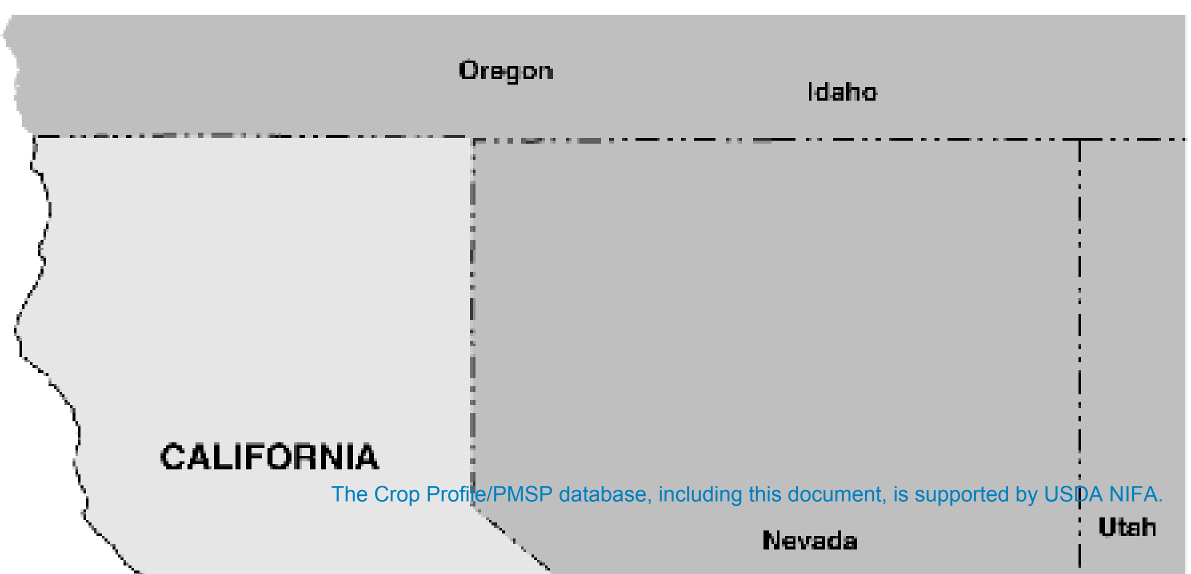
Crop Profile for Brussels Sprouts in California

Prepared: November, 1999

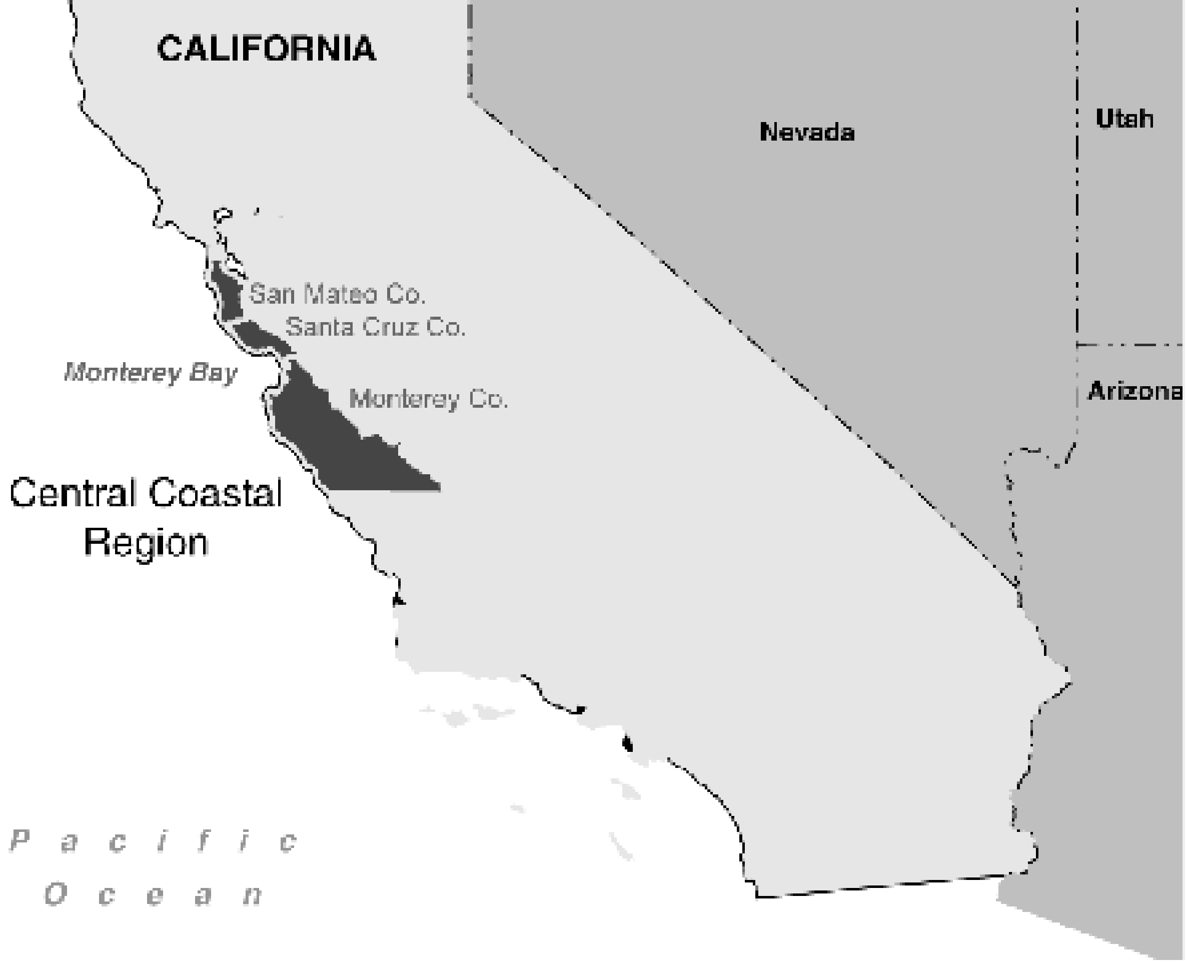
General Production Information

- California produced approximately 98% of all commercially grown Brussels sprouts in the United States in 1997, with New York accounting for the remaining 2% (NASS, 1999 and NYASS, 1999)
- Commercial Brussels sprouts acreage planted in California was 3,200 acres in 1997 and the same amount in 1998 (NASS, 1999).
- Brussels sprouts production in California totaled 25,600 tons in 1997 and the same amount in 1998 (NASS, 1999).
- Total value of California Brussels sprouts was $21,180,000 in 1997 and $22,249,000 in 1998 (NASS, 1999).
- A substantial majority of California Brussels sprouts, 80 to 85%, is processed for the frozen food market; the remaining 15 to 20% is sent to the fresh market.
- Total production costs for Brussels sprouts, including harvest costs, averages approximately $4100/ac.

Production Regions



Brussels sprouts were first introduced to commercial California agriculture *circa* 1920 with small plantings in San Mateo County (Knaster and Jarrell, 1997). Since that



time, Brussels sprouts production acreage has extended southward into Santa Cruz County and along the southern rim of Monterey Bay in Monterey County. Today, virtually all of California's Brussels sprouts acreage is located in this district (Fig. 1), which is part of the northern Central Coastal Region.

The cool temperatures and coastal fog that are characteristic of this district are ideal for Brussels sprouts production. This vegetable is considered to be "hardy," in that it is relatively resistant to frost and light freezes (Maynard and Hochmuth, 1997).

Brussels sprouts are grown in a wide range of soil types. The soil in San Mateo County, the northernmost Brussels sprouts county, is clay, which is prone to saturation during prolonged rains. Further south, the soils range from clay loam to silty sand.

Cultural Practices

Brussels sprouts, *Brassica oleracea* Gemmifera, belongs to the *Cruciferae* (mustard) family. Other members of *B. oleracea*, commonly referred to as cole crops, include cabbage (Capitata group), cauliflower (Botrytis group), and broccoli (Italica group).

Planting:

Brussels sprout seed is planted in greenhouses at the beginning of the annual growing season. This typically occurs from January through May, with seedlings ready for transplanting into fields 50 to 60 days later.

In preparation for transplanting, Brussels sprouts fields are treated with lime to raise the pH as a preventative treatment for club root disease. In addition to liming, A large percentage of fields is also fumigated with metam-sodium or 1,3-dichloropropene to control nematodes, and to provide additional suppression of club root. Bed size in Brussels sprouts fields is 36 inches, and the seedlings are planted in a single line, 12 to 18 inches apart depending on the variety planted.

Field Maintenance:

After the Brussels sprouts are transplanted, fields are irrigated through overhead sprinklers. This type of irrigation incorporates pre-plant herbicides and fertilizers into the soil and stabilizes the planting beds until root systems become established. Irrigation continues at weekly intervals in sandy soil, or two to three week intervals in heavier soil.

Pesticide applications begin soon after the Brussels sprouts are transplanted, and continue every 15 to 21 days until about two weeks before harvest.

Harvesting:

Prior to the 1960s, a typical Brussels sprouts field would be harvested by hand eight or nine times. Harvesters would pick from the bottom of the plant and work their way upwards with each subsequent harvest as the plant matured (Knaster and Jarrell, 1997).

Development of "one harvest" varieties in the 1960s led to a radical change in Brussels sprouts growing practices. Growers had been looking for a variety that could be mechanically harvested in one pass, so that labor costs could be reduced. Japanese-developed *Jade* hybrids allowed this. Rather than being harvested continuously, the plants are "topped" (*i.e.*, the apical mainstem is pinched or removed) when the sprouts at the bottom of the stalk begin to mature. This procedure stops the growth of the plants and forces the remaining sprouts to mature uniformly, thereby allowing the field to be harvested mechanically, in one pass, 50 to 60 days after topping. This harvesting method has greatly reduced labor requirements in what previously had been a labor intensive crop production system.

Since the introduction of *Jade* hybrids, newer machine-harvested varieties have been developed. *Capitola* and *Content* mature in 130 to 150 days after transplanting and are generally grown for the October-through-November market. *Rowena*, a variety that matures 180 to 195 days after transplanting, is a popular variety grown for the November-through-January market (Pfyffer, 1999).

Although the majority of fields are mechanically harvested, approximately 18% are hand picked for the fresh market. A widely grown variety for this market is *Oliver*, which matures relatively quickly at 90 days after transplanting. Brussels sprouts fields growing *Oliver* are hand picked four to five times over a period of eight to ten weeks (Pfyffer, 1999). Another popular hand-picked variety, *Rampart*, is normally harvested later in the season than *Oliver*.

Insect Pests

Aphids

Prior to 1997, aphids were the most threatening pests to Brussels sprouts production in California, and attempts to control this insect dominated pest management strategies. In 1997, diamondback moth (*Plutella xylostella*, see below) began to infest Brussels sprouts fields, and causing serious crop losses that year. Today, diamondback moth is considered to be the primary pest in Santa Cruz and Monterey Counties, while aphids remain the key pest in San Mateo County, where cooler temperatures have kept diamondback moth in check.

It is critically important to prevent initial aphid infestation of the plant, since once aphids have infested the sprouts, further pest control measures are largely futile. The most troublesome species is the cabbage aphid, followed by the green peach aphid.

Brussels sprouts plants grow to approximately three feet in height, with 80 to 100 sprouts at plant maturity. The complex morphology of the plant, comprising leaves and the sprouts themselves, provides many hiding places for aphids. This makes the crop so desirable to this pest, that it is sometimes planted at the borders of fields growing other crops to attract aphids away from those fields.

Cabbage Aphid, *Brevicoryne brassicae*

Adult cabbage aphid females asexually produce live offspring, and populations can increase to damaging levels very rapidly. As many as 21 generations per year can occur in warmer climates. When populations become numerous, winged forms are produced, which then disperse and re-infest new plants (UC, 1987).

Generally the cabbage aphid is gray green in appearance with a waxy bloom. Aphids are sap sucking insects 1/16 to 1/8 inch long and feed by inserting a stylet into the plant’s vascular system and sucking cell sap, causing the leaves to become curled and crinkled. If untreated, moderate levels of infestation will cause yellowing and stunted plant growth. The presence of aphids on the commodity at harvest

constitutes adulterated, unmarketable product, and damage from larger infestations can result in death of the plant. Infestations of cabbage aphid threaten marketable yield losses of 100% if not treated.

Green Peach Aphid, *Myzus persicae*

Green peach aphid also infests fields sporadically. Heavy populations are particularly injurious to seedlings. This aphid tends to feed on the leaves of older plants, and does not usually damage mature sprouts. However, if untreated, this insect will infest mature sprouts on the lower part of the plant.

Chemical Control:
It is important to prevent the establishment of cabbage aphid in Brussels sprouts during the early stages of plant growth. This aphid is a difficult pest to control once the canopy has developed and the sprouts have formed.

Chemical control of aphid on California Brussels sprouts is dominated by the organophosphate (OP) class of compounds.

Chlorpyrifos [OP] *See also Cabbage Maggot, Worms (Alternative)*

- Trade Name & Formulation: Lorsban 50 W, 4 E

- Typical Application Timing & Frequency: First application is made 3 weeks after transplanting (before cultivation), then reapplied at 3 to 4 week intervals, for a total of 3 to 6 applications per season. (Maximum allowed by label is 6 applications per season.)
- Typical Application Method & Rate: Applied by tractor boom at label maximum rate of 1.0 lb ai/ac.
- REI & PHI: 24 hour restricted entry; 21 day pre-harvest interval

  Chlorpyrifos [OP] (Lorsban) has been called the "linchpin" of commercial Brussels sprouts production, because pest control programs for this vegetable revolve around it (D. Lea, personal communication, 1999). Chlorpyrifos is faster acting than oxydemeton-methyl (Metasystox-R), dimethoate, and imidacloprid (Provado, Admire), three materials that are used to a lesser extent on Brussels sprouts for aphid control (Pfyffer, 1999).

  Chlorpyrifos was applied to 9,175 ac in 1997 (*see Appendix 1, Terminology, Aggregate Treated Acreage*). As determined by usage of the 50 W and 4 E formulations, 7,433 ac were treated with this material for cabbage aphid control.

  Statewide Coverage for 1997, based on 4.5 applications per field, is estimated to be 64% (*see Appendix 1, Terminology, Statewide Coverage*).

Dimethoate [OP]

- Trade Name & Formulation: Dimethoate 4 EC
- Typical Application Timing & Frequency: Applied 3 to 4 times per season. (Label limits number of applications to 6 per season.)
- Typical Application Method & Rate: Ground applied at label maximum rate of 1.0 lb ai/ac, tank-mixed with chlorpyrifos.
- REI & PHI: 48 hours restricted entry; 10 days pre-harvest interval.

Although the primary pest control material applied against cabbage aphid is chlorpyrifos (Lorsban), the systemic insecticide dimethoate is added to the "tank mix" with (non-systemic) chlorpyrifos approximately two times per season. This helps to prevent pest resistance to chlorpyrifos, and to increase aphicidal efficacy during periods of high infestation. Dimethoate is also effective against green peach aphid .

Dimethoate was applied to 5,660 ac in 1997. This represents a 53% increase over 1995 usage. It was the third most commonly used pesticide on Brussels sprouts, behind chlorpyrifos (Lorsban) and the fungicide chlorothalonil (Bravo).

Statewide Coverage for 1997, based on an average of 3.5 applications, is estimated to be 51%. However, with the phasing-out of methamidophos (Monitor, *cf.* Alternatives, below), dimethoate usage is likely to be higher now than in 1997.

Oxydemeton-methyl [OP]

- Trade Name & Formulation: Metasystox-R Spray Concentrate (25%)
- Typical Application Timing & Frequency: 2 to 3 applications (Label restricts applications to 3 times/season.)
- Typical Application Method & Rate: Applied by air or ground spray at 0.50 lb ai/ac (label maximum).
- REI & PHI: 48 hours restricted entry, extended to 72 hours where average rainfall is less than 25 inches per year; 10 days pre-harvest interval.

Oxydemeton-methyl (Metasystox-R) was applied to 5,112 ac in 1997. It was the third most commonly used material for aphid control, and the sixth most commonly applied pesticide on Brussels sprouts. The label prohibits ground spray applications of this product within 100 feet of an occupied building, or within 150 feet for aerial applications. Because of this restriction, imidacloprid (Provado, see below) is sometimes substituted for oxydemeton-methyl for aphid control in these areas.

Statewide Coverage for 1997, based on average of 2.5 applications, is estimated to be 64%.

Diazinon [OP] *See also Cabbage Maggot (Alternative)*

- Trade Name & Formulation: Diazinon 4E
- Typical Application Timing & Frequency: 2 to 3 times per season.
- Typical Application Method & Rate: Applied by air or ground spray at label maximum rate of 0.50 lb ai/ac
- REI & PHI: 24 hours restricted entry; 7 days pre-harvest interval

  Diazinon was applied to 3,563 ac in 1997, predominantly for cabbage aphid control. However, some applications may have been made in an attempt to control the diamondback moth outbreak that year, prior to the registration of spinosad (Success). Total ai applied to Brussels sprouts in 1995 was 2,130 lb (DPR, 1996) vs. 3,563 lb in 1997, although planted acreage was actually less in 1997. With the registration of spinosad for DBM, current usage may have declined to 1995 levels.

  Statewide Coverage for 1997, based on an average of 2.5 applications, is estimated to be 45%.

<u>Imidacloprid</u>
Imidacloprid is a systemic, chloronicotinyl insecticide with foliar and soil uses. It interferes with transmission of stimuli in insect nervous systems, and the chemical is selectively toxic to insects only. It is manufactured in two formulations, Provado 1.6 F (a foliar spray).and Admire 2 F (a systemic soil treatment):

Provado 1.6 F (Foliar Spray)

- Typical Application Timing & Frequency: Applied 2 to 3 times towards end of season.
- Typical Application Method & Rate: Foliar application at average rate of 0.04 lb ai/a. Label restricts foliar use to a total of 0.23 lb ai/ac per year, and prohibits applications through irrigation system.
- REI & PHI:12 hours restricted entry; 7 days pre-harvest interval.

  The foliar spray formulation of imidacloprid was applied to 1,187 ac in 1997. It ranks behind four OPs in treated acreage for cabbage aphid control. This relatively low usage against a key pest may be explained by high product cost, coupled with poor efficacy as a foliar application. The manufacturer’s label states: "Provado 1.6 Flowable will not knock down heavy aphid or whitefly populations." However, it is still an important insecticide for management of aphid resistance to OPs.

  Statewide Coverage for 1997, based on 1.5 applications, is estimated to be 25%.

Admire 2 F (Soil Treatment)

- Typical Application Timing & Frequency: Applied to soil once at sidedressing.

- Typical Application Method & Rate: Soil incorporated at application at average rate of 0.26 lb ai/a.
- REI & PHI:12 hours restricted entry; 21 days pre-harvest interval.

The soil treatment formulation of imidacloprid was applied to only 441 ac in 1997. Usage is limited by the relatively high cost of the product and the difficulty in applying it. It is efficacious for approximately 80 days after application. This is long enough for the relatively few fields planted with the hand-picked *Oliver*, which matures in approximately 90 days after transplanting. For most other varieties, with transplant-to-harvest intervals from 130 to 195 days, a supplemental foliar spray program is necessary to control aphid for the late season.

Statewide Coverage for 1997, based on 1 application, is estimated to be 14%.

Imidacloprid controls green peach aphid as well as the primary pest, cabbage aphid. Most usage of this material was in San Mateo County, in the northern tip of the Central Coastal Region.

While the foliar spray (Provado) was applied to more aggregate acreage than the soil formulation (Admire), more lb ai was applied as a soil treatment than as a foliar spray, by a ratio greater than 2:1.

Manufacturer's labels for Admire and Provado limit total imidacloprid (soil applications + foliar applications) to a cumulative 0.50 lb ai/ac per year.

Imidacloprid (Provado + Admire) was applied to 1,627 ac in 1997, ranking usage of this material tenth highest among all pesticides applied to Brussels sprouts.

Disulfoton [OP]

- Trade Name & Formulation: Di-Syston, 8 EC and 15% Granular
- Typical Application Timing & Frequency: Disulfoton is usually applied once at side dressing. (Label maximum is 2 applications/season.)
- Typical Application Method & Rate: Soil incorporated at the maximum label rate of 1.0 lb ai/ac.
- REI: 72 hours restricted entry in areas with less than 25 inches rainfall/year; otherwise, 48 hours.
- PHI: 30 days pre-harvest interval.

Disulfoton is a systemic insecticide that was applied to 595 ac in 1997, a decrease of over 40% from 1995 usage. It is being replaced to some extent by another systemic insecticide, imidacloprid (Admire), for control of cabbage aphid and green peach aphid.

Statewide Coverage for 1997, based on 1 application, is estimated to be 19%.

Endosulfan *See also Diamondback Moth (Alternative)*

- Trade Name & Formulation: Thiodan 3 EC, 50 WP
- Typical Application Timing & Frequency: Two early-season applications; label restricts applications to four per year.
- Typical Application Rate & Method: Applied by ground at 1.00 lb ai/ac (label maximum).
- REI & PHI: 24 hours restricted entry; 7 days pre-harvest interval.

Endosulfan was applied to 376 ac in 1997. It is applied to control aphid, and as a rotational material with spinosad for diamondback moth. This pesticide is a non-systemic organochlorine.

Statewide Coverage for 1997, based on 2 application, is estimated to be 6%.

Malathion [OP]

- Trade Name & Formulation: Malathion 8 EC
- Typical Application Timing & Frequency: Applied 2 to 3 times per season.
- Typical Application Method & Rate: Spray applied by ground equipment at 1.50 lb ai/ac (low end of label rate) as part of tank mix with chlorpyrifos or imidacloprid.
- REI & PHI: 12 hours restricted entry; 3 days preharvest interval.

Malathion (Malathion 8) was applied to only 114 ac in 1997, less than 4% of California Brussels sprouts acreage.

Alternative Chemical Controls:

Naled [OP] (Dibrom) *See also Worms*
Naled is registered for aphid on Brussels sprouts. However, the application rate in 1997 was predominantly 2.0 lb ai/ac, which is twice the rate for aphid, but which is appropriate for looper control. This suggests that grower preference was to apply this material for cabbage looper, although the higher rate would control aphid as well.

Potash Soap (M-Pede)
Potash soap (also known as potassium salts of fatty acids) is an acceptable pest control material for organically certified production. Due to the attractiveness of Brussels sprouts to aphid and the morphology of the plant, cabbage aphid is difficult to control with soaps. Numerous applications, at weekly intervals in some cases, are necessary to reduce aphid populations. Even with this usage regime, control of cabbage aphid on Brussels sprouts with insecticidal soap is extremely difficult.

In 1997, potash soap was used on an insignificant amount of Brussels sprouts acreage (9 ac).

Methamidophos [OP] (Monitor 4 L) *See also Worms*
Methamidophos was applied to 2,255 ac in 1997, ranking this material ninth in usage of all pesticides

applied to Brussels sprouts that year. It was applied for aphid and cabbage looper. However, the manufacturer no longer supports registration for cole crops.

Pymetrozine (Fulfill)
Pymetrozine, in EPA review for registration, is a reduced risk alternative to organophosphate insecticides. This is a new chemistry that should be excellent as a resistance management material.

Pirimicarb [CARB] (Pirimor)
Pirimicarb is a carbamate in the registration process for cole crops. It is unusual in that it is highly selective for *Aphididae*.

Piperonyl butoxide
Piperonyl butoxide is an insecticide synergist that is often tank mixed with pyrethrins for aphid control on other cole crops, but it was not applied to Brussels sprouts in 1997. Piperonyl butoxide is listed as an insecticide, but it would not be highly efficacious if applied alone. However, some product formulations (*e.g.*, Diacide, Pyrenone) are a mixture of piperonyl butoxide and pyrethrins.

Biological Controls:
Diaertiella rapae, a parasite, can help aid in the control of aphid, but cannot control large infestations. Aphids are also preyed upon by lady beetles, green lacewing and syrphid larvae (Metcalf, 1993). However, once the aphid gets inside the sprout, predators have difficulty reaching them, and their effectiveness as biological control agents is minimized. Commercial Brussels sprouts growers tend to be skeptical regarding the practicality of using predators for cabbage aphid control.

In addition to issues of efficacy, the *availability* of biological control agents is an important consideration when planning a pest control program. Organic growers typically release large quantities (25,000 to 100,000/ac) of lacewing eggs and young larvae for control of cabbage aphid on some crops, in combination with insecticidal soaps (*e.g.*, M-Pede). This has been successful, in some cases, during periods of low to moderate insect pressure. In medium to high pressure situations, however, fields so treated are often not harvestable due to insect contamination in sprouts.

Cultural Control Practices:
Owing to their genetic similarity to wild mustards, Brussels sprouts and other cole crops are often surrounded by non-crop unsprayed areas that are alternate hosts for cabbage aphid. Cabbage aphid can infest Brussels sprouts and wild mustard concurrently, and therefore adjacent weedy areas must be kept clean of this source of aphid colonization. Tillage and herbicides can be used in an effective field sanitation program to minimize aphid pressures.

Hand washing of the commodity, which may effectively remove aphids from other crops at harvest, does not work for Brussels sprouts due to the tightness of the heads and the propensity for cabbage aphid to infest inner sprout leaves.

<u>Diamondback Moth</u>, *Plutella xylostella*

The adult diamondback moth is about 1/3 inch long and is gray in color. It overwinters under the remnants of *Brassica* foliage left in the field (Metcalf, 1993), and infests Brussels sprouts throughout the growing season. Eggs are laid in small groups of 1 to 3 on the under side of leaves, and hatch in 5 to 10 days. Young larvae often mine within the leaf tissue, and as they mature, feed on the young heart shaped leaves and the under side of the leaves of more mature plants (Phillips, 1998). In 10 to 14 days the larvae reach maturity and spin a cocoon on the leaves, stems, or under the plant. The adult moth emerges within 1 to 2 weeks.

Larval damage can destroy the growing tip and bud tissue early season when plants are juvenile. Later in the season, larvae can also infest the developing sprouts, causing direct damage to the harvestable portion of the crop.

DBM can produce up to ten generations in one year.

The 1997 DBM outbreak on Brussels sprouts was extremely severe. Pest control costs were doubled from insecticides applied for control of this pest, and several fields were abandoned entirely from high levels of DBM infestation in sprouts. Since that year, DBM has not been a threat in the cooler areas of San Mateo County, but it persists in the warmer counties to the south.

Chemical Control:
The propensity for DBM rapidly to develop resistance to insecticides distinguishes it from the other lepidopterous pests of Brussels sprouts. Resistance to organophosphates and carbamates in the early 1980's was followed by resistance to pyrethroids and the *kurstaki* strain of *Bacillus thuringiensis* in the early 1990's. In response to heavy infestations of DBM in 1997, spinosad was issued a California Section 18 Emergency Exemption for use on leafy vegetables and non-leafy brassica. Since that time it has increased in usage rapidly and become the product of choice by Brussels sprouts growers for control of DBM.

<u>Spinosad</u> *See also Worms*

- Trade Name & Formulation: Success (suspension concentrate)
- Typical Application Timing & Frequency: Applied 2 times per season, at any stage of plant development. Label restricts number of applications to 3 within a 30-day period, and 6 per season.
- Typical Application Rate & Method: Foliar spray by tractor-mounted boom or aircraft at average rate of 0.09 lb ai/ac.
- REI & PHI: 4 hour restricted entry; 1 day pre harvest interval

A Section 18 emergency exemption for use of spinosad on *Brassica* was issued late in 1997. It is

now fully registered for use in California. Spinosad was applied to only 627 ac of Brussels sprouts in 1997, but data for that year can be expected to understate current annual usage due to the timing of the Section 18.

Spinosad is also used to control cabbage looper, imported cabbageworm, and beet armyworm on Brussels sprouts. The product label prescribes very low rates (0.023 lb to 0.062 lb ai/ac) for diamondback moth, higher rates (0.047 lb to 0.094 lb) for imported cabbageworm and cabbage looper, and the highest rates (0.062 lb to 0.156 lb) for beet armyworm. This product is very safe to use and is highly selective to lepidopterous larvae.

Alternative Chemical Controls:

Endosulfan (Thiodan) *See also Aphid*
The primary utility of endosulfan for control of DBM is as a rotational larvacide for resistance management.

Lambda-cyhalothrin (Warrior) *See also Worms (Alternative)*
Lambda-cyhalothrin is only efficacious against DBM populations that are not resistant to pyrethroids. It was not labeled for use on Brussels sprouts until 1998. Current usage data is therefore not available, although anecdotal information indicates that this product is now being widely used by Brussels sprouts growers (K. McCaig, personal communication, 1999).

Cryolite (Kryocide) *See Worms (Alternative)*

Emamectin benzoate (Proclaim) *See also Worms (Alternative)*
This semi-synthetic avermectin insecticide was registered for use in the United States in May, 1999. California registration is pending. The product has been used commercially in Hawaii, and has proven to be highly efficacious against diamondback moth. The product label also lists uses for cabbage looper, beet armyworm, and imported cabbageworm. When fully registered, this material will become a sound resistance management partner with spinosad.

Biological Controls:

Bacillus thuringiensis, subsp. aizawai

- Trade Name & Formulation: Agree WP (soluble pouch)
- Typical Application Timing & Frequency: 1 to 3 applications early-season, when plant coverage is maximized.
- Typical Application Rate & Method: Sprayed from tractor-mounted boom at average rate of 0.08 lb ai/ac (label maximum). For this material to be effective, applications must be made when the larvae are young and feeding on treated, exposed plant surfaces.
- REI & PHI: 4 hour restricted entry, no pre-harvest interval.

DBM was the first insect to demonstrate resistance to *Bacillus thuringiensis* (*Bt)* in field populations. This initial resistance was to the *kurstaki* strain in Hawaii, and by the early 1990's, the product was failing to control DBM. Another *Bt* strain; *aizawai*, has subsequently increased in usage. However, field testing (Liu, 1996) indicates that DBM has developed a low level of resistance to the *aizawai* strain as well. Although the product is only moderately efficacious against DBM, it is commonly used early season and is needed to retard the development of DBM resistance to spinosad, the primary control material at this time.

The *aizawai* strain of *Bt* was applied to 474 ac in 1997. Statewide Coverage with this strain, based on 2 applications, is estimated to be 7%.

Predators

Several natural enemies can help control the level of diamondback moth in the field. *Trichogramma pretiosum* attack diamondback eggs, and ichneumonid wasp, *Diadegma insularis* attack the larvae. None are effective alone for control of DBM in commercial fields.

Cultural Control Practices:

Keeping plants and adjacent fields clean, and practicing a crop rotation program, can help lower the incidence of economic damage from diamondback moth. These controls are currently practiced by Brussels sprouts growers.

Cabbage Maggot, *Delia radicum*

The cabbage root maggot fly is dark gray and about 12 mm (0.47 in) in length. The white larvae are 8mm (0.31 in) at maturity, and are found in dense colonies developing on the feeder and taproot of cole crops. Several hundred larvae can be found on one plant. Larvae feed for 3 to 5 weeks, and then pupate in the soil or on the roots of a host plant. After 2 to 3 weeks pupation the adult fly emerges. Two to 3 or more generations may occur per year.

Injury from maggots can cause stunting, yellowing, and even plant wilting during the hot period of the day. The young seedling is most susceptible to permanent damage (UC, 1987). Injury from root maggots also provides an entry point for pathogens.

Chemical Control:

Chlorpyrifos [OP] *See also Cabbage Aphid, Worms (Alternative)*

- Trade Name & Formulation: Lorsban 15 G
- Typical Application Timing & Frequency: One treatment per season, applied at time of

transplanting.
- Typical Application Rate & Method: Soil incorporated at average rate of 1.18 lb ai/ac.
- REI & PHI: 24 hours restricted entry; no pre-harvest interval (applied at planting).

Lorsban is the most efficacious insecticide for the control of cabbage maggot in Brussels sprouts. Pesticide usage data for 1997 indicate that chlorpyrifos as a cabbage maggot treatment (determined by usage of the 15 G formulation) was applied to 1,743 ac, for Statewide Coverage of 54%.

Azinphos-methyl [OP]

- Trade Name & Formulation: Guthion 50 WP
- Typical Application Timing & Frequency: One application, generally late in season after rainfall.
- Typical Application Rate & Method: Foliar spray from tractor-mounted boom at 0.75 lb ai/ac (label maximum).
- REI & PHI: 48 hours restricted entry, extended to 72 hours if rainfall < 25 inches/year; 21 days pre-harvest interval

Azinphos-methyl is normally tank-mixed with chlorpyrifos (Lorsban) 4 E or 50 W for control of cabbage maggot after periods of rainfall. This material also has activity against worms.

Azinphos-methyl was applied to 1,046 ac in 1997, for Statewide Coverage of 33%. Total lb ai applied was more than double the 1995 amount (DPR, 1996), though planted acreage was less in 1997. Azinphos-methyl is also labeled for DBM, which suggests that some of the 1997 applications may have been made in an attempt to control the outbreak of DBM that year. Subsequent to the registration of spinosad (Success) in 1997, usage of azinphos-methyl may have decreased to 1995 levels. (Post-1997 usage data is not available.)

Alternative Chemical Controls:

Diazinon [OP] *See also Aphid*
Diazinon is registered for use against cabbage maggot, but it is not as efficacious as chlorpyrifos. Application rates for diazinon in 1997 confirm that the material was used very little as a soil treatment for cabbage maggot. The rates were predominantly in the 0.50 lb ai/ac range, which is too low for control of cabbage maggot, (but appropriate for aphid).

Fonofos [OP] (Dyfonate)
Fonofos can be used as a preplant insecticide. However, the manufacturer has discontinued the product because of low profitability. Existing supplies can be used until December 31, 2001, at which time registration will expire and the manufacturer will buy back remaining product.

Biological Controls:

There are no known effective biological controls for this pest.

Cultural Control Practices:
Cultural practices offer an alternative to prophylactic applications of soil insecticides. Since maggots require crop residue and high organic matter in soil to persist between crops, fallowing fields for even short periods can reduce maggot incidence significantly. This is particularly true if soil is allowed to dry between plantings. Deep plowing and cultivation to bury organic matter deep underground can also reduce maggot pressure. Any other method of cultivation or crop management directed at avoidance of organic matter in the seed row, can reduce maggot incidence and damage to the young crop.

Worms

While diamondback moth has distinguished itself as an especially troublesome pest, Brussels sprouts growers typically refer to other lepidoptera in the aggregate as simply "worms." These include primarily cabbage looper, imported cabbageworm, and beet armyworm.

Cabbage Looper

Loopers are distinguished from most other common worms by the loop that is formed by the arch of their backs as their rear legs move forward to meet their front legs when they crawl. Cabbage loopers are green in color, with a white stripe along each side, and several narrow lines down their back (UC IPM, 1997). The larvae feed for 2 to 4 weeks, then spin a cocoon and pupate. Adults are brown in color and emerge in about 10 days (UC, 1987).

Cabbage looper feeds on the leaves, occasionally damaging seedlings, but they inflict the most economic damage directly to the sprout heads. Aside from the damage caused to the sprouts from chewing, cabbage loopers deposit fecal matter and their post-mortem remains on the sprouts, rendering the commodity adulterated and unmarketable.

Imported Cabbageworm

Imported cabbageworm larvae are green, often with a faint yellow stripe down their back, and reach 1 inch in length. Larvae feed for two to three weeks on the leaves and bore into the sprout heads. As with the cabbage looper, economic damage from imported cabbageworm is the result of direct feeding or contamination of the heads.

Beet Armyworm

Beet armyworm (BAW), as well as other armyworms, attacks many crops including lettuce and cole crops. The coastal areas are subject to infestations of armyworm from June through October.

The adult beet armyworm (BAW) moth is mottled brown with gray front wings, and lighter gray hind wings. This pest overwinters in the adult stage (Davidson and Lyon, 1979). BAW eggs are laid in scale-covered cottony masses on the leaf surface. The larvae are normally olive green with light stripes down the back and sides. The first instar feeds near the hatch, skeletonizing the leaf, and can consume the entire seedling leaf. Mature larvae are up to 1.5 inches long (UC IPM, 1997).

BAW is most threatening to young foliage and buds, and economic damage is primarily from stunted plant growth as a result of feeding damage.

Chemical Control:

Permethrin

- Trade Name & Formulation: Pounce, 3.2 EC and 25 WP; Ambush 25 W
- Typical Application Timing & Frequency: 2 to 4 applications at any plant growth stage.
- Typical Application Rate & Method: Sprayed by air or ground 0.10 lb ai/ac (maximum label rate).
- REI & PHI: 12 hours restricted entry; 1 day pre-harvest interval.

  While diamondback moth has shown resistance to permethrin in California, cabbage looper and imported cabbageworm remain highly susceptible to this product. It is efficacious to a lesser extent against beet armyworm.

  Permethrin was applied to 5,654 ac in 1997, ranking this material fourth in usage of all pesticides on California Brussels sprouts.

  Estimated Statewide Coverage for 1997, based on 3 applications, is 59%.

Methomyl [CARB] (Lannate)

- Trade Name & Formulation: Lannate 90 SP (water soluble bags)
- Typical Application Timing & Frequency: 3 applications. Label limits total number of applications to 10/season.
- Typical Application Rate & Method: Sprayed from tractor-mounted boom at average rate of 0.78 lb ai/ac. Label limits total applications to 5.4 lb ai/ac per season
- REI & PHI: 48 hours restricted entry; 3 days pre-harvest interval

  Methomyl was applied to 5,141 ac in 1997, ranking this material fifth in usage of all pesticides applied to Brussels sprouts in 1997. However, methomyl usage increased sharply from 1995 to 1997. Data for 1995 (DPR, 1996) indicate that 269 lb ai was applied that year, compared to 4,019 lb ai in 1997 (when planted acreage was less). This increase can be attributed to an unusually heavy infestation of Diamondback moth (DBM) in 1997. It is estimated that Statewide Coverage

with methomyl in an attempt to control DBM was 90% that year. Unfortunately, DBM had developed resistance to carbamates, as well as to OPs, pyrethroids, and some *Bt'*s. The solution was a new "naturalyte" chemistry, spinosad (Success), which was registered for use in late 1997.

Post-1997 usage data is not currently available, but it is expected that methomyl usage has dropped substantially from the 1997 level. It is used mainly for control of beet armyworm and, to a lesser extent, cabbage looper and imported cabbageworm.

Naled [OP] *See also Aphid (Alternative)*

- Trade Name & Formulation: Dibrom 8 EC
- Typical Application Timing & Frequency: Applied 2 to 3 times per season, with one application close to harvest to benefit from relatively short PHI.
- Typical Application Rate & Method: Applied by ground at 2.0 lb ai/ac (maximum label rate)
- REI & PHI: 24 hours restricted entry; 1 day pre-harvest interval.

Naled was applied to 349 ac in 1997. Statewide Coverage for that year, based on 1.5 applications, is estimated to be 7%.

Spinosad (Success) *See also Diamondback Moth*
Spinosad is typically tank mixed with permethrin (Ambush, Pounce) or *Bacillus thuringiensis* (*cf.* Biological Controls, below) for control of lepidopterous larvae in general (although its primary target is diamondback moth). Label rates are highest for beet armyworm (0.062 to 0.156 lb ai/ac).

Alternative Chemical Controls:

Chlorpyrifos [OP] (Lorsban) *See also Cabbage Aphid, Cabbage Maggot*
Cabbage looper, imported cabbageworm, and beet armyworm are not generally the target pests for chlorpyrifos, but when it is applied for aphid control, this pesticide has the effect of reducing these populations as well. It is also an effective resistance management alternative to permethrin.

Carbaryl [CARB] (Sevin)
Carbaryl was applied to less than 1% of the California Brussels sprouts acreage in 1997. It can be used in place of methomyl [CARB] (Lannate) for control of beet armyworm, cabbage looper, and imported cabbageworm, but it is only effective at relatively low population pressure.

Cypermethrin (Ammo 2.5 EC)
Cypermethrin is a pyrethroid that can be rotated with organophosphates and carbamates for resistance management. It was not registered for use on California Brussels sprouts until 11/19/97. Current usage data is not available, although anecdotal information indicates that this product is being used to a significant extent by some Brussels sprouts growers (K. McCaig, personal communication, 1999).

Lambda-cyhalothrin (Warrior) *See also Diamondback Moth (Alternative)*
Lambda-cyhalothrin is efficacious against cabbage looper, imported cabbageworm, and first and second instars of beet armyworm. It was not labeled for use on Brussels sprouts until 1998. Current usage data is not available, although anecdotal information indicates that this product is being widely used by Brussels sprouts growers (K. McCaig, personal communication, 1999).

Azadirachtin (Neemix)
This product is a botanical pesticide that is allowed restricted usage in certified organic production. However, this product is relatively expensive, and inconsistently efficacious. It was applied to negligible Brussels sprouts acreage in 1997.

Emamectin benzoate (Proclaim)
Emamectin benzoate should receive federal registration in 1999, followed by California registration in 2000. It is expected to become an important larvacide for lepidopterous pests.

Cryolite (Kryocide)
Cryolite is an alternative chemical worm control material. This material is a mineral compound (sodium aluminofluoride) that is an effective stomach poison on many types of chewing insects, particularly *lepidoptera*. It is also effective against DBM as well as beet armyworm, but it is slow-acting. It has the advantage of having no adverse impact on beneficial insects, and can be an effective resistance management material. In its pure, mined, mineral form, it is an acceptable restricted-use organic farming insecticide.

In 1997, cryolite was not applied to Brussels sprouts acreage. This lack of usage may have been due to the difficulty in achieving complete leaf coverage for acceptable levels of control, given the complex canopy of mature Brussels sprouts plants.

Methamidophos [OP] (Monitor 4 L) *See also Aphid*
Methamidophos was applied to 2,255 ac in 1997, ranking this material ninth in usage of all pesticides applied to Brussels sprouts that year. It was applied for aphid and cabbage looper. However, the manufacturer no longer supports registration for cole crops. It is being replaced by permethrin for looper control.

Bifenthrin (Capture)
Bifenthrin received a Section 18 exemption in 1997 for use on broccoli and cauliflower. Registration has not been reactivated for these crops. It is currently registered only for use on cotton. It would be a useful material for resistance management were it to receive registration for BAW and cabbage looper on Brussels sprouts.

Esfenvalerate (Asana)
Esfenvalerate is used for looper control on other cole crops, but it is not registered for use on Brussels sprouts.

Thiodicarb [CARB, B1B2] (Larvin)
Thiodicarb is used for looper control on other cole crops, but it is not registered for use on Brussels sprouts.

Tralomethrin (Stryker)
Tralomethrin has shown good efficacy against looper on broccoli, but it is not registered for use on Brussels sprouts.

Tebufenozide (Confirm 2F)
This material was granted Section 18 Emergency Exemptions for BAW on broccoli in 1997 and 1998. It is not registered for Brussels sprouts. However, this chemistry is potentially an important resistance management tool. Its high degree of selectivity for BAW also makes it well suited for Integrated Pest Management strategies.

Biological Controls:

Bacillus thuringiensis, subsp. kurstaki

- Trade Name & Formulation: Mattch Aqueous Flowable
- Typical Application Timing & Frequency: 1 to 3 applications during early stages of plant development. (At later stages, when canopies close, spray penetration is obstructed and a higher level of insecticidal efficacy is required. In these cases, pyrethroids are preferred.).
- Typical Application Rate & Method: Sprayed by ground at 0.64 lb ai/ac. Commonly tank mixed with other materials.
- REI & PHI: 4 hours restricted entry, no pre-harvest interval.

  Bacillus thuringiensis materials in general are an important component of resistance management for pyrethroids and all other conventional chemistries on this crop. *Bt'*s have no effect on beneficial insects, and are not hazardous to field personnel. The short PHI (*i.e.*, 4 hours restricted entry) allows applications to be made very close to harvest.

  The *kurstaki* strain of *Bt* was applied to 2,561 ac in 1997. It is efficacious against cabbage loopers and imported cabbageworm, and is relatively inexpensive to apply.

  Statewide Coverage for this strain in 1997, based on 2 applications, is estimated to be 40%.

Bacillus thuringiensis, subsp. aizawai (Agree) *See also Diamondback Moth*
Bt aizawai is effective against cabbage looper, imported cabbageworm, and beet armyworm, but it is more commonly used for control of diamondback moth.

Predators:

Cabbage looper control benefits from natural predators and parasitoids through encouragement of, and to a more limited extent, inundative releases of these agents. Egg parasites such as *Trichogramma pretiosum*, and larval parasites including *Hyposoter exigue*, *Copidosma truncatellum*, and *Microplitis brassicae*, parasitic tachinid fly, *Voria ruralis*, can be of some use in an integrated pest management program (UC IPM 1997).

Imported cabbageworm control benefits from the pupal parasite *Pteromalus puparum*, the larval parasites such as *Apanteles glomeratus* and *Microplitis plutella, and Trichogramma* egg parasites (UI IPM, 1997).

Beet Armyworm control benefits from predators such as the wasps *Hyposoter exiguae* and *Chelonus insularis;* and the tachinid fly, *Lespesia archippivora* (UI IPM, 1997).

Cultural Control Practices:
There are no known cultural practices for control of cabbage looper, beet armyworm, or imported cabbageworm.

Diseases

Ringspot, *Mycosphaerella brassicicola*

Ringspot is the most serious foliar disease in Brussels sprouts production. It is a disease exclusive to Brussels sprouts among the cole crops. Ringspot disease pressure can be extreme, particularly in San Mateo County where fog is common. Spores of ringspot can become airborne and spread from plant to plant or field to field. The pathogen can persist on infected plant residue in the soil, and it may also be present on Brussels sprouts seed (UC IPM, 1997).

Ringspot disease symptoms are circular, light brown to black spots that appear on the plant leaves and on the outer leaves of the sprouts. Growers risk heavy losses if they do not control this disease.

Chemical Control:
It is important to treat for ring spot before symptoms develop. It is impossible to stop the spread of disease once the spores become airborne. Because of the importance of preventative treatment, environmental conditions are relied upon more that field scouting to determine the timing of fungicide applications. Applications are normally made in the later, rainy period of the growing season.

Chlorothalonil [B1B2] *See also Downy Mildew*

- Trade Name & Formulation: Bravo 720 S (720 grams/liter)
- Typical Application Timing & Frequency: 2 to 3 applications, usually in the later part of the season. Often applied in rotation with benomyl (*see below*).
- Typical Application Rate & Method: Foliar spray from tractor-mounted boom at 1.50 lb ai/ac (label maximum). This material also has activity against downy mildew and *Alternaria* leaf spot, diseases for which it is occasionally applied at a lower rate.
- REI & PHI: 48 hours restricted entry; no pre-harvest interval

Chlorothalonil was applied to 5,751 ac in 1997, ranking this material second only to the insecticide chlorpyrifos (Lorsban) in pesticide usage on California Brussels sprouts.

Statewide Coverage in 1997, based on 2.5 applications, is estimated to be 72%.

Benomyl [CARB]

- Trade Name & Formulation: Benlate 50 WP
- Typical Application Timing & Frequency: 2 applications per season, usually alternated with chlorothalonil. Normally these occur in the later part of the year when rainfall is common. Label limits total number of applications to 3 per season.
- Typical Application Rate & Method: Sprayed from aircraft or tractor-mounted boom at 0.50 to 1.0 lb ai/ac; average rate in 1997 was 0.58 lb ai/ac. These are low rates for ring spot; label maximums are 3.0 lb ai/ac for ground applications, and 1.0 lb ai/ac when sprayed from aircraft. However, because label limits total applications to 3 lb ai/ac per season, the low rates allow multiple applications.
- REI & PHI: 24 hours restricted entry; 7 days pre-harvest interval.

Benomyl is applied in rotation with chlorothalonil, the primary fungicide for ring spot control.

Benomyl was applied to 657 ac in 1997. Benomyl is more expensive, and it is used on significantly less acreage, than chlorothalonil.

Statewide Coverage, based on 2 applications, is estimated to be 10%.

Alternative Chemical Controls:

Maneb [B1B2] (Manex) *See also Downy Mildew*
This product is used minimally for ringspot, *i.e.*, only under low disease pressure situations or as a rotational material for chlorothalonil and benomyl.

Biological Controls:
There are no effective biological controls for foliar diseases on Brussels sprouts.

Cultural Control Practices:
Drip irrigation contributes less than overhead sprinkler irrigation to the spread of this disease.

Downy Mildew, *Peronospora parasitica*
Alternaria Leafspot, *A. brassicicola*

Downy mildew survives between crops on host weeds, or as an oospore in crop residue. Spores can also be airborne, spreading the disease easily throughout the field. The majority of economic damage is to seedlings. Young leaves become damaged through lesion development and systemic infection. This leads to stunting of plants, delay in harvest, and a decrease in the number of harvestable sprouts. As the stand matures, lesion development is usually restricted to the lower leaves, and the crop becomes more tolerant to downy mildew infection.

In excessively wet years, *Alternaria* leaf spot, also known as "black leaf spot," can become established in Brussels sprouts plantings. The product of choice by growers is chlorothalonil (Bravo), which is applied for downy mildew control during these same environmental conditions.

Chemical Control:

Maneb [B1B2] *See also Ringspot (Alternatives)*

- Trade Name & Formulation: Manex 4 FL
- Typical Application Timing & Frequency: Applied 3 times/season at 7 to 10 day intervals, beginning when environmental conditions favor disease.
- Typical Application Rate & Method: 1.0 lb ai/ac by aircraft or tractor-mounted sprayer. Label limits total applications to 9.6 lb ai/ac per season.
- REI & PHI: 24 hours restricted entry; 7 days pre-harvest interval.

  This fungicide is registered for use against downy mildew and *Alternaria* leaf spot. It was applied to 480 ac in 1997.

  Statewide Coverage in 1997, based on 3 applications, is estimated to be 5%.

Chlorothalonil [B1B2] *See Ringspot*

Alternative Chemical Controls:

Copper hydroxide (Kocide)
Copper hydroxide is registered for control of downy mildew and *Alternaria* leaf spot. It can be used as a

fungicide on organic farms, and it is inexpensive. Copper hydroxide was applied to only 17 ac in 1997.

Fosetyl-al (Aliette)
This fungicide is a highly effective compound for fungal diseases of many cole crops, including Brussels sprouts. It is, however, somewhat expensive and was used on only 6 ac in 1997.

Neem oil
This product was used primarily for downy mildew control in organic acreage, along with copper hydroxide. Neem oil is relatively expensive, but provides some fungicidal efficacy when spray coverage is good. It was used on only 3 ac in 1997.

Phosphorous acid (Phosgard, Nutri-phos)
These products are registered as fertilizers, but they have been shown to be effective fungicidal materials.

Actigard
This is a new product in development that is unconventional in the sense that it is not a fungicide, but a plant resistance stimulator. Actigard is applied to plants prior to infection, and elicits an immune response in plants to a variety of fungal and bacterial pathogens. The entire study science of Systemic Acquired Resistance (SAR) is in its infancy, but potentially offers Brussels sprouts farmers an alternative to conventional disease control with chemical fungicides. In the case of Actigard, early season applications minimize disease infection to leaves, stems, and roots. It has also been shown to be effective against bacterial organisms, in addition to most fungal pathogens in the phycomycetes family. This includes downy mildew of cole crops. A possible limitation with this product, however, is that repeated applications are required since biomass dilution occurs with the addition of new foliage, and elevated levels of disease resistance proteins do not persist for long in plant tissue. Actigard must therefore repeatedly be applied to maintain high levels of SAR in new tissues where pathogen infection can be severe.

Biological Controls:
There are no effective biological controls for foliar diseases on Brussels sprouts.

Cultural Control Practices:
Cultural control, in conjunction with spraying of fungicides, is essential in the management of downy mildew. Transplant nurseries and farms must manage their irrigation practices to avoid unnecessary moisture on the leaves of the seedlings. Adequate drying of the leaves after irrigation, prior to cool moist evening temperatures will help lower the survivorship of fungal lesions and the incidence of mildew on the young foliage. Seedling nurseries spray their cole crops as a preventative measure to avoid inevitable economic damage. After the seedlings are past their juvenile stage in the field, mildew control is still important, but usually economic damage can be avoided with one or two sprays of an effective fungicide.

To guard against *Alternaria* infection in Brussels sprouts seedlings, and to prevent the spread of the disease, Brussels sprouts seeds can be treated with hot water (122 °F) for 25 minutes (Maynard and

Hochmuth, 1997).

Clubroot, ***Plasmodiophora brassicae***

Clubroot is a soil-borne disease that attacks the root system of Brussels sprouts. It can be introduced into a field by infected transplants, or by movement of contaminated soil (as when carried by farm machinery) from infected fields.

Symptoms of clubroot disease include stunting of plant growth, and yellowing and wilting of plant tissue. Infected roots become enlarged, developing an elongated spindle shape composed of thin-walled cells. These cells are attractive to insects and secondary pathogens. This secondary injury and decay can cause extensive loss of root tissues, increasing the stunting and causing early plant decline. The effect of clubroot infection ranges from substandard or unmarketable sprouts at harvest, to the death of the plant. Entire fields can be lost if this pathogen is not controlled.

Chemical Control:

PCNB

- Trade Name & Formulation: Terraclor 75 WP
- Typical Application Timing & Frequency: One pre-plant application.
- Typical Application Rate & Method: Sprayed onto beds from tractor-mounted boom, and incorporated into the soil at an average rate of 20.6 lb ai/ac.
- REI & PHI: 12 hours restricted entry; no pre-harvest interval (applied pre-plant)

  Unlike metam-sodium (below), the range of pests controlled by PCNB is quite narrow. The only Brussels sprouts pest of any consequence controlled by this material is club root.

  PCNB was applied to 362 ac in 1997, for Statewide Coverage of 11%. Virtually all of the treated acreage was in San Mateo County.

Metam-Sodium [B1B2] *See also Nematodes*

- Trade Name & Formulation: Nemasol 426 S (4.26 lb ai/gallon)
- Typical Application Timing & Frequency: Applied once as a pre-plant soil fumigant.
- Typical Application Rate & Method: Shank injected into soil at average rate of 76 lb ai/ac.
- REI & PHI: 48 hours restricted entry; no pre-harvest interval (applied pre-plant)

  This general-purpose soil fumigant is effective against nematodes as well as club root, and is applied to fields with both pests. It is efficacious also against weeds and minor soil-borne

diseases.

Metam-sodium was applied to 1,401 ac in 1997, for Statewide Coverage of 44%.

Alternative Chemical Controls:

1,3-Dichloropropene [B1B2] (Telone) *See also Nematodes*
This material provides moderate control of club root, but it is not labeled for use against this disease.

Dazomet (Basamid)
This material is a general purpose soil fumigant, similar to metam-sodium, that is not currently registered for Brussels sprouts.

Biological Controls:
There are no biological controls for club root.

Cultural Control Practices:
Most fields are treated with lime before transplanting to raise the soil pH. This does not kill the fungus, but pH levels at 7.2 or higher have the effect of suppressing spore germination (UC IPM 1997). In some cases, fields that have been rotated out of Brussels sprouts for at least one year are not limed.

Other preventative measures can be taken to prevent spread of clubroot to other fields. One is to clean all farm machinery that has been in contact with diseased soil. Also, minimizing irrigation run-off can help reduce the spread of disease. Finally, any transplants that are used should have been produced in sterilized soil. California growers practice most or all of these measures as routine management of their Brussels sprouts plantings.

Minor Diseases

Other diseases may at times be present in Brussels sprouts fields, but they do not generally present sufficient economic threat to warrant pesticide applications. Many are also controlled fortuitously by fungicide applications for more threatening diseases. Minor diseases include *Fusarium* wilt, *Verticillium* wilt, *Phytopthora* root rot, and *Sclerotinia*.

Nematodes

<u>Sugarbeet cyst nematode</u>, *Heterodera schachtii*
<u>Cabbage cyst nematode</u>, *H. cruciferae*
<u>Rootknot nematodes</u>, *Meloidogyne incognita, M. javanica, M. arenaria, M. hapla*

Nematodes are parasitic, microscopic roundworms less than 4 mm (0.16 in) in length and live on the roots and surrounding soil of all vegetable crops. Overall, nematodes may infest as much as 75% of the cole crop acreage in California.

The cyst nematode (*Heterodera spp*.) is the most harmful genus to cole crops, and can be found throughout California. Cole crops are the only host for cabbage cyst nematode (*H. cruciferae),* which can cause more plant injury and stunting than the root knot nematode when abundant. In the case of the sugarbeet cyst nematode (*H. schachtii*), cole crops, beets, spinach and related weeds have all been shown to harbor large populations (UC IPM, 1997). The cyst nematode can be found on all soil types, but its limited host range allows management by crop rotation with non host plants.

Rootknot (*Meloidogyne*) nematode can also be a problem for cole crops in California, but to less extent then cyst nematode. Root knot nematodes produce small distinct galls from the size of a pin head to one inch in diameter.

Nematodes, usually in the egg stage, over-winter in the soil in decaying vegetable matter, where they may persist for long periods of time. Symptoms from nematodes can mimic other problems in the field, particularly clubroot. Nematodes primarily cause an overall stunting of the plant, wilting, small head formation, and lower yields. When cyst nematodes attack seedlings, the entire Brussels sprouts planting may be ruined economically (personal communication, F. Laemmlen, 1999).

Chemical Control:
Soil fumigation can be used to control nematodes in cases where rotation or other non-chemical practices are not feasible. When fumigants are used, many have the added benefit of weed control and suppression of soil borne diseases.

<u>1,3-Dichloropropene [B1B2]</u> *See also Clubroot, Mollusks*

- Trade Name & Formulation: Telone II
- Typical Application Timing & Frequency: Applied once before planting.
- Typical Application Rate & Method: Shank injected at average rate of 75 lb ai/ac.
- REI & PHI: Prohibited from the start of application until 5 days after application; no PHI (applied pre-plant).

  This soil fumigant was applied to 999 ac in 1997 for nematode control. It is also moderately efficacious against clubroot.

Statewide Coverage in 1997 was 31%.

Metam-Sodium [B1B2] *See also Clubroot, Weeds*
In addition to being an effective nematicide, this material provides the additional benefit of providing good control of club root and weeds. By comparison, 1,3-dichloropropene (above) is only moderately efficacious against club root and ineffective against weeds.

Alternative Chemical Controls:

Fenamiphos [OP] (Nemacur)
This organophosphate is rarely used, although it is labeled for nematode control in Brussels sprouts fields. The product manufacturer cautions that Nemacur has been known to leach through soil to contaminate ground water, necessitating that measures are taken to avoid use in areas where this potential is high. It was applied to 47 ac in 1997, for statewide coverage of 1%.

Ethoprop [OP] (Mocap)
This organophosphate is not registered for use on Brussels sprouts. It currently is registered for cabbage, for which it is the preferred material due to its effectiveness and relatively low cost.

Dazomet *See Clubroot*

Biological Controls:

Myrothecium verrucaria (Ditera ES)
This biological nematicide received California registration for other cole crops in 1996, but it is not currently registered for California Brussels sprouts. However, in some field situations, this reduced-risk product can be a viable alternative to 1,3-dichloropropene and metam-sodium.

Cultural Control Practices:
Crop rotation with non-host plants, deep plowing, and good sanitation are the primary cultural practices in use for nematode control on Brussels sprouts.

Weeds

Weeds (*e.g.*, mustard, malva, and stinging nettle) are a field maintenance issue for Brussels sprouts growers, but weed management does not drive significant pesticide usage. Only two materials, the herbicides chlorthal-dimethyl (Dacthal) and trifluralin (Treflan), were applied exclusively for weed

control in 1997, and only to a combined 26 ac. However, fields that are fumigated with metam-sodium for more serious pests, such as nematodes or clubroot, also benefit from the weed control properties of this material. Most weed control is accomplished through cultivation by tractor or by hand weeding.

Vertebrate Pests

Voles, ***Microtus californicus***

Voles, commonly referred to as "field mice," feed on Brussels sprouts plants. The amount of acreage requiring rodenticide applications varies from season to season. In 1997 very little Brussels sprouts acreage was treated for voles, but the infestation level was higher the following year (McCaig, 1999, personal communication).

Chemical control of field mice is usually accomplished through field applications of rodenticide, such as aluminum phosphide (Phostoxin). This product is used by the agricultural industry primarily for fumigation of storage structures (*e.g.*, silos and railroad cars). It is, however, also registered for control of burrowing pests, and is highly efficacious as a rodent mitigation material in Brussels sprouts fields.

Aluminum phosphide was applied to 34 ac in 1997. All treated acreage was in San Mateo County. Statewide Coverage was less than 2%.

No biological controls for field mice are available.

Mollusks
Gray Garden Slug, ***Deroceras recticulatum***
European Brown Snail, ***Helix aspersa muller***

The weather in coastal San Mateo County, the northernmost Brussels sprouts growing area, is cooler and foggier than in the other areas, making the San Mateo fields more prone to slug and snail (mollusk) infestations. Mollusks are a threat to plant vigor during the early stages of Brussels sprouts growth. Later in the season, they can scar the Brussels sprouts buds, compromising the marketability of the yield.

The pesticide most commonly directed at slug and snail infestation is metaldehyde. In 1997, only 28 ac were treated with this material, all in San Mateo County, for Statewide Coverage of less than 1%. While this suggests that mollusks were not a major pest control problem in 1997, it has been reported that they were a much more severe the following year (McCaig, 1999, personal communication).

Although not labeled specifically for slugs, it has been reported that application of 1,3-dichloropropene (Telone II) for nematode control also lowers slug incidence in the treated field (D. Lea, personal communication, 1999).

No biological controls for mollusks are available.

Contacts

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: J.T. Wingett and Mary Van Ryn

Editing and Data Analysis: J.T. Wingett

Reviewed by:
California Pesticide Impact Assessment Program
University of California, Davis
(530) 754-8378

Acknowledgments:

David Lea, Cabrillo Farms. Half Moon Bay, California

John Giusti and Aldo Giusti, Giusti Farms. Half Moon Bay, California

Kelley McCaig, Western Farm Service. Watsonville, California

Hank Sciaroni, UC Cooperative Extension, Retired. San Mateo, California

William Chaney, UC Cooperative Extension. Salinas, California

Franklin Laemmlen, UC Cooperative Extension. Santa Maria, California

Agricultural Commissioners from the following counties have supplied 1997 pesticide use information for this report:

Santa Cruz	Monterey	Orange
San Mateo	San Luis Obispo	

Prepared for
United States Department of Agriculture

Cooperative State Research,
Education and Extension Service
Washington, DC
Agreement no. 98-39427-6934

Submitted by
Alliance for Alternative Agriculture
San Luis Obispo, California

Final Report November 29, 1999

Disclaimer:

The statements and conclusions in this report are those of the Alliance for Alternative Agriculture and not necessarily those of United States Department of Agriculture.

The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products. Trade names are included only as an aid to identification of materials used in the field.

References

1. National Agricultural Statistics Service (NASS). 1999. *Vegetables 1998 Summary*. United States Department of Agriculture.

2. New York Agricultural Statistics Service (NYASS). 1999. *1997 Census of Agriculture, New York State and County Data*. vol. 1, part 32. United States Department of Agriculture. http://usda.mannlib.cornell.edu/reports/census/ac97any.pdf

3. California Department of Pesticide Regulation (DPR). 1996. *Pesticide Use Report, Annual 1995, Indexed by Commodity*. California Environmental Protection Agency

4. California Agricultural Statistics Service (CASS). 1998. *1997 Agricultural Commissioners' Data*. California Department of Food and Agriculture.

5. Knaster, Meri, and Randall Jarrell. *Jack L. Debenedetti, Jr., Brussels Sprouts and Artichoke Growing on the North Coast*. 1997. UC Santa Cruz.

6. Pfyffer Associates. 1999. *Brussels Sprouts Info*. http://members.cruzio.com/~bsprouts/

7. Maynard, Donald N. and George J. Hochmuth. 1997. *Knott's Handbook for Vegetable Growers.* 4th ed. John Wiley & Sons, Inc. New York.

8. University of California (UC). 1987. *Integrated Pest Management for Cole Crops and Lettuce. In* M.L. Flint and J.K. Clark (ed.) Publ. 3307. UC Davis IPM Project.

9. Metcalf, L., and R. A. Metcalf. 1993. *Destructive and Useful Insects: Their habits and control*. 5th ed. McGraw, New York.

10. Phillips, P. A. 1998. "Diamondback Basics: Effective control of diamondback moth means knowing your enemy." *Amer. Veg. Grower*. Vol 46, No. 11.

11. Liu, Yong-Biao, B. E. Tabashnik, and M. Pusztai-Carey. 1996. "Field-Evolved Resistance to Bacillus thuringiensis Toxin CryIC in Diamondback Moth (Lepidoptera: Plutellidae)." *Journ, Econ. Ent.* Vol. 89, No.4.

12. University of California (UC IPM). 1997. "Cole Crops Pest Management Guidelines." Publ. 3339. Division of Agriculture and Natural Resources http://www.ipm.ucdavis.edu/PMG/selectnewpest.cole-crops.html

13. Davidson, R.H. and W.F. Lyon. 1979. Insect and Pests: Of farm, garden and orchard. 7th ed. John Wiley and Sons, N.Y.

Appendices

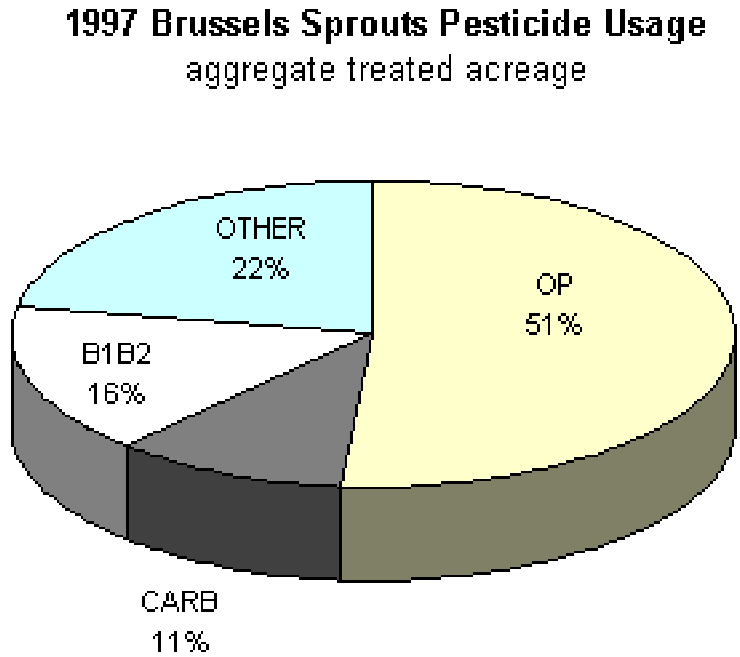
Post Harvest Control Issues:
After Brussels sprouts for the processed market are harvested, they are transported to a packing house and run through a pre-cooling washer. A chemical preservative is added to the wash to prevent oxidation and discoloration of the sprouts. Sprouts are then taken to the processor for freezing (Knaster and Jarrell, 1997).

Fresh market sprouts are immediately refrigerated after harvest, and do not go through the pre-cooling wash. They are transported from refrigerated storage to local markets.

Neither processed sprouts nor fresh market sprouts are treated with pesticide after harvest.

Discussion and Summary:
During the early history of California Brussels sprouts production, usage of chemical pest control materials was relatively minimal. There was also little diversity in the pesticides applied. Most growers used a nicotine derived insecticide, such as Black Leaf 40 (Knaster and Jarrell, 1999), primarily directed at the cabbage aphid. Since that time, regulatory standards for insect-free fresh and processed foods have become higher, while the public has become more critical of pesticide use in agriculture. This paradox is the focal point of considerable debate today, but these issues are not new to growers. The dilemma presented by these seemingly incompatible objectives is expressed in these remarks from a longtime Brussels sprouts grower to an interviewer, twenty-two years ago:

> …they don't want us to spray but on the other hand they don't want insects. So they can't have both. Due to these restrictions [federal regulations], naturally, the processors who buy the produce are very strict on the deliveries that we give them. In order for us to have a clean Brussels sprout, we have to go in there and spray like mad (Knaster and Jarrell, quoting Debenedetti, 1997).



Today, pesticides are an integral part of commercial Brussels sprouts production in California, and a significant percentage of these materials fall within the three priority groups for Food Quality Protection Act (FQPA) review: organophosphates (OP), carbamates (CARB), and B1 and B2 (B1B2) potentially carcinogenic pesticides. When the "cocktail" of pesticides applied to Brussels sprouts fields throughout 1997 is separated by class of material, with each class weighted by total acreage covered, the contribution of OP, CARB, and B1B2 products to the mix is 78% (Fig. 2). The OPs were the largest "at risk" group, contributing 51% of the total, and were applied mainly for control of aphid and cabbage maggot. The B1B2s, 16% of the total, were used mainly for foliar disease and nematode control. Finally, carbamates contributed 11% to total treated acreage, and were used mainly for control of lepidopterous insects and foliar diseases.

Organophosphate Usage

Aphid, particularly cabbage aphid, is the most threatening insect pest to Brussels sprouts production. The list of pesticides used against aphid is dominated by the OP class of compounds (*cf.* Table 1). The single most important material is chlorpyrifos (Lorsban), a pesticide that is considered by Brussels sprouts growers to be indispensable to successful cabbage aphid control. The use of another OP, dimethoate, in rotation with chlorpyrifos, has been very effective in controlling green peach aphid. The only chemical class outside of the OPs that is widely used for aphid control is the chloronicotinyls, represented by the systemic insecticide imidacloprid (Admire, Provado). This has become an important material for management of aphid resistance to the OPs. It has partially replaced the systemic OP disulfoton, but it cannot totally replace the OPs for aphid control since plant growth dilution and product dissipation reduce late season efficacy of the more effective soil application formulation (Admire).

Chlorpyrifos and azinphos-methyl (Guthion), two OPs applied for aphid control, are also key pesticides for the control of cabbage maggot. There are no alternative treatments for this pest.

The OP methamidophos was widely applied in 1997 for control of aphid and worms, although the manufacturer no longer supports registration for cole crops. It is being replaced by dimethoate for aphid control, and permethrin for worms.

Usage of Potential Carcinogens (B1s and B2s)

Historically, the most problematic foliar disease faced by Brussels sprouts growers has been ringspot. The most popular material for control of ringspot is the B1B2 chlorothalonil (Bravo), which is typically applied in rotation with the carbamate benomyl (Benlate). There are no alternatives to replace these materials when disease pressure is heavy, although some growers rely on the B1B2 maneb during light ringspot seasons.

Alternaria leafspot and downy mildew can also be troublesome during unusually wet years. Both of these diseases are treated with the B1B2s maneb (Manex) and chlorothalonil (Bravo). These fungicides have been used for many years without indications of disease resistance. Although there are a number of potential reduced risk alternatives to the B1B2s for control of *Alternaria* and downy mildew, these alternative materials have not been widely used by Brussels sprouts growers due to inconsistent product performance.

Two other B1B2 potential carcinogens, metam-sodium (Nemasol) and 1,3-dichloropropene (Telone), are widely applied for control of nematodes and club root disease in Brussels sprouts fields. The only practical, registered alternatives to these two fumigants is PCNB (Terraclor) for club root, and the OP fenamiphos (Nemacur) for nematodes.

Carbamate Usage

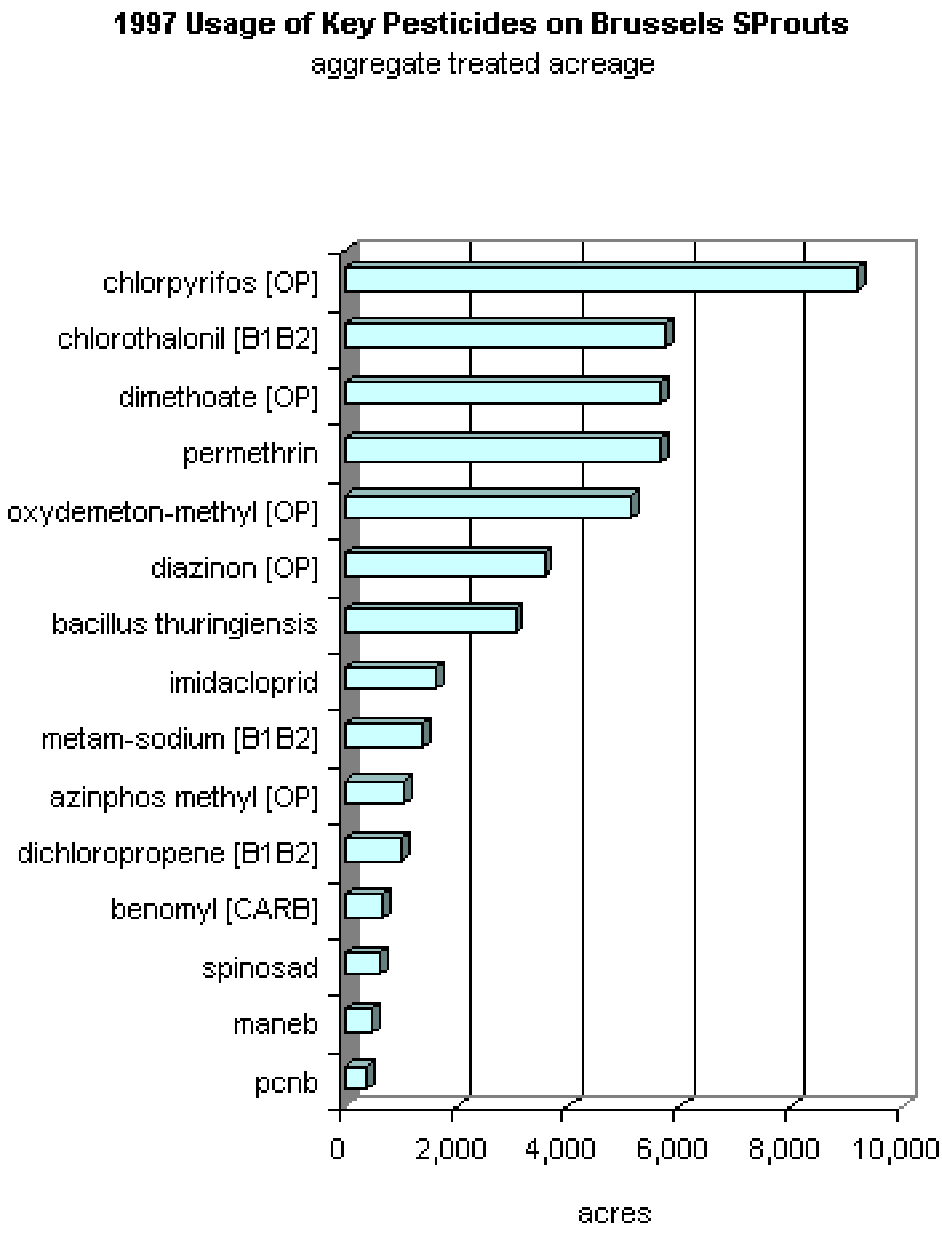
In 1997, carbamates were the least represented the three FQPA-targeted groups. Current usage may be even less. The most commonly used carbamate was methomyl (Lannate), applied in response to a severe diamondback moth infestation. Since then, a naturalyte product, spinosad (Success, registered in late 1997), has become the primary pesticide for diamondback moth control, virtually eliminating the usage of carbamates for this pest. At present, methomyl use is limited to the control of other worms (*e.g.*, cabbage looper, imported cabbageworm, beet armyworm) during periods of unusually heavy pest pressure.

The primary target for carbamates is now ringspot disease. While the main fungicide for ringspot control is the B1B2 chlorothalonil (see above), the carbamate benomyl (Benlate) is an important rotational material. These two products represent the primary fungicides applied to control ringspot.

"Other" Pesticides

Pesticides that are not currently on the priority list for FQPA review ("Other") comprise 22% of total Aggregate Treated Acreage (Fig.2). The most widely used materials in this group are the pyrethroid permethrin, the biological pesticide *Bacillus thuringiensis*; the chloronicotinyl imidacloprid; and the naturalyte spinosad.

Most Important Pesticides for Brussels Sprouts Production



The method for determining the pesticides most important to Brussels sprouts production begins with Aggregate Treated Acreage (ATA) data from 1997, a measurement that incorporates area treated with the frequency of application. Various additional considerations, however, are required when utilizing this data. As has been discussed (*cf.* Organophosphate Usage), methamidophos, which was applied to significant acreage in 1997, is being phased-out and should no longer be considered as a chemical standard. Another organophosphate, disulfoton (Di-Syston) was applied to significant acreage in 1997, but was less applied than many other OPs for aphid control. Usage of this product is declining in favor of imidacloprid. While disulfoton is no longer a key Brussels sprouts pesticide, PCNB (Terrachlor) remains important although it was applied to only 11% of statewide Brussels sprouts acreage in 1997. This is a key soil fungicide, particularly to growers in San Mateo County, because there are few products available to treat clubroot. Finally, methomyl (Lannate, *cf.* Carbamate Usage),

which had the fifth highest ATA in 1997, has largely been replaced by spinosad (Success) for control of diamondback moth, and is now a secondary pesticide for worm control.

Following incorporation of the adjustments cited above, the most important pest control materials for Brussels sprouts are listed as the 15 pesticides shown in Fig. 3 and Table 1. These materials control the key pests that repeatedly challenge California growers.

Total Active Ingredient

When usage is considered by total lb ai applied, the ranking diverges somewhat from that of Aggregate Treated Acreage. Soil fumigants increase in significance due to their high application rates. For example, 821 lb of methyl bromide were applied to California fields in 1997, ranking this material above permethrin in total lb ai. However, methyl bromide was applied to only 0.1% (3.5 ac) of statewide Brussels sprouts acreage (*cf.* Appendix 2, Table A1), compared to an estimated 59.0% Statewide Coverage for permethrin. Methyl bromide clearly is not a key pest control material for this commodity, while permethrin, by contrast, is the primary insecticide for worm control.

Table 1.
1997 Pesticide Usage. Fifteen most important Brussels sprouts pest control materials, based on 1997 usage data, grower interviews, and pesticide label research. Listing is in order of total Aggregate Treated Acreage (*cf.* Fig. 3). (*See Appendix 2, Tables A1 for full listing.)*

Common Name	**Trade Name**	**Pest**	**Total lb ai**
chlorpyrifos [OP]	Lorsban	aphid, cabbage maggot	9,285
chlorothalonil [B1B2]	Bravo	ringspot	7,663
dimethoate [OP]	Dimethoate	aphid	5,274
permethrin	Pounce, Ambush	worms*	561
oxydemeton-methyl [OP]	MetaSystox-R	aphid	2,556
diazinon [OP]	Diazinon	aphid, cabbage maggot	1,937
Bacillus thuringiensis	Agree, Mattch	worms	1,682

imidacloprid	Admire, Provado	aphid	167
metam-sodium [B1B2]	Nemasol	nematodes, clubroot	106,626
azinphos-methyl [OP]	Guthion	cabbage maggot	778
1,3,-dichloropropene [OP]	Telone	nematodes	74,568
benomyl [CARB]	Benlate	ringspot	383
spinosad	Success	diamondback moth	57
maneb [B1B2]	Manex	*Alternaria*, downy mildew	477
pcnb	Terrachlor	clubroot	596

* cabbage looper, imported cabbageworm, beet armyworm

Data Collection and Processing Procedures:

Individual County Brussels Sprouts Acreage

California agricultural commissioners' data, as published by California Agricultural Statistics Service (CASS) in August 1998, indicate that a total of 2,206 ac of Brussels sprouts were harvested in California in 1997. The commissioners' report lists Orange, San Mateo, and Santa Cruz counties as the location of this acreage. However, pesticide use records for 1997, collected directly from individual agricultural commissioners by Alliance for Alternative Agriculture (Alliance) staff, indicate that Brussels sprouts were grown also in Monterey and San Luis Obispo Counties.

The National Agricultural Statistics Service (NASS) also collects acreage data for vegetable commodities, independently of data collection for the CASS report. The NASS report, *Vegetables, 1998 Summary*, published in January 1999, lists planted and harvested Brussels sprouts acreage at 3,200 ac for 1997. This is inconsistent with the acreage reported by CASS, and deference is given herein to the NASS report for statewide harvested acreage. However, the NASS report does not indicate regional distribution of Brussels sprouts acreage within the state. Consequently, the contribution made by each region to total statewide acreage is determined from data in the CASS report, as well as from additional data obtained from agricultural commissioners in Monterey and San Luis Obispo Counties. Regional acreage figures, as reported in "Production Regions" (above), are calculated as the percent contribution of each region multiplied by 3,200 acres.

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 principal Brussels sprouts growing regions of California.

All county agricultural commissioners' offices responded with the requested data. Five reported pesticide usage on Brussels sprouts. Data was submitted to the Alliance in electronic media (*i.e.*, floppy disk or E-mail).

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 Brussels sprouts of Ambush 25 W Insecticide, with EPA no. 10182-35, where units of product applied were expressed in pounds, 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. 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 Brussels sprouts.

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, Appendix 2, Table A1, lists for

permethrin 561 lb ai applied to 5,654 ac. The average rate is 0.10 lb ai/ac:

$$\frac{561 \text{ lb ai}}{5654 \text{ ac}} = 0.10 \text{ lb ai/ac}$$

Permethrin is typically applied on Brussels sprouts for worm control in the form of Pounce 3.2 EC. The calculated average application rate of 0.10 lb ai/ac is at the top of the product label application range of 0.05 to 0.10 lb ai/ac.

Terminology

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 where there are multiple applications to the same acreage. 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 Brussels sprouts planted. He/she may report to the county agricultural commissioner four application instances of a specific pesticide, covering 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 (ATA) for this 100 ac field would be 200 ac, and would not indicate whether or not all of the field was treated.

It should be noted that pesticides are commonly combined in a "tank mix" and applied together. Continuing the example above, the grower could mix four pesticides in a tank and spray 50 ac. Each pesticide would be recorded as covering 50 ac, resulting in 200 ATA for the four pesticides as a group.

Unless otherwise noted, all pesticide use acreage figures in this report are Aggregate Treated Acres based on 1997 data.

Statewide Coverage

Data from county Agricultural Commissioners data, which is the basis for the 1997 pesticide usage data in this report, provides the number of Brussels sprouts acres for each application instance and allows for an Aggregate Treated Acres summation. "Statewide Coverage" is the percentage of planted acreage that is treated with at least one application of a given pesticide and, as discussed under Aggregate Treated Acreage (above), this information can not always be determined from the summation of treated acres. However, if a product label restricts usage to one application per season, or if grower information indicates that the material is applied only once, then Statewide Coverage can be estimated. For example, metam-sodium was reported to the agricultural commissioners to have been applied to 1,401 ac

(Appendix 2, Table A1). Because this product is applied to Brussels sprouts fields only once per season, it can be stated that the Statewide Coverage for this product was 44%:

$$\frac{1401\ \text{ATA}}{3200\ \text{planted ac}} = 0.44 = 44\%\ \text{of planted acres treated}$$

In fact, whenever the average number of applications/field can be approximated, ATA can be utilized to estimate Statewide Coverage as follows, where *n* = average number of applications:

$$\frac{\left(\text{ATA}/n\right)}{\text{planted ac}} \times 100 = \text{Statewide Coverage (\%) (eqn. 1)}$$

For example, chlorpyrifos Statewide Coverage cannot be determined directly from treated acreage, but based on an average of 4.5 applications per season, it can be estimated:

$$\frac{\left(9175/4.5\right)}{3200} \times 100 = 0.64 = 64\%\ \text{Statewide Coverage}$$

For many pesticides the number of applications varies too widely, or is too difficult to ascertain from the available information, for *n* to be quantified with confidence. If, however, *n* is assigned a value of 1, then the result will be the maximum possible Statewide Coverage. If this *maximum* is less than 10%, then Statewide Coverage is reported herein as "less than *x* %."

Appendix 2

Pesticide Use Tables:

Appendix Table A1 presents a listing of all chemical pest control materials applied to California Brussels sprouts in calendar year 1997, based on data from county agricultural commissioners. Adjuvants (*e.g.*, spreaders and stickers) are not included.

Column Heading Key:

- *common name* refers to the chemical name of the active ingredient.
- *number of applications* refers to the total number of times the active ingredient was applied to

Brussels sprouts.

- *lb ai applied* refers to total pounds of active ingredient applied to Brussels sprouts.
- *acres treated* refers to Aggregate Treated Acreage.
- *avg. rate* is *total lb ai* applied divided by *acres treated*, for average lb ai/ac.

Table A1. 1997 Total Pesticide Usage on California Brussels Sprouts

Common Name	Number of Applications	lb ai applied	Acres Treated	Avg. Rate
acephate	3	22.50	30.00	0.75
azadirachtin	1	0.03	3.00	0.01
azinphos methyl	50	777.88	1045.50	0.74
bacillus thuringiensis	250	1682.16	3034.57	0.55
benomyl	45	382.88	656.50	0.58
carbaryl	3	62.08	31.00	2.00
chloropicrin	2	400.58	3.50	114.45
chlorothalonil	380	7662.59	5750.50	1.33
chlorpyrifos	697	9285.18	9175.25	1.01
chlorthal-dimethyl	2	36.90	14.00	2.64
copper hydroxide	3	12.59	17.00	0.74
diazinon	297	1936.71	3562.50	0.54
dichloropropene	55	74568.19	999.40	74.61
dimethoate	318	5273.85	5660.25	0.93
disulfoton	26	567.10	595.25	0.95
endosulfan	23	376.08	375.50	1.00
fenamiphos	6	114.76	47.00	2.44
fonofos	2	19.94	20.00	1.00
fosetyl-al	3	6.00	3.25	1.85
imidacloprid	134	167.39	1627.00	0.10
malathion	10	174.21	113.50	1.53
maneb	53	476.68	480.25	0.99

metalaxyl	2	0.03	2.25	0.13
metaldehyde	1	0.32	28.00	0.01
metam-sodium	100	106625.56	1401.25	76.09
methamidophos	123	2224.63	2255.00	0.99
methomyl	365	4018.56	5141.25	0.78
methyl bromide	2	820.75	3.50	234.50
methyl parathion	1	17.25	23.00	0.75
naled	33	595.91	348.50	1.71
neem oil	1	20.25	3.00	6.75
oxydemeton-methyl	350	2555.90	5111.75	0.50
pcnb	29	7448.25	362.25	20.56
permethrin	361	560.99	5653.75	0.01
potash soap	5	32.76	9.39	3.49
pyrethrins	11	1.34	122.50	0.01
rotenone	11	1.12	122.50	0.01
spinosad	37	56.99	627.25	0.09
trifluralin	1	3.61	12.00	0.30
