Crop Profile for Fennel in California

Prepared: September, 2000

General Production Information

- Fennel is a minor crop in the U.S. with approximately 1,200 acres produced annually in California (2).
- California produces approximately 40% of the fennel grown in the U.S. (2).
- California and Arizona produce approximately 50% of the fennel grown in the U.S. (2)
- Monterey is the top fennel-producing county in California with 492 acres having a value of $3,243,000 in 1998. (3).
- The cost to produce (i.e., grow) a carton of fennel weighing in the range of 35-40 pounds and containing 18, 24, 30, or 36 bulbs of fennel ranges from $4.00 to $5.00 per carton (2).
- The cost to harvest (i.e., harvest and handling) a carton of fennel containing 18, 24, 30, or 36 bulbs of fennel ranges from $4.25 to $5.00 per carton (2).

Introduction

The purpose of this document is to provide the general conditions associated with the production of fennel, also commonly referred to as anise or sweet anise, in California with comments on other production areas as appropriate. This document is provided in cooperation with D'Arrigo Brothers Company of California (D'Arrigo) under the United States Department of Agriculture CSREES Award No. 99-34381-8346. D'Arrigo is a family owned company that was formed in 1923. D'Arrigo farms in California and Arizona and produces fennel on a year round basis.

Fennel is a native of the Mediterranean region, and is grown for the bulb like enlargement of fleshy overlapping petiole leaf bases. It is frequently called sweet anise or finocchio. All parts of the plant are aromatic and edible. The bulb portion is used fresh for salads, as a cooked potherb, or pickled, while the finely divided leaves are used as potherbs, and for seasoning and garnishes (1).

The results of almost twenty (20) years of research conducted on fennel by D'Arrigo points to the need to have as many pest management tools as possible in order to continue to be able to provide the United States (U.S.) consumer with an economical supply of high quality fennel on a daily basis throughout the year.

It is clear that plant breeding, and the development of resistant cultivars is one of the keys to the economical production of fennel in California. However, it is also clear that, at least in the near future, plant breeding by itself can not provide all the desired characteristics of weed, insect, and disease resistance along with all of the other desirable traits required for the major fennel production regions in

California and Arizona.

Production Regions

Fennel is primarily produced in the coastal production regions of Monterey and Santa Barbara Counties, with winter production primarily in Riverside County and the Yuma region of Arizona (2). Fennel is also produced in San Diego, San Luis Obispo, and Stanislaus Counties.

Cultural Practices

General Information
Fennel is considered a cool-season crop and is grown on a number of soil types. Planting and harvesting schedules are determined well in advance of planting to ensure a continuous supply of fennel throughout the year. Producers of fennel either own and/or lease land for production to ensure adequate acreage to meet their marketing requirements.

Cultivar Development
D'Arrigo maintains their own breeding program and develops fennel cultivars for their own use. Other fennel growers normally purchase seed from seed companies. Plant breeding is one of the key components of an Integrated Pest Management (IPM) program, and D'Arrigo-supported research is designed to develop cultivars with resistance to disease related problems and to meet the specific needs of the individual growing areas.

Planting
Fennel seed is planted by the grower at depths of approximately 1/4 to 1/2 inches primarily on 40-42 inch raised beds with 2 seedlines per bed. Fennel seed is usually coated to facilitate precision planting although thinning is required to achieve the final stand. Fennel is also transplanted, particularly in the winter months, from plants produced under greenhouse conditions.

Production
Growers are primarily responsible for all production-related activities including land preparation, cultivation, fertilization, irrigation, and the use of pesticides. The primary spring, summer, and fall production regions in California occur in Monterey, Santa Barbara and San Luis Obispo Counties, with

winter (desert) production in Riverside County, and the Yuma region of Arizona. The general growth period from planting to harvesting for direct seeded fennel ranges of 90 to 160 days; and 110-125 days for transplanted fennel (2).

Harvest

Fennel produced in California is harvested much like celery by hand laborers who sever the plant from the bulb by cutting through the stem just below the fleshy bulb-like overlapping petiole leaf bases. The bulb portion of the plant is trimmed by cutting away most of the top growth, which is discarded in the field, however, some top growth is left on to maintain bulb turgidity during shipment. Fennel bulbs of similar size are packed into fiberboard cartons. Depending on plant size, the cartons will contain either 18, 24, 30, or 36 fennel bulbs. The average weight of individual cartons ranges from 35 to 40 pounds.

All fennel is harvested in the field and not subject to washing at the time of harvest. Cartons of harvested fennel bulbs are placed onto trucks and transported to a cooling facility. All fennel is cooled, usually within 1 to 4 hours after harvesting, and fennel is typically vacuum cooled at temperatures of approximately 34 degrees F.

Fennel is shipped to the market in refrigerated trucks and temperatures in the range of 34-36 degrees F are maintained during shipment.

Pest Management

All applications of pesticides in California are under the control of the growers, and/or their Pest Control Advisor (PCA), or Pest Control Operator (PCO). Growers, PCA's, and PCO's work closely to insure that only registered pesticides are used and that they are used in compliance with all state and federal laws, rules and regulations, and labeled recommendations. Communication between growers, PCA's, and PCO's is maintained during the planting and production periods through frequent field visitations by grower representatives and/or their PCA's. The applicator must inform all affected parties in close proximity to the intended treated area (e.g., harvesting crews, weeding crews, irrigators etc.) of their intent to apply pesticides in advance of the application and must also post fields and file post-application paperwork with the appropriate state and/or federal agency. Closed systems are also mandatory for the application of Category 1 pesticides in California.

All information on pests and pesticides listed in this report relate to the production of fennel in California. All pests and pesticides mentioned in this report are listed in alphabetical order, and each such listing may, or may not, have any relationship to the importance of the pest or the use of an individual pesticide. Listing of percentage of acres treated for any material represents the total use of that individual pesticide as determined by the California Department of Pesticide Regulation (4). When the same material is used on more than one pest (e.g., aphids and lepidopterous larvae), the percentage of acres treated is the total for the state and each such use is not additive.

Data on individual pesticide use, as taken from the California Department of Pesticide Regulation (4), is

presented in the text for 1998. Included in Attachment 1 are data about use for the three year period from 1996 - 1998.

Insect Pests

Insect Management

Aphids and lepidopterous larvae (worms) are the predominant pests in California. From the standpoint of Integrated Pest management (IPM) and pest resistance management, it is essential that pesticides with different modes of action (e.g., organophosphates, carbamates, pyrethroids and insect growth regulators [IGR]) be available to reduce the potential for the buildup of resistance to one type of material. There are only a limited number of organophosphates, carbamates and pyrethroids registered for use on fennel, with new IGR type materials in the process of being registered or under development. Pesticides are used alone, in combination, or in an alternative treatment regime to control the various insect pests that cause economic damage to fennel. Very seldom, if ever, are the individual types of products (e.g., organophosphates) used in combination or as an alternative treatment with another registered product in the same chemical family. Bacillus thuringiensis (BT) provides control of many worm species, but is not as effective as other chemicals, and often requires additional treatments to maintain economic control. While worms are feeding, and accumulating toxic amounts of BT, leaf damage and the deposition of frass invariably occurs.

The management of insect populations is extremely critical to the production of fennel. Not only do insects damage fennel, they also contaminate fennel by their presence, from their feeding, or from the depositing of excrement. The high quality standards currently in place in the fennel industry allow for minimal, if any, contaminated products reaching the market place.

APHIDS

Yellow Willow Aphid (*Cavariella aegopodii*): This aphid causes serious problems primarily in the coastal regions. High populations of this aphid can stunt young plants, and can also deposit honeydew, which causes quality problems in fennel. This insect also vectors Carrot Motley Dwarf Virus, which can be a serious problem in carrot production. Although methomyl and permethrin will suppress populations of this aphid, there are no currently registered products that will provide control of this aphid. A total of 1 to 2 annual foliar treatments are applied for this aphid, primarily in the coastal regions.

The following information is provided to indicate the importance of this aphid by production region (2, 5):

PEST	COASTAL	DESERT
Yellow Willow Aphid	O	NA

COASTAL= Monterey, San Luis Obispo, and Santa Barbara Counties
DESERT= Riverside County and Yuma, AZ.

P = Primary
S = Secondary
O = occasional
NA indicates that the listed pest is not yet known to be a problem in that region.

Controls

Biological

There are no efficient parasites or predators that provide economic control of the yellow willow aphid (6).

Chemical

Malathion - Labeled PHI is 7 days. Malathion is only used on a limited number of acres with < 0.5% of the state acreage treated in 1998 (4). Research data and grower experience indicates that malathion is not an effective treatment for any of the aphid species attacking fennel (2, 5, 6).

Methomyl - Labeled PHI is 7 days. Typical PHI ranges from 14 to 21 days (2, 5). Methomyl is applied as a foliar treatment to approximately 16% of the acreage (4) at an average rate of 0.9 lb. ai. per acre, and will suppress aphid populations at this rate (2, 5). Approximately 77% of use was in the coastal region, 16% in the desert in 1998, and 7% in the central valley area (4).

Permethrin - Labeled PHI is 1 day. Typical PHI ranges from 14 to 21 days (2, 5). Permethrin is applied as a foliar treatment to approximately 35% of the acreage (4) at an average rate of 0.125 lb. ai. per acre, and will suppress aphid populations at this rate (2, 5). All permethrin use was in the coastal region in 1998 (4).

Pyrethrins - Labeled PHI is 0 days. Pyrethrins are not widely used, with 1998 use reported on < 2% of the state acreage (4). Research data and grower experience indicates that Pyrethrins are not an effective treatment for any of the aphid species attacking fennel (2, 5). Loss of foliar treatments of this insecticide would have little, if any, impact on aphid resistance management and IPM programs.

Rotenone - Labeled PHI is 0 days. Rotenone is not widely used, with 1998 use reported on < 1% of the state acreage (4).

Note to use by region:

COASTAL (75% of CA production) - Monterey, San Luis Obispo, and Santa Barbara Counties.
DESERT (25% of CA production) - Riverside County.

LEPIDOPTEROUS LARVAE

Beet Armyworm (*Spodoptera exigua*): This insect causes serious damage to fennel, and is most prevalent during fall production in the desert regions. Reduced stands can result from high insect populations. The primary materials used for this pest are methomyl, permethrin, tebufenozide, thiodicarb, and spinosad, with 1 to 2 total annual treatments applied in the coastal and desert regions (winter and spring) and 1 to 3 total applications under the high populations in the desert in the fall.

The following information is provided to indicate the importance of this lepidopterous pest by production region (2, 5):

PEST	COASTAL	DESERT
Beet Armyworm	P	P

COASTAL= Monterey, San Luis Obispo, and Santa Barbara Counties
DESERT= Riverside County and Yuma, AZ.

P = Primary
S = Secondary
O = occasional
NA indicates that the listed pest is not yet known to be a problem in that region.

Controls

Biological

The most common parasites of the beet armyworm are wasps (e.g., *Hyposoter exiguae* and *Chelonus insularis*), and the tachinid fly (*Lespesia archippivora*) - (7).

Predators also play a role in reducing populations of lepidopterous larvae. Two predators that feed on

lepidopterous eggs are minute pirate bugs (*Orius* spp.), and bigeyed bugs (*Geocoris* spp.) - (7).

Viral diseases (e.g., nuclear polyhedrosis virus) also play a role in reducing populations of lepidopterous larvae (7).

Parasites, predators, and viral diseases may assist in reducing lepidopterous egg and/or larval populations. However, their use is limited because of the high crop quality standards, and a low tolerance for insect contaminated products in the market place.

Chemical

***Bacillus thuringiensis* (BT)** - 0 day PHI. BTs play an important role in IPM programs, however, their use is limited, with approximately 4 % of the state acreage treated in 1998 (4). BTs usually require additional applications to be as effective as other products (e.g., carbamates, pyrethroids and IGR), and foliar damage, along with the deposition of frass normally occurs from feeding while worms are ingesting toxic amounts of BT type products.

Methomyl - Labeled PHI is 7 days. Typical PHI ranges from 14 to 21 days (2, 5). Methomyl is applied as a foliar treatment to approximately 16% of the acreage (4) at an average rate of 0.9 lb. ai. per acre (2, 5). Approximately 77% of use was in the coastal region and 16% in the desert in 1998 (4). Loss of this product would impact worm resistance management and IPM programs as it is used as an alternative treatment to other products (e.g., pyrethroids, and IGR). Resistance to the beet armyworm has been documented in the desert, however, resistance varies with geographical production region. Loss of this product would impact worm resistance management and IPM programs as it is used as an alternative treatment to other products (e.g., pyrethroids and IGR).

Permethrin - Labeled PHI is 1 day. Typical PHI ranges from 14 to 21 days (2, 5). Permethrin is applied as a foliar treatment to approximately 35% of the state acreage (4) at an average rate of 0.125 lb. ai. per acre (2, 5). All permethrin use was in the coastal region in 1998 (4). Loss of this product would impact worm resistance management and IPM programs as it is used as an alternative treatment to other products (e.g., carbamates and IGR).

Spinosad - Labeled PHI is 1 day. Typical PHI ranges from 14 to 21 days (2, 5). Spinosad is applied as a foliar treatment to approximately 2% of the state acreage (4) at an average rate of 0.1 lb. ai. per acre (2, 5). Approximately 70% of use was in the coastal region in 1998 (4). Use of this material is expected to increase, and the loss of this product would impact worm resistance management and IPM programs as it is used as an alternative treatment to other products (e.g., carbamates, pyrethroids and IGR).

Tebufenozide - Labeled PHI is 7 days. Typical PHI ranges from 14 to 21 days (2, 5). Tebufenozide is applied as a foliar treatment at an average rate of 0.125 lb. ai. per acre (2, 5). Tebufenozide was only recently registered and limited data are available on use by region. Use of this material is expected to increase, and the loss of this product would impact worm resistance management and IPM programs as

it is used as an alternative treatment to other products (e.g., pyrethroids and carbamates).

Thiodicarb - Labeled PHI is 14 days. Typical PHI ranges from 14 to 21 days (2, 5). Thiodicarb is applied as a foliar treatment to approximately 2% of the state acreage (4) at an average rate of 0.75 lb. ai. per acre (2, 5), and all use was in the coastal region in 1998 (4). Use of this material is expected to increase, and the loss of this product would impact worm resistance management and IPM programs as it is used as an alternative treatment to other products. (e.g., pyrethroids, and IGR).

Note to use by region:

COASTAL (75% of CA production) - Monterey, San Luis Obispo, and Santa Barbara Counties.
DESERT (25% of CA production) - Riverside County.

Other Insect Pests

Fennel is a host for other insects that do not presently cause economic damage. These insects include: Lygus bug (Lygus *Hesperus*); Western Flower Thrips (*Frankliniella occidenttalis*); and Whiteflies (*Bemisia tabaci* and *B. argentifolii*).

Diseases

There is one primary foliar and one primary soil disease that affect fennel production in California.

The management of diseases is extremely critical to the production of fennel. Not only do diseases cause yield losses, they also contaminate the foliage and bulbs as a result of tissue decay during harvesting and shipment to market. The high quality standards in place in the fennel industry allow for minimal, if any, contaminated products reaching the market place.

Fungal Diseases

Leaf Blight (*Cercosporidium punctum*): This blight-like disease can cause serious yield losses of fennel if not controlled. Mancozeb is currently the product used for the control of this disease.

Stem Rot (*Sclerotinia minor*): Stem rot, commonly referred to as "drop," is an extremely important disease of fennel, and is very prevalent in the coastal production areas (8). The sclerotia of S. minor

populations may remain viable in the soil for prolonged periods (e.g., up to 8 to 10 years). Under normal disease conditions, approximately 75% of the fennel acreage is treated for drop, and even with the use of fungicides losses from this disease range from 5 to 20%. The loss of dicloran would have serious impacts on the control of this disease as it is the only labeled product available for use on fennel.

The following information is provided to indicate the importance of each individual disease by production region (2, 5):

PEST	COASTAL	DESERT
Leaf Blight	P	P
Stem Rot	P	S

COASTAL= Monterey, San Luis Obispo, and Santa Barbara Counties
DESERT= Riverside County and Yuma, AZ.

P = Primary
S = Secondary
O = occasional
NA indicates that the listed pest is not yet known to be a problem in that region.

Controls

Biological

There are no current methods of providing biological control for fungal diseases that infest fennel.

Chemical - Foliar Disease Management

Fosetyl-al - Labeled PHI is 3 days. Typical PHI ranges from 10 to 14 days (2, 5). Fosetyl-al is applied as a foliar treatment at an average rate of 2.4 lb. ai. per acre (2, 5). Fosetyl-al was used on approximately 7% of the state acreage, with all use the coastal region in 1998 (4).

Mancozeb - 14 day PHI. Typical PHI ranges from 14 to 21 days (2, 5). Mancozeb is used as a preventative fungicide and is applied as a foliar treatment to approximately 56% of the acreage (4), at an average rate of 1.6 lb. ai. per acre (2, 5). All use of mancozeb was in the coastal region in 1998 (4). Mancozeb is the current product used for leaf bight management, and the loss of this product would severely impact resistance management and IPM programs as it is only one of two foliar fungicides currently labeled for fennel.

Chemical - Soil Disease Management

Dicloran - 7 day PHI. Typical PHI ranges from 21 to 30 days (2, 5). Dicloran may be applied either as a single or multiple application treatment. The average rate for the single application is 4.0 lb. ai. per acre (2, 5). The average rate for the multiple applications is 2.0 lb. ai. per acre (2, 5). Dicloran is applied to approximately 43% of the acreage, with essentially all use in the coastal region in 1998 (4). Usually only 1 application is made to an individual fennel crop. Even with fungicide use, losses from this disease range from 5 to 20%, and the loss of this fungicide would have serious economic impacts on fennel production.

Note to use by region:

COASTAL (75% of CA production) - Monterey, San Luis Obispo, and Santa Barbara Counties.
DESERT (25% of CA production) - Riverside County.

Bacterial Diseases

One bacterial disease of fennel has been reported in California, and the bacterium associated with this disease was identified as *Pseudomonas syringae* (9). To date, this disease has not been prevalent or caused economic damage to fennel in California (2).

Controls

Biological

There are no current methods of providing biological control for bacterial diseases that infest fennel.

Chemical

There are no chemicals registered for the control of bacterial diseases on fennel.

Viral Diseases

Viruses are not currently considered economic pests of fennel in California.

Nematodes

Nematodes are not currently considered economic pests of fennel in California.

Weeds

Weed control is essential, as weeds can increase production costs, and cause yield losses in fennel. Annual broadleaf and grassy weeds are the predominant problems in fennel fields. The primary losses occur from competition with the crop for nutrients and water during stand establishment and production, and loss of plants during thinning and hand weeding operations.

There are only a limited number of herbicides available for use in controlling weeds in fennel, and they are usually applied with ground equipment. The wide range of production areas and the extreme diversity of weed species allow for many problems in maintaining acceptable control during the production season. No individual herbicide or combination of materials will control all weed species under all production conditions and soil types.

Weed management is extremely critical to the production of fennel. If not controlled, weeds increase the cost of production due to increases in the time required for their removal. Individual weeds (e.g., burning nettle) can also create problems at harvest, while weed foliage can contaminate fennel. The high quality standards currently in place in the fennel industry allow for minimal, if any, contaminated products reaching the market place.

Controls

Biological/Cultural

There are no current methods of providing biological control for either annual or perennial weeds that infest fennel.

Hand weeding is a weed control option on fennel following crop emergence, and many small weeds are eliminated during the thinning operation. Hand weeding after thinning is only done to remove large weeds that may either present problems during harvesting (i.e. burning nettle), or contaminate the crop at harvest. Mechanical cultivation of the bedtop and furrow areas possible during the early stages of crop development but is not possible in the last 30 days before harvest as bulb damage may occur. Weeding crews require careful supervision to reduce the potential for yield reductions resulting from plant (i.e., bulb) damage or the loss of fennel plants during these operations.

Chemical

Control of weeds prior to planting is usually accomplished through the normal preplant ground

preparation procedures or with preplant or fallow bed treatments of glyphosate. The use of herbicides in this period varies from year to year primarily depending upon weather conditions, with increased use during wet periods when cultivation is not possible. In most instances, herbicide use at this time is followed by a light cultivation to destroy any remaining plant material prior to planting.

Fallow Bed Uses

Glyphosate - PHI is restricted by use as a fallow bed treatment prior to planting. Glyphosate is applied as a preplant - fallow bed treatment prior to planting (2, 5). Glyphosate was not applied to any state acreage in 1998 (4).

Preplant, Preemergence, or Postemergence Uses

Bensulide - PHI is restricted by use as either a preplant or a preemergence treatment at planting. Typical PHI ranges from 90 to 160 days (2, 5). Bensulide is applied as either a preplant or preemergence treatment to approximately 6% of the state acreage (4) at a typical rate of 6.0 lb. ai. per acre (2, 5). Approximately 22% of use was in the coastal region and 78% in the desert in 1998 (4). The loss of this product would have an economic impact on the production of fennel, particularly in the desert areas.

Metam-sodium - PHI is restricted by use as a preplant treatment. Metam-sodium is not widely used and < 1% of the state acreage was treated in 1998 (4).

Prometryn - PHI is restricted by use as either a postplant/preemergence, or a postemergence treatment after transplanting. Typical PHI ranges from 90 to 160 days for the at planting treatments and 110 to 125 for the treatments made after transplanting (2, 5). Prometryn is available under EPA SLN NO. CA-960025. It is applied at a typical rate of 1.6 lb. ai. per acre for direct seeded and 2.0 lb. ai. per acre for transplants (2, 5). Prometryn was used on approximately 39% of the state acreage with all use in the coastal region in 1998 (4). The loss of this product would have serious economic impacts on the production of fennel, particularly in the coastal areas.

Note to use by region:

COASTAL (75% of CA production) - Monterey, San Luis Obispo, and Santa Barbara Counties.
DESERT (25% of CA production) - Riverside County.

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Appendices

Fennel Use Data 1996-1998

	Acres Treated 1998	Acres Treated 1997	Acres Treated 1996
Azadirachtin	11	0	21

Bacillus thuringeinsis	57	163	45
Bensulide	105	0	0
Dichloran	616	342	460
Fosetyl-Al	104	67	0
Malathion	4	0	85
Mancozeb	1230	1133	756
Metalaxyl	8	4	0
Metam-Sodium	10	24	7
Methomyl	248	425	198
Permethrin	579	176	23
Prometryn	630	606	0
Pyrethrins	25	26	2
Rotenone	24	48	4
Thiodicarb	20	0	126
