamide (Kerb), oxyfluorfen (Goal) or sethoxydim (Poast) are available at this time.

It expected that diuron (Karmex) will replace simazine for chickweed control.

Biological Control:
There are no known biological controls for weed management in artichoke fields.

Cultural Controls:
Mechanical cultivation and hand hoeing are practiced until the winter drainage ditches are dug. Herbicides are relied on for the remainder of the season to control weeds in the ditches.

Annual Artichokes:
Fields growing annual artichokes in Monterey Bay have the types of weeds as described for perennials in that region. Winter weed varieties on the southern coast include shepherdspurse, stinging nettle, malva, groundsel, chickweed, and, in spots, oxalis. Summer weeds include nightshade, pigweed, goosefoot nettle, grasses, and London rocket.

In the desert, weeds include goosefoot, purslane, lambsquarter, malva, and watergrass.

Chemical Control:

- **Pronamide [B1B2]**
  - **Trade Name & Formulation:** Kerb WP
  - **Application Timing & Frequency:** On the coast and in the desert, 1 application just prior to, or soon after, transplanting.
  - **Typical Application Rate & Method:** On the coast, 1 lb to 2 lb ai/acre is applied to bed top, then overhead sprinkled to carry the herbicide into the soil. In the desert, 1 lb to 2 lb ai/ac is applied by ground or air.
  - **REI & PHI:** 1 day re-entry, 60 days pre-harvest.
  - Pronamide is routinely applied prior to transplanting on most of the coastal annual artichoke acreage. It is used on less than half of the desert acreage.
- **Oxyfluorfen**
  - **Trade Name & Formulation:** Goal 2 XL
  - **Application Timing & Frequency:** Applied in desert at "layby;" 2 applications/season
  - **Typical Application Rate & Method:** Applied in desert fields in furrows and bedtop shoulders, 0.50 lb to 1.0 lb ai/ac by ground
  - **REI & PHI:** 1 day re-entry; 60 days pre-harvest
  - Oxyfluorfen is widely used in the desert, but it is not used directly on coastal annual artichoke fields. However, it is applied to other crops in rotation with southern coastal artichoke. The subsequent artichoke plantings derive some weed abatement benefit from that previous application.
- **Metam-sodium [B1B2]**
  - **Trade Name & Formulation:** Vapam

- **Application Timing & Frequency:** pre-plant, one application
- **Typical Application Rate & Method:** 230 lb ai/ac on the coast, shanked into the soil or applied through buried drip tape. 500 lb ai/ac in the desert.
- **REI & PHI:** 48 hour restricted entry
- Metam-sodium (Vapam) is applied for Verticillium control on the southern coast at rates ranging from 58 lb to 116 lb ai/ac (*see listing under Verticillium*).In fields with a history of severe weed infestation, the application rate is sometimes increased to kill weed seed also. It is applied on a small percentage of desert artichoke acreage prior to planting for weed control and after harvest to desiccate artichoke plants for faster reincorporation into the soil.
- Metam-sodium is not used in Monterey Bay for artichoke.

Alternative Chemical Controls:
See listing under Perennial Artichokes, Weeds

Biological Control:
There are no known biological controls for weed management in artichoke fields.

Cultural Controls:
On the southern coast, weed abatement is done by hand after the pre-plant application of pronamide.

On some organically maintained fields in the desert the ground is "solarized" by installing clear plastic over the ground for about 30 days before planting. Summer heat penetrates the soil and kills weed seed (J. Hurt, personal communication, 1999).

Plant Growth Regulation

Growers of both perennial and annual types of artichoke routinely apply gibberellic acid, a plant growth regulator, to accelerate the beginning of harvest.

- **Gibberellic Acid**
  - **Trade Name & Formulation:** Progibb 4% Solution, Gibro 4LS Growth Regulator
  - **Application Timing & Frequency:** Applied twice at bud initiation.
  - **Typical Application Rate & Method:** 0.01 lb to 0.08 lb ai/ac, applied by ground spray.
  - **REI & PHI:** 12 hour restricted entry, 7 day pre harvest interval.
  - Gibberellic acid is applied primarily to the winter perennial artichokes in the Monterey Bay area, and to the annuals in the other regions. In the desert, more aggregate acreage was treated with this product than any of the pesticide materials in 1997.

Vertebrate Pests

Perennial Artichokes:

Voles, *Microtus californicus*

All perennial fields in the Monterey Bay region experience rodent infestation. Field mice, or "voles," eat all plant parts. With an active pest control program, growers have been able to keep yield losses to the rodents down to less than 5%.

Chemical Control:

- **Aluminum phosphide**
  - **Trade Name & Formulation:** Phostoxin (tablets)
  - **Application Timing & Frequency:** Applied twice early season when burrow entrances are visible; approximately 90% of perennial acreage is treated.
  - **Typical Application Rate & Method:** One to 4 tablets are placed by hand into the mice burrows and covered with dirt. (Soil moisture activates the tablets, creating a fumigation effect.)
  - Aluminum phosphide is used by the agricultural industry primarily for fumigation of storage structures (e.g., silos and railroad cars). However, it is also registered for control of burrowing pests, and is highly efficacious as a rodent mitigation material in perennial artichoke fields.
- **Chlorophacinone**
  - **Trade Name & Formulation:** Rozol Mineral Oil Concentrate
  - **Application Timing & Frequency:** Applied 2 to 3 times per year in the fall.
  - **Typical Application Rate & Method:** Bracts from culled artichoke buds are placed in a cement mixer. Chlorophacinone is added to mixer and churning action coats bracts. Two to three bracts are placed by each artichoke plant as rodent bait.
  - **REI & PHI:** (not listed on label)
  - Approximately 90% of perennial acreage is treated with multiple feedings of chlorophacinone.

Alternative Chemical Control:
Diphacinone (Ramik Green) was used in 1997, but Monterey County records indicate that the product was not used 1998, or to date in 1999. Registration appears to restrict usage to drainage ditches or field periphery. It is a dry rodenticidal bait applied directly to the soil.

Biological Control:
There are no known biological control programs for management of this pest.

Cultural Controls:
Due to the large population of field mice in commercial production fields, trapping is not practical. Weed control in the winter and field cultivation in the summer help to minimize mice infestation levels.

Mollusks

Perennial Artichokes:

Gray Garden Slug, *Deroceras reticulatum*

European Brown Snail, *Helix aspersa muller*

Slugs and snails are present in 100% of the perennial acreage in the Monterey Bay region. They cause cosmetic damage to the floral buds in the form of scarring, and this lowers the quality of buds harvested. Summer artichokes are affected, but the problem is particularly severe on the winter harvested artichokes. An estimated 10% to 15% of artichoke yield suffers a reduction in quality as a result of mollusk damage, and approximately one-third of these damaged artichokes is unmarketable (Bari, 1998).

Chemical Control:

- **Metaldehyde**
  - **Trade Name & Formulation:** Deadline Bullets, Clean Crop Metaldehyde 7G
  - **Application Timing & Frequency:** Applied June through August, several applications
  - **Typical Application Rate & Method:** Application rates vary, but average rate is 0.76 lb ai/ac, applied by ground.
  - **REI & PHI:** 12 hour restricted entry; no PHI indicated on label (Deadline Bullets).

Alternative Chemical Control:
Iron phosphate (Sluggo) is a new possible alternative. Information on product efficacy is not available at this time.

Biological Control:
No biological controls for mollusks are available.

Cultural Controls:
The yearly cut-back process, combined with weed control measures, helps to control mollusk population levels.

Annual Artichokes:

Mollusks are not an economic issue for growers of annually cropped artichoke.

Discussion and Summary

As important as Monterey County is to artichoke production nationally, growing an estimated 75.5% of U.S. production (CAAB a), artichoke represented only 3.3% of that county's market value of crops sold in 1997 (CASS, NASS b). However, this may be more of a testament to Monterey's stature as one of the top farming counties in a state rich in agriculture, than a reflection of the artichoke industry. Artichoke is the "Official Vegetable" of Monterey County,

contributing an estimated $55.8 million to the economy there, and it is also a significant component of community identity for the town of Castroville. Located in northern Monterey County, Castroville bills itself as "The Artichoke Center of the World." This is not an altogether inaccurate appellation, given that most of the nation's artichoke, and virtually all of the perennially cropped *Green Globe*, is grown in the vicinity of Castroville.

Perennial artichoke production has a long and storied history in California, dating back almost 100 years. By contrast, the development and commercial production of seeded annual varieties is a relatively recent development. However, seeded artichoke production presents many advantages to growers over the perennially cropped *Green Globe*. For example, annuals can be planted at greater density than the perennials, thereby increasing the per-acre yield. In addition, the planting season is shorter, which reduces the costs of production for annuals. The annual cropping system also appears to offer pest control advantages over the perennial system, particularly with respect to organophosphate and carbamate usage.

Organophosphate and Carbamate Usage:

Perennial fields are more conducive to the development of serious pest control problems than annual fields. APM and the artichoke aphid, the two most important insect pests to perennial growers, are of little concern to those growing annuals. The organophosphate methidathion, a key material for controlling these insects, is not used on annual artichokes.

Table 1 lists total pounds of active ingredient applied in 1997 to California artichoke for fifteen pest control chemicals considered to be most important to growers. Methidathion is the only organophosphate on the list, and it is second only to the soil fumigant metam-sodium in total lb active ingredient applied. All methidathion was sprayed on perennials, with 98% applied in Monterey Bay, and the remaining 2% applied to the limited perennial acreage in Santa Barbara County.

There is also one carbamate (carbofuran) listed as being important. It was used only in the Monterey Bay region, and only on perennials.

Table 1.
Most important artichoke pest control materials, based on grower interviews and 1997 usage data. Listing is in order of Monterey Bay usage, not necessarily in order of perceived importance. (*See Appendix 2, Tables A1 - A4 for full listing*.)

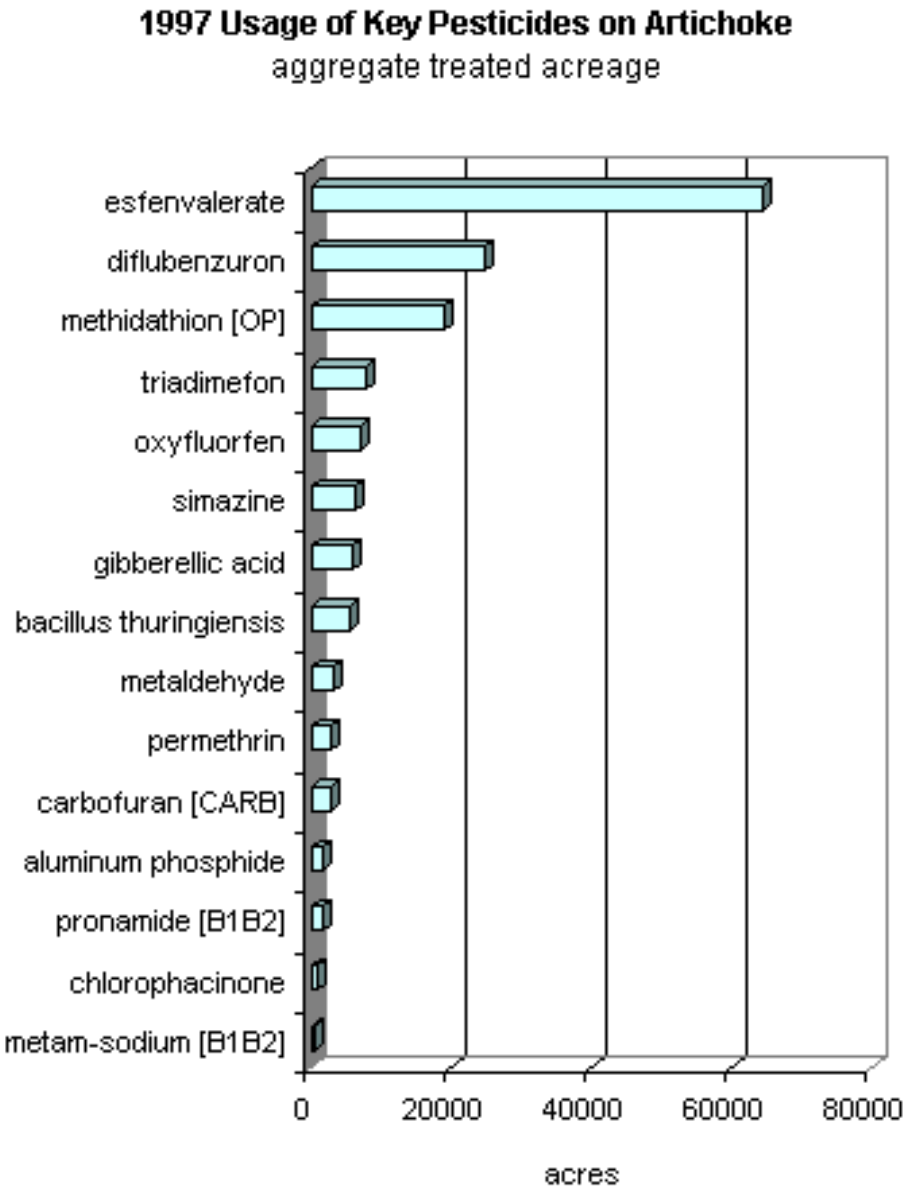
			Total lb ai applied, 1997		
Common Name	**Trade Name**	**Pest**	Monterey Bay	South Coastal	Desert
Methidathion [OP]	Supracide	APM and Artichoke Aphid	16307	291	0
Oxyfluorfen	Goal	Weeds	6337	0	36
Simazine*	Simazine	Weeds	3934	0	0
Diflubenzuron	Dimlin	APM	3235	0	0
Carbofuran [CARB]	Furadan	Cribrate Weevil	2801	0	0

Esfenvalerate	Asana	APM	2506	44	29
Metaldehyde	Deadline Bullets	Slugs and Snails	2383	0	0
Pronamide [B1B2]	Kerb	Weeds	1256	177	228
Bacillis thuringiensis	Xentari	Worms	658	152	96
Triademefon**	Bayleton	Powdery Mildew	598	1	0
Permethrin	Ambush	Aphid	127	423	84
Aluminum phosphide	Phostoxin	Voles	92	0	0
Gibberellic Acid	Progibb	(Plant Growth Regulator)	33	91	53
Chlorophacinone	Rozol	Voles	1	0	0
Metam-sodium [B1B2]	Vapam	*Verticillium* and weeds	0	25621	13681

* No longer registered for artichoke
** Section 18 will expire August 1999

While Table 1 shows usage in terms of total lb ai applied, another indicator of pesticide usage is *aggregate treated acreage*, which is a measure of the total surface area to which these materials are applied, usually by spray application (*See Appendix 1, Data Collection and Processing Procedures, Aggregate Treated Acreage*). This statistic incorporates the effects of multiple applications, and serves to add additional environmental exposure information to the lb ai data. Figure 2 represents the aggregate treated artichoke acreage for 1997, summed across all regions, for each of the fifteen important chemicals listed in Table 1. Although esfenvalerate ranked seventh in terms of total lb ai applied, it was applied on significantly more acreage than any other pesticide- more acreage than for the next four materials combined. By contrast, usage of the organophosphate methidathion was 3.4 times the total lb ai of esfenvalerate, but, as seen in Figure 2, it was applied to a fraction of the amount of acreage recorded for esfenvalerate. This is reflected by the average application rates of 0.88 lb ai/ac for methidathion vs. 0.04 lb ai/ac for esfenvalerate (*see Appendix 2, Table A4*).

Figure 3 represents the percentage contribution of *all* organophosphates, carbamates, and B1 and B2 potential carcinogens to aggregate treated artichoke acreage. Organophosphates account for 12%, all of which was applied to perennials, and for nearly all of the 12%, the chemical was methidathion (a small amount of acreage was treated with the organophosphate azinphos-methyl for APM).

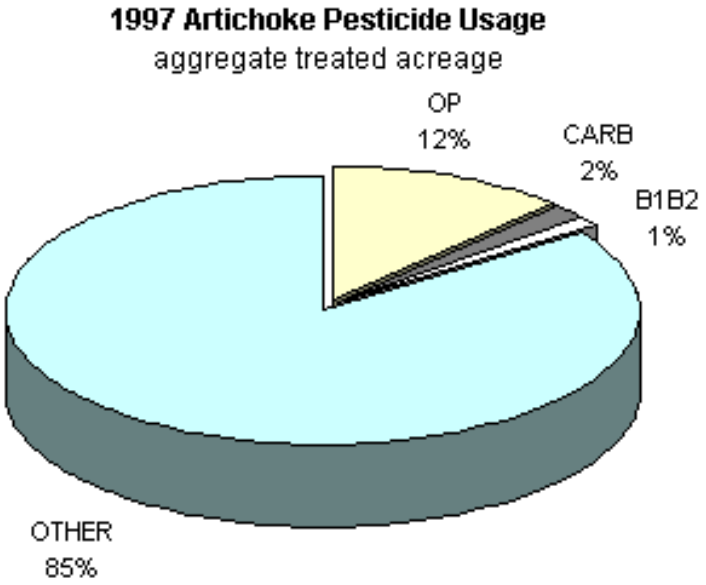


Cribrate weevil, a pest that is spread primarily by the method used to propagate perennials, is not an issue for growers of annuals. Importantly, the material utilized to control cribrate weevil is the carbamate carbofuran. Referring again to Figure 3, carbamate materials contribute 2% to the aggregate treated acreage in 1997. Of this usage, almost all was in the form of carbofuran, applied to Monterey Bay perennials; the other carbamate was benomyl, a product no longer registered for artichoke, applied minimally in Orange County (probably for *Ramularia* leaf spot).

In sum, organophosphates and carbamates accounted for 14% of artichoke aggregate treated acreage in 1997, and virtually all of it was for pest control problems associated strictly with perennial artichoke cropping. These materials are generally considered by commercial growers to be indispensable to the large-scale production of perennial artichoke.

Usage of Potential Carcinogens (B1's and B2's):

Weeds are a problem in all three regions, in perennial and annual fields, and all use the potential carcinogen pronamide for weed abatement. It is used to control weeds during the early phase of artichoke plant establishment. It is generally considered by growers to be an indispensable pre-emergent herbicide with no alternative chemical materials. The other potential carcinogen used on artichoke fields is metam-sodium. At low rates, it kills soil borne diseases *Verticillium* and *Phthium*. At higher rates, it acts as an herbicide. Its usage in 1997 was limited to the South Coastal fields for disease control, and the desert for weeds and possibly for post-harvest desiccation of artichoke plants. As indicated by Figure 3, combined usage of potential carcinogens (B1's and B2's) on California artichoke contributed only 1% to aggregate treated acreage in 1997.



Appendix 1

Data Collection and Processing Procedures

Individual County Artichoke Acreage
Total artichoke acreage of 9300 ac for calendar year 1997, as reported in the California Vegetable Review (CASS) was consistent with total acreage of 9382 ac reported by the California Artichoke Advisory Board (CAAB) for *crop year* (July 1 - June 30) 1997-98. The CAAB report also provided total acreage by county. To estimate the county-by-county acreage for the 1997 calendar year CASS acreage, the percentage contribution of each county to the CAAB 1997-98 total was calculated, and the corresponding percentages were applied to the CASS total.

County Pesticide Use Reports
At the time of data compilation for this report, the most recent year for which statewide pesticide usage data were compiled and published by the California Department of Pesticide Regulation (CDPR) was 1995. However, individual counties had collected and processed 1997 data. To provide the most current usage statistics, Alliance staff requested pesticide

usage information for calendar year 1997 from agricultural commissioner's offices in each county in the San Joaquin Valley Region, Central Coast Region, South Eastern Region, and South Coastal Region. In addition, the agricultural commissioner's office in Sutter County (Northern Region) was contacted. This group of counties comprised all counties with artichoke acreage reported to CAAB, as well as other counties in the principal artichoke growing regions of California.

All counties responded with the requested data; only twelve reported pesticide usage on artichoke. Data was given to the Alliance in electronic media (i.e., floppy disk or E-mail) with the exception of data from Imperial County, which sent hard copy.

Summation of County Data
Individual county data was grouped by pesticide product, product application amount unit, and application method. For example, one group would consist of all applications on artichoke of Asana XL, with EPA no. 352-515, where units of product applied were expressed in gallons, and application method was by ground equipment. For these groups, the amount of product applied and the acres treated were summed, and the application instances were counted. This summed data from each county was combined into a single, statewide searchable database.

Active Ingredient Calculations
After the statewide database was compiled, all units of measure for dry materials were converted (if necessary) to pounds, and all units for liquids to gallons. The objective of making the conversions was to express applications of materials in units of lb ai/ac. For dry materials, once a material was expressed in lb, the percentage of active ingredient, as listed by the CDPR, was used to calculate the amount of active ingredient that was applied. Liquid products required the additional step of factoring in the product density, also obtained from CDPR. Density (lb/gal) was multiplied by the gallons of product applied for a corresponding weight, and the percentage of active ingredient was applied to this weight.

When all individual product applications were expressed in lb/ai, it was possible to combine data for applications of the same active ingredient regardless of product formulation. This report utilizes database queries to provide pesticide usage information for each active ingredient applied to artichoke, grouped by region and summed across all regions.

Aggregate Treated Acreage
The term "aggregate" acreage is the sum of area treated by a pesticide material. This summation may exceed the total planted acreage in some instances. It is not a definitive indicator as to whether or not all planted acreage was treated with pesticide. For example, a grower may have 100 ac artichoke planted. He/she may report four application instances of 50 ac each. This may mean that each half of the field was sprayed twice; it may also mean that same half of the field was sprayed four times. Regardless, the aggregate treated acreage for this 100 ac field would be 200 ac.

One statement that can be made based on the total aggregate acreage, however, arises when the aggregate treated acreage is less than the total acreage planted. If, for example, the aggregate treated acreage is 9 ac vs. 100 total acres planted, it is accurate to say that "less than 10% of planted acreage was treated," or "at most, 9% of planted acreage was treated."

Average Application Rate
The average rate of pesticide application is calculated simply as the total applied amount of active ingredient divided by the aggregate treated acreage. For example, Table A1 lists for esfenvalerate 2506.17 total lb ai applied to 62779.87 acres. The average rate is 0.04 lb ai/ac:

$$\frac{2506.17 \text{ lb ai}}{62779.87 \text{ ac}} = 0.04 \text{ lb ai/ac}$$

Esfenvalerate is typically applied on artichoke in the form of Asana XL, 0.66 Emulsible Concentrate. The calculated average application rate of 0.04 lb ai/ac is midway between the product label parameters of 0.03 to 0.05 lb ai/ac for artichoke plume moth.

Appendix 2

Pesticide Use Tables

Appendix Tables A1 - A4 present a listing of all chemical pest control materials (and plant growth regulators) applied to artichoke in calendar year 1997, based on data from county agricultural commissioners. Adjuvants (e.g., spreaders and stickers) are not included). Tables A1 - A3 show data for individual regions; Table A4 shows data for all regions combined.

Column Heading Key

- "chemical name" is the common name of the active ingredient.
- "number of applications" is the total number of times the active ingredient was applied to artichoke.
- "lb ai applied" is total pounds of active ingredient applied to artichoke.
- "acres treated" is aggregate treated acres.
- "avg. rate" is total lb ai divided by aggregate treated acres, for average lb ai/ac.

Table A1. 1997 Pesticide Usage on Central Coastal Artichoke

chemical name (ai)	*number of applications*	*lb ai applied*	*acres treated*	*avg. rate*
esfenvalerate	1442	2506.17	62779.87	0.04
diflubenzuron	749	3234.62	24672.84	0.13
methidathion	464	16307.18	18641.55	0.87
triadimefon	151	597.61	7923.00	0.08
oxyfluorfen	161	6336.48	7101.30	0.89
simazine	93	3933.97	6118.93	0.64
metaldehyde	64	2383.27	3141.50	0.76
gibberellic acid	156	33.08	3124.60	0.01
bacillus thuringiensis	221	657.99	3069.10	0.21
carbofuran	76	2801.87	2633.00	1.06

aluminum phosphide	37	91.71	1745.00	0.05
diphacinone	21	0.01	1417.50	0.00
pronamide	64	1256.17	885.79	1.42
permethrin	45	126.46	719.70	0.18
chlorophacinone	12	1.17	673.00	0.00
endosulfan	11	600.03	608.90	0.99
sethoxydim	12	177.48	497.40	0.36
azinphos methyl	4	578.85	385.90	1.50
pyrethrins	20	2.03	136.20	0.01
potash soap	12	729.86	124.00	5.89
rotenone	15	0.77	100.7	0.01
strychnine	2	0.04	64.00	0.00
napropamide	5	26.80	44.60	0.60
neem oil	4	161.98	36.00	4.50
piperonyl butoxide	5	11.05	35.50	0.31
azadirachtin	8	0.44	35.50	0.01
diuron	1	20.00	25.00	0.80
zinc phosphide	3	0.15	17.50	0.01

Table A2. 1997 Pesticide Usage on South Coastal Artichoke

chemical name (ai)	*number of applications*	*lb ai applied*	*acres treated*	*avg. rate*
permethrin	94	423.31	1705.63	0.25
bacillus thuringiensis	51	151.56	1221.70	0.12

gibberellic acid	78	90.86	1163.73	0.08
esfenvalerate	55	44.39	944.70	0.05
pyrethrins	36	7.05	653.90	0.01
rotenone	36	5.87	653.90	0.01
pronamide	40	177.15	545.38	0.32
metam-sodium	26	25621.46	472.40	54.24
methidathion	30	290.70	290.70	1.00
piperonyl butoxide	5	134.01	125.80	1.07
sulfur	2	27.30	110.00	0.25
benomyl	1	1.50	80.00	0.02
neem oil	3	116.25	48.50	2.40
endosulfan	2	23.11	40.00	0.58
sethoxydim	6	13.67	39.00	0.35
glyphosate	1	19.99	36.00	0.56
copper hydroxide	1	13.90	13.00	1.07
triadimefon	1	0.50	4.00	0.13
potash soap	1	4.37	1.00	4.37

Table A3. 1997 Pesticide Usage on South Eastern (Desert) Artichoke

chemical name (ai)	*number of applications*	*lb ai applied*	*acres treated*	*avg. rate*
gibberellic acid	46	53.12	1468.30	0.04
bacillus thuringiensis	50	95.48	1041.90	0.09
esfenvalerate	33	28.65	758.80	0.04

permethrin	19	84.01	516.20	0.16
pronamide	12	227.50	200.10	1.14
metam-sodium	4	13681.48	107.70	127.03
pyrethrins	6	1.04	95.10	0.01
rotenone	6	0.87	95.10	0.01
neem oil	6	288.79	95.10	3.04
oxyfluorfen		35.93	68.00	0.53
endosulfan	2	51.22	68.00	0.75
glyphosate		49.97	50.00	1.00
azadirachtin		0.71	40.00	0.02
spinosad	1	0.57	18.20	0.03
sethoxydim		3.15	9.00	0.35
mefenoxam		0.26	0.48	0.54

Table A4. 1997 Total Pesticide Usage on California Artichoke

chemical name (ai)	***number of applications***	***lb ai applied***	***acres treated***	***avg. rate***
esfenvalerate	1531	2579.82	64503.37	0.04
diflubenzuron	749	3234.62	24672.84	0.13
methidathion	494	16597.88	18932.25	0.88
triadimefon	152	598.11	7927.00	0.08
oxyfluorfen	161	6372.41	7169.30	0.89
simazine	93	3933.97	6118.93	0.64
gibberellic acid	285	183.95	5975.93	0.03

bacillus thuringiensis	323	906.95	5352.70	0.17
metaldehyde	64	2383.27	3141.50	0.76
permethrin	158	633.78	2941.53	0.22
carbofuran	76	2801.87	2633.00	1.06
aluminum phosphide	37	91.71	1745.00	0.05
pronamide	116	1660.82	1631.27	1.02
diphacinone	21	0.01	1417.50	0.00
pyrethrins	62	10.11	885.20	0.01
rotenone	57	7.51	849.7	0.01
endosulfan	16	685.35	727.90	0.94
chlorophacinone	12	1.17	673.00	0.00
metam-sodium	30	39302.94	580.10	67.75
sethoxydim	18	194.31	545.40	0.36
azinphos methyl	4	578.85	385.90	1.50
neem oil	13	567.03	179.60	3.16
piperonyl butoxide	10	145.06	161.30	0.90
potash soap	13	734.23	125.00	> 5.87
sulfur	2	27.30	110.00	0.25
glyphosate	1	69.96	86.00	0.81
benomyl	1	1.50	80.00	0.02
azadirachtin	8	1.15	75.50	0.02
strychnine	2	0.04	64.00	0.00
napropamide	5	26.80	44.60	0.60

diuron	1	20.00	25.00	0.80
spinosad	1	0.57	18.20	0.03
zinc phosphide	3	0.15	17.50	0.01
copper hydroxide	1	13.90	13.00	1.07
mefenoxam[3]		0.26	0.48	0.54

Contacts

Mohammad A. Bari,Ph.D.
Artichoke Research Association
1636 East Alisal
Salinas, CA 93905-3018
Phone: 831/755-2871
E-mail: mohdabari@aol.com

Frank V. Sances, Ph.D.
Alliance for Alternative Agriculture
1840 Biddle Ranch Road
San Luis Obispo, CA 93401
Phone: 805/594-1700
E-mail: alliance@thegrid.net

Research and Editing: J.T. Wingett

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California Artichoke Advisory Board. Castroville, California

Mohammad A. Bari, Ph.D. Artichoke Research Association. Salinas, California

Dale D. Huss. Sea Mist Farms. Castroville, California

Thomas K. Shannon. Kleen Globe, Inc. Castroville, California

John Giusti. Giusti Farms. Half Moon Bay, California

Steve Jordan & Charles Kolding. Jordan Brothers Farms. Lompoc, California

Frank Lenser. Western Farm Service. Santa Maria, California

Don Emanuelli. J. Emanuelli & Sons. Brawley, California

Daniel A Jungers. Pest Control Advisor. El Centro, California

Jim Hurt. Crop Protection Services. Holtville, California

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Fresno	Orange	San Joaquin
Imperial	Riverside	San Mateo
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Merced	Santa Cruz	Ventura

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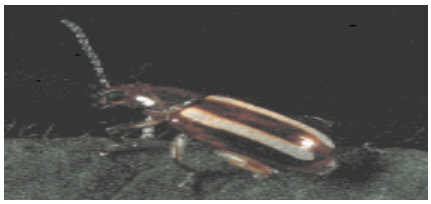

Alliance for Alternative Agriculture
San Luis Obispo, California

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