A Pest Management Strategic Plan for California Celery Production

December 2004

California Celery Research Advisory Board

California Minor Crops Council

The California Minor Crops Council (CMCC) received funding for this project from the USDA Cooperative States Research, Education, and Extension Service (CSREES) Pest Management Alternatives Program (PMAP). CMCC received additional support from the California Celery Research Advisory Board and the Western Integrated Pest Management Center at UC Davis. Funding for this project also has been made available by the Governor's Buy California initiative, the California Department of Food and Agriculture, and the U.S. Department of Agriculture, through the University of California's Specialty Crops Research Program.

Executive Summary

California is the primary celery producing state in the U.S., accounting for over 85% of the national production. There are approximately 25,000 harvested acres of this crop in California yielding from 30 – 34 tons per acre. The gross value per acre of celery ranges from $8,000 to $10,000, depending on price fluctuations in the market. Celery production in California is year round, unlike other states, with about a third of the crop grown to meet demands for the Thanksgiving and holiday markets.

The primary pest problems for most celery growers are diseases and insects. The major tactics that growers have employed as components of their system of integrated pest management (IPM) have been the use of clean planting stock, resistant varieties, celery free periods, irrigation management, and chemical control. Research programs designed to address issues for the celery industry are largely funded by grower funds; through the California Celery Research Advisory Board, the industry works closely with breeders, consultants, and the land grant university system.

New safety standards set forth by the 1996 Food Quality Protection Act (FQPA) have significantly impacted the availability and/or use patterns of important crop protection chemicals used in agriculture, especially organophosphate and carbamate insecticides/miticides. While the celery industry hopes to maintain very low levels of chemical inputs, the low profit margins and high consumer standards, makes the availability of cost effective pest management tools imperative. The California celery industry continues to work diligently with its state and federal partners to evaluate, register, and implement reduced risk production practices.

“Minor use” crops, such as celery, have challenges in getting new crop protection tools registered. As the costs to conduct required research and register new materials increases, registrants are less willing to focus on commodities like celery since there are relatively few acres (as compared to major crops, e.g., corn, soybeans, etc.); their return on investment is significantly lower in minor use crops. Due to these pressures and competition from foreign markets, California growers have seen a clear need to identify their primary pest management issues and focus their resources in areas that will deliver the most benefits to their industry. In light of this, the California celery industry, through the California Minor Crops Council, initiated the development of a pest management strategic plan (PMSP).

A meeting was held in January of 2004 to discuss broad issues impacting pest control problems encountered by the California celery industry. Input was provided by a work group that consisted of growers, packers, shippers, processors, Pest Control Advisers (PCAs), Farm Advisors and researchers from throughout the state. Input gathered at this meeting provided the basis for the development of a long term plan to address the pest management needs of their industry. The discussions focused on the pests that have the most significant economic impact on the California celery industry; the “product” of the workgroup meeting was a summary of the critical research, regulatory and educational needs of California celery industry.

It is hoped that this strategic plan will help agencies involved in research and regulatory issues to have an increased understanding of the pest management needs of the California celery industry. A contact list is provided at the end of the document for follow-up communication with representatives of this commodity. The foundation for this Pest Management Strategic Plan (PMSP) is the Crop Profile for California Celery (http://www.ipmcenters.org/cropprofiles/docs/cacelery.html); UC IPM Guidelines for Celery (website) also provided helpful information in the process. A comprehensive summary of the crop production and pest management practices used in California are included in the appendices of this plan. Information relating to the importance of pesticides and alternative pest control strategies used in recent production seasons has been presented. Information about new technologies is discussed, including proposed research and educational needs to insure that new products will provide acceptable levels of pest control and fit well into an integrated pest management system.

Stakeholder Recommendations

The Celery Work Group identified the following research, regulatory, and educational priorities for their industry. These critical areas must be addressed in order to maintain the economic viability of the celery industry in California.

Research Priorities

Finding effective techniques to detect and manage insect and disease pests are of the most immediate concern to celery growers in California. Studies on basic biology and management of soil pests and *Sclerotinia* diseases should be undertaken. Disease resistant varieties should be evaluated and commercially developed. Research on weed control, use of biofumigants, resistance management, and the indirect impact of the planned phaseout of methyl bromide in rotational crops should be investigated. University research and extension programs will remain critical to identifying and adopting new technologies for pest management in California celery production; these important systems should be supported on a continued basis by the appropriate local, state and federal agencies.

- Evaluate insect management tools alternatives to organophosphates and carbamate products (especially those products which are subject to restriction or loss due to FQPA and other regulations – e.g., acephate, diazinon, carbamates)
- Study the biology and management of soil pests
- Study management of *Sclerotinia* (airborne and soil borne)
- Evaluate new celery varieties for resistance to insects and diseases
- Evaluate biofumigants as tools for pest control in celery
- Develop resistance management strategies for all pest categories
- Continue weed control research to find complimentary or replacement products for Lorox®/linuron and Caparol®/prometryn
- Evaluate the secondary effect of loss of methyl bromide as a tool used in rotational crops in celery production areas (i.e. methyl bromide is not used in celery, however, the use of this product in other crops provides pest control in celery)

Regulatory Priorities

The celery industry should work with the registrant community to insure that all aspects of label language are appropriate for product use patterns and pest management needs in this crop. Fair policies need to be established for the registration and use of multiple products in resistance management programs by state regulatory authorities. Full registrations are sought for herbicides, particularly herbicides such as Dual Magnum®/S-metolachlor which is used for control of nutsedge. Improved harmonization between CDPR and US EPA is needed to facilitate timely registration of reduced risk products; the IR-4 program should be used efficiently to identify product candidates for research and registration.

- Registrants should insure that air and chemigation labels are a part of all new product registrations
- Address REI issues/concerns for products used in late season (e.g. aphicides)
- Multiple products should be allowed under 24(c) and Section 18s for resistance management (California issue)
- Expedite registration of Dual Magnum®/S-metolachlor for control of nutsedge

Educational Priorities

All stakeholders (growers, PCAs, regulators, consumer groups and the urban community) must be educated about the use of Integrated Pest Management (IPM) in California celery production, and how this system optimizes food production and ensures safety for workers and the environment. Growers need to be educated on pest identification, pest management, resistance management, and the most efficient and environmentally safe manner in which pesticides can be applied in celery. The regulatory and legislative communities need to be educated on the critical need for the availability of multiple products to effectively manage resistance. Growers and urbanites need to be educated on good agricultural practices and waterway issues with regard to state and county regulations. Consumers should be reminded that eating California celery is an important part of a healthy, low carbohydrate diet and that this produce is grown under the highest standards of safety and quality in the world.

- Educate regulators, legislators, and policy makers on need for more than one product for a particular pest for effective resistance management
- Educate regulators on what a suitable replacement product is and what constitutes commercially acceptable levels of control
- Educate growers, PCAs, agencies and the urban community on the relationship of waterway management to weed and insect pests
- Educate the urban population about agricultural practices necessary for celery production
- Educate the public on the nutritional values of California grown celery and the high level of food safety and quality standards established for this commodity

The Pest Management Strategic Plan for California Celery is a “working” document and will be updated periodically to reflect pertinent changes in pest management practices.

The mention of any trade name in the strategic plan does not indicate any endorsement of any product by any member of the California celery work group.

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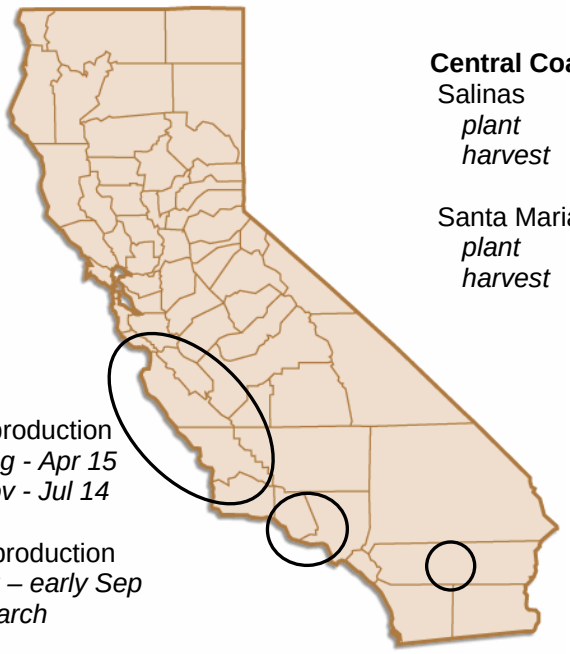
Celery Production in California

The three main celery production areas in California are shown below. Crop production and pest occurrence calendars for these areas are provided in the Appendix.



Central Coast ~ 55% of production
Salinas
plant *late Feb - early Aug*
harvest *mid Jun - early Nov*

Santa Maria
plant *mid Feb - mid Sep*
harvest *early Jun - mid Dec*

South Coast ~ 40% of production
plant *early Aug - Apr 15*
harvest *early Nov - Jul 14*

Desert Valleys <2% of production
plant *late Aug – early Sep*
harvest *Dec - March*

Production Overview

- California produces approximately 85% of the celery grown in the United States; other important production states in the US are Michigan, Florida and Texas.
- There are approximately 25,000 acres of celery in California; acreage numbers are quite variable from year to year according to market prices and consumer demand.
- California produces celery year-round. Crops from Florida and south Texas augment winter supplies, while those from Michigan, and to a much lesser extent Ohio and Wisconsin, contribute to summer totals.
- Fresh celery accounts for over 95% of California production; processed products are dehydrated or lightly processed celery is juiced, frozen, or cut into sticks.
- The majority of the crop is domestically consumed; about 12 – 15% of the crop is exported to Canada, Mexico, Europe and Pacific Rim countries.
- Insects and diseases are the major pests of celery.
- Widespread use of biological control has not been shown to be economically feasible in celery production; natural enemies are conserved as much as possible through selective pesticides.
- Less than 2% of California celery is grown using organic production practices.
- Since relatively few materials are registered for celery, it is very important that replacement tools are developed and registered before older materials are phased out due to FQPA and other regulatory actions.
- The encroachment of the urban environment upon the agricultural regions of California continues to exert pressure on celery growers.

Growing Conditions: Celery is a cool season biennial that grows best from 60^{O}F – 65^{O}F, although it can tolerate temperatures from 45^{O}F to 90^{O}F. The crop responds best to a long, cool growing season with cool nights, however cold temperatures and stress can induce bolting. High temperatures can decrease the time frame in which bolting is expressed.

Crops Per Year and Harvest Timing: California celery areas can produce up to 2 crops per acre per year. Important rotational crops include strawberries, lettuce, and cole crops. Planting and harvest dates vary by production region and are driven by celery-free periods unique to Ventura and Monterey Counties. Planting and harvesting schedules are coordinated to provide a steady supply of fresh celery throughout the year with a peak in November for Thanksgiving and December for Christmas.

Stand Establishment/Transplanting: Most (>95%) of the commercial celery in California is planted from greenhouse-grown transplants. Transplants decrease the field-growing period, provide uniformly sized plants and confer a competitive advantage over newly emerging weeds. After approximately 70 days in the greenhouse, celery seedlings are transplanted at an average rate of 45,000 per acre onto double-rowed 40-inch beds. The transplants are spaced 7 inches apart. Firm, succulent bunches are harvested 85-140 days later depending on season and weather.

Variety Selection: There are 5 – 6 major commercially available varieties of celery grown in California. Breeding programs have focused on *Fusarium* and leaf miner resistance; other characteristics relate to yield, flavor, bolting resistance, pithiness, quality, and plant architecture.

Fertilizer Use: Celery requires a great deal of nutrients. Fertilizers are used prior to planting and at several specific intervals after transplanting. A crop will typically remove 400 pounds of nitrogen, 400 pounds of phosphorous, and 400 pounds of potassium from each acre.

Irrigation: Celery, due to its shallow root system, requires a steady and uniform supply of moisture. Transplants are immediately sprinkler-irrigated after planting followed by drip, furrow or sprinkler irrigation during the rest of the season. Uniformity of irrigation is critical to overall crop quality.

Use of Labor: Hand labor is essential to growing a celery crop. Specific labor practices include: transplanting, irrigation, hoeing, tractor operation for fertilizer and pesticide applications, harvesting.

Typical Number of Days in Various Stages of Celery Production

Planting to Germination	Germination to Transplanting	Transplanting to 1st Cultivation	1st Cultivation to 2nd Cultivation	Days from Transplanting to Harvest
7-28 days	60-70 days	21-28 days after transplanting	Occurs 10-14 days after 1st cultivation	Spring & Fall Crop: 85 – 100 Summer Crop: 75 – 90 Winter Crop: 100 –140

All celery crops grown in California are managed in a similar manner regardless of planting date; due to the longer growing season for the winter planted crops, additional cultivations my be required. The time it takes to grow a celery crop is dependent upon the time of year in which it is planted. Typically, celery is an 85-100 day crop in spring & fall, a 75 – 90 day crop in summer, and a 100 – 140 day crop in the winter. Fall plantings of celery begin in August; harvests begin in October. Winter plantings begin in December; harvests begin in March. One quarter to on third of the California crop is planted in the fall to meet the market demand for the Thanksgiving and Christmas markets.

Historical Perspective on IPM Integrated Pest Management Issues in Celery

The following information provides an overview of the major pest management issues of California celery production over the last two decades.

1980s – Major insect pests included beet armyworms, aphids, leafminers (*L. trifolii*). *Fusarium* (primary issue), celery mosaic virus, septoria (late blight), *Sclerotinia*, and bacterial soft rot were disease concerns. Annual broadleaf weeds were the major weed problems. Insecticide use included pyrethroids, organophosphates, and carbamates (used as both baits and sprays).

1990s – A new leafminer species was found (*Liriomyza huidabrensis*), which needed to be managed differently than *L. trifolii*. Beet armyworm and *Lygus* became more important. *Fusarium* continued to be very important, with septoria (late blight), early blight, *Sclerotinia*, bacterial blight, and bacterial soft rot severe in certain areas.

2000 and beyond – Additional leafminer species were found and aphids, whiteflies and *Lygus* became more important. Widespread use of *Fusarium* resistant cultivars was extremely successful for managing this disease; bacterial blight and bacterial soft rot became more important. Nutsedge emerged as a primary weed problem as planting areas were shifted to poorer soils and into rotations that encouraged this particular weed.

Current Pest Management Issues and Industry Trends

Cultural Practices – Today, the use of resistant varieties and increased use of drip irrigation systems has been very helpful in managing several diseases. Heat treatment of seeds has proven very effective for controlling certain diseases such as septoria. The use of clean transplants as a standard practice has improved the establishment of vigorous insect and disease free celery plantings. A trend towards low till management in certain areas (e.g. Santa Maria area) has actually led to increased insect problems. Crop rotations have changed with a tendency to have back-to-back celery crops, which leads to pest problems.

Biological Control – Augmentative releases of parasites and predators are rarely used because these biological controls generally do not work quickly enough for growers to avoid damage to their crop. Growers and PCAs, do, however, avoid using harsh materials that disrupt natural enemies. The availability of softer chemistries and outreach programs of industry and Cooperative Extension have been beneficial for the industry. In recent years, it has become more understood by growers and PCAs that the crop can take some insect damage (e.g., beet armyworm) in the early part of the season (first six weeks); this alone has led to the conservation of natural enemies and an overall reduction in insecticide use.

Chemical Control – Insecticide use in celery has evolved significantly. The industry has moved from the widespread use of organophosphates and carbamates to softer chemistries such as Success®/spinosad. In the past, there were a greater number of broad-spectrum products available; however resistance problems have developed with several of these older materials. Newer products used in celery are now more specific. There continues to be a need for aphicides that will provide control up until harvest. Nutsedge is still a huge weed issue in celery production. The widespread use of certain herbicides such as Lorox®/linuron and Caparol®/prometryn have selected for weeds. These products, particularly Caparol®/prometryn, are critical until suitable alternatives are registered.

Pest Management Goals of the California Celery Industry

- Utilize reduced risk practices which provide commercially acceptable levels of pest control
- Have workable and realistic reentry intervals for crop protection tools
- Obtain timely registrations for pesticides that are approved for use on both domestic and internationally consumed product
- Effectively manage irrigation water runoff

Foundation for a Pest Management Strategic Plan

The remainder of this document is an analysis of pests, horticultural practices, and pest management techniques used during the major stages of celery production as practiced by California growers. A calendar of seasonal pest occurrence, pest management and cultural activities for the major production areas in the state is found in the appendices.

The following seasonal intervals have been identified as important in terms of horticultural and pest management events in celery production; the pest management issues of each of these phases are examined in each section.

- Bed Preparation
- Transplanting through First Cultivation
- First Cultivation through Second Cultivation
- Third and Fourth Cultivations (if needed for winter planted crops)
- Harvest
- Post Harvest

Additional issues regarding IR-4 minor crop research and registrations, international trade, and food safety have also been summarized.

Bed Preparation

Good bed preparation prior to transplanting is essential to managing a celery crop for maximum yield and quality. Proper soil conditioning and leveling of fields prior to planting will provide the optimal environment for celery transplants. Weed control is the result of several practices including cultivation and use of herbicides. Crop rotation, pre-plant irrigation, and disking to remove weed seedlings reduce the potential for weed problems in celery; these practices will contribute to overall weed management throughout the production season.

Effective pest control in celery is often a "by-product" of pest management activities in prior crops such as lettuce and strawberries. Methyl bromide, Telone®/1,3-dichloropropene and Vapam®/metam sodium are fumigants used in these and other rotational crops; these products provide varying degrees of control of several insect, disease, and nematode pests of celery. The potential loss of fumigants for use in rotational crops, particularly methyl bromide, could cause long-term problems for celery growers in California, even though this product is not directly used in celery.

Growers in certain regions have established "Farmers' Districts" which are designated areas within counties that require a mandatory celery free period. These districts have been created to reduce the incidence and severity of Western celery mosaic viruses (WCMV) spread by insect vectors.

Cultural and Worker Activities

Field Work to Bed Up:	Bedding Up:
• Pre-irrigation • Disk up to 8 times/as needed • Land plane • Apply gypsum • Disk • Chisel plow	• Make furrows • Shape beds to compact and smooth soil

Insects

Insects are generally not a major concern during this particular phase of celery production. Working previous crop residue into the soil through cultivation will help to destroy leafminers and their habitat. Celery free periods as required in local pest management districts will help to reduce the presence of host material for insect vectors and viruses.

Work Group Recommendations for Insect Management During Bed Preparation

RESEARCH	• Evaluate rotational products to be used in conjunction with Admire® for whitefly and leafminer control. • Evaluate whitefly resistance to insecticides; develop a resistance management program that includes area-wide approaches to resistance management • Evaluate new techniques and materials for leaf miner control
REGULATORY	• Register alternatives to Admire® for whiteflies and leafminers
EDUCATION	• Educate growers and PCAs on resistance management • Educate regulators on resistance management issues and the need to have multiple products available to use in a resistance management plan • Educate growers and PCAs on minimum tillage and potential leafminer problems that result from the presence of trash in the field

Diseases

Bed preparation is critical in managing disease problems since water management is a primary means by which to reduce the incidence and/or severity of several pathogens of celery. Fields should be even and allow for uniform movement of moisture; there should never be any standing water in the fields.

Plowing at this time is a cultural technique used to bury *Sclerotinia*, which reduces inoculum levels in the soil. Minimum tillage, therefore, is not an effective technique for management of *Sclerotinia*; if this inoculum is not worked deep into the soil, disease problems may develop.

Management of soil borne diseases is mainly accomplished through cultural techniques such as planting when conditions are not optimal for disease development. Crater rot is an increasing problem in minimum till ground; this disease is more prevalent with certain varieties and in warm, wet springs. *Fusarium* can be managed in part by making sure that transplanting is done during the cooler times of the year. A new biological material called Contans® has some potential for reducing losses due to pink rot.

Work Group Recommendations for Disease Management During Bed Preparation

RESEARCH	Evaluate Contans® and other biological/chemical materials for *Sclerotinia* and *Fusarium* under California conditions; there are many new and interesting concepts (composts, products, etc.) Evaluate the relationship between groundsel and the incidence of *Sclerotinia* (alternate host, etc.)

Note: There are no recommendations for regulatory or educational activities for this phase.

Weeds

Control of weeds is accomplished through good weed management in previous crops (such as dry beans, peppers, tomatoes, cole crops, onions, celery, lettuce, and strawberries), and/or residual control provided by fumigations. It cannot be understated that the planned phaseout of methyl bromide in rotational crops will indirectly impact weed problems encountered in celery production.

It is important to reduce weed seed banks during this early phase so that young celery plants will not have to compete with weeds later on in the season. The practice of irrigating to germinate weed seedlings followed by applications of contact herbicides is very effective for this purpose. In reality, however, there is seldom time to do this.

The most challenging weed for celery growers is nutsedge since there are no control options currently registered; Dual Magnum®/S-metolachlor is in the registration process for celery. Other than this, the best option for management of nutsedge is to treat for this weed in rotational crops.

Caparol®/prometryn provides fair to good control of nettle and pineappleweed, however, this product is very weak on groundsel and London rocket. The use of Caparol®/prometryn is limited… Treflan® is a good residual herbicide for grasses, pigweed, and lambsquarters.

Work Group Recommendations for Weed Management During Bed Preparation

RESEARCH	• Evaluate alternatives to Caparol®/prometryn and Lorox®/linuron • Evaluate new formulations of Goal®/oxyfluorofen for efficacy and crop safety • Evaluate weed control options for organic growers • Evaluate the relationship between groundsel and the incidence of *Sclerotinia* • Need herbicide to use prior to transplanting (e.g. Chateau®)
REGULATORY	• Register Dual Magnum®/S-metolachlor; resolve indemnity issues in CA • Maintain availability of Eptam® availability; ease plant back restrictions in certain geographies • Critical to maintain Caparol®/prometryn and Lorox®/linuron • Register Goal®/oxyfluorfen through the IR-4 program
EDUCATION	• Educate growers and PCAs on probable weed issues common in celery that follows strawberries (in strawberries, bed treatments have left the middles untreated; appropriate control measures should therefore be taken in the celery crop or serious weed issues will arise)

Nematodes

Root knot nematode is the primary nematode species of concern in celery. Nematodes interfere with normal water and nutrient uptake in celery plants. Like other soil pests, some residual control of nematodes is provided by good crop and nematode management practices used in the prior crop. Growers are able to take advantage of nematode control provided by products used in rotational crops. Fumigations using methyl bromide, Telone®/1,3-dichloropropene, or Vapam®/metam sodium are effective nematicides, but these materials are seldom used in celery due to cost or a lack of registration. It cannot be understated that the loss of methyl bromide in rotational crops will indirectly impact nematode problems encountered by celery growers. Crop rotation helps to limit the buildup of economically important levels of nematodes in celery.

Work Group Recommendations for Nematode Management During Bed Preparation

RESEARCH	• Determine the impact methyl bromide phaseout (in rotational crops) as it impacts nematode issues in celery • Evaluate new nematicides/practices in absence of methyl bromide • Evaluate "biofumigant" crops
REGULATORY	• No recommendations
EDUCATION	• No recommendations

Vertebrate Pests

Gophers disrupt the soil, making for poor bed shaping and irrigation during the growing season. Strychnine poison, phostoxin and box traps used underground are effective tools for management of gopher problems.

There are no work group recommendations for vertebrate control during the bed preparation phase.

Transplanting Through First Cultivation

The use of clean, vigorous transplants is critical to producing high yielding and high quality celery. Transplants are grown under contract to be ready in specific quantities by a specific date to meet market demands. Seed is planted into heat-treated planting media, which contains sand, vermiculite, and perlite. Greenhouse grown transplants are about 60 to 70 days old when they are brought to the field; the young plants are 3 to 4 inches tall and should have strong, healthy roots at planting and be free of insects and diseases. Occasionally, the flats of transplants will be "mowed" to insure uniformity of size for the transplanting machine and to promote even growth in the field.

Fusarium and virus resistant varieties are widely used in celery production. In addition, characteristics such as yield potential, height, stalk diameter, resistance to bolting, pithiness, color and ribbing are important considerations for growers as they select which cultivars.

Transplanting of celery should be done at cooler times of the year to avoid problems with *Fusarium*, which can be a major problem. Residual control from fumigations done in rotational crops provides some level of control of certain pathogens. The planned phaseout of methyl bromide in rotational crops will directly impact disease problems encountered in celery production.

Transplanting of celery plants is done on a tractor-mounted unit that carries field workers. Workers place the small plants into a rotating device that makes a groove in the prepared bed; after the transplant is in the hole, the machine covers the root mass with soil. Workers will check fields to make sure that the soil is firmly packed around the root mass. Young plants are irrigated using sprinklers very shortly after transplanting.

Cultural and Worker Activities

• Transplant young celery plants
• Apply fertilizer
• Irrigate
• Pest scouting
• Pesticide applications

Insects

Once transplants are in the field, insects can cause major damage to very young celery plants. In severe cases, up to 100% of a field can be infested. Insect problems vary from year to year, but tend to be heaviest in the summer and fall months. It is common for fields to require repeated applications of insecticides; some materials disrupt the natural enemy complex and the use of biological control agents as a sole control tactic is therefore rare.

Availability and use of softer chemistries in recent years has been beneficial in preserving natural enemies and maintaining the efficacy of all insecticides registered in celery. Judicious use of pesticides and rotation of chemistries is important in resistance management programs since there are relatively few products registered for celery.

A common practice at this time of the season is to shank Admire® into the transplant line or run the product through the drip line. This application method and timing has proven very effective in limiting losses due to whiteflies, aphids and other piercing sucking insects.

There are few effective biological control agents commercially available for insect pests in celery.

Major Pests:

Leafminers Using clean transplants and selecting field sites that do not have a history of leafminer problems is important in avoiding problems with leafminers. Naturally occurring parasites work fairly well. It is recommended to use soft chemistries to not disrupt natural enemies and flare up leafminers. Variety selection is also a means of culturally managing leafminers, as some varieties seem to be more susceptible, especially some of the new “stick” varieties that are very vulnerable to cosmetic damage.

Trigard® and Avermectin® both provide good to excellent control of leafminers. Both of these products are expensive to apply; Trigard® is a more economical option.

Beet Armyworm Bt and Confirm®/tebufenozide are good materials for beet armyworm; fields are treated only if infestations are severe.

Cabbage Looper Bt products and Confirm®/tebufenozide work very well.

Aphid Good control of aphids is achieved through preplant applications of Admire® or use of this product applied through the drip system. Assail®, Vydate® and Orthene®/acephate also provide good control of aphids. Vydate® can be applied through drip irrigation; this product is soft on beneficials and controls root aphids and whiteflies which are problematical in some production regions.

Minor Pests:

Lygus Pyrethroids (LIST) provides good control of *Lygus*, but this class of chemistry is harsh on beneficials and can lead to leafminer problems. This is an issue more in the Salinas production area.

Cutworms Pyrethroids, Bt and Confirm®/tebufenozide are good materials for beet armyworms and cutworms; fields are treated only if infestations are severe.

Corn Earworm This is a rare pest; Bt and pyrethroids are good materials for corn earworm; fields are treated only if infestations are severe.

Seedcorn Maggots Banded applications of diazinon provide fair levels of control. A chemigation label is needed for this product.

Saltmarsh Caterpillars This is a very rare pest in celery. Bt applications provide good control of this pest.

Work Group Recommendations for Insect Management
From Transplanting Through First Cultivation

RESEARCH	• Evaluate leafminer adulticides; prefer to use a product that is soft on beneficials • Evaluate *Lygus* materials; prefer to use product soft on beneficials • Develop an area-wide pheromone disruption program for beet armyworm
REGULATORY	• Register additional aphid materials for use on celery • Register rotational compounds for use in resistance management programs (*Lygus*, leafminers, etc.)
EDUCATION	• Educate growers on use of Fulfill® for aphid control • Educate regulators on the need for multiple chemistries to avoid resistance issues

Snails and Slugs

These pests can become established in young celery and become a big problem later in the production season. Fields should be scouted for these pests. Metaldehyde baits can be used with some success to reduce populations. There are no effective biological control agents commercially available for these pests in celery production.

There are no work group recommendations for snail and slug control.

Diseases

Two critical techniques that contribute to disease management in young celery are the use of clean planting stock and proper irrigation. Some diseases are also effectively managed using preventative measures such as seed treatments and early season fungicide treatments. Crop rotation and good sanitation (preventing movement of infested soil, etc.) helps to limit some disease problems. In certain areas, “celery free” time periods have been established; this regulatory approach to limiting losses due to viruses has been extremely effective to break the disease cycle.

Seed borne diseases:

Late Blight (*Septoria apiicola*) This disease is more common in the coastal production regions. Preventative sprays of Tilt®/propiconazole work well. Bravo®/chlorothalonil provides good control. Copper provides very little control of late blight and this product is widely used in organic production. The use of drip irrigation will help to limit disease spread by reducing inoculum transmitted by splashing water. There are no effective biological control agents commercially available for this disease.

Northern Bacterial Blight (*Pseudomonas syringae*) This disease is favored by warm, moist conditions. Copper hydroxide is the major product used to control this disease and it provides fair to good control. There are no effective biological control agents commercially available for this disease.

Soil borne diseases:

Crater Rot (*Rhizoctonia solani*) Soil fumigations used in rotational crops limit the presence of this pathogen in celery. An effective cultural method to reduce disease incidence is to plant at the optimal depth in the soil and keep dirt off of plants to reduce the spread of the disease. Bravo®/chlorothalonil provides good control of crater rot. There are no effective biological control agents commercially available for this disease.

Fusarium (*Fusarium oxysporum*) Use of resistant varieties, proper irrigation management and avoiding fields with a history of this disease are major cultural methods to avoid problems with *Fusarium*. The relative importance of this disease has been reduced over the last 2 decades due to progress in the area of plant breeding. Plant stress and injury should also be avoided. There are no effective biological control agents commercially available for this disease.

Viruses Western Celery Mosaic WCMV is the primary virus of concern; the use of host free periods and mandated "celery free" periods is a highly effective technique to break the disease cycle. Care should also be taken to use clean transplanting stock and alternative hosts (wild celery types) should be removed from the vicinity. Drainage ditches should be kept free of volunteer celery, as this harbors both disease organisms and vectors.

Work Group Recommendations for Disease Management
From Transplanting Through First Cultivation

RESEARCH	• Evaluate and develop resistant varieties (viruses, *Fusarium*, late blight, etc.) • Evaluate the relationship between stress (nematode, temperature, etc.) and the onset and severity of *Fusarium* yellows • Develop "precision ag" practices which integrate geographic information systems (GIS), field history, site selection, etc.
REGULATORY	• Change the Bravo®/chlorothalonil REI from 6 days to 2 days
EDUCATION	• Educate regulators on the need for multiple chemistries to avoid resistance issues

Weeds

Weeds management in celery is most critical until the transplants are established and can form a canopy to compete with weeds. The use of vigorous transplants in combination with other control tactics helps celery to have a competitive edge over weeds, especially in fields which were recently fumigated. Several species can pose significant problems for celery growers if not managed properly. Infestations reduce uniformity of growth, can harbor insects and diseases, and they will interfere with efficient harvesting at the end of the season.

Weeds are effectively controlled using pre-plant and post-emergent herbicides if application timing is correct. Chemigation is a very good method to use in celery because of the reduced likelihood of phytotoxicity to the young plants. Weeds such as mallow and nutsedge must be mechanically removed. There are no effective biological control agents commercially available for weed control in celery.

Typical weeds in celery include the following species:

Broadleaves
Little Mallow
Knotweed
Lambsquarters
Shepard's-purse
Sowthistle
Nettle
Groundsel
Pineappleweed
London Rocket
Nettleleaf goosefoot
Pigweed

Grasses
Barnyardgrass
Annual bluegrass

Sedges
Yellow nutsedge
Purple nutsedge

Caparol®/prometryn is a broad-spectrum herbicide active on several broadleaf and grass species. The use of this product and its availability through chemigation systems (sprinkler) is critical for celery production. Prism® provides good grass control, including annual bluegrass; Poast® is a good grass herbicide, but misses annual bluegrass. Lorox®/linuron is another important herbicide used in combination with Caparol®/prometryn or alone; this herbicide controls several broadleaf and grass species in addition to partially controlling sedges during the warmer part of the season. Hand hoeing and weeding at this timing is not common.

Work Group Recommendations for Weed Management
From Transplanting Through First Cultivation

RESEARCH	• Precision ag practices should be evaluated for celery production • Develop "machine vision" and weed mapping technologies for selective herbicide treatments • Evaluate mulches, especially for use in organic production • Evaluate postemergence herbicide alternatives for Lorox®/linuron and Caparol®/prometryn • Evaluate mechanical cultivation techniques
REGULATORY	• Preserve sprinkler labels for Caparol®/prometryn and Lorox®/linuron
EDUCATION	• Educate growers and PCAs on scouting and field selection • Educate growers and PCAs on need for sanitation, especially as it relates to nutsedge management • Educate growers and PCAs on the critical need for rotational products to use in resistance management programs • Educate growers, PCAs, and field workers on the importance of waterway management in controlling weeds • Educate government officials (state, county, city, etc.) on the need to manage weeds in waterways; this will provide multiple benefits for effective weed management, efficient water use, etc.

Nematodes

There are few in-season techniques and products available for nematode control in celery. Vydate® provides fair to good control of nematodes when used as a shanked in application or if chemigated through drip lines, however, this product will eventually be phased out. There are no effective biological control agents commercially available for nematode control in celery.

There are no work group recommendations for nematode management for the period spanning from transplanting to the first cultivation.

Vertebrate Pests

There are several vertebrate pests that can directly or indirectly interfere with celery production once the plants are in the field: squirrels, rabbits, gophers, and deer. Some of these pests feed on the young plants; others such as gophers, ground squirrels and coyotes take out drip lines or disrupt the soil profile, interfering with irrigation.

Bait stations containing diaphacinone anticoagulants work fairly well for management of squirrels. Strychnine poison, phostoxin and box traps used underground are effective tools for management of gopher problems.

There are no work group recommendations for vertebrate management for the period spanning from transplanting to the first cultivation.

First Cultivation Through Second Cultivation (35 Days On)

During this phase of celery development, the marketable petioles are starting to form. It is extremely important, therefore, to manage pests that directly consume or damage the plants, as well as those which reduce the vigor of the plants. During this time, pest scouting and insect management activities in particular are intensified.

Once transplants are established, frequent irrigations and applications of fertilizers are needed to maintain good growth. Drip and furrow irrigation methods will predominate over sprinkler irrigation from this point forward.

Cultural and Worker Activities

• Break furrow bottoms
• Apply fertilizer
• Irrigate
• Pest scouting
• Pesticide applications

Insects

As the celery plants continue development insect populations are carefully monitored, heavy infestations of insects often require repeated applications of insecticides; resistance management should be practiced as much as possible to preserve chemical tools. The judicious use of pesticides and rotation of chemistries is important in resistance management programs since there are relatively few products registered for celery.

Unfortunately, some insecticides disrupt the natural enemy complex, and secondary pest outbreaks can occur. The use of biological control agents as a sole control tactic is rare because these products simply do not provide the needed levels of control quickly enough to prevent serious damage to the plants. A positive development for the industry in recent years has been the availability and use of softer chemistries. These products are not only softer on beneficials and safer for workers to use, they work very well in a resistance management program that rotates product chemistries.

Major

Leafminers Growers need to be extremely careful in proper identification of leafminer species, since *L. huidabrensis* and *L. trifolii* are managed differently. It is recommended to use soft chemistries to not disrupt natural enemies and blow up leafminers. Trigard® and Avermectin® both provide good to excellent control of leafminers. Both of these products are expensive to apply; Trigard® is a more economical option. Vydate® provides good control of *L. huidabrensis*, but is not effective for *L. trifolii*.

Beet Armyworm Bts, Proclaim®, Success®/spinosad, and Confirm®/tebufenozide are good materials for beet armyworm; unlike earlier in the season, it is critical to control this pest at this phase of the season.

Cabbage Looper This pest is rare in celery, but if present, Bt products provide fair to good control, but they have a short residual. Plants cannot tolerate damage at this time of the season.

Aphid Fulfill® is an excellent aphid product but is extremely expensive. Orthene®/acephate and diazinon are good aphid materials, but care needs to be taken to not use these products in warmer months or leafminer problems can escalate. Vydate® used in the drip system provides fair to good control of aphids; this product is soft on beneficials and controls root aphids and whiteflies which are problematical in some production regions.

Minor

Lygus Good control of this pest is achieved using Orthene®/acephate, Vydate®, Mustang® or Pounce®\permethrin. These broad spectrum materials can result in disruption of leafminer beneficial insect complexes.

Cutworms Bts, Proclaim®, Success®/spinosad, and Confirm®/tebufenozide are good materials for cutworms; unlike earlier in the season, it is critical to control this pest at this phase of the season. Pyrethroids also effectively control cutworms.

Corn Earworm Bt and Pyrethroids are good materials for corn earworm; fields are treated whenever the pest is present.

Earwigs Sevin® bait is effectively used on the perimeter of field, but cannot be used in the field.

Two Spotted Mites This is a rare pest; avermectin is a very good miticide when needed.

Thrips Lannate®/methomyl and Pyrethroids are an effective control of thrips.

Work Group Recommendations for Insect Management
From First Through Second Cultivation

RESEARCH	• Evaluate neonicotinoid resistance in insects, especially for in leafminers • Develop a resistance management program for all pests • Evaluate new bait formulations (wax, etc.) for earwigs and other soil pests
REGULATORY	• Register Avaunt® and Intrepid® through the IR-4 program • Register pyriproxyfen • Obtain an air label for Proclaim® (a primary rotational material for Success®/spinosad) • Determine the status of Sevin® bait • Evaluate status of new bait formulations (wax, etc.) earwigs, etc.
EDUCATION	• Educate growers and PCAs on the use of neonicotinoid products and their use and role in resistance management

Snails and Slugs

Snails and slugs feed directly on developing petioles later in the production season. Fields should be scouted for these pests. Metaldehyde baits can be used with some success to reduce populations. There are no work group recommendations for this pest category.

Diseases

Disease management during this time of the season is the culmination of several management activities done earlier in the season (variety selection, use of clean transplanting stock, sanitation, etc.) Throughout the season, scouting for diseases, proper irrigation management, and use of fungicides will help to avoid or control disease buildup. A critical cultural factor that needs to be adhered to at this time is to make sure that all worker activities are conducted when fields are dry as to avoid spreading inoculum.

Foliar diseases

Late Blight (*Septoria apiicola*) Bravo®/chlorothalonil, Tilt®/propiconazole and Quadris® provide good control. Benlate® is also effective, but the registration for this product is being phased out. Copper provides very little control of late blight and this product is widely used in organic production. The use of

drip irrigation will help to limit disease spread by reducing inoculum transmitted by splashing water. There are no effective biological control agents commercially available for this disease.

Northern Bacterial Blight (*Pseudomonas syringae*) This disease is favored by warm, moist conditions. Sulfur and copper hydroxide are the major products used to manage this disease; these products provide fair control during this time of the season. There are no effective biological control agents commercially available for this disease.

Soil borne diseases

Pink Rot There are no highly effective fungicides for this disease. Serenade®, an option for organic production, requires multiple applications but only provides fair levels of control. Bravo®/chlorothalonil, Echo® and Botran®/dichloran provides only fair efficacy. Botran®/dichloran is a short-lived product and requires proper placement at the base of the plant. There are no effective biological control agents commercially available for this disease.

Crater Rot (*Rhizoctonia solani*) Quadris® is a good material for this disease; Bravo®/chlorothalonil provides fair to good control of crater rot. There are no effective biological control agents commercially available for this disease.

Fusarium There are no products available to manage this disease. The only cultural option growers can practice is to avoid overwatering and double cropping of fields. There are no effective biological control agents commercially available for this disease. Fumigation with Methyl Bromide and Chloropicrin can reduce problems.

Work Group Recommendations for Disease Management
From First Through Second Cultivation

RESEARCH	• Evaluate new fungicides for control of soil borne diseases • Evaluate the in season use of Contans® • Refine late blight models
REGULATORY	• Reregister Topsin M® for late blight • Register new products for control of soil borne diseases
EDUCATION	• No recommendations

Weeds

As celery plants grower taller, the use of hand weeding will become more important, since herbicide applications and cultivations will become more difficult. The use of drip irrigation itself does not increase weed pressure, but it does hinder the utilization of mechanical control methods therefore increasing the necessity for effective chemical control. Grass herbicides Prism® and Poast® as well as Lorox®/linuron and Caparol®/prometryn are occasionally used at this time. Growers and PCAs should be aware that weeds should not be allowed to go to seed at this time in order to prevent weed seed build up for subsequent crops.

Work Group Recommendations for Weed Management
From First Through Second Cultivation

RESEARCH	• Continue evaluation of materials available for potential adaptation for this time period
REGULATORY	• No recommendations at this time
EDUCATION	• Educate growers and PCAs on the need to prevent weeds from going to seed at this time of the season • Educate growers and PCAs on the value of sanitation for weed control

Nematodes

Vydate® provides fair to good control of nematodes when shanked into the soil or applied through drip lines. Growers and PCAs need to be aware that there is a 21-day PHI if using this product.

There are no work group recommendations for nematode management for the period spanning from the first cultivation to the second cultivation.

Vertebrate Pests

The potential for vertebrate problems increases as the season progresses. The pest spectrum includes squirrels, rabbits, gophers, deer and coyotes. These animals feed on developing plants and/or disrupt cultural practices and irrigation activities.

Ground squirrels and coyotes take out drip lines, interfering with irrigation. Bait stations containing diaphacinone anticoagulants work fairly well for management of squirrels. Gophers disrupt the soil, making for poor bed shaping and irrigation during the growing season. Strychnine poison, phostoxin and box traps used underground are effective tools for management of gopher problems

There are no work group recommendations for vertebrate management for the period spanning from the first cultivation to the second cultivation.

Third and Fourth Cultivations
(For Winter Plantings)

Dependent upon the season in which the celery is planted, up to four cultivations may be done. Winter planted celery will have an extended production season, since the crop takes longer to develop. Winter planted crops can take up to 140 days to develop mature stalks.

Pest issues during this time are generally the same as in the earlier mentioned sections. Pesticides are applied at this time by air or through chemigation, since the crop height will limit field entry by ground equipment. Many products are not as effective when used by air since the crop canopy is not as easily penetrated.

Cultural and Worker Activities

• Break furrow bottoms
• Apply fertilizer
• Irrigate
• Pest scouting
• Pesticide applications

Work Group Recommendations for Mature Celery

RESEARCH	• Evaluate Tilt®/propiconazole for use in chemigation
REGULATORY	• Register Proclaim® by air • Register a low PHI type aphicide for late season applications close to harvest • Request air and chemigation labels for all new registrations to increase flexibility of use in late season
EDUCATION	• Educate registrants and regulatory agencies on the need for air and chemigation labels for pesticides

Harvest

Celery is intensively managed for uniformity and most fields are harvested only once. All celery destined for the fresh market is harvested by hand; most produce used by the processing and dehydrator industry is both machine and hand harvested.

Fresh-market celery is field packed into cartons, bags, or boxes and then hydro-cooled. The product is then kept in cold storage until it is shipped to distribution centers. There are also foodservice and secondary markets that utilize celery for lightly processed products such as sticks, diced or sliced, and for use in cooked products.

There are naturally occurring chemicals in celery (furanocoumarins) that may cause allergic reactions in some people.

Cultural and Worker Activities

• Fresh market celery is hand cut at ground level
• Plants are trimmed to the desired length
• Plants placed in box for transport to cooler
• Processor celery is harvested by machine or hand, then cooled
• Dehydrator celery is harvested by machine then direct to dehydrator

There are no work group recommendations indicated for the harvest period.

Post Harvest Field Management Issues

The work group felt it was important to indicate the important of educating growers and PCAs that back to back plantings of celery contribute to pest problems. Pest pressures increase if continuous celery is present in the fields.

Processor Issues

Color is a very important quality factor for celery used in processed markets and any leaf or stalk discoloration is undesirable. Because fungal diseases may impact color, it is imperative that pathogens are effectively controlled at the appropriate time of the season. In addition, prior to mechanical harvesting, all weeds must be removed from the field so that no weeds are harvested with the celery.

In terms of pesticide used, processors must carefully monitor the types of products used on celery to be used in the dehydrator and juice markets. Even biologicals such as BT are limited in certain European markets. The California League of Food Processors has developed an approved list of pesticides; certain customers may be even more prohibitive, depending on the end market use of the product.

The workgroup recommends that the status of the following products used on celery bound for the juice market are established: Orthene®/acephate, Botran®/dichloran, Lorox®/linuron.

IR-4 Minor Crop Registration Issues

The IR-4 minor crop registration process is of vital importance to the registration of new products for celery growers in California. There are several products currently in the system that are of interest to California celery growers. It should however, be noted that some products currently in the program (e.g., Brigade®) are not of interest to California growers; the IR-4 prioritization process should adequately reflect the needs of all growing regions and their relative importance to U.S. production.

Work Group Recommendations for IR-4 Registration Issues

RESEARCH	• Upgrade Avaunt®/indoxacarb to an A priority • Upgrade Knack®/pyriproxyfen • Obtain chemigation label for Caparol®/prometryn herbicide • Submit a pesticide clearance request (PCR) for Intrepid®

International Issues

The export market for celery accounts for 12-15% of overall production, depending upon the year. Exports go to Canada, Mexico, Pacific Rim countries and Europe. There are not any specific products used for celery destined for foreign markets, however, it is extremely important that the best quality and pest free fields are selected for these destinations.

The use of BT products is not allowed on celery, which is sold in Europe due to concern over use of genetically modified organisms. The presence of western flower thrips and leafminers may be very problematical if trying to move fresh celery into Pacific Rim countries. Attention must also be given to maximum residue levels (MRLs) in both dehydrator and frozen celery. Care should be taken to use pesticides that have established Codex or specific country registrations and tolerances.

The work group recommends that all products used in celery have approved international registrations through CODEX or other regulatory agencies in importing countries.

Work Group Recommendations for International Issues

RESEARCH	• Evaluate post harvest management tools for leaf miners (CO_2 etc.)
REGULATORY	• Insure that all US registered products are in compliance with MRL requirements of importing countries • Register Botran®/dichloran and Bt
EDUCATION	• No recommendations

Ag Urban Interface Issues

Areas of concern that might impact the ability to grow celery in California could be urban area runoff of storm waters, and ground water increases of both nitrates and chlorides along with other elements from urban and suburban areas. These problems can affect celery production though the flooding of fields adjacent to high drainage areas provided by the concrete and asphalt coverage that comes from the urban area. With these floods, new infestations of weeds and diseases can be deposited in production areas. At the same time, ground water can be affected by increased deposits of chlorides from urban soft water conditioners or nitrates from suburban areas serviced by septic systems.

In turn, agriculture can affect the urban environment through its use of pesticides, high volumes of waters that may provide odor problems along with other sources of organic matter that can provide obnoxious odors. Another example of an issue of how agriculture can affect city dwellers is the migration of whiteflies from agricultural areas into urban plantings of ornamentals.

The work group recommends that stewardship efforts in this area continue and increase.

Food Safety Issues

Consumers are increasingly concerned about food safety. In response to this issue, many retailers have begun to require third party testing and audits on growers and packers. Typical activities associated with audits include trace back to field sites, water sources, harvesting operations and crews.

There have been no specific food borne disease issues associated with celery to date; however, education on personal hygiene for field workers and packinghouse personnel is critically important. Consumers must also be informed as to proper handling and preparation of celery and celery containing foods.

The work group recommends that educational efforts in this important area be continued to adequately inform workers and consumers about food safety.

Critical Issues for the California Celery Industry

The following issues were identified by the Celery Work Group as being the most critical to the sustained viability of the California Celery industry.

RESEARCH	• Evaluate insect management tactics and products as alternatives to organophosphates and carbamate products (especially those products which are subject to restriction or loss due to FQPA and other regulations – e.g., acephate, diazinon, carbamates) • Study the biology and management of soil pests • Continue weed control research (Lorox®/linuron and Caparol®/prometryn) • Study disease management techniques for *Sclerotinia* (foliar and soil borne) • Evaluate new celery varieties for resistance to insects and diseases • Evaluate biofumigants as tools for pest control in celery • Develop resistance management strategies for all pest categories • Evaluate the secondary effect of loss of methyl bromide as a tool used in rotational crops in celery production areas (i.e. methyl bromide is not used in celery, however, the use of this product in other crops provides pest control in fields planted to celery in the following season)
REGULATORY	• Registrants should insure that air and chemigation labels are a part of all new product registrations • Address REI issues/concern (*indicate specific products*) • Multiple products should be allowed under 24C and Section 18s (California issue) • Expedite the full registration of Dual/Magnum® for control of nutsedge in celery
EDUCATION	• Educate regulators, legislators, and policy makers on need for more than one product for a particular pest for effective resistance management • Educate regulators on what a suitable replacement product is and what constitutes commercially acceptable levels of control • Educate growers, PCAs, and agencies on waterway management issues within the state and county and how these relate to effective integrated pest control • Educate the urban population about ag practices necessary for celery production • Educate the public on the nutritional values of California grown celery and the high level of food safety and quality standards established for this commodity

References

Crop Profile for California Celery Production
http://www.ipmcenters.org/cropprofiles/docs/cacelery.html

University of California Pest Management Guidelines for Celery
http://www.ipm.ucdavis.edu/PMG/selectnewpest.celery.html

University of California Vegetable Research and Information Center
http://vric.ucdavis.edu/usesites/ressite.htm

California Department of Pesticide Regulation – Pesticide Use Reports
http://www.cdpr.ca.gov/docs/pur/purmain.htm

National Ag Statistics
http://www.usda.gov/nass/

California Ag Statistics Service
http://www.cdfa.ca.gov/publications.htm

Appendices

Appendix 1: 2002 California Celery Production Statistics

Food Service

COUNTY	HARVESTED ACREAGE	YIELD (Tons/Ac.)	PRODUCTION (Tons)	TOTAL VALUE ($)
Monterey	609	30.62	18,650	15,227,000
STATE TOTALS	**609**	**30.62**	**18,650**	**15,227,000**

Source: County Agricultural Commissioners' Data (USDA/NASS/CASS)

Fresh Market

COUNTY	HARVESTED ACREAGE	YIELD (Tons/Ac.)	PRODUCTION (Tons)	TOTAL VALUE ($)
Monterey	8,873	30.64	271,880	75,251,000
Santa Barbara	4,083	36.81	150,278	34,313,500
STATE TOTALS	**12,956**	**32.58**	**422,158**	**109,564,500**

Source: County Agricultural Commissioners' Data (USDA/NASS/CASS)

Processing

COUNTY	HARVESTED ACREAGE	YIELD (Tons/Ac.)	PRODUCTION (Tons)	TOTAL VALUE ($)
Monterey	64	30.47	1,950	229,000
STATE TOTALS	**64**	**30.47**	**1,950**	**229,000**

Source: County Agricultural Commissioners' Data (USDA/NASS/CASS)

Unspecified

COUNTY	HARVESTED ACREAGE	YIELD (Tons/Ac.)	PRODUCTION (Tons)	TOTAL VALUE ($)
Orange	301	39.00	11,739	1,819,500
Riverside	343	36.72	12,595	3,077,400
San Benito	541	33.83	18,302	4,466,000
San Luis Obispo	1,074	34.62	37,182	7,486,000
Santa Clara	215	34.80	7,482	1,668,000
Santa Cruz	116	51.40	5,962	1,526,000
Ventura	10,662	38.09	404,583	114,707,000
STATE TOTALS	**13,212**	**37.68**	**497,845**	**134,749,900**

Source: County Agricultural Commissioners' Data (USDA/NASS/CASS)

Notes: The *CDFA Resource Directory – 2003* contains additional production statistics which may be seen at their website (http://www.cdfa.ca.gov/publications.htm).

Acreage reports vary according to reporting sources.

Appendix 2: Cultural Practices and Pest Management Activities

Oxnard District

Cultural Practices	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bed Preparation												
Fumigation												
Irrigation												
Transplanting												
Fertilizer Applications												
First Cultivation												
Second Cultivation												
Harvest												
IPM Activities	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling												
Scouting/Monitoring												
Release of Beneficials												
Insecticide Applications												
Pheromones												
Fungicide Applications												
Herbicide Applications												
Hand Hoeing												
Nematicide Applications												

Salinas

Cultural Practices	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Bed Preparation												
Fumigation												
Transplanting												
Irrigation												
Thinning												
Fertilizer Applications												
First Cultivation												
Second Cultivation												
Harvest												
IPM Activities	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling												
Scouting/Monitoring												
Release of Beneficials												
Insecticide Applications												
Pheromones												
Fungicide Applications												
Herbicide Applications												
Hand Hoeing												
Nematicide Applications												

Appendix 3: Seasonal Pest Occurrence

Oxnard District

Insects and Mites	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Leafminers –*trifolii*												
Leafminers –*huidabrensis*												
Beet Armyworm												
Cabbage Looper												
Aphids												
Lygus												
Cutworms												
Corn Earworm												
Thrips												
Saltmarsh Caterpillar												
Greenhouse Whitefly												
Earwigs												
Maggots												
Spider Mites												
Diseases	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Late Blight												
Bact. Blight												
Pink Rot												
Crater Rot												
Fusarium												
Bacterial Soft Rot												
Viruses												
Nematodes	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Rootknot												
Weeds	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Mallow												
Knotweed												
Lambsquarters												
Shephardspurse												
Sowthistle												
Annual Bluegrass												
Barnyardgrass												
Y. Nutsedge												
Burning Nettle												
Groundsel												
Purslane												
Vertebrate Pests	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Birds												
Rabbits												
Gophers												
Squirrels												
Voles												

Salinas District

Insects and Mites	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Leafminers –*trifolii*												
Leafminers –*huidabrensis*												
Beet Armyworm												
Cabbage Looper												
Aphids												
Lygus												
Cutworms												
Corn Earworm												
Thrips												
Saltmarsh Caterpillar												
Greenhouse Whitefly												
Earwigs												
Maggots												
Spider Mites												
Diseases	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Late Blight												
Bact. Blight												
Pink Rot												
Crater Rot												
Fusarium												
Bacterial Soft Rot												
Viruses												
Nematodes	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Rootknot												
Weeds	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Mallow												
Knotweed												
Lambsquarters												
Shephardspurse												
Sowthistle												
Annual Bluegrass												
Barnyardgrass												
Y. Nutsedge												
Burning Nettle												
Groundsel												
Purslane												
Vertebrate Pests	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Birds												
Rabbits												
Gophers												
Squirrels												
Voles												

Appendix 4: Efficacy of Insecticides

Rating System: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

PRODUCT	TRADE NAME	Leaf Miners - *trifolii*	Leaf Miners - *huidabrensis*	Beet Armyworm	Cabbage Looper	Aphids	*Lygus*	Cutworms	Corn Earworm	Thrips	Saltmarsh Caterpillar	Greenhouse Whitefly	Earwigs	Maggots	Spider Mites
Abamectin	Agrimek®	E	G	P	P				GE				P	G	
Bacillus thuringiensis	various			G	G			F	P				P		
Acephate	Orthene®			F	F	G	G	G	G	F			F		P
Malathion	Malathion				F	G		P	P	F			F		P
Methomyl	Lannate®			G	F	G	E	E	FP	G	G		G		
Pyrethrin + Rotenone						F							P		
Methamidiphos	Monitor®	F	F	G									P		
Cyromazine	Trigard®	E	E										P	G	
Azadirachtin	Neemix®	P	P	P	P	E				G			F	F	P
Thiodocarb	Larvin®			E	E	P		G					P		
Tebufenozide	Confirm®			G	G			F	F				P		
Endosulfan	Thiodan®				P	G		P	P	G			F		P
Imidachloprid	Admire®, Provado®	F	F	G	G	G	P	F	F	G		G			E
Dimethoate	Dimethoate			P	P	G	GF	P		F			F		P
Oil – summer	Oil									P			P		
Oxamyl	Vydate®	P	F	F	F	G	G	F	P	F		G	F		
Permethrin	Pounce®			F	G	P	E	E	F	P			F	F	
Pheromones	Isomate®			G	G			G	G						
Phosmet	Imidan®												F		
Pyridaben	Pyramite®														
Pyriproxyfen	Esteem®														G
Soaps	M-pede®														
Spinosad	Success®	F	P	E	G			P	G	E					
Zeta-cypermethrin	Mustang®			G	G						F			F	
Carbaryl	Sevin®												PG		

Appendix 5: Efficacy of Non-Chemical Insect Management Tools

Rating System: E = Excellent, G = Good, F = Fair, P = Poor/None

TECHNIQUE	Leaf Miners – *trifolii*	Leaf Miners – *huidabrensis*	Beet Armyworm	Cabbage Looper	Aphids	*Lygus*	Cutworms	Corn Earworm	Thrips	Saltmarsh Caterpillar	Greenhouse Whitefly	Earwigs	Maggots	Spider Mites
Cover Crops	P	P												
Monitoring/ action thresholds	E	E	E	E	E	E	E	E	E	E	E	G	F	
Natural enemies	E	E	P	P	F	P	P	P	P	P	P	P	F	
Nutrition	P	P	P	P	P	P	P	P	P	P	P	G	P	
Sanitation/Weed	F	F	F	F	F	F	F	F	G	F	F			
Soil/dust management	P	P	P	P	P	P	P	P	P	P	P	P	P	FG
Use of models	P	P	F	P	P	P	P	P	P	P	P			P
Resistant varieties	P	P												
Water management												F		
Weed control	P	F	F	F	F	F	P	P	F	P	P	PG	P	P
Mulching												P	P	
Trap Crops												F		
Netting														
Pheromones (mating disrupt)														
Pheromones (pop monitoring)			G	P				G						
Predatory Mites														

Data based on collective field observations and experiments

Appendix 6: Efficacy of Weed Management Tools

Rating System: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

PRODUCT	TRADE NAME	Broadleaves	Annual Grasses	Perennial Grasses	Perennial Broadleaves
Chemical					
Prometryn	Caparol®	G	F	P	P
Linuron	Lorox®	G	F	P	P
Glyphosate	Roundup®	PE	G	FG	F
Methyl Bromide	Methyl Bromide	PE	G	F	P
Metam Sodium	Vapam®	G	G	F	P
Trifluralin	Treflan®	F	G	F	F
Sethoxydim	Poast®	P	G	G	G
Oxyfluorfen	Goal®	G	F	P	P
Clethodim	Prism®	P	G	G	P
Non-chemical					
Cultivation		G	G	FG	FG
Soil/Water management		F	F	F	F
Cover crops					
Hand weeding		G	G	G	G
Mowing					
Burning					

Data based on collective field observations and experiments

Appendix 7: Efficacy of Disease Management Tools

Rating System: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

PRODUCT	TRADE NAME	Late Blight	Bacterial Blight	Pink Rot	Crater Rot	*Fusarium*	Bacterial Soft Rot	Viruses	Nematodes
Chemical Tools									
Benomyl	Benlate®								
Methyl Bromide	Methyl Bromide	F	P	G	G	F	P		E
Metam Sodium	Vapam®	G	P	F	G	P	P		FG
Chloropicrin	Chloropicrin	G	P	G	G	G	P		P
Chlorothalonil	Bravo®	G	P	F	F	P			P
Propiconazole	Tilt®	E	P	P	P	P			P
Anilazine	Dyrene								
Copper Hydroxide	Copper Hydroxide	F	F	P	P	P	P		P
Dicloran	Botran®	P	P	G	F	P			P
Thiophanate-methyl	Topsin ®	G	P	P	P	P			P
Azoxystrobin	Quadris®	F	P	F	F	P	P		P
Ziram	Ziram®								
Non-chemical Tools									
Models (i.e. disease forecasting)									
Irrigation management		F	F	F	F	F	F		P
Weed control		G	G	G	F		P	G	G
Resistant varieties		P	G	F	F	E	PG	F	P
Cover crops									
Fertilizer management		F	F	F	F	F	P	F	F
Vector control							P	G	
Sanitation		G	P	F	F	G	F	E	G
Hot Water Seed Treatment		E					F		

Data based on collective field observations and experiments

Appendix 8: Efficacy of Nematode Management Tools

Rating System: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

PRODUCT	TRADE NAME	Root Knot
Chemical		
Methyl Bromide	Methyl Bromide	E
Metam Sodium	Vapam	G
Non-Chemical		
Clean Cultivation		P
Soil Sampling		G
Crop Rotation		FG

Appendix 9: Efficacy of Vertebrate Management Tools

Rating System: E = Excellent, G = Good, F = Fair, P = Poor/None, R = Known Resistance

PRODUCT	TRADE NAME	Birds	Rabbits	Gophers	Ground Squirrels	Voles
Chemical						
Al Phosphide	Phostoxin	P	PF	G	G	G
Strychnine	Strychnine			G		G
Zinc Phosphide	Zinc Phosphide	P	PF	G	G	G
Non-Chemical						
Trapping		P	PE	F	F	F
Baits		P	F	G	G	G
Repellants		P	PF	P	P	P
Frightening		F	P	P	P	P
Shooting (Lethal Control)		P	PF	P	P	P
Prevention		P	P	P	P	P
Exclusion		P	PG	P	P	P
Explosive Devices		F	P	P	P	P
Owl Boxes		P	P	F	P	P
Cultural Barriers		P	PG	P	P	P
Predators		P	P	P	P	P
Noise		F	P	P	P	P
Mylar Strips		P	P	P	P	P

Data based on collective field observations and experiments

Appendix 10: Major Crop Protection Tools Used in California Celery (2002 CDPR)

Chemical Name	Trade Name	Gross Pounds	Acres Treated
METAM-SODIUM	Vapam®	60,941	274
CHLOROTHALONIL	Bravo®	53,143	32,017
DICHLORAN	Botran®	43,792	16,714
PROMETRYN	Caparol®	23,282	18,053
ACEPHATE	Orthene®	15,873	18,147
MALATHION	Malathion	15,343	10,895
COPPER HYDROXIDE	Champ®	13,398	15,524
OXAMYL	Vidate®	13,392	19,953
1,3-DICHLOROPROPENE	Telone®	10,278	105
PERMETHRIN	Pounce®	6,750	42,591
METHOMYL	Lannate®	5,077	6,297
COPPER OXYCHLORIDE	Various	4,906	3,314
LINURON	Lorox®	4,316	9,234
METHYL BROMIDE	Methyl Bromide	3,851	21
SPINOSAD	Success®	3,677	41,141
DIMETHOATE	Dimethoate	3,210	6,555
CHLOROPICRIN	Chloropicrin	2,878	21
MINERAL OIL	Mineral Oil	2,819	3,177
PROPICONAZOLE	Tilt®	2,462	22,314
TEBUFENOZIDE	Confirm®	2,029	16,247
PETROLEUM OIL	Petroleum Oil	1,930	353

Note: For a complete list of all products used in this crop, please refer to http://www.cdpr.ca.gov/docs/pur/pumain.htm. The above reported chemical use data was the most recent CDPR information available at the time of publication.

Appendix 11: California Celery Industry – Contact Information

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