A Pest Management Strategic Plan for Garlic Production in California

July 1, 2019

California Garlic & Onion Research Advisory Board (CGORAB)

California Specialty Crops Council (CSCC)

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EXECUTIVE SUMMARY

California ranks first in the U.S. in both the number of farms growing garlic and in harvested acres with over 21,472 acres harvested in 2017 compared to the U.S. total harvested acreage of 24,600. More than 3,516,713 cwt. of garlic were produced in the state in 2017 with a value of nearly $220 million. California produced approximately 90% of all commercially grown garlic in the U.S. in 2017. Approximately 40% of the California garlic crop is grown for processing/dehydration, while 60% is for fresh market. Garlic for seed is grown in Nevada, Oregon and Washington and represents over 2,000 acres. Although garlic is grown in several regions in California, nearly 92% of the total garlic grown in the state is in the western San Joaquin Valley counties of Fresno, Kings and Kern.

Integrated pest management (IPM) information is continuously being developed for weed, insect, nematode and disease problems of California garlic. The industry, through the California Garlic & Onion Research Advisory Board, provides more than $100,000 annually in research grants to address production problems, mostly concerning pest management issues.

California is ideally suited to growing high quality garlic. While the major production region is located in the western San Joaquin Valley, minor production regions include the southeast desert counties of Riverside and San Bernardino, northern California counties of Lassen, Siskiyou and Mono, and central coastal counties of San Benito and Santa Clara. Pest issues vary according to area of production, but in the major production areas in the San Joaquin Valley, the key problems in garlic production consist of diseases, weeds, insects and mites and, to a lesser extent, nematodes. These pests have in large part been controlled, or managed, by a program of crop rotation, sanitation, use of certified seed, fertility and irrigation management, avoidance (such as avoidance of known infested white rot fields) and use of pesticides. Organic garlic production in California is estimated to be about 5 to 8 % of the total acreage grown.

The California garlic industry faces significant challenges with the increasing spread of the white rot (*Sclerotium sepovorum*) organism throughout prime Westside farmland, increase in thrips resistance to pyrethroids, more weed control issues, increasing production costs, and a highly competitive global marketplace. In addition, the industry is concerned that new regulations set forth by both state and federal agencies may significantly impact the availability or use patterns of important crop protection chemicals and water used by growers. While this industry has recognized the need to evaluate, register, and implement reduced risk production practices, there are relatively few new products being evaluated. As the costs to conduct required research and register new materials increases, registrants are less willing to focus on commodities with relatively few acres (as compared to major crops such as corn, soybeans, etc.), simply because their return on investment is significantly lower. Therefore, many minor crop commodities, such as garlic, are more likely to lose pest management tools, with less likelihood they will be replaced by new products. Also, of great concern to the industry is the loss of University of California Cooperative Extension support for the industry and there is a need to replace current specialists and advisors who are retiring or moving on to other positions.

This Pest Management Strategic Plan for California Garlic includes a comprehensive summary of the crop production and pest management practices used by the garlic industry in California. The foundations for this document are the "Crop Profile for Garlic in California" (https://.ipmcenters.org/documents/cropprofiles/CAgarlic.pdf) and the "UC IPM Guidelines for Garlic" (http://ipm.ucanr.edu/).

Previous PMSP

In 2006, several key members and allies of the garlic industry met to specifically discuss long-term issues associated with disease, weed, insect, mite and nematode control. This led to the development of the first 2007 Pest Management Strategic Plan for the industry. During the next 11 years there were updates to the pest management tactics used, new crop care materials registered, and older materials removed from use. Thus, the purpose of a 2018 industry meeting was to review and update the Pest Management Strategic Plan to address the issues of greatest concern for garlic growers in California. The input gathered at this meeting provided an important perspective on the pest management products and techniques used in this commodity. The stakeholders focused on the pests that have the

most significant economic impact on the California garlic industry. This document is the culmination of the work group meeting and discussions to identify and update the critical research, regulatory and educational needs of California garlic growers to guide the industry in terms of allocating time and other resources. A full copy of the 2007 PMSP is online and on file with the Western IPM Center.

Stakeholder Critical Issues Recommendations for the Garlic Industry

As a result of the industry meeting held in Five Points, California, in May 2018, and with subsequent industry input, the Garlic Work Group identified the following research, regulatory, and educational priorities. These critical issues must be addressed to maintain the economic viability of the garlic industry in California.

Research Priorities

Finding effective techniques to manage or control white rot is the most immediate concern to garlic growers in California. With 144 fields representing almost 22,000 acres of prime farmland in the western San Joaquin Valley infected with white rot, controlling the spread of this disease is of paramount importance. Research has shown that effective white rot management is dependent upon a two-fold approach which must include a biostimulant one or more seasons prior to planting an Allium crop and then application at planting of tebuconazole (Orius®, Folicur®), fludioxonil (Cannonball®), penthiopyrad (Fontelis®) or boscalid (Endura®). New pre-emergence herbicides are needed that provide longer residual activities and are broader in spectrum because existing herbicides like DCPA (Dacthal®), pendimethalin (Prowl®), flumioxazin (Chateau®), dimethenamid (Outlook® and oxyfluorfen (Goal®) are the only pre-emergence herbicides registered for use on garlic and often do not provide satisfactory season-long control of the weed spectrum or provide the desired crop safety.

Garlic rust has become a serious, consistent pest of garlic in all of the growing areas and continued research on new fungicides that control this disease is necessary. At the present time only tebuconazole (Orius®, Folicur®) FRAC 3 and azoxystrobin (Quadris®) FRAC 11 are registered. There is now a concern for resistance as both products are classified as high risk. One fungicide representing a different FRAC group is being registered in California. This new product is benzovindiflupyr (Solatenol®). Although this product provides excellent rust control, ecotox concerns have slowed registration in California. Also needed is more research to identify alternate hosts for the garlic rust organism. By understanding which plants serve as hosts for the disease, it may be possible to control it or reduce its spread by rotating or eliminating the alternate hosts. Reports of garlic rust on dehydrated onions in the Imperial Valley were observed in 2018. This is of concern as garlic rust has only been a pest on garlic and leeks in the past.

The main insect pest of garlic is bulb mite. Leafminers can also cause foliar damage to garlic. Currently there are no registered pesticides for these pests. There is concern that the Allium Leafminer (a new invasive pest from Europe) could become a problem as it is now widespread in the Eastern US. Spinetoram (Radiant SC®), cyantraniliprole (Exirel®) and dinotefuran (Scorpion®) are effective on this pest. Thrips (Onion and Western Flower) can occasionally be a problem. Pyrethroids have been the common treatment, but thrips have developed resistance to the pyrethroid insecticides which have been used for years for control. In regard to stem and bulb nematode, data suggests abamectin (Agri-Mek®, Abba®) can provide effective control as seed piece drench or soak. Also, the new fungicide fluensulfone (Nimitz®) has not proven effective yet, but control may be improved with water activation. The availability of new insecticides, especially replacement products for the pyrethroids, such as spinosad and spinetorum, is a critical need for the Allium industry.

Likewise, an aggressive research program to establish economic thresholds for onion thrips and to understand the relationship of onion thrips to the potential spread of the Iris Yellow Spotted Virus (IYSV) to garlic are also important research needs. New varietal development should be focused on developing garlic varieties which are resistant to diseases, such as white rot or garlic rust. Methods to prevent or ameliorate freezing damage to vegetative seed and seedlings would be helpful. University research and extension programs will remain critical to identifying and adopting new technologies for pest management in California garlic production; these important systems should be supported on a continued basis by the appropriate local, state and federal agencies.

- Study white rot biology and other soil borne diseases and evaluate management techniques including deep plowing, soil disinfestation and efficacy of sclerotial stimulants.
- Identify economical organo-sulfur compounds that could be used as biostimulants for white rot management.
- Develop better detection methods for seed infestations of white rot, such as polymerase chain reaction (PCR) method.
- Evaluate new management practices for weed and disease control.
- Screen new insecticides, fungicides, and herbicides with different modes of action to maintain control and manage resistance.
- Determine alternate hosts of garlic rust and evaluate new products for rust control.
- Study basal root rot, *Fusarium oxysporum* biology and evaluate management techniques.
- Research potential insectides for bulb mite control.
- Evaluate water management techniques, including chemigation and the use of drip vs. furrow irrigation and if the use of drip is creating disease incidence.
- Investigate biology, ecology, and management of yellow nutsedge, marestail, hairy fleabane, field bindweed and morning glory specific to garlic production.
- Develop a resistance management program for garlic rust.
- Develop economic thresholds and evaluate efficacy of chemicals for thrips [onion (*Thrips tabaci*) and western flower (*Frankliniella Occidentalis*)].
- Evaluate the relationship between onion thrips and spread of IYSV in onions and potential infection in garlic.
- Explore use of biotechnology to develop garlic plants that have resistance to diseases.
- Evaluate fluensulfone (Nimitz®) for nematode control using water to activate the product.
- Request IR-4 work on abamectin for stem and bulb nematode as a seed treatment.
- Study root plate degradation (shattering).
- Study methods to prevent or ameliorate freezing damage to vegetative seed and seedings.
- Develop an economical testing method for nematodes and white rot.
- Study worker safety issues associated with garlic seed treatments and develop mitigation plans should seed treatments be disallowed by regulators.
- Develop fungicides that are effective for longer time periods, especially when trying to control white rot.
- Develop alternative rodenticides.

Regulatory Priorities

The garlic industry depends on the support of U.S. EPA, IR-4 and the California Department of Pesticide Regulation (CDPR) to register new products for California growers as well as to maintain an equitable regulatory system that keeps pest control products available to growers of minor crops like garlic. Registrations on garlic are being sought for the fungicide benzovindiflupyr (Solatenol®) for rust control, an herbicide combination of glyphosate-carfentrazone (Roundup®-Shark®) to be approved by a Section 24c registration, and boscalid (Endura®) for white rot management. It is imperative that specialty crop producers are kept abreast of new pesticide registrations and potential cancellations of existing products so that products essential to pest management are not lost and resistance-management efforts continue.

Continued work with CDPR and the County Agricultural Commissioners is needed to refine drift mitigation measures to prevent further injury to garlic crops from off-target movement of herbicides sprayed on other crops. Continued funding and staffing for the state inspection and certification

programs to prevent the spread of white rot is critical. In addition, continued cooperation between seed producing states on the white rot certification of seed fields is needed. Importation of garlic from China has affected sales of California garlic. Regulatory matters dealing with importation of garlic from China need to be enforced so there is equity in the marketplace. It is especially important that imported garlic be checked not only for illegal pesticides, but also for heavy metal contaminants that may be present. It is hoped the Food Safety Modernization Act (FSMA) regulations will help level the playing field for this situation. Likewise, harmonization in international markets is needed for tolerances, such as maximum residue limits (MRLs).

- Ensure equity in regulatory issues with export/import markets (like China).
- Regulate heavy metal contamination on dehydrated garlic from China.
- Register benzoyindiflupyr (Solatenol®) for white rot management in CA.
- Continued funding and staffing for the state seed certification programs.
- Support spray drift mitigation regulations (larger droplet size, buffer zones, etc.) to prevent further damage to garlic from drift.
- Work with other specialty crop producers to develop a tracking system to monitor possible cancellations of pesticides critical to crop production.
- Accelerate registration of new materials for resistance management, especially different classes of fungicides.
- Encourage continued cooperation between states on certification program for garlic seed.
- Encourage states to continue funding their certification programs for garlic seed.
- Provide regulatory flexibility in registering white rot resistant plant varieties developed through gene-editing technology to turn on/off specific traits.
- Work with state agricultural departments to address monitoring programs for white rot and other issues to help prevent the demise of the garlic industry.
- Register carfentrazone (Shark®) or flumioxazin (Chateau®) as a burndown herbicide following glyphosate (Roundup®) for pre-harvest weed control.
- Work with the Air Resources Board (ARB) and other agencies to mitigate dust issues (PM-10).
- Register alternative rodenticides.
- International harmonization on tolerances, including maximum residue limits (MRLs).

Educational Priorities

The public, including regulators and consumer groups, needs to be educated about the use of integrated pest management (IPM) in California garlic production, and how this system optimizes production and ensures safety for workers, consumers and the environment. Along with this training, growers and PCAs need to be educated about resistance management for all pesticides. White rot management techniques must be a key component of grower education and outreach activities.

- Reinforce white rot management through continuing grower education and outreach activities and by continuing and updating the industry White Rot Management Plan.
- Develop and implement a multi-faceted management program for all pests.
- Provide training on sclerotial stimulants (if research suggests these are commercially viable products).
- Engage the garlic processors in the program to help educate growers and PCAs on white rot issues.
- Develop Best Management Practices for growers for treatment of rust.

- Provide training on proper weed identification and control strategies.
- Educate growers to instruct weeding crews on the importance of weed management and preventing buildup of seed bank in soil.
- Provide sanitation guidelines and best management practices (BMPs) education regarding movement of soil on equipment, and how this can contribute to the contamination of new fields; and develop a protocol for sanitation of all field equipment to avoid the spread of inoculum for crop diseases.
- Communicate to the public a consumer education program how the garlic industry practices IPM and employs sustainable agriculture practices to maintain a high-quality product, including FSMA regulatory compliance.
- Participate with other specialty crop groups to organize field tours for state and federal regulators and other policy and decision makers to see current pest and crop management practices.
- Conduct resistance management training for all pesticides.
- Conduct an annual research symposium for growers and PCAs.
- Provide education to garlic growers regarding the potential for nematode infestations and damage.
- Grower education about techniques for limiting non-target risk from burrow fumigant and anticoagulant rodenticide applications.
- Provide training as needed and required for dust management.
- Provide information on export regulations related to white rot, and bulb and stem nematodes.

This pest management strategic plan for California garlic production highlights the most important issues the industry currently faces; and this document will need to be updated periodically. A list of individual growers, pest control advisors, industry representatives, and university research and extension personnel is located in Appendix 9 of this document for those seeking more detailed input on garlic production and pest management practices in California.

Product names listed in this document do not represent an endorsement of a trade brand by any member of the garlic work group. For reference, all chemical names and the accompanying trade names of each product are listed in this document.

Pesticides are an integral part of agricultural pest management. Consequently, their usage, timing and target pests are discussed throughout this document. However, no portion of this document constitutes a literal pesticide recommendation. While every effort was made to ensure accuracy and completeness of the information contained herein, no guarantees can be provided as to its accuracy. Always READ THE LABEL before applying pesticides.

A PEST MANAGEMENT STRATEGIC PLAN FOR CALIFORNIA GARLIC PRODUCTION

California Garlic Production Overview

Garlic, *Allium sativum* Gemmifera, originated in Central Asia several thousand years ago and has been grown for cooking, for herbal medicine and as part of religious ceremonies. Garlic belongs to the Alliaceae (onion) family. Other members of Alliaceae include chives (*Allium schoenoprasum*), leek (*Allium ampeloprasum,* Porrum group) and shallots (*Allium cepa,* Aggregatum group). Elephant garlic, which is grown for commercial production, is a different species, *Allium ampeloprasum*, and is not true garlic. It is a type of leek that produces large cloves and a large scape and umbel that may be cut and sold to florists.

Allium sativum comprises two subspecies, *A. sativum ophioscorodon* and *A. sativum*. The former, commonly referred to as "hardneck garlic," is not significant in commercial garlic production,

although it is planted by some home gardeners and by growers selling into the organic and other specialty markets. The latter, *A. sativum*, is commonly called "softneck garlic". While both types begin growth with leaf production, the hardneck types produce flower stalks, called scapes. It is the softneck subspecies that dominates commercial production. The two most popular softneck varieties among California growers are California Early and California Late. Early garlic, which has a growing period about one month shorter than late garlic, is grown primarily for the dehydration market; late garlic is favored by fresh market growers. Garlic is responsive to temperature and photoperiod for proper clove and bulb formation.

Planting

Garlic is propagated vegetatively through the planting of cloves, also referred to as garlic seed. It is critically important that garlic seed, most of which is produced out of state, is grown in soil that is free of nematodes and white rot disease. This is a disease that can be transmitted from the soil to the seed and vice versa, and ruin entire garlic crops subsequently planted with that seed. There is no treatment that is 100% effective for fields infected with white rot. Garlic seed is sometimes treated with hot water for protection from sclerotial white rot or stem and bulb nematodes. It may also be treated with thiophanate methyl (Topsin M®) prior to planting to guard against *Penicillium*, another seed-related disease. Research is underway by the IR-4 Program to secure a registration for abamectin (Agri-Mek®).

Garlic has a shallow rooting depth, averaging 6 to 8 inches. It is moderately tolerant of acid soils and grows best in soils with a neutral pH, usually ranging from 6.0 to 7.5. Light soils are best for garlic production; soils which are too heavy can cause bulb deformation. Soil in the San Joaquin Valley growing region, where most California garlic is planted, ranges from sandy loam to clay loam.

Growers typically plant garlic from mid-September through November. Bed size is 40 inches, and the garlic seed is planted in double rows at a density of about 18 plants per foot. In preparation for planting, garlic beds may be treated with a post-emergent contact herbicide to burn down existing weeds or treated with metam-sodium (Vapam®) to control weed seeds. There are no pre-plant herbicides registered for use in garlic, although post plant/pre-emergence herbicides are used. The garlic is first irrigated with overhead sprinklers for herbicide activation until stand establishment, then it is irrigated by furrow or drip. In some cases, only drip is used for herbicide activation and germination. There are concerns that planting depth coupled with drip irrigation might be causing some root plate problems.

Field Maintenance

After planting, the primary maintenance concern is weed management. Garlic fields are normally treated with pre-emergence herbicides immediately after planting, with additional applications made once or twice as the season progresses. Hand weeding has been eliminated in many fields. After first irrigation, the area around the garlic clove should not be allowed to become dry to the point where the roots do not have sufficient moisture to develop.

Insecticides are used very little. However, garlic grown for dehydration tends to remain in the field for a longer period than fresh market garlic, and growers will occasionally treat for insects, primarily thrips, to protect the crop (as well as to protect neighboring fields from migrating thrips).

While soil-borne diseases can seriously affect the garlic crop, foliar diseases in general have historically been of minor concern. Fungicides are applied to only a small percentage of California garlic acreage. Garlic rust disease is an annual threat to crop production and has increased the importance of fungicide applications, particularly tebuconazole (Folicur®) and azoxystrobin (Quadris®).

Irrigation of garlic fields is stopped a few weeks prior to harvest to allow the plants to dry. "Water cutoff" normally occurs when the garlic is mature. This is usually mid-May to June in the San Joaquin Valley, where the majority is grown.

Harvesting

Fresh market garlic can dry in the beds for three to four weeks after water cutoff, then the beds are mechanically "undercut" (a process that loosens the bulbs in preparation for harvest). The plants (leaves, bulbs, and roots) are then harvested immediately by hand and windrowed for further drying before being put in bins for transport from the field to the marketplace.

Garlic grown for dehydration is allowed to dry for approximately 4 to 6 weeks. The tops of the plants are mechanically mowed just prior to harvest. The bulbs may remain in the ground for as long as two additional months before being harvested. Just prior to harvest, the beds are sprinkled with water to facilitate harvest, which is done with mechanical diggers. At the processing facility, the garlic bulbs are placed in a warm air tunnel for additional drying, a process that has the added benefit of killing any mites that may be present, then are processed or placed in storage.

Crop Rotation

Growers rotate from garlic to other unrelated crops such as leafy vegetables, tomato, sugar beets, cotton or melon, and try not to reintroduce garlic into the field for a minimum of three years, and optimally at least four years, from the previous garlic crop.

California Garlic Production Summary

- California ranks first in the U.S. in both the number of farms growing garlic and in harvested acres.
- California produced approximately 92% of all commercially grown garlic in the U.S. in 2017 and virtually all garlic marketed as a consumable commodity.
- In 2017, a total of 21,472 acres of garlic were grown in California. Approximately 40% of California garlic is grown for processing/dehydration and 60% is for fresh market.
- Approximately 3,516,713 cwt. Of garlic were produced in California during 2017; the 2017 crop was valued at nearly $220 million.
- California garlic averaged about 7.5 tons (150 cwt.) per acre in 2017. Average garlic yield is 8 to 9 tons per acre.
- There are four primary areas of garlic production in California: The Western San Joaquin Valley, the Southeastern Desert Region, the Central Coastal Region and Northeastern Region. The Western San Joaquin Valley produces about 92% of the state's garlic.
- The major pest problems encountered in garlic include foliar and soil borne diseases, weeds, nematodes and insects/mites.

Stages of Crop Management (Range of Months of Activity in Each Growth Stage)

Cultural Practices	J	F	M	A	M	J	J	A	S	O	N	D
Bed Preparation												
Planting												
Irrigation												
Fertilizer Applications												
First Cultivation												
Second Cultivation												
Vegetative Development												
Final Irrigation												
Harvest												

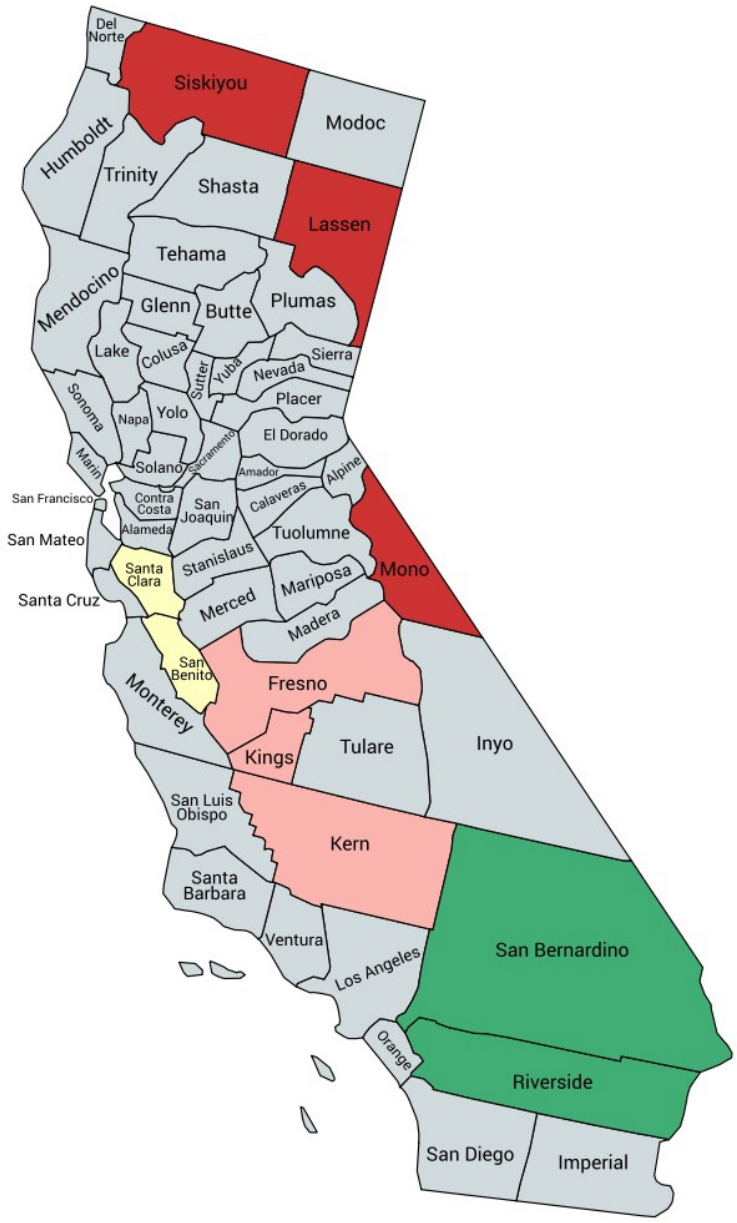
Major Pests of Garlic in California

Diseases, weeds, insects, mites, nematodes and vertebrates are the most important pests of garlic in California. The following are the most common pests found in California garlic.

Diseases	White rot, Garlic rust, Purple blotch, Stemphylium leaf blight, Bacterial rot, Fusarium, Botritis and Penicillium decay
Weeds	Cheeseweed, Chickweed, Field bindweed, Henbit, Lambsquarters, Marestail, Annual Morningglory, Pigweed, Purslane, Shepardspurse, Annual bluegrass, Barnyardgrass, Foxtail, Hairy Fleabane, Nutsedge, Swine crest, Nightshade and Volunteer Cereals
Insects/Mites	Onion thrips, Western flower thrips, Bulb mites, seed corn and onion maggot, leafminers and earwigs
Nematodes	Stem and Bulb nematodes
Vertebrates	Gophers, coyotes and wild pigs

Garlic Production Areas in California

The main garlic production areas in California are shown below. Statewide crop production statistics are provided in Appendix 1. Cultural practices and pest management activities and seasonal pest occurrence calendars for the main growing area, the western San Joaquin Valley, are provided in Appendices 2 and 3, respectively.



Production Area	Approximate Acres[1]	% of Production	Counties
Western San Joaquin Valley	19,754	92	Fresno, Kings, Kern
Central Coastal Region	859	4.0	Santa Clara, San Benito
Northeastern Region	86	0.4	Mono, Lassen, Siskiyou
Other Counties	773	3.6	Riverside, San Bernardino
Totals	21,472	100.0	

1. Source: CA Garlic and Onion Research Board 2017 Report

Historical Perspective on California Garlic: Production Trends and Integrated Pest Management

Key Pest Developments in California Garlic Production

During the 1970's, nematodes and Penicillium decay were greater problems than they are today. The standard practice to control nematodes was soaking the garlic in hot water with formaldehyde. This was a time-consuming practice and the use was eventually stopped. The treatment did control *Botrytis* spp. Well, however.

In the 1980s, virus-free garlic seed was introduced and gained widespread use. White rot was not identified as a problem largely because the thinking at the time was that it could not get established in the San Joaquin Valley. Obviously, this was not correct. Several new herbicides were introduced that were a major aid to weed control in garlic. Garlic production on the west side of the San Joaquin Valley increased dramatically because growers were forced to reduce production in coastal counties due to escalating production costs and introduction of white rot which rendered fields useless for garlic production.

During the 1990s there was significant importation of fresh garlic from China. In 1992, a dumping action was initiated, and a tariff was imposed on garlic from China. In 1996, garlic rust was first diagnosed in California garlic and in the spring of 1998 the disease reached epidemic levels. Because garlic rust caused significant decreases in California garlic production, there were increased imports of garlic to meet the needs of processors. In 1998, there was a large influx of imports of dehydrated garlic from China.

Since early 2000, both onion thrips and western flower thrips have become greater problems for garlic producers. Garlic can become a refuge for thrips that move in from other crops. When not treated, thrips can then migrate from garlic into onions. This is problematic because thrips have the potential to spread plant viruses to other crops. Due to constraints on the irrigation water supply, there has been a widespread increase in the use of sprinkler irrigation and drip irrigation (chemigation) in garlic production. Water availability and use on more permanent crops in the San Joaquin Valley may require more garlic growers to convert to drip irrigation. If this does not occur, production may have to move further north in the state where there is more water, but with climatic conditions less favorable for production. Seed production is moving north into Washington due to the loss of seed producing areas in eastern California, Nevada and Oregon due to infection with the white rot organism. Urbanization has also reduced potential seed acreage. Dust control regulations to reduce dust as an air pollutant in the western San Joaquin Valley growing area is another key issue that has been impacting garlic production.

Cultural Control

Key developments in cultural pest control in the last few years have involved the control (management) of stem and bulb nematodes (*Ditylenchus dipsaci*), white rot, rust and purple blotch. The garlic seed certification program to ensure that garlic seed is grown in nematode-free areas has resulted in far less problems with nematodes in production fields. Likewise, use of disease-free fields and participation in garlic seed certification programs to have disease free planting seed has helped minimize the spread of white rot. Soil solarization and flooding have shown promise in reducing white rot in preliminary research studies in the Klamath Basin of northern California where Bureau of Land Management ground is periodically flooded and then after a time drained and released for commercial farming. It has also shown utility for spot treatment in commercial fields. Preliminary research in anaerobic soil disinfestation is also being evaluated in commercial fields. Also, if foliar and soil borne diseases can be moved by equipment and people moving throughout the field, those activities need to be eliminated or minimized.

Organic production is increasing. Most recently, 5 to 8% of the crop by acreage was organically produced. Limited availability of materials with organic registrations is problematic. Garlic rust has

limited fungicides registered for control with sulfur and copper compounds providing fair to poor control. Neem oil (Trilogy®) is registered as a fungicide, miticide and an insecticide. Smaller organic producers can use flaming as a spot treatment for weed control.

Chemical Control

New developments in disease control include the registration of tebuconazole (Orius®) boscalid (Endura®) fludioxonil (Cannonball®) and penthiopyrad (Fontelis®) for control of white rot. There are only two products registered for control of garlic rust, azoxystrobin (Quadris®) and tebuconazole (Orius®). A new rust control product, benzovindiflupyr + propiconazole (Aprobia Top®) is pending registration in California. The germination stimulant DADS® (diallyl disulfide) was introduced to aid in management of white rot. It was very effective at stimulating sclerotial germination but cost of material and limited availability severely restricted its use. It is no longer registered. Stem and bulb nematode is primarily controlled through seed inspection and seed certification. Oxamyl (Vydate®) can be applied in-furrow or as a band followed by irrigation for stem and bulb nematode. Insect pests are of minimal concern in garlic production. Seedcorn maggots can occur occasionally. There are no effective pesticides registered. Both Western flower and onion thrips are occasional pests on garlic. Spinosad (Entrust®), spinetoram (Radiant®), spirotetramat (Movento®) and abamectin (Agri-Mek®) shows usefulness in control of pyrethroid resistant thrips. Weed control products include bromoxynil (Buctril®), clethodim (Select Max®), fluazifopo-P-Butyl (FusiladeV, oxyfluorfen (Goal®/Galigan®), pendimethalin (Prowl®) and DCPA (Dacthal®). Glyphosate (Roundup®) is registered under a SLN (Special Local Need) registration for spot treatment of field morningglories, bindweed and yellow nutsedge.

Biological Control

There have been no new developments in the biological control of nematodes and insects. There are no known biological control measures for weeds. Likewise, there are no known biological controls for foliar diseases of garlic, white rot or Penicillium decay. There is ongoing research with biopesticides to aid in the control of white rot and other soil borne pathogens. New bio-stimulants are being developed, mostly sulfur compounds, for white rot control. Use of virus free seed adds to vigor of the plant. There are very few organically acceptable herbicides for use on organic garlic production. All the organic herbicides are nonselective contract materials that contain various essential oils. Mulches, hand hoeing cultivation, flaming and soil solarization provide some control.

Scouting

A key component of integrated pest management in large-scale garlic production is the use of routine scouting and use of field pest history. This is especially important in detection and then mapping of white rot infestations. If white rot is found in a field during the growing season those areas should be marked and avoided at harvest. Treatment of those areas after harvest is recommended.

FOUNDATION FOR A PEST MANAGEMENT STRATEGIC PLAN

The Garlic Work Group identified several distinct phases that are important to horticultural and pest management events in California garlic production. These include:

- Field Selection and Crop Rotation
- Seed Selection and Seed Quality
- Pre-Plant/Bed Preparation
- Planting to Early Vegetative Development
- Field Maintenance and Vegetative Development
- Final Irrigation

- Harvest
- Post-harvest (Produce Handling and In-field Activities)
- Food Safety Issues

The following sections track production under California conditions and provide information on typical field activities and important pest issues during each of these intervals. The use of trade names does not imply endorsement by the work group or any of the organizations represented. Trade names are used as an aid in identifying various products.

Field Selection and Crop Rotation

The key to field selection for garlic production is knowing the history of onion and garlic production in the field as well as knowing the history of white rot and nematode infestations in the field. A four-year rotation out of garlic, or onions, is generally common for nematode management. As part of the industry's White Rot Management Plan, growers try to avoid planting garlic back into a field where white rot has been detected, regardless of the level of infection shown. As discussed in detail below, the white rot problem in California cannot be understated. Thousands of acres have been rendered useless to garlic growers, affecting both seed and bulb production efforts in the state. According to Robert C. Ehn, CEO/Technical Manager of California Garlic & Onion Research Committee, a total of 144 fields in the San Joaquin Valley representing approximately 22,000 acres are infected with white rot.

Seed certification programs result in detailed inspections of seed producers for white rot and nematode infestations. This is an integral part of the process to prevent the introduction of white rot into production fields. However, when white rot first appears in a garlic field it is reported and mapped. Field records on white rot infestations in the San Joaquin Valley garlic fields have been kept since 1997. Development and implementation of a white rot management program is vital to the industry to maintain production.

Work Group Recommendations for Disease, Weed, Insects/Mites and Nematode Management During Field Selection and Crop Rotation

- Follow white rot management guidelines as listed in the White Rot Management Plan
- Avoid the replanting of garlic within 4 years
- Maintain all sanitation and inspection guidelines as noted in the plan

[Please see the CGORAB White Rot Management Plan in Appendix 10.]

Seed Selection and Seed Quality

Garlic is propagated vegetatively through the planting of cloves, also referred to as garlic seed. It is critically important that garlic grown for seed, most of which is produced out of state, is grown in soil that is free of the white rot disease and nematodes. It is believed that the white rot infections in the San Joaquin Valley were probably brought in from the Gilroy/Santa Clara Valley area on seed that carried the white rot sclerotia or in seed boxes that had been used for production garlic that had white rot infected bulbs. [Freeze losses of garlic in seed fields in No. CA, NV, OR & WA occurs from time to time. A widespread freeze of garlic seed in 1991-92 killed most garlic seed in all seed states and forced planting of commercial garlic as seed in the subsequent year, which led to widespread transfer of white rot to many seed fields.] Since this disease can be transmitted from the soil to the seed, any observance of white rot infected plants in a field for seed renders that field unfit for seed use and it can only be used for processing. For growers who produce garlic for seed, the loss in revenue between garlic for seed and for processing is significant. Garlic bulbs for seed are harvested the same season that they are cracked, and the cloves planted. Bulbs for seed production for the upcoming season are not stored from season to season of time because germination viability decreases dramatically from time of harvest to planting.

Insects and weeds are not a problem at this phase of the production cycle. Bulb mites, however, can exist in the soil and become a problem in both commercial and seed garlic. Bulb mites can vector bulb decay or rot as well as cause direct damage through feeding on the garlic seed. Growers should plant only clean seed. If bulb mites do occur in the garlic seed, hot water treatment before planting can reduce the infestation in the seed. Fields where decaying organic matter from summer harvested crops is present, such as melon or tomato fields, can serve as a reservoir to support bulb mites and cause damage to fall planted garlic.

Eriophyid mites can occasionally be problems in seed production areas. Although rare, if eriophyid mites are found in garlic seed, it should not be planted.

Stem and bulb nematodes are transmitted to garlic fields through infected plant material, including the planting seed. A more detailed discussion of stem and bulb nematodes is provided later in this text.

Management Tactics

At this stage of production, growers need to be sure to select certified seed free of white rot, nematodes and bulb mites.

Chemicals

There are no chemical treatments that are needed at this time of the production season.

Work Group Recommendations for Insects/Mites, Nematode, Diseases and Weed Management During Seed Selection/Seed Quality

There were no work group recommendations for this period of garlic production.

[Please see the CGORAB White Rot Management Plan in Appendix 10.]

Pre-Plant/ Bed Preparation

Garlic has a shallow rooting depth, averaging 6 to 8 inches. It is moderately tolerant of acid soils and grows best in soils with a neutral pH. Light soils are best for garlic production; soils which are too heavy can cause bulb deformation. Soils in the San Joaquin Valley growing region, where most garlic are planted, range from sandy loam to clay loam. Soils from other areas are highly variable in texture with most garlic seed growing areas ranging from loamy sands to silty loams. Soils are commonly amended for low or high pH conditions.

In preparation for planting, and after current crops have been harvested, fields are deep tilled, tri-planed, fertilizer is spread and then beds are listed. If weeds emerge prior to fall planting, a contact herbicide such as carfentrazone (Shark) or glyphosate (Roundup) is used on these stale beds. Garlic is grown in rotation with most commercial San Joaquin crops. Garlic can typically follow tomatoes or melons and the window between crop harvest and garlic planting is too narrow to use cover crops or soil solarization.

Cultural and Worker Activities

- Land/seed bed preparation
- Fertilization/soil amendments
- Sanitation of planting equipment between fields
- Soil sampling (for fertility)
- Post-emergent herbicide applications for emerged weeds

Insects/Mites

There are no pest management issues noted for this period.

Weeds

Garlic is a slow growing, shallow rooted crop that is very susceptible to decreases in yield from weed competition. Garlic is planted in the fall and is not harvested until July and August of the following year. This lengthy growing season allows for successive flushes of weeds. After water is removed in May, the garlic plants dry down; this opens up the crop canopy and allows another flush of weeds to emerge. During this time period, weeds such as field bindweed (*Convolvulus arvensis*), yellow nutsedge (*Cyperus esculentus*), black nightshade (*Solanum nigrum*) and annual morningglories (*lpomoea spp.*) can become very problematic.

In garlic production areas, the broadleaf weeds most commonly found in garlic include: nightshade species, cheeseweed (*Malva parviflora*), chickweed (*Stellaria media*), field bindweed, annual morningglories, henbit (*Lamium amplexicaule*), lambsquarters (*Chenopodium album*), marestail/horseweed (*Conyza canadensis*) hairy fleabane (*Conyza bonariensis*), mustard species (*Brassica spp.*), nettle species (*Urtica spp.*), pigweed species (*Amaranthus spp.*), purslane (*Portulaca oleracea*), Russian thistle (*Salsola tragus*), shepardspurse (*Capsella bursa-pastoris*) and sowthistles (*Sonchus spp.*). Grassy weeds most commonly found in garlic include annual bluegrass (*Poa annua*), barnyardgrass (*Echinochloa crus-galli*), foxtail species (*Setaria spp.*), rabbitsfootgrass (*Polypogon monspeliensis*) and volunteer cereals. Yellow nutsedge is commonly found in all garlic regions and purple nutsedge is problematic in areas south of Fresno County.

In garlic seed growing areas, volunteer alfalfa, cereals and field bindweed are the most common weeds encountered. All of the other weeds listed above can also occur.

Management Tactics

Field selection to avoid fields with heavy infestations of known hard-to-control weeds is a key way to help avoid weeds in garlic fields. Keeping field borders and roadsides clean of weeds is an effective means to reduce weed seeds that are blown or otherwise transported into the field. Bed orientation is better north to south vs. east to west. Cultivation is a key component to weed control in all garlic fields. Mechanical cultivation is the preferred method on large fields. Hand weeding is expensive, and weeding crews require careful supervision to prevent damage to the garlic plants during the process. For these reasons, most growers, except organic growers, try to avoid the need to weed by hand, and strive to develop an herbicide-based weed control program. Some growers have eliminated hand weeding altogether in commercial garlic fields. Organic growers utilize hand weeding and flame burning for weed control. The practice of flame burning weeds is expensive, requires multiple applications but is now being used more often in commercial production, especially for spot treatments. This procedure also requires a permit from the California Air Resources Board.

Chemicals

At the pre-plant/bed preparation timing, post-emergent herbicides such as paraquat (Gramoxone®) and glyphosate (Roundup®) are useful for weed control. Metam-sodium (Vapam®) is used on a limited basis for weed control because it is expensive, difficult to use near dwellings and provides variable performance against soil pathogens. A limited amount of metam-sodium is used on fields where difficult-to-control weeds have become established. Paraquat and glyphosate are used on land prior to bedding up and planting the crop to eliminate surface vegetation. There is a limited number of acres treated per day due to regulations.

Work Group Recommendations for Weed Management During Pre-Plant/ Bed Preparation

There were no work group recommendations for this period of garlic production.

[Please see the CGORAB White Rot Management Plan in Appendix 10.]

Diseases

The only disease requiring control during this phase of production is white rot. Unfortunately, there are a lack of options beyond biostimulants and site rotation, to control the disease. Again, growers seek avoidance by using certified seed and land rotation.

Work Group Recommendations for Disease Management During Pre-Plant/ Bed Preparation

RESEARCH	• Evaluate deep plowing of white rot sclerotia as part of a control strategy. • Evaluate efficacy of sclerotial stimulants for white rot management and whether they are practical and economical for commercial development. • Continue development of biological controls for all diseases of garlic.
REGULATORY	• Accelerate registration of new materials. • Provide regulatory flexibility in registering white rot resistant plant varieties developed through gene-editing technology to turn on/off specific traits.
EDUCATION	• Develop and implement a multi-faceted management program for all pests. • Provide training on sclerotial stimulants (if research suggests these products are commercially viable.

Nematodes

See discussion below.

Work Group Recommendations for Nematode Management During Pre-Plant/ Bed Preparation

The work group recommendation is for growers to avoid planting in field known to be infested with nematodes.

Planting to Early Vegetative Development (up to 12 inches)

California produces two major varieties of garlic, California Late and California Early. California Late is sometimes less productive than California Early, but is considered better quality for the fresh market. A small amount of Creole garlic is grown in the Imperial and Palo Verde Valleys in Southern California. Seed is grown in a number of high desert areas in Oregon, Washington, Nevada, California and Arizona.

Growers typically plant garlic from mid-September through November. California Early is planted typically from mid-September to mid-November; California Late is planted in November. Bed size is typically 40 inches, but some can range between 60 or 80 inches, and the garlic seed is planted in double rows, approximately 12 to 14 inches apart, at a density of approximately 18 plants per foot. The cloves are placed just below the soil surface, 2 to 3 inches apart. The garlic is then irrigated with overhead sprinklers until stand establishment, then furrow or drip irrigated.

After a field is planted, the primary maintenance concern is weed management. Garlic fields are normally treated with a combination of pre-emergence herbicides (pendimethalin +oxyfluorfen, or pendimethalin + flumioxazin) immediately after planting, or at the first irrigation, with additional applications of pre-emergent and post-emergent herbicides made once or twice as the season progresses. In many seed growing areas, split applications of a pre-emergence herbicide are applied.

Cultural and Worker Activities

• Planting	• Sprinkler irrigation set up and irrigation
• Herbicide applications post plant pre-emergent	• Fertilization
• In-furrow fungicide treatments	• Cultivation (mostly mechanical)
• Scouting	• Leaf tissue sampling
• In seed production post-emergence herbicide treatments	• Insecticide applications (thrips)

Insects/Mites

Insects are not a major pest for garlic growers. It is widely known that garlic exhibits insect repellant properties and several garlic extracts or juices are marketed, mostly to organic growers and home gardeners as insecticides.

Onion thrips (*Thrips tabaci*) and western flower thrips (*Frankliniella occidentalis*) are occasional problems in garlic. Mature onion thrips are about 0.05 inches (1.3 mm) long and flower thrips are slightly larger at 0.06 inches (1.5 mm) long. Thrips have two pairs of wings with long hairs. Adults are pale yellow to light brown in color with immature stages displaying the same body shape as adults but having lighter color and are wingless. These pests feed on the leaves of garlic plants. Damage occurs from the rasping and sucking feeding behavior of the nymphs and adults. Thrips rasp the plant surface and then suck plant fluids. If this damage is heavy, the bulbs may become distorted or undersized, or, in extreme cases, the plant will die. Thrips can be monitored by observing populations on foliage or by whole plant sampling. Whole plant sampling has the advantage of observing thrips on the clove as well as the foliage. Thirty thrips per plant at mid-season is a suggested threshold (lower for very young plants and higher for larger mature plants).

Bulb mites (*Rhizoglyphus* spp., *Tyrophagus* spp.) are rarely found in garlic plantings. These shiny, creamy white, bulbous mites have four pairs of short brown legs and look like tiny pearls with legs. They occur in clusters and damage the area under the root plate. Bulb mites can survive on decaying vegetation in the field until it is completely decomposed. No insecticide treatments are registered for bulb mite control. Metam-sodium (Vapam®), applied prior to planting, will provide fair to good control of mites living in the field on organic matter. Hot water treatment of garlic cloves before planting can reduce mite infestation when infestation is in cloves.

Management Tactics

For thrips control, biological control using predaceous mites, minute pirate bugs and lacewings are often found feeding on thrips. These beneficials are very susceptible to insecticide sprays, however, and may not be important in fields where insecticides have been used. Sprays of Entrust® formulation of spinosad are acceptable for use on organic crops.

Growers should avoid planting garlic fields next to grain fields, if possible, because that will cut down on migration from the cereal crops when they dry down. If planted next to a grain crop, monitor for thrip migration at this time frame. For bulb mites, good sanitation practices can help in reducing infestations. Since they feed on decaying vegetation in the field, plowing or otherwise reducing the amount of decaying vegetation on the surface through tillage will help cut down on bulb mite infestations. Hot water treatment of garlic cloves before planting can reduce mite infestations when the infestation is in cloves.

Chemical

Use of insecticides on garlic is rare and only used under severe infestations. Pyrethroids are the predominant pesticide used for control of thrips in garlic in California. While resistance to pyrethroids has not been documented in California, data from other states suggest that control has dropped due to resistance to pyrethroids. There are no insecticide treatments registered for bulb mite control in garlic.

New insecticides that show promise in research work on garlic include spinosad (Success®, Entrust®) spinetoram (Delegate®, Radiant®) and neem oil for thrips control.

Work Group Recommendations for Insect/Mite Management During the Planting to Early Vegetative Development

RESEARCH	• Evaluate efficacy of existing and new chemicals in garlic. • Research potential insectides for bulb mite control.
REGULATORY	• No recommendations.
EDUCATION	• No recommendations.

Weeds

Weed control at this timing of garlic production is very important. Weeds present at this timing include those mentioned above (cheeseweed, chickweed, henbit, lambsquarters, marestail/fleabane, nettle, mustard species, pigweed, purslane, shepardspurse, annual bluegrass and foxtail). In addition to those weeds, other weeds are important at this timing and include barnyardgrass, nightshade, nutsedge and rabbitsfootgrass.

Management Tactics

As stated previously, cultivation is the key component to weed control in garlic fields at this time. Hand weeding can be important, but it is expensive, and workers must be carefully watched to ensure that they do not injure the garlic. Flaming can also be used; however, it is labor intensive and costly.

Chemicals

Pre-Plant: Paraquat (Gramoxone®), glyphosate (Roundup®), oxyfluorfen (Goal®), carfentrazone (Shark®) and metam-sodium (Vapam®) are used preplant. A limited amount of metam-sodium is used on fields where difficult to control weeds have become established. Paraquat and glyphosate are used on land prior to bedding up and planting the crop to eliminate surface vegetation.

Preemergence: Dimethol-tetrachloroterephthalate, or DCPA (Dacthal®), pendimethalin (Prowl®), oxyfluorfen (Goal®) and Galigan®), and flumioxazin (Chateau®) are registered for post plant and pre-emergence of the garlic. Besulide (Prefar®) is registered for use on garlic during this time period but controls a limited number of weeds. Organic growers can use acetic and fatty acids during this phase of growth. They are very expensive and effective on small weeds only. On the seed crop, pendimethalin is used during this stage of production.

Post-emergence crop: After the garlic crop emerges, a number of herbicides can be used for weed control. They include oxyfluorfen (Goal® and Galigan®), sethoxydim (Poast®), fluazifop-P-butyl (Fusilade®), and clethodim (Prism®). Oxyfluorfen controls both broadleaf weeds and grasses. Sethoxydim and fluazifop-P-butyl are used to control emerging grasses as well as some perennial grasses. Fluazifop-P-butyl also is used to control filaree in seed garlic. Clethodim is also used on grasses.

Carfentrazone (Shark®), dimethenamid-P (Outlook®), and ethofumesate (Nortron®) have shown good to excellent control of a broad spectrum of weeds in garlic.

Work Group Recommendations for Weed Management During Planting to Early Vegetative Development

RESEARCH	• Previous crop carryover effects on weeds in garlic. • Screen new herbicides for pre- and post-emergence weed control and crop tolerance. • Weed control under drip irrigation situations. • Evaluate management tools for hard to control weeds like marestail/fleabane, barnyard grass and lambsquarters; and for herbicide resistance.
REGULATORY	• Continue to work with regulators to refine drift mitigation measures for herbicides applied to other crops and drift on to garlic.
EDUCATION	• Provide training on proper weed identification and control. • Educate growers to teach weeding crews about the importance of weed management and their help in preventing buildup of seed bank in the soil.

Diseases

White Rot

White rot is a disease caused by the fungus, *Sclerotium cepivorum*. Once established in a field, it will persist for decades in the absence of a suitable host, which is limited to garlic, onions and a few close relatives. Several fungicide classes can reduce incidence and severity of this disease when applied at planting, but these may not deliver commercially acceptable levels of control under conducive conditions and high inoculum levels. The only cultural control to prevent white rot is to move to a field free of the causing organism. The use of the biostimulant DADS (diallyl disulfide) offered early promise of one part of a white rot management program. DADS treatment at a susceptible stage with the use of a conventional fungicide in subsequent years showed great promise. DADS, unfortunately is not widely available, produced only twice per year in China in large enough quantities for production, and unfortunately their price per gallon was raised to an uneconomical level. Since that time work has been underway to develop a natural organo-sulfur compound that will be effective and not cost prohibitive. Under a just approved NIFA grant, development of sclerotia germinating stimulants is underway and may lead to their introduction into commercial garlic production (see Chemical Control section below).

Pathogenic activity of white rot increases as the root systems develop. Mycelial growth spreads upwards from the roots to the stem plate, the bulb, and then onto the leaves above ground. Soil conditions and the pathogen population in the field will determine the extent of damage inflicted on the garlic crop. In cool, moist soil where disease inoculum is high in the field, the sclerotia (survival structures) will germinate in the presence of garlic root and bulb exudates. The fungus then attacks the roots, developing bulb and lower plant stem. Ideal temperature for development is 55-70 degrees. Depending on soil conditions and inoculum levels, plants may be partially or completely destroyed. In the process, new sclerotia are formed that can persist in a dormant state in the soil for many years, waiting for a susceptible host. Under conditions that are less favorable to rapid sclerotial germination, the plant may survive to harvest, although the bulb may then rot in storage. Normally, disease symptoms appear from mid-season to harvest.

The white rot problem cannot be overstated. Thousands of acres have been rendered useless to garlic growers, affecting both seed and bulb production efforts in California. Without the development of measures to control white rot, the future of garlic production in California cannot be considered promising.

White rot control efforts by the garlic industry have often been overlooked or poorly coordinated. Historically, garlic growers have simply moved from contaminated fields into pathogen-free fields, often moving inoculum via equipment that was not sanitized. The situation now is such that the supply of clean fields is rapidly diminishing in California (and other areas of the Western U.S.). The CA Garlic & Onion Research Board reports a total of 144 fields in the western San Joaquin Valley representing approximately 22,000 acres are infected with white rot. This is up from 100 fields and 14,000 acres in 2007. Some small growers have practiced removal of symptomatic plants, but this doesn't result in eradication of the problem.

Commercial garlic is dependent on seed production efforts (approximately five acres of commercial garlic requires one acre of seed production). Fungal infestation often begins at the seed stage, being transported into fields by contaminated equipment or the seed itself. Coordinated garlic seed certification programs have been in place for several years to halt the further spread of the disease. However, the continuous spread of this disease throughout the seed producing areas is forcing state agriculture departments to reevaluate the cost effectiveness of their certification programs.

UC IPM Guidelines for White Rot

Garlic rust

Garlic rust is caused by the organism *Puccinia porri*, a wind-borne pathogen. Although it is not a new disease to California garlic, unusual rain during May created an ideal environment for disease development and it became a serious problem causing significant yield loss. In many fields, yield reduction of over 50% has been observed. The disease was originally unexpected, and growers could not respond in time to prevent heavy losses. Effective, registered fungicides were not available at that time. Since then, the Garlic & Onion Research Board has sponsored registration of two effective fungicides. The disease is triggered by wet spring conditions, such as in those years when the month of May receives unseasonable rainfall. Garlic rust infects the leaves of the garlic plant. Symptoms begin as white to yellow spots on the leaves, which then expand to produce orange-colored pustules. This rust can cover entire leaves, causing them to die and the resultant lack of skins are not enough to hold the cloves together. The fungus does not attack the garlic bulb directly, but damage to the leaves has the indirect effect of reducing the size and quality of the bulbs at harvest, thereby reducing their marketability. At the present time only azoxystrobin (Quadris®) and tebuconazole (Orius®, Folicur®) are registered to control garlic rust. However, the fungicide solatenol (Aprovia Ace) is pending registration in California.

Other Fungal Diseases

Purple blotch, *Alternaria porri,* and Stemphylium leaf blight, *Stemphylium vesicarium,* occur primarily on onions, but can be occasional problems in garlic. Stemphylium leaf blight is more common than purple blotch in California. Both diseases are most likely to infect garlic fields during periods of warm weather with high relative humidity. Symptoms begin as small lesions on the leaves or stem. As the disease progresses, these spots enlarge and become tan to purple in color. Advanced stages of either disease will kill the leaf and can cause plant dieback. Yield reductions are possible.

Penicillium decay (blue mold) is caused by the organism *Penicillium hirsutum*. The fungal disease infests the seed cloves, resulting in poor stands after planting. This organism does not persist for long periods of time in the soil; its primary mode of transmission is through infection of the cloves before planting. These infected cloves will decay, and the fungus will often sporulate, resulting in the formation of a blue mold on the clove surface. If the interval between cracking (separation of cloves) and planting is too long, blue mold incidence increases. Seed should be planted when soil temperatures are warmer (Late September to early November in the San Joaquin Valley). Planting later when temperatures are cooler increases the risk of blue mold developing.

Other disease organisms like *Botrytis* spp., *Fusarium* spp., and *Sclerotium rolfsii* can also be passed with infected seed. A good crop rotation program and the application of good cultural practices are

important tools in preventing a buildup of these diseases in a seed field and transmission with the seed to new fields.

Basal rot caused by the organism *Fusarium culmorum* can occur during this phase of garlic production. This disease is transmitted to fields through the planting of infected seeds, as well as through the transport of soil from infected fields to clean fields on cultivation equipment. The fungus survives indefinitely in soil. Plants affected by basal rot show progressive yellowing and dieback from the tips of leaves. Affected roots are dark brown to dark pink. A white fungal growth is sometimes evident at the base of the infected bulbs. When an infected bulb is cut vertically, a brown discoloration of the stem plate tissue is apparent. Later, the stem plate tissue becomes pitted and shows a dry rot. Under dry conditions, the stem plate and dry outer scales crack open. Basal rot can continue in storage. It is more likely to be observed in fields with drip irrigation.

Management Tactics

As described above, use of quality certified seed of a high quality will help decrease the likelihood of seed borne problems from white rot. Limited cultivation and cleaning equipment before moving from contaminated fields reduces the risk of spreading white rot, nematodes or other organisms.

For white rot, as part of the certification program, seed fields are walked prior to harvest to identify any white rot infestations. White rot infested seed cannot be certified, and garlic growers should only use certified seed. Seeds should be air dried immediately after cracking and planted within a few days after cracking to help cut down on disease development like blue mold. Crop rotation and field sanitation are also very important in preventing spread of nematodes, diseases and cutting down on bulb mite infestations.

The primary cultural control of basal rot is curing bulbs properly before storage and storing the garlic at cool temperatures. Also, avoid fields with a history of basal rot problems and rotate fields with other crops. Control of soil insects, which can damage the developing bulb, is critical along with controlling foliar diseases.

Chemicals

There are several fungicides that provide suppression of white rot in infested fields, but under high inoculum levels and optimum temperatures, they will not provide commercially acceptable levels of control; tebuconazole (various trade names), penthiopyrad (Fontelis®), fludioxonil (Cannonball® WG) and boscalid (Endura®). Organo-sulfur bio-stimulants have shown promise. An original stimulant, DADS, provided some control, but is no longer available. Research is continuing to evaluate new organo-sulfur bio-stimulants for commercial use.

Garlic rust has been controlled with tebuconazole (Folicur®) and azoxystrobin (Quadris®). However, the fungicide solatenol (Aprovia Ace) is pending registration in California and will provide an additional chemistry for control.

Work Group Recommendations for Disease Management During Planting to Early Vegetative Development

RESEARCH	• Continue to study white rot biology and management. • Identify economical sulfur compounds that could be used as biostimulants for white rot management. • Study worker safety issues associated with garlic seed treatments and develop mitigation plans should seed treatments be disallowed by regulators. • Continue to evaluate and support registrations of new products for garlic rust control. • Develop better detection methods for seed infestations of white rot, such

	as a polymerase chain reaction (PCR) method. • Identify alternative sources of funding for white rot research such as crop insurance, grants, SCRI, other federal specialty crop grants, etc. • Continue to fund programs to develop white rot IPM controls.
REGULATORY	• Continue funding and staffing of the seed certification program. • Work with state agricultural departments to address monitoring programs for white rot and other issues to help prevent the demise of the garlic industry.
EDUCATION	• Develop industry-wide multi-level awareness campaign for white rot management. • Educate all growers on white rot mitigation measures to avoid total loss of garlic production in the San Joaquin Valley. • Engage the garlic processors in the program to help educate growers and PCAs on white rot issues. • Develop Best Management Practices for growers for treatment of rust.

Nematodes

Stem and bulb nematode (*Ditylenchus dipsaci*) is a migratory nematode that is transmitted to garlic fields primarily through infected plant material. The nematode can live in stored plant tissue for several years, but they decline rapidly in soil. Garlic, onion, leek and chive serve as a host for stem and bulb nematode. It initially attacks the germinating clove after planting, and if there is abundant moisture on the plant, the nematode will move upwards and invade young foliage. It will also migrate from plant to plant if there is high moisture content in the soil.

Damage to the garlic crop resulting from nematode feeding, as well as from secondary diseases and insect infestations induced by such feeding, is manifested by a poor plant stand at mid-season. By harvest, the affected bulbs are shrunken and decayed. Although stem and bulb nematode have the potential to devastate a garlic crop, a grower's primary control strategy is to plant clean seed into clean ground. As a result, the overall usage of nematicides in garlic is minimal.

Management Tactics

Garlic growers in California can take preventative steps to guard against nematode infestations. These steps include: 1) a certification program to ensure that garlic seed is grown in nematode-free environments, 2) plant garlic into virgin ground that has not had an *Allium* spp. Crop, 3) use crop rotation program of four years (longer if a seed field) to keep their fields free of this pest, 4) treatment of garlic seed with hot water immediately prior to planting when stem and bulb nematode infestation in cloves is suspected and 5) good sanitation practices with equipment to prevent spread of nematodes from field to field.

Chemicals

There are only a few chemical products available now for the planting period that can provide good control of stem and bulb nematode. Oxamyl (Vydate®) is the only product that can be used in season for stem and bulb nematode. Application of fumigant products such as chloropicrin and 1,3-dichloropropene (Telone®) are not practical in garlic production because they are labor intensive and very expensive. Data suggest abamectin (Agri-Mek®, Abba®) can provide effective control of stem and bulb nematode as seed piece drench or soak. The new fungicide fluensulfone (Nimitz®) has not proven effective, but control may be improved with water activation of the nematodes.

Work Group Recommendations for Nematode Management During Planting to Early Vegetative Development

RESEARCH	• Develop an economical testing method for nematodes. • Evaluate the efficacy of biological nematicides. • Determine the host range of stem and bulb nematode. • Evaluate fluopyram (Luna®) for nematode control. • Evaluate fluensulfone (Nimitz®) for nematode control using water to activate the product. • Request IR-4 work on abamectin for stem and bulb nematode as a seed treatment.
REGULATORY	• Continue funding and staffing for the seed certification programs.
EDUCATION	• Provide education to garlic growers regarding the potential for nematode infestations and damage.

Field Maintenance and Vegetative Growth

In the western San Joaquin Valley, garlic starts its growth in the fall or very early spring and bulbs mature by midsummer. If garlic is going to yield well, it must make enough top growth before the bulb begins to enlarge. Bulb formation occurs in response to higher temperatures and day length as hours of sunlight increase later in the season. Visible bulbing occurs April through June. Hand weeding has been eliminated in many fields. Herbicide applications need to be stopped before harvest, based on the chemical's label pre-harvest interval (PHI) recommendations. Insecticides are used very little. Fresh market growers may go an entire season without needing to treat for insects. However, garlic grown for dehydration tends to remain in the field for a longer period than fresh market garlic, and growers will occasionally treat for insects, primarily thrips, to protect the crop (as well as to protect neighboring fields from insect migration).

While soil-borne diseases can seriously affect the garlic crop, foliar diseases in general have historically been of minor concern. However, the widespread emergence of garlic rust disease as a serious threat to crop production has increased the importance of fungicide applications. Garlic rust is not usually a concern in seed growing regions of the West. However, most seed fields are irrigated with sprinklers throughout the season. This creates a micro-climate that encourages the development of *Botrytis* spp. And *Fusarium* spp. That can only be partially controlled with registered fungicides.

Cultural and Worker Activities

- Scouting
- Fertilization
- Cultivating
- Hand weeding
- Flaming
- Irrigation
- Insecticide applications
- Fungicide applications
- Herbicide applications

Insects/Mites

Onion thrips and western flower thrips can be problematic during this period of garlic growth development. See the discussion above regarding thrips and other insects. The work group recommendations for insect/mite management during field maintenance and vegetative growth are the same as those described above under Planting to Early Vegetative Development.

Work Group Recommendations for Insect/Mite Management During the Field Maintenance and Vegetative Growth Stage

RESEARCH	• Develop economic thresholds for thrips on garlic. • Evaluate the relationship between thrips and disease incidence/severity. • Evaluate efficacy of existing chemicals.
REGULATORY	• No recommendations.
EDUCATION	• No recommendations.

Weeds

Problem weeds during the field maintenance and vegetative growth stages of garlic production include: lambsquarters, marestail/fleabane, pigweed, purslane, barnyardgrass, foxtail, rabbitsfootgrass, nightshade, bindweed and nutsedge.

Management Tactics

As describe above, cultivation, hand weeding and flaming are all management tactics that can be utilized for some weed control during this timing. Using water management in terms of moving from sprinkler irrigation to drip irrigation is a good tactic to reduce weed infestations.

Chemicals

Several herbicides are available for use during this phase of garlic development including clethodim (Prism®), fluazifop-P-butyl (Fusilade®) and sethoxydim (Poast®). These products, however, only control emerged grass species. Goal® can be used for nightshade control if it is applied no closer than 60 days PHI. Pendimethalin (Prowl®) can be applied at layby for weed control in seed garlic.

Work Group Recommendations for Weed Management During Field Maintenance and Vegetative Growth

RESEARCH	• Continue to screen new herbicides. • Evaluate management tools for marestail/fleabane/lambsquarters.
REGULATORY	• Continue to work with regulators to refine drift mitigation measures.
EDUCATION	• Provide training on proper weed identification and control. • Educate growers to instruct weeding crews on the importance of weed management and preventing buildup of seed bank in soil.

Diseases

Prevalent diseases at this stage of garlic production include white rot, purple blotch, garlic rust, basal rot and Botrytis. All these diseases were discussed in detail above.

Management Tactics

Field inspection is important to identify any plants or areas where disease infestations are starting. Equipment sanitation is important to help keep from spreading disease from one field to another. Irrigation management is especially important to the control or prevention of diseases caused by *Botrytis* spp. And *Fusarium* spp. Virus free seed has improved vigor which improves the plant's tolerance of stemphyllium, purple blotch and other foliar diseases.

Chemicals

Several fungicides are registered for use in garlic for disease control during this phase of production. Chlorothalonil (Bravo Weather Stik®), mancozeb (MZ®), maneb and pyrmethonil (Scala®) can be used for purple blotch control. Garlic rust can be controlled by azoxystrobin (Quadris®) and tebuconazole (Folicur®). Pyraclostrobin (Cabrio®) is available for rust control while boscalid (Endura®) and boscalid + pyraclostrobin (Pristine®) are available for purple blotch and temphylium control. A discussion of fungicide use was presented in a previous section in more detail.

Work Group Recommendations for Disease Management During Field Maintenance and Vegetative Growth

RESEARCH	• Determine varietal susceptibilities to diseases and planting timing. • Determine effects of water management on diseases. • Evaluate chemigation uses of various fungicides.
REGULATORY	• No recommendations.
EDUCATION	• Educate PCAs on proper timing for rust control. • Provide resistance management training to growers and PCAs.

Vertebrate Pests

The three main concerns regarding vertebrate pests in garlic are the damage done to the garlic, damage to equipment and food safety issues. The main pests are pocket gophers (*Thomomys bottae*), coyotes (*Canis latrans*) and wild pigs (*Sus scrofa*). Damage done by gophers is the feeding on the roots, drip tape and creating breaks in levees and canals adjacent to garlic fields. Gophers can be controlled by natural predators, such as owls (Owl boxes), traps, rodenticide baits and burrow fumigants including aluminum phosphide and pressurized exhaust injection systems. The damage done by coyotes is damage to the drip tape and food safety issues. The damage done by wild pigs can be extensive as they can root around in a wet field and cause significant damage along with being a food safety problem. For coyotes and pigs, fencing is sometimes a possibility, along with trapping. Birds generally don't cause damage to garlic.

Work Group Recommendations for Vertebrate Management During Field Maintenance and Vegetative Growth

RESEARCH	• Develop alternative rodenticides.
REGULATORY	• Register alternative rodenticides.
EDUCATION	• Grower education about techniques for limiting non-target risk from burrow fumigant and anticoagulant rodenticide applications.

Final Irrigation/Pre-harvest

Irrigation of garlic fields is stopped a few weeks prior to harvest to allow the plants to dry. This final irrigation cutoff" normally occurs in late May for early garlic, early June for fresh market fields (late garlic) and late May for fields growing garlic for dehydration.

Cultural and Worker Activities

• Preharvest weed management (burndown) • Deep cultivate within furrows • Flaming especially for organic • Field sanitation around field borders	• Remove irrigation pipe or surface drip tape/lines. • Weed scouting • Topping/Pre-harvest activities

Weeds

Weeds important at this time of garlic production include field bindweed, annual morningglories, nightshade, lambsquarters, marestail hairy fleabane, pigweed, prickly lettuce, sowthistle and nutsedge.

Management Tactics

Deep cultivation helps remove weeds from the furrows. Topping of the garlic will also help control weeds. This is not used in garlic grown for the fresh market. Hand weeding is still practiced by organic producers.

Chemicals

At this stage of development, the only herbicide used is glyphosate (Roundup®) for burndown weed control. It can only be used on garlic grown for processing and only under Special Local Needs registration.

Work Group Recommendations for Weed Management During Water Pull to Harvest

RESEARCH	• Evaluate flumioxazin (Chateau®) and carfentrazone (Shark®) in combination with glyphosate (Roundup®) as burndown herbicides.
REGULATORY	• Register Shark® or Chateau® as a burndown herbicide following Roundup®.
EDUCATION	• No recommendations.

Diseases

Aspergillis causes black spotting on garlic and this can be a problem in fresh market garlic. Infestation is largely based on soil moisture. It can be managed by pre-harvest irrigation, undercutting and pre-harvest crop management.

Vertebrate Pests

Same as during Field Maintenance and Vegetative Growth.

Harvest

The harvest of garlic is accomplished by different methods that are dictated by its intended use in the marketplace. Garlic harvested for supermarket or roadside sales requires a more labor-intensive

harvest than garlic harvested for processing or seed. All of these need a dry harvest period which facilitates a long harvest window. A brief description of each method is described below.

Fresh Market Harvest Operations: Garlic sold in the fresh market is required to have high visual appeal to the consumer. Fields that are intended for the fresh market are typically planted to a thinner stand to allow the garlic a chance to size more uniformly by not growing into adjacent garlic. Garlic skins (leaves surrounding the clove) are counted and irrigation is terminated at 6-7 skins. After 2 or 3 weeks of drying the garlic is lifted and pulled from the bed and placed in windrows in such a manner that the tops (leaves) shade the bulbs from the sun. The garlic is cured in this manner for a period of 2-3 weeks and then the roots and tops are hand-clipped by a harvest crew that may number in the hundreds. The garlic is dumped into bins and left in the field, covered by tops until it is loaded onto trucks for shipment to a packing shed. There it is sized and graded, placed into boxes and either shipped to the market or placed into cold or controlled atmosphere storage for later shipment.

Processing Garlic Harvest Operations: Garlic harvested for processing is much less labor intensive. The need for high visual appeal is much less than that required for fresh market uses. Fields are planted to thicker stands to increase overall yields. This crowding sometimes produces oblong bulbs that would be less desirable for the fresh market. Garlic skins are counted, and irrigation is terminated at 4-5 skins. As the tops begin to dry the grower is expected to deep cultivate the furrows to help increase the garlic curing rate. In 3 or 4 weeks, when the tops are completely dry, the pre-harvest operation begins. The first step in pre-harvest is to high-top the garlic. This operation is followed by, one or more, low topping passes to completely remove and shred the tops. The last step of the pre-harvest could include running coulters on a tool bar to cut any tops that might not have been removed by topping.

At this point, the field is ready for the pre-harvest irrigation. This is used to soften the soil to allow for easier and less damage to garlic bulbs by harvest operations. Typically, the pre-harvest irrigation is finished two days before digging. The garlic is then dug mechanically and windrowed by placing four beds into each windrow. After curing for 3 to 5 hours the garlic can be loaded and placed in bins or bulk trailers for hauling to the processing plants.

Seed Garlic Harvest Operations: Seed garlic is pre-harvested and harvested in a manner like that employed for processing garlic. Growers dig the garlic after topping and then either utilize a hand crew to pick up the garlic and dump it into bins or a machine to load the crop into bins mechanically. In some cases, harvested garlic is placed into burlap bags to allow more curing before being dumped into bins. The binned garlic is hauled to a processing facility where it is stored for one to two months, then it is processed (cracked) into individual cloves that are used for seed. Harvested seed garlic is best stored in a cool dry environment until processed.

Cultural and Worker Activities

• Assess fields for harvest timing	• Harvesting
• Clipping tops and roots by hand for fresh only and place in bins	• Dig and load for transport
• Mowing (cut tops off garlic) for dehydrated	• Growers will disk or till ground to get ready for next crop.

Diseases

If white rot was present in the field, it is very important to evaluate the extent of the infestation and to create a harvest plan for that part of the field to avoid, or at least reduce, the potential for contaminating harvesting equipment with white rot disease. It is also critical to prevent that garlic from being used as seed by any growers.

Management Tactics

Segregation of the infected area and sanitation of equipment are the only tactics available. Dumping or burning the garlic are also possible ways to destroy the infected bulbs.

Chemicals

There are no pesticide applications made during the harvest period.

Work Group Recommendations for Disease Management During Harvest

RESEARCH	• Study root plate degradation (shattering).
REGULATORY	• Work with the Air Resources Board (ARB) and other agencies to mitigate dust issues (PM-10).
EDUCATION	• Provide training as needed/required for dust management.

Vertebrate Pests

Same as during Field Maintenance and Vegetative Growth.

Post-Harvest Issues

Garlic may be marketed immediately after harvest, but varieties for fresh market such as California Late may be stored in cold warehouses for several months. Garlic for processing is almost never stored for any length of time. Rather, it is "stored" in the field and harvested on a schedule so that plants can continually process product being delivered to the processing plant. If garlic is stored, it must be kept dry with relative humidity of less than 60%. Higher humidity, at any temperature, will cause bulbs to mold and start developing roots and sprouting.

Cultural and Worker Activities

• Inspection and grading	• Put on air to cure
• Storage in bulk or in bins, bags or boxes	• Curing in the field for fresh market

Garlic Storage

Garlic handling and storage methods after crop maturity and harvest differ depending upon whether garlic is destined for the fresh market (whole bulbs or peeled cloves) or for dehydration.

Garlic bulbs destined for fresh market use or peeling are allowed to dry down and cure in the field after the last irrigation. After the crop has cured and dried adequately bulbs are harvested into large bins. These bulk bins may remain in the field for additional curing time after which they are transported to the packing/peeling facility. At the facility, bins will be placed into differing storage conditions. Garlic destined for "immediate" or near-term use is stored under ambient conditions. Garlic planned for use later in the season is stored either under simple refrigeration or under controlled atmosphere conditions with the latter storage conditions reserved for the longest stored material. All bulbs destined for storage should be clean and dry. For refrigerated storage, temperature is typically maintained at approximately 29 degrees F with relative humidity of 60% to 70%. Controlled atmosphere storage uses the same temperature and humidity profile combined with a reduction in oxygen and/or an increase in carbon dioxide. Too high of moisture in storage can result in disease development in the bulbs or the bulbs can start to sprout.

Garlic for dehydration is also allowed to dry down in the field after the last irrigation. Generally, after four to five weeks, tops are completely dry, and the bulbs are ready for harvest. At this point, the crop

could be harvested immediately. However, while the total crop slated for dehydration tends to mature over a short time period, the dehydration facilities are limited as to how many loads of garlic they can process each day. Mature garlic destined for dehydration is thus typically kept in the ground until there is capacity at the dehydration plant to receive and process it. This period of ground storage can last for up to 90 to 100 days. Once a field is scheduled for harvest bulbs are topped and dug from the ground, picked up by large harvesters, placed into bulk trailers and transported to the processing facility. Here garlic is unloaded and transferred to storage bays where warm air is forced through the pile of garlic bulbs to remove moisture and further dry the bulbs in preparation for "cracking" (breaking the bulbs into individual cloves). Garlic is typically held on these drying tunnels for 10 days before cracking and processing.

Garlic for seed can be stored longer at higher elevations where there is lower humidity and fewer insect problems. Insects can attack stored garlic, so it is important to monitor insect infestations using sticky traps and pheromone traps. Seed garlic shipped from Oregon, Washington and Nevada is inspected and graded as part of their state seed certification programs.

Work Group Recommendations Insect Management Post-Harvest Issues

RESEARCH	• No recommendations.
REGULATORY	• International harmonization on tolerances, including maximum residue limits (MRLs).
EDUCATION	• Provide information on export regulations related to white rot, and bulb and stem nematodes.

Food Safety Issues

The Food Safety Modernization Act (FSMA) was signed into law January 4, 2011. It aims to ensure that the US food supply is safe by proactively preventing food contaminations. The Act established standards for the growing, harvesting, packing and holding of produce for human consumption. A key requirement of the law is the requirement that no detectable generic *E. coli* are allowed for certain uses of ag water where it is likely there could be a transmission to produce through direct or indirect contact. The Allium industry has provided data that show garlic and onions, because of their high level of organosulfur compounds provide a natural control mechanism for *E. coli* contamination. The new law also provides guidance on use of biological soil amendments, including manure and composts, and prevention of water contamination, domestic and wild animals' containment and worker training, health and hygiene.

To prevent contamination of bulbs, most garlic growers and processors maintain historical records for fields planted to garlic. All growers are required to maintain records of fertilizer use as well as pesticide and adjuvant use on each field and report this usage to the state. Several companies use outside agencies to track product from field to processing facility and employ a pesticide clearance system that clears all loads before they enter the processing chain. Buyers are increasing their demand for complete field histories from garlic growers and requiring various types of audits.

Ecoterrorism is always a concern when processing plants are used. The dehydrated garlic industry is controlled by two major companies, and access to processing facilities is highly controlled, thus the likelihood of terrorist activities is low. However, all processors must maintain a high level of diligence to prevent any intentional contamination of finished product.

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APPENDICES

Appendix 1: 2016 Statewide Garlic Production Statistics

Processing & Fresh Market	Harvested Acreage	Yield (Tons/Ac.)	Production (cwt)	Total Value ($ Million)
CALIFORNIA [1]	20,852	6.7	2,794,433	205
UNITED STATES [2]	24,600	7.5	3,690,000	269
CA PERCENT OF TOTAL	**85**	**n/a**	**76**	**76**

2. Source: USDA/NASS, California Field Office – County Agricultural Commissioner's Data 2016
3. Source: USDA/NASS Vegetables – 2016 Summary.

Notes: The *California Agricultural Statistics Review – 2016-17* contains additional production statistics which may be seen at their website: https://www.cdfa.ca.gov/Statistics/PDFs/2016-17AgReport.pdf

Appendix 2: Cultural Practices and Pest Management Activities

Production Region: Western San Joaquin Valley

Cultural Practices	J	F	M	A	M	J	J	A	S	O	N	D
Bed Preparation								■	■	■		
Planting									■	■	■	■
Irrigation	■	■	■	■	■				■	■	■	■
Fertilizer Applications		■	■					■	■			
Second Cultivation				■								
Vegetative Development	■	■	■	■								
Water Pull					■	■						
Harvest						■	■	■	■			
IPM Activities	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Soil Sampling	■	■						■	■			
Scouting/Monitoring		■	■	■	■	■						
Release of Beneficials				■	■	■						
Insecticide Applications			■	■	■	■						
Fungicide Applications		■	■	■	■							
Herbicide Applications		■	■			■		■	■	■	■	■
Hand Hoeing			■	■	■							
Nematode Sampling	■	■	■	■	■				■	■	■	■

Appendix 3: Seasonal Pest Occurrence

Production Region: Western San Joaquin Valley

Insects & Mites	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Onion Thrips												
Western Flower Thrips												
Beet Armyworm												
Bulb Mites												
Diseases												
White Rot												
Purple Blotch												
Stemphylium												
Garlic Rust												
Penicillium Decay												
Basal Rot												
Nematodes	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Stem and Bulb Nema.												
Weeds	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Cheeseweed												
Chickweed												
Henbit												
Lambsquarters												
Marestail												
Pigweed												
Purslane												
Shepardspurse												
Annual Ryegrass												
Foxtails												
Nightshades												
Field bindweed												
Sowthistle												
Prickly lettuce												
Volunteer cereals												
Hairy fleabane												
Nutsedges												
Rabbitfootgrass												

Appendix 4: Efficacy of Insect/Mite Management Tools

PRODUCT/ TECHNIQUE	TRADE NAME	Onion Thrips	W. Flower Thirps	Beet Armyworm	Bulb Mites
Chemical Tools					
Z-CYPERMETHRIN	Mustang®	G	E	G	P
LAMBDA-CYHALOTHRIN	Warrior®	G	G	E	P
PERMETHRIN	Pounce® /Ambush®	F	F	G	P
METHOMYL	Lannate®	F	F	G	P
SPINOSAD	Success®	G	F	G	P
AZADIRACHTIN	Aza-Direct®/Azatin® Ecozin®/Neemix®	F	F	P	P
SPINETORAM	Radiant®	E	E	N	N
ABAMECTIN	Agri-Mek®	E	G	N	G
Non-Chemical Tools					
Cover Crops		P	P	P	P
Habitat management		F	F	P	F
Natural enemies		F	F	F	P
Sanitation/ Weed management		F	F	P	F
Resistant varieties		P	P	P	P
Water management		P	P	P	P
Weed control		P	P	P	P
Trap Crops		P	P	P	P
Field Selection		F	F	P	E
Crop Rotation		P	P	P	G

Rating System: E = Excellent, G = Good, F = Fair, P = Poor, N = Not registered
Data based on collective field observations and experiments

Appendix 5: Efficacy of Weed Management Tools

PRODUCT/TECHNIQUE	TRADE NAME	Annual Broadleaf Weeds	Annual Grasses	Perennial Grasses	Perennial Broadleaf Weeds
Chemical Tools					
FLUAZIFOP-P-BUTYL	Fusilade®	P	G	G	P
PARAQUAT	Gramoxone®	G	F	P	F
GLYPHOSATE	Roundup®	E	E	G	G
CLETHODIM	Prism®	P	E	G	P
DCPA	Dacthal®	F	F	P	P
PEMDIMETHALIN	Prowl®	F	G	P	P
METAM SODIUM	Vapam®, others	E	E	P	P
BENSULIDE	Prefar®	F	G	P	P
BROMOXYNIL	Buctril®	G	P	P	P
OXYFLUOROFEN	Goal®	G	F	P	P
SETHOXYDIM	Poast®	P	G	G	P
CARFENTRAZONE	Shark®	E	E	P	F
FLUMIOXAZIN	Chateau®	G	G	P	F
DIMETHENAMID	Outlook®	G	E	P	P
ETHOFUMESATE	Nortron®	G	G	P	P
Non-chemical Tools					
Cultivation		F	F	P	P
Soil/Water management		P	P	P	P
Cover crops		P	P	P	P
Hand weeding		G	G	P	F
Mowing		P	P	P	P
Flaming		P	P	P	P
Crop Rotation		F	F	F	F
Stale seedbeds		G	G	P	P

Rating System: E = Excellent, G = Good, F = Fair, P = Poor/None
Data based on collective field observations and experiments

Appendix 6: Efficacy of Disease Management Tools

PRODUCT/TECHNIQUE	TRADE NAME	Damping Off	White Rot	Purple Blotch	Stemphylium	Garlic Rust	Penicillium Decay	Basal Rot
Chemical Tools								
AZOXYSTROBIN	Quadris®	G	P	G	P	E	P	P
TEBUCONAZOLE	Folicur®	P	E	P	P	E	P	P
PYRACLOSTROBIN	Cabrio®	P	E	G	E	G	P	P
IPRODIONE	Rovral®	P	F	P	P	P	P	P
MEFENOXAM METALAXL	Ridomil Gold®	E	P	P	P	P	P	P
CHLOROTHALONIL	Bravo Weather Stik®	P	P	G	G	P	P	P
BOSCALID	Endura®	P	G	E	P	P	P	P
BOSCALID + PYRACLOSTROBIN	Pristine®	P	F	E	E	P	P	P
METAM SODIUM	Vapam®	G	F	P	P	P	G	G
THIOPHANATE-METHYL	Topsin 4.5®	P	F	P	P	P	E	F
FLUDIOXONIL	Cannonball®	P	G	G	G	P	P	P
PYRIMETHANIL	Scala®	N	N	E	N	N	N	N
BENZOVINDIFLUPYR (not registered)	Solatenol®					E		
Non-chemical Tools								
Irrigation management		E	P	E	E	E	P	P
Weed control		P	P	P	P	P	P	P
Resistant varieties		P	P	P	P	P	P	P
Cover crops		P	P	P	P	P	P	P
Fertilizer management		P	P	F	F	F	P	P
Sanitation		P	E	P	P	P	P	P
Crop rotation		E	G	P	P	P	P	G
Hot water seed treatment for nematodes		P	P	P	P	P	P	F
Inspection of seed crop		E	E	E	E	E	E	E

Rating System: E = Excellent, G = Good, F = Fair, P = Poor, N = not for use/not registered
Data based on collective field observations and experiments

Appendix 7: Efficacy of Nematode Management Tools

PRODUCT/TECHNIQUE	TRADE NAME	Stem and Bulb Nematode
Chemical		
CHLOROPICRIN	Chloropicrin	E
1,3-DICHLOROPROPENE	Telone®	E
OXAMYL	Vydate®	E
Non-Chemical		
Clean Cultivation		F
Soil Sampling		P
Resistant Rootstock		P
Trap Crops		P
Crop Rotation		E
Seed Inspection		E

Rating System: E = Excellent, G = Good, F = Fair, P = Poor/None
Data based on collective field observations and experiment

Appendix 8: California Garlic and Onion Research Subcommittee – Contact Information

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CAGORAB

CALIFORNIA ONION AND GARLIC MASTER PLAN FOR WHITE ROT MANAGEMENT

CAGORAB WHITE ROT SUB-COMMITTEE

2/13/2012

EXECUTIVE SUMMARY

The attached report is a result of the Board of Directors (Board) request for the Research Sub-Committee to prepare a "Master Plan" dealing with the problems associated with white rot in the western onion and garlic production areas. This plan was developed as a joint effort between representatives of the Research Sub-Committee and other member growers, processors and handlers of the CA Garlic and Onion Research Advisory Board (CGORAB) and their CEO. The report is split into four subsections as follows:

Introduction
Existing State and County Regulations/Ordinances
Control
Recommendations

A brief review of each subsection is provided as follows:

INTRODUCTION

This section contains a reference to the world-wide distribution of white rot and a review of the history of this disease in California. References are also made to the Committee's involvement through the CGORAB sponsored grant programs and other issues of importance to the potential development and spread of this disease in the western onion and garlic production areas of the United States (U.S.).

EXISTING STATE AND COUNTY REGULATIONS/ORDINANCES

This section includes references to existing state and county regulations and/or ordinances dealing with white rot and related issues in the western states and provides copies of existing ordinances for the states of: California; Idaho; Nevada; Oregon; and Washington.

CONTROL

At this time there are no known economical control methods for white rot. Most known techniques may provide some control, but none are known to be 100% effective. Research has been conducted on a number of control methods and a brief description of these methods and results is provided in this section.

RECOMMENDATIONS

This section includes the Committee's recommendations for policies to be established by the Board and adhered to by all CGORAB members with detailed recommendations on the following issues:

- Inspection Of All Garlic Seed Fields
- Planting And Harvesting In Areas Known To Be Infested With White Rot
- Reporting Of Fields With White Rot Infestations
- Treatment For Known Infestations Of White Rot – All Allium Producers
- Establishment Of Certified Garlic Seed Programs
- Development Of Methods To Reduce Soil Populations Of White Rot Sclerotia
- Approval Of Board And CEO

INTRODUCTION

White rot caused by *Sclerotium cepivorum* Berk. is one of the most limiting factors associated with the production of onions, garlic and related *Allium* species. This disease has been found in many of the onion and garlic producing regions of the United States (U.S.), Canada, and Mexico. It has also been reported in most of the major onion and garlic production areas of the world including Europe, Asia, Africa, the Middle East, Central and South America, Australia, and New Zealand.

White Rot ((*Sclerotium cepivorum*) was first recorded as found in California in 1939. By 1950 it was widespread in the Gilroy area, soon to spread to the Salinas Valley and then to Tulelake in northern California. It was not identified in the San Joaquin Valley until the mid-1980's and

for the first time in Kern County, in the southern San Joaquin Valley, in 1996. Throughout the western U.S., white rot has been identified in several locations in each of the states

Concern over white rot infestations in the garlic seed production regions, Tulelake, and the initial white rot infestations in the San Joaquin Valley, and discussions on potential methods to reduce the spread of this disease in these, and other areas, have been documented in CGORAB reports of research, correspondence, and at numerous Field Committee meetings and News Bulletins. References to CGORAB reports and individual discussion included with Field Committee News Bulletins, meetings and/or minutes may be found on the CGORAB web site at http://www.cagarlicandonion.com.

This disease is more prevalent under cool temperature conditions, such as occur with fall planted onion and garlic crops in California and other areas of the western U.S. It is less of a problem under spring planting conditions, but spring planting followed by temperatures conducive to sclerotia germination and development have resulted in severe infestations with resultant crop losses in areas such as the Klamath Basin including Tulelake, CA.

Controlling White Rot in garlic and onion fields has the best potential for success when following a comprehensive approach to manage the disease. To date, no single practice has shown to effectively control White Rot, particularly after a disease outbreak has occurred in a field. This presentation provides direction for an integrated pest management approach for management of white rot.

The number of infested fields in the San Joaquin Valley was only a few, with sporadic new finds, until the last 5-8years. Attached to this document is a table that shows a summary of documented white rot strikes in the San Joaquin Valley from 1994 through 2011. The summary includes strikes in both garlic and processed onions.

Since that time, the number of infested fields has increased markedly. The current number of fields is now 111 with over 16,000 acres infected. The primary strategy of the California Allium industry in white rot control has been avoidance. When a field was identified as having white rot, it was placed on a centralized map, and the industry avoided planting onions or garlic in that field. Much of the world has not had the luxury of this strategy. Mexico and Egypt, for example, have such widespread infestation of the pathogen, that garlic and onions are knowingly planted into infested fields. Thus, they have moved from the strategy of avoidance to the strategy of living-with-it. The California industry may be fast approaching the time when avoidance will no longer be the strategy of choice. Hopefully, a broad system, multi-faceted approach to disease prevention and control will be available when that choice is made. A combination of biological and chemical control, plant disease resistance, sclerotia stimulants, and others will probably be needed.

White rot has moved from plant to plant, field to field, county to county, area to area, and state to state by several primary methods – onion transplants, equipment movement, seed garlic, air/wind, and water. To minimize disease occurrence and spread, each of these primary infestation methods must be continually addressed.

Economic losses to White Rot are also manifested in varied and extensive methods. Accurate statistics on actual monetary losses due to White Rot are not commonly available because the individual loss components are either difficult to quantify or difficult to separate from other costs. The components of economic loss include removal of fields from cultivation of Alliums, direct crops losses when white rot occurs, the cost of seed increase and propagation programs, seed certification programs, and the salaries of hundreds of plant pathologists using public and private funds to conduct research and education programs. Notably absent, until recently, has been the cost of chemicals, or other direct control or prevention methods. No

effective chemical or biological control measures have been available. Research reports indicate that this is not necessarily the situation now and should improve in the near future. As California changes from avoidance to a live-with-it approach, the costs of these compounds will increase. Hopefully, components such as removal of fields from cultivation of Alliums and direct crop losses will decrease by equal or greater amounts.

The unique ability of sclerotia of *S. cepivorum* to lie dormant in the soil for many years (e.g., 30-40+) presents a significant problem in the ability to either reduce or eliminate this pest from a specific site. Once roots of host plants come in close proximity to the dormant sclerotia they germinate and attack the host resulting in death of individual plants or groups of plants in close proximity to the infection site(s). Initial symptoms occur as yellowing or dying of the onion or garlic tops. White rot infestations on the bulbs of both crops are easily identified by the presence of either a white fluffy growth, which is the mycelium of the fungus, or by numerous round black bodies about the size of a pin's head called sclerotia.

Minimal numbers of white rot sclerotia in the soil profile can result in moderate to severe losses in garlic or onion fields under conditions conducive to sclerotial germination. Data generated by various university researchers have indicated for garlic and over-wintered onions that populations as low as 0.0001 sclerotia per gram of soil (0.1 sclerotia/Liter of soil) can result in as much as 10% disease, while populations in the range of 0.001-0.01 per gram of soil (1- 10 sclerotia/Liter of soil) can result in 40-85% disease incidence. For spring planted onions in cool regions, slightly more sclerotia are needed for similar disease incidence.

A typical initial field infestation usually occurs with a few isolated plants, which may not be detectable in large fields. However, the sclerotia produced by these plants constitute the basis for increasing populations in subsequent plantings. Based on the degree of the initial populations and subsequent tillage practices, fields will usually become implantable after the first or second crop following the initial infestation. Land leveling is one of the most efficient methods of spreading sclerotia across individual fields.

White rot sclerotia may be introduced to fields with garlic seed and with onion sets, bulbs, or transplants. Sclerotia may also be inadvertently introduced by dumping garlic and/or onion plant waste into fields, and by movement of infested soil on equipment, harvest containers, tires, and on the shoes of individuals who walk through infested fields. Animals may also contribute to the movement of sclerotia from field to field.

EXISTING STATE AND COUNTY REGULATIONS/ORDINANCES

There are a number of existing state and county regulations/ordinances dealing with white rot and related issues. The following are known to exist in the western states, and are included:

California

- California Department of Food & Agriculture – Certified Seed Garlic Program
- California Department of Food & Agriculture – Transport of a Class B pest
- Lassen County – Ordinance 335-A § 1 (part), 1989( ).
- Modoc County – Ordinance 165 (12-12-62).
- Mono County (Amended 9-15-85).
- Shasta County – Ordinance 494-327 (part). 1987
- Siskiyou County – Ordinance 342 (10-29-59).

Idaho

- Idaho Department of Agriculture – Title 22, Chapters 19 & 20, Idaho Code.

Nevada

- Nevada Department of Agriculture – Nevada Administrative Code Chapter 554.020, 554.030 and 587.360; §2, NRS 554.020 (effective December 30, 2011).

Oregon

- Oregon Department of Agriculture – Oregon Onion and Garlic Disease Control Area Order for Crook, Deschutes, and Jefferson Counties (Amended 8-31-88 & 1996). This order was discontinued as ODA felt the disease was widespread. ODA can still be contacted to inspect fields as an independent inspection service. Current Rules for White Rot Certification of Vegetative Allium Seed: 603-051-1050: Certification of agricultural products, such as Allium seed is a function of the Department of Agriculture. Participation by Allium seed companies and seed growers in the certification program shall be voluntary.

Washington

- Washington State Department of Agriculture – Rules Relating to Garlic Grown for Production of Certified Seed. No regulated articles for the purpose of planting or propagation including bulbs, sets or seedlings may be imported into Adams, Franklin, or Grant counties except: (a) from areas of this or other states where onion white rot is not known to occur and (b) each shipment has been certified as free from onion white rot. No equipment or tools used on fields outside of Adams, Franklin, and Grant counties where onions or garlic are produced may be moved into these counties until the equipment or tools have been cleaned of soil and sterilized by use of steam under pressure.

CONTROL

At this time there are no known economical control methods for white rot. Most known techniques may provide some control, but none are known to be 100% effective. The CA Garlic and Onion Research Advisory Board have funded research on a number of control methods and a brief description of these methods and results follows:

DADS (diallyl disulfide): DADS is a liquid that acts as a biological stimulator for the germination of white rot sclerotia. It mimics the presence of an Allium crop, which in turn stimulates the germination of the white rot sclerotia. When the germinating sclerotia do not find a host, the either die or are weakened to point they ultimately perish. The high cost of DADS ($200/gallon) at 1 gallon per acre rate with application either the season before or even earlier to a non-Allium crop are deterrents to use.

Tebuconazole (Folicur/Orius/Tebuzole): These tebuconazole products are now registered for white rot management. An in-furrow application can provide control of low sclerotial levels in fields. There is some concern of phytotoxicity to onion plants when tebuconazole is applied directly to the seed. Cool/cold soil temperatures amplify the expression of phytotoxicity.

Boscalid (Endura): Endura, when applied either as a foliar drench or as an in-furrow application has shown utility for management of the white rot pathogen. Although not specifically labeled for in-furrow use, labeled rates for foliar diseases are effective against white rot.

Fludioxonil + cyprodinil (Switch): When compared to Cannonball (fludioxonil) no differences in control when compared to Switch were noted suggesting fludioxonil was the effective compound against white rot. Switch is registered for in-furrow use and Cannonball registration is pending.

Fludioxonil (Cannonball): Registration at the CA Department of Pesticide Regulation has been granted and product is available for use in CA and all states where white rot is of concern.

Methyl Bromide (MeBr): Soil fumigation with this product along with plastic tarping will reduce sclerotial populations, and this chemical may be useful as a "Spot Treatment" to reduce soil populations of sclerotia. Cost is a factor, especially for the treatment of large areas. In addition, MeBr is currently scheduled to be eliminated as a soil treatment at some time in the near future. As present time it is only registered for use on strawberries, nursery crops and crops under state quarantine guidelines. Research is being initiated on Methyl Iodide, which may eventually become a replacement for MeBr. However, environmental pressure for use of Methyl Iodide may result in cancellation of use in California.

Rovral: In-furrow applications of this fungicide to garlic at planting will provide control of low sclerotial populations. However, this treatment will not provide complete control under any population levels and will not provide economic control under moderate to high sclerotial populations.

Biotechnology: CAGORAB has a long term research program established with the New Zealand Institute for Plant & Food Research, Ltd. researcher Dr. Colin Eady. This program is geared toward development and assessment of biotech Allium germplasm resistant to white rot. Progress has been made, however this is a long term project that will take 5-10 years to provide any tolerant germplasm.

Flooding: Flooding, especially under warm season conditions has been shown to reduce sclerotial populations, but does not provide complete control. Additionally, this control technique takes the land out of production for a period of time and also requires large amounts of water.

Soil Solarization: This technique has been shown to be somewhat effective in the Middle East, and any potential use in the United States would be limited to production areas with prolonged periods of warm to hot temperatures. This control technique also takes the land out of production for a period of time.

Tolerant Varieties: Some research has been conducted in this area on onions, without much success. One of the major problems with this approach is the relationship of onion root systems and the products they give off in relation to the germination of the sclerotia.

Cultural Control in the San Joaquin Valley: White rot is rare in the hot summer regions of the Treasure Valley (far Eastern OR and Western ID) and in onion regions of the Columbia Basin (Tri-Cities and Patterson, WA, Hermiston-Boardman, OR) because spring-planted, fall

harvested onions cause sclerotia to germinate but soil temperatures are too hot for white rot to develop on bulbs, so sclerotial populations decline precipitously. This is essentially the effect being achieved artificially with the DADs soil treatment. Rotating over-wintered Alliums with such spring-planted, fall-harvested onions can be done without risk of substantial white rot, but requires that there is a good market for the spring-planted, fall harvested onions. This rotation is not effective in regions with cool summers.

RECOMMENDATIONS

The Research Sub-Committee of CGORAB recommends that the following policies be established by the Board of Directors (Board) and adhered to by all CGORAB members:

1 – Inspection Of All Garlic Seed Fields

The Committee recommends that CGORAB members inspect all garlic seed fields during the spring/early summer period or when soil temperature and plant growth conditions are conducive to white rot infection. Inspections shall be carried out by a single walk through starting the month before water cut-off. Each field shall be walked at least every fourth row, depending upon foliage cover and plant condition, to ensure that all areas of the field are observed during this period. The results of all field inspections shall be recorded on a form approved by all CGORAB members. Any field shown to be infested with white rot shall be processed and no seed from an infested field shall be used for planting of other seed fields or for planting for production of garlic for fresh market or for processing. In specific situations where the incidence of white rot in a garlic seed field is localized and easily identified and the remainder of the field has been walked and certified no other white rot has been detected, seed from uninfected areas may be harvested for seed. The infected area must be destroyed and treated for white rot using available chemical and cultural control methods.

Inspection of fields shall not be limited to seed production areas but shall also include any fields in the California production areas that may be considered for seed for the following year(s). In this case the individual CGORAB member shall designate such fields in adequate time to complete inspection prior to water cutoff.

Further to this issue, the Committee recommends that CGORAB members, when there is evident that a specific seed lot may have contributed to a white rot infestation, trace the history of all garlic seed lots involved in infestations of white rot to ensure that individual seed lots will not contribute to white rot infestations in either seed or production regions. Should the cause of the infestation be traced (i.e., tracing shall include field inspections of both production and seed fields as noted in paragraph 1 of this section) to an individual seed lot, as opposed to an infestation traced to the previous history of the field, all remaining seed from that lot and/or lots, shall be used only for fresh market use or for processing.

The results of any inspection, along with data on seed lots and seed lot tracing that clearly shows that a specific seed lot contributed to a white rot infestation shall be forwarded to the CEO of CGORAB who shall certify to the Board and the Committee that the inspection data meets the requirements of this policy.

2- Garlic Seed Field Maintenance

The following practices must be observed for seed fields:

a. All seed bins will be washed before use.
b. All seed fields will be inspected for white rot and other pathogens as noted above inspection section.
c. Access for trucks entering seed fields should be limited to essential complete seed harvest.
d. The amount of equipment entering seed fields shall be limited to only those activities essential to seed field maintenance and production.
e. All equipment must be sanitized before entering a field grown for seed.

3- Planting And Harvesting Garlic and Onions In Areas Known To Be Infested With White Rot

The Committee recommends that CGORAB members not plant in areas with known serious white rot infestations or in fields where white rot infections have been previously identified and mapped.). Due to the low level of infection that can cause economic damage (1-2 sclerotia per liter of soil corresponds to 10% bulb infection at harvest), soil sampling has proven not a practical approach for determining potential for white rot infections.

The Committee recommends avoidance as a primary tool in reducing the possibility of white rot infection. However, with the spread of the white rot organism throughout our primary growing areas, it is practical to plant in fields with known white rot infections as long as the following procedures are followed:

a. Fields where white rot infection are observed shall be identified and areas of infection in that field mapped (when practical)
b. Previously infected fields shall be treated with a fumigant or the biostimulant DADS (diallyl disulfide) or a comparable biostimulant such as garlic juice at least one season prior to planting an Allium crop.
c. Where white rot infestations have been light (low frequency of infected plants) and where the use of a biostimulant is economically not practical, the use of one of the approved white rot management conventional chemicals, such as Folicur, Boscalid, Switch or Cannonball, shall be applied at planting.
d. All seed bins will be washed before use.

Prior to planting, and as a part of the contract process, the grower and the processor/handler members shall sign a “Waiver of Liability” agreement noting the history and potential for white rot in each individual field scheduled for planting and absolving both parties of any liability should white rot occur. Further to this issue the Committee recommends that CGORAB members who elect to plant back into previously infected fields inspect all fields for white rot infection. Inspections shall be carried out by a single walk through starting the month before water cut-off. Each field shall be walked at least every fourth row, depending upon foliage cover and plant condition, to ensure that all areas of the field are observed during this period. The results of all field inspections shall be recorded and reported to the CGORAB CEO. Any field shown to be infested with white rot shall be processed and no seed from an infested field shall be used for planting of other seed fields or for planting for production of garlic for processing.

Any field shown to be infested with white rot shall be processed and all trucks involved in hauling garlic and/or onions taken from each individual field, along with any other vehicles entering each field, shall be cleaned (i.e., soil removed from tires and other portions of vehicles) prior to leaving the field and all truck loads shall be tarped to reduce the potential of

spread of this disease during shipment from the field to the processing facility. In addition, all equipment involved in harvesting operations associated with individual infested fields shall be cleaned in a manner agreed to by all CGORAB members prior to being used in other fields.

Further to this issue it is recommended that loads of garlic and/or onions known to be infested with white rot be handled and processed in a manner that will ensure that there is little likelihood of contamination of garlic and onion (i.e., bulb storage or processing) seed production facilities.

The results of all subsequent field inspections, documentation of equipment cleaning, handling of infested loads, and related information shall be forwarded to the CEO of CGORAB who shall certify to the Board and the Committee that the inspection data and related documentation meets the requirements of this policy.

3 – Reporting Of Fields With White Rot Infestations

The Committee recommends that CGORAB members report any known infestations of white rot in both garlic and onion seed and production for processing areas no later than June 15 of each year. Infestations shall be reported to the CEO of CGORAB who will then inform Mike Davis of the Department of Plant Pathology at the University of California at Davis and shall include the exact location of each field and the year the infestation was discovered. Data should also be provided, if possible, on the history of Allium production for each infested site. Fields will be GPS mapped with reference for latitude and longitude clearly delineated. Where possible, infections in fields will also be mapped to allow for precision treatment of infected areas. CAGORAB CEO shall also coordinate the reporting of infested fields in Nevada with Steve Marty and in Oregon with Bo Ming Wu.

The CEO of CGORAB shall be responsible for updating maps of all areas and disseminating this information to CGORAB Board and Committee members no later than July 15 of each year.

4 – Treatment For Known Infestations Of White Rot – All Allium Producers

The Committee recommends the following practices be followed by all Allium growers, processors and handlers:

a. All fields found to be infested with the white rot fungus should be placed under quarantine and treated with a fumigant or other soil biocide immediately after harvest. Surface application of metam sodium, metam potassium or dazomet can provide effective spot treatment control. For larger defined areas, a fumigant treatment may be needed. Even though an infected field may be scheduled to be planted to a permanent crop, there must be an effort to minimize the transfer of infected soil from the permanent crop to other fields.

b. Where possible, all fields found to be infested should also receive a treatment of the biostimulant DADS (diallyl disulfide) or garlic juice no sooner than 6-months after a field is harvested. (since sclerotia go through a dormant period, a minimum of 6-months should pass before biostimulant treatment).

All machinery and equipment used in an infested field, regardless of the crop grown, should be decontaminated after use in a field known to have white rot. Sanitation of equipment from infested fields should help restrict movement of sclerotia to unaffected parts of the farming operation.

It is the Committee's intent to find a path forward either through grants or a form of assessment to treat previously infested fields with white rot without causing undue economic hardship to grower, handler or processor members. The lynch pin of an effective white rot management program lies first with disease, nematode and virus free seed garlic and then with field and equipment sanitation once white rot is found.

5 – Establishment of Certified Garlic Seed Programs

The Committee recommends that CGORAB members establish regulations dealing with the certification of garlic seed production. Further to this issue the Committee recommends that CGORAB initiate this program in cooperation with the fresh market garlic industry. Such a program would be to the benefit of all parties in that it would ensure that all are abiding by approved policies aimed at ensuring the production of "clean" garlic seed. Due to the complicated nature of such a policy, the Committee recommends, subject to Board approval, the establishment of an AD HOC Certified Garlic Seed Committee. This committee shall be responsible for determining the feasibility of developing a program that will meet the needs of all parties, without requiring undue economic burdens, and for presenting their recommendations to the Board and fresh market garlic industry.

6 – Development of Methods to Reduce Soil Population of White Rot Sclerotia

The Committee recommends that CGORAB work with state and federal research and regulatory personnel to develop and establish acceptable methods for dealing with the problem of existing soil populations of white rot sclerotia. As a part of this effort CGORAB shall continue to fund research on this issue and shall become involved in applying, in cooperation with individual researchers, for grants for research on methods of controlling and/or reducing white rot.

Further to this issue, CGORAB shall continue to work with the IR-4 and chemical manufacturers in the development of efficacy data and, if necessary, residue data to support the use of all products deemed to be effective for reducing soil populations of white rot sclerotia.

All activities related to research shall be coordinated by the Research Sub-Committee, subject to Board approval.

7 – Approval of Board and CEO

The Committee recommends that each Board member and the CEO, subject to approval of these recommendations, sign a document noting the approval of all recommendations and further agreeing to implement and abide by all such recommendations.

This report is submitted on behalf of the following processors, handlers and their growers:

Christopher Ranch

Sequoia Packing
The Garlic Company
Harris Fresno
Olam West Coast
Sensient Dehydrated Flavors, LLC
George Chiala Farms, Inc.

May 18, 2012

Appendix 10 - Photographs

Garlic/Onion - Land Preparation

Garlic Planting

Garlic/Onion - Land Preparation

Garlic Planting

Garlic/Onion - Land Preparation

Garlic Plant Emergence

Early Growth

Early Growth

Early Growth

Garlic Field Mid Season

Early Growth

Garlic - Harvest

Garlic Harvest

Diseases of Garlic

Garlic - White Rot

Garlic - Harvest

White Rot

Garlic - Harvest

Schlerotia of White Rot

Early Stress from White Rot

Garlic - Leaf Rust

Field Stress from White Rot

Garlic - Purple Blotch

Garlic - Leaf Rust

Severe Botrytis

Botrytis in Growing Plant

Nightshade Before Garlic Harvest

Iris Yellow Spotted Virus

Field Bindweed Before Garlic Harvest

Weeds in Garlic

Volunteer Cereals in Garlic

Horseweed Before Garlic Harvest

Morningglories in a Garlic Field