Crop Profile for Garlic in California

General Production Information

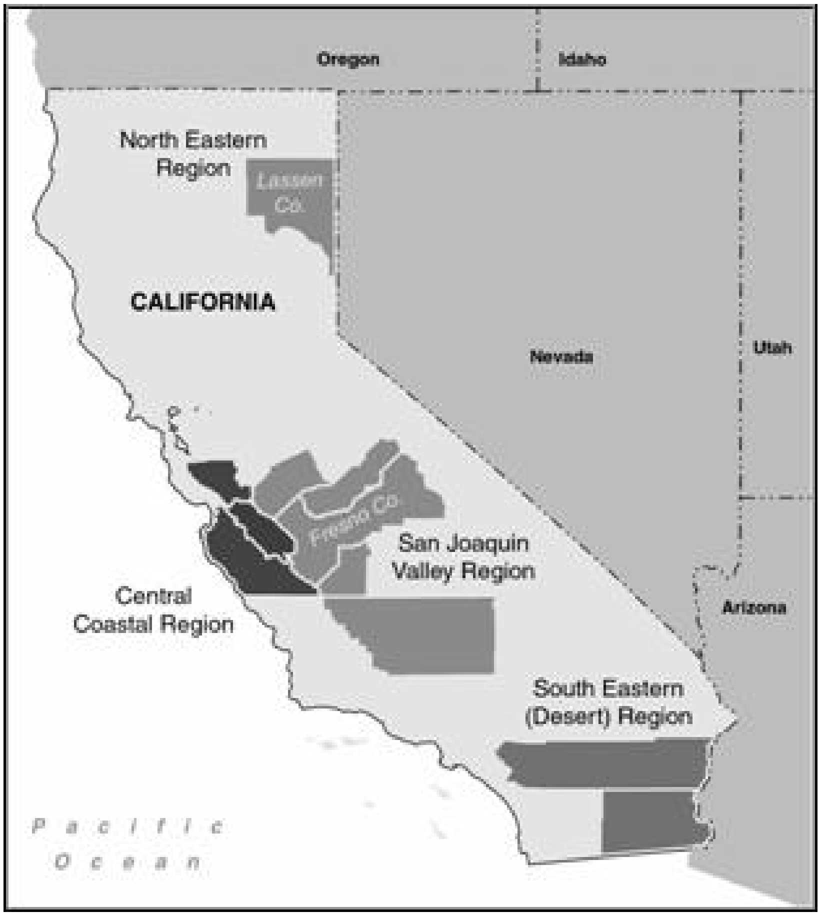
Prepared: August, 2004

- California ranks first in the United States in both the number of farms growing garlic and in harvested acres (USDA/NASS 2001)
- California produced approximately 87% of all commercially grown garlic in the United States in 2000 (CDFA, 2001) and virtually all of the garlic marketed as a consumable commodity. Garlic seed is produced primarily in Nevada and Oregon (California Onion and Garlic Research Committee)
- In 2001 a total of 29,240 acres of garlic were grown in CA. Approximately 65% of California garlic is grown for processing/dehydration, 20% for fresh market, and 15% for seed. (California Onion and Garlic Research Committee)
- Total value of California garlic was $151,866,000 in 2001 and $115,543,900 in 2000 (CA County Ag Commissioners' Data, 2000/2001). Garlic yield for the years 1994-2001 averaged 16.5 cwt./acre.
- Total production costs for garlic, excluding seed and harvest costs, range from $900/A to $1,300/A.

Production Regions

California garlic growers obtain most of their seed from growers in Nevada and Oregon, although there is a relatively small amount of garlic seed acreage in northern and eastern California.

Figure 1.
Principal California garlic producing counties, grouped by region.
The San Joaquin Valley region grew 91% the harvested garlic acreage in 1997.



The western San Joaquin Valley, which includes the counties of Fresno and Kern, represents 96.5% of the total state garlic acres. Fresno County represents the majority of these acres with 86% and Kern County grows 12.5%. Some garlic is grown in the Southeast desert counties of Riverside and San Bernadino counties. Lassen and Siskiyou counties in northern California and Mono county in the eastern Sierras produce a small amount of garlic, which is used mainly for seed. In the Central Coastal Region, primarily around Gilroy and Hollister,, some garlic is still grown, but the area now serves primarily as the center for fresh market shippers and dehydrators who still have their facilities located in this area. At one time, this was the original garlic-growing center of California.

Cultural Practices

Garlic, *Allium sativum* Gemmifera, belongs to the *Alliaceae* (onion) Family. Other members of *Alliaceae* include, in addition to onion (*Allium cepa*, Cepa group), chives (*Allium schoenoprasum*), leek (*Allium ampeloprasum,* Porrum group) and shallots (*Allium cepa,* Aggregatum group).

Allium sativum comprises two subspecies, *A. sativum ophioscorodon* and *A. sativum sativum*. The former, commonly referred to as “hardneck garlic,” is not significant in commercial garlic production, although it is planted by some home gardeners. The latter, *A. sativum 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 (ERS, 1996). Early garlic, which has a growing period about one month shorter than late garlic, is grown primarily for the dehydration market; late garlic was favored by fresh market growers, but is being displaced by early varieties due to import competition. (CSA, 1999). Garlic is responsive to temperature and photoperiod for proper clove and bulb formation.

Planting

Garlic is propagated vegetatively through the planting of cloves, referred to also 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 white rot disease. This is a disease that can be transmitted from the soil to the seed, 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 nematodes, or treated with thiophanate methyl(Topsin M) prior to planting to guard against *Penicillium*, another seed-related disease.

Garlic has a shallow rooting depth, averaging 18 to 24 in. It is moderately tolerant of acid soils and grows best in soils with pH of 5.5 to 6.8 (Maynard and Hochmuth, 1997). 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 garlic is planted, ranges from sandy loam to clay loam.

In preparation for planting, garlic beds are normally treated with a pre-emergent herbicide. 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 approximately 18 plants/foot. The garlic is then irrigated with overhead sprinklers until stand establishment, then furrow irrigated.

Field Maintenance

After a field is planted, the primary maintenance concern is weed management. Garlic fields are normally treated with herbicide immediately after planting, with additional applications made once or twice as the season progresses. Hand weeding has been eliminated in many fields. Herbicide applications stop at a minimum of 80 days before harvest (CA O&G Research Committee).

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 of time 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. Fungicides were applied to only a small percentage of California garlic acreage.

However, the widespread emergence in 1998 of garlic rust disease as a serious threat to crop production has increased the importance of fungicide applications, particularly tebuconazole (Folicur).

Irrigation of garlic fields is stopped a few weeks prior to harvest to allow the plants to dry. “Water cutoff” normally occurs in early June for fresh market fields, and mid June for the fields growing garlic for dehydration.

Harvesting

Fresh market garlic is allowed to 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 transport from the field to the marketplace.

Garlic grown for dehydration is allowed to dry for approximately one month, then the tops of the plants are mechanically mowed. The bulbs may then 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, before being 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 their fields for four to five years from the previous *Allium* spp. crop.

Insect Pests

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

Onion Thrips, *Thrips tabaci*
Western Flower Thrips, *Frankliniella occidentalis*

Mature onion thrips are about 0.05 inches (1.3mm) long and flower thrips are slightly larger at 0.06 inches (1.5 mm) long. Thrips have two pairs of wings fringed 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 in 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). (UCIPM Guidelines) Thrips tend to be more of a problem on onions than garlic.

Biological Controls

Lady beetles, green lacewing larvae, predatory mites and the minute pirate bug, *Orius insidiosus*, are thrips predators (Metcalf, 1993) and are used in inundative releases by organic growers. None of these control agents provides acceptable thrips control. Research to find the role of natural enemies in managing onion thrips is needed.

Cultural Control Practices

Avoidance in planting fields next to grain may reduce spring migrations from cereals. Overhead irrigation has some effect on reducing thrips populations, but grower’s transition from sprinklers to furrow irrigation as soon as the crop is established to reduce disease pressure.

Chemical Controls

<u>Pyrethroids</u> are the predominant pesticide used for control of thrips in garlic in CA. While resistance to pyrethroids has not been documented in California, data from other states suggest control has dropped from over 90% in 1995 to less that 70% control in 2000. (Jensen & Simko, Oregon State University)

During the 2001 crop year, 3664 acre treatments (12.6% of total acres) were made with pyrethroids for thrips control. Cypermethrin, zeta cypermethrin and lambda cyhalothrin were the pyrethroids most often used. When thrips are a problem, growers typically spray one or two times to maintain control during the season.(CA Dept. of Pesticide Regulation 2002 Pesticide Use Report)

<u>Organophosphates</u> were widely used in California for thrips control until the late 1970’s when levels of tolerance began to appear. Although resistance to organophospate pesticides by thrips has not been evaluated in CA, it has been documented in other states and is suspected in CA. No measurable acres of garlic were treated with organophosphates in 2002.

<u>Methomyl</u> has been used as a tank mix partner with pyrethroids for thrips control. However, during the 2001 crop year, only 100 acres were treated for thrips. In 2002, no acres were reported treated with methomyl.

Alternative Chemical Controls

Because of the potential increase in tolerance of thrips to pyrethroid insecticides, it is critical that other pest control measures be investigated. The biological insecticides azadirachtin (Neem oil extract) and spinosad (product of bacterial fermentation) have been evaluated for thrips control. By themselves, neither product has given satisfactory control of thrips. However, combination treatments of azadirachtin and spinosad have shown promise in small plot trials. The plant activator Messenger (harpin protein) may also have some utility in managing thrips populations. The organophospate, acephate, is not registered on onions and garlic. Based upon preliminary testing, it may have utility as a tank mix partner with either the pyrethroids or spinosad.

Minor Insect Pests

Lepidopterous larvae (*e.g*., beet armyworm) are minor pests in garlic fields. Acreage treated with the most common worm control materials, such as methomyl (Lannate) and the biological insecticide *Bacillus thuringiensis*, indicate that these pests were an economic threat to less than 1% of planted garlic acreage in 2001.

Bulb mites (*Rhizoglyphus spp., Tyrophagus spp.)* are sporadically 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. (UC IPM Pest Management Guidelines 1996). No insecticide treatments are registered for bulb mite control. Metam sodium, 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.

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 opening up the crop canopy and allowing another flush of weeds to emerge. During this time period, yellow nutsedge and field morningglory can become very problematic. Weeds most commonly found in garlic include cheeseweed, chickweed, henbit, lambsquarters, marestail, pigweed, purslane, shepherdspurse, annual bluegrass, barnyardgrass, and foxtail.

Herbicides used in garlic are typically grouped as (1) those used prior to planting, (2) those used preemergence, and (3) those used postemergence. A table from Kurt Hembree, Farm Advisor, Fresno County (Appendix 3) shows susceptibility of annual broadleaf weeds and grasses to herbicides registered in garlic in California.

Chemical Controls

Preplant:

Paraquat, glyphosate and metham sodium are use preplant. A limited amount of metham 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. In 2002 ~ 1,500 acres were treated with glyphosate and less than 100 acres were treated with paraquat. It is possible that some of the 1,500 acres were treated under a Section 24(c) registration for use late season, after plant dry down, for morningglory control.

Preemergence:

DCPA (Dacthal) and pendemethalin (Prowl) are registered for use preemergence in garlic. However, pendemethalin is the predominant herbicide used with 11,333 acres treated in 2002. DCPA is used most often in onions and no significant use was reported on garlic during a three year period from 2000-2002.

Postemergence:

After the crop emerges, bromoxynil (Buctril), oxyfluorfen (Goal/Galigan), sethoxydim (Poast), fluazifop-P-butyl (Fusilade), and clethodim (Prism) can be used. Bromoxynil controls a wide spectrum of broadleaf weeds and can be used on garlic from emergences up to 12 inches in height. Sethoxydim and fluazifop-P-butyl are used to control emerging grasses as well as some perennial grasses. Clethodim is also used on grasses, but additionally has activity on annual bluegrass.

<u>Oxyfluorfen</u> (Goal, Galigan)

Oxyfluorfen is a diphenyl ether herbicide that is applied to garlic fields for postemergence control of selected species of broadleaf weeds and grasses (it is not effective against watergrass). The garlic plant needs to be well-established, approximately 12 inches high, before this material is sprayed to lower the risk of plant damage. This precludes oxyfluorfen applications early in the season. An important characteristic of this herbicide is its residual weed suppression activity in the soil. It can be applied in March or April, and provide weed control for approximately 2 months, or near the time of water cutoff.

During the 2002 crop year, oxyfluorfen was applied to 20,561 acres of garlic. Statewide Coverage, based on 1 application per field, is estimated to be 88%.

<u>Pendimethalin</u> (Prowl)

Pendimethalin is a nitro compound pre-emergence herbicide with a weed spectrum similar to that of oxyfluorfen. It is not effective against established weeds. It is effective against grasses, and also controls pigweed, but does not control volunteer wheat or other volunteer cereals.

Pendamethalin was applied to 11,331 acres in 2002. Statewide Coverage, based on 1 application per field, is estimated to be 38%.

Bromoxynil

This selective postemergence contact herbicide is effective against broadleaf weeds only Bromoxynil was applied to 14,300 ac in 2002. Statewide Coverage, based on 1 to 2 applications per field, is from 24% to 48% .

Fluazifop-P-butyl (Fusilade)

This selective systemic herbicide provides postemergence control of grasses.

Fluazifop-P-butyl was applied to 1,678 ac in 2002. Statewide Coverage range is estimated to be 6%.

Clethodim (Prism)

It was applied to 1,083 ac in 2002, for Statewide Coverage of less than 4%

Sethoxydim (Poast)

Alternative Chemical Controls

Glyphosate (Roundup)

This is a nonselective postemergence herbicide. A Section 24(c) was issued to Monsanto Corporation for the use of Roundup Ultra after water has been pulled from garlic and after tops and bulbs have dried down. This use allows management of field bindweed that proliferates after canopy cover from the drying garlic plant diminishes. Glyphosate was applied to ~ 1,500 acres in 2002, for Statewide Coverage of less than 6%. However, as previously mentioned, some of this reported use may be pre-plant use on fallow beds.

Paraquat (Gramoxone Extra)

Paraquat is a contact postemergence herbicide for control of grasses and broadleaf weeds. Paraquat was applied to 61ac in 2002. Use is not significant on garlic.

Biological Controls

There are no known biological control measures for weeds.

Cultural Control Practices

Cultivation is a key component of 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, growers try to avoid the need to weed by hand, and strive to develop an herbicide-based weed control program. As a result, some growers have eliminated hand weeding altogether in commercial garlic fields. Organic growers utilize flame burning for weed control. However, this procedure is expensive and is not used in commercial production.

Post Harvest Control Issues

Blue mold, *Penicillium* spp., is related to *Penicillium* decay, but it is caused by a wider range of *Penicillium* species, including *P. hirsutum.* It does not interfere with the growth of the garlic plant, but it is manifested in post-harvest storage as pale yellow blemishes, watery soft spots, or a blue mold. Control of blue mold is generally accomplished through harvesting techniques that minimize bulb wounding, and storage of the bulbs in cool, dry environments (Schwartz and Mohan, 1996).Mites are occasionally present on bulbs harvested for processing if they have remained in the ground for a number of weeks after water cutoff. However, bulbs for processing are subjected to a warm air treatment before being placed in storage. This procedure kills the mites without the need for chemical treatment.

Diseases

White Rot, *Sclerotium cepivorum*

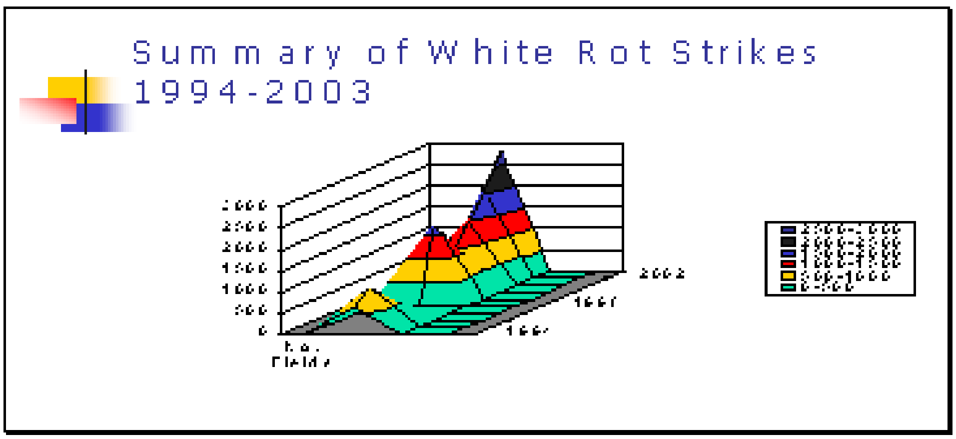
White rot is a fungal disease that, once established, permanently renders a field unusable for garlic production. There are currently no chemical or cultural controls available to garlic controls other than moving on to *S. cepivorum*-free fields. However, development of sclerotia germination stimulants 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 strong 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. 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 as disease symptoms continue to progress (Schwartz and Mohan, 1996) Normally, disease symptoms appear from mid-season to harvest (UC IPM).

Disease Management Issues

The white rot problem cannot be understated. 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 ones. The situation now is such that the supply of clean fields is rapidly diminishing in California (and other areas of the western U.S.). Essentially there is nowhere new to go. The CA Onion and Garlic Research Committee reports a total of 71 fields in the San Joaquin representing over 10,000 acres are infected with white rot. (CA Onion & Garlic Committee annual report 2003).



Commercial garlic is dependent on seed production efforts (5 acres of commercial garlic requires 1 acre of seed production). Fungal infestation often begins at the seed stage, being transported into fields by contaminated equipment or the seed itself. This, in fact, occurred in Central Oregon seed production fields during the 1990's. Failure to completely clean the boxes transporting the bulbs to be grown for seed is blamed for white rot infestation in dozens of newly-planted garlic fields. Coordinated certification programs have been in place for a number of years in an attempt to halt the further spread of the pathogen (Fred Crowe, personal communication, 2004). However, the continuous spread of this disease throughout the seed producing areas is forcing state ag departments to reevaluate the utility of certification programs.

Chemical Controls

No currently available materials will provide economic control of *Sclerotium cepivorum* in contaminated fields. However, a specific sclerotia-germinating stimulant is available for commercial garlic production. This stimulant is designed to be applied, under proper climatic conditions, at a time when no garlic (or other alliums) is in the ground. The stimulant causes early germination of 98-99% of the sclerotial population and, without the garlic root and bulb to infect, the germinated sclerotia die. While total eradication cannot be achieved, use in conjunction with a commercial fungicide may provide control adequate to produce a crop in a previously infected field.

This material is identical to one of the flavor/odor components of alliums. The cost is expected, at least initially, to be high. Moreover, the stimulant serves only as one component of an integrated strategy relying as well on newer fungicides that are not yet registered. Currently available fungicides such as iprodione (Rovral) are not sufficiently efficacious to play this role (Fred Crowe, personal communication, 2000).

The CA Onion and Garlic Research Committee have implemented a White Rot Master plan designed to help manage the potential spread of white rot in the western San Joaquin Valley. This program allows for inspection of all garlic seed fields, no planting in areas know to be infested with white rot, special precautions for harvesting and hauling garlic and/or onions from infected fields, reporting of all fields with white rot, treatment for known infestations and development of methods to reduce soil populations of white rot sclerotia.

Alternative Chemical Controls

Iprodione (Rovral) is registered for control of white rot on garlic. Research work conducted by M. Davis (UC Davis) and F. Crowe (Oregon State Univ.) indicate fair initial control, but lack of residual make treatments ineffective. Some research is currently underway to evaluate the use of Rovral through chemigation, in the spring when soil temperatures favor white rot development.

Propiconazole (Folicur) has shown promise a both a seed treatment and as an in-furrow treatment at planting. The combination product Switch (cyprodinil + fludioxonil) has also been evaluated and may have utility when used in a program that includes a biostimulant used as part of a treatment regime.

Natural sclerotial stimulants (e.g. dehydrated garlic powder) are also being tested for white rot control and may be released in the near future. The mode of action is the same as for the synthetically-derived stimulant described above. Garlic powder is currently listed as a 25(b) material under EPA guidelines, and is thus exempted from registration requirements.

Biological Controls

There are no biological controls currently in use for white rot.

Cultural Control Practices

The strategy for white rot disease prevention, both in seed and bulb (clove) production is basically limited to using only disease-free fields. Once infected, the fields are permanently unusable for garlic production as no measures currently exist for eliminating the sclerotia from the soil. Crop rotation is practiced every five years for bulb nematode control but has no efficacy against white rot. The sclerotia can persist indefinitely in the soil and new introductions occur from the other rotational crops. Growers now participate in certification programs to guarantee that their seed cloves are free of the disease.

Soil solarization and flooding have both have shown some promise in reducing white rot sclerotia populations in the field in preliminary research studies. The University of CA Cooperative Extension Service, Tulelake garlic growers and the CA Onion & Garlic Field Research Committee are conducting studies to further evaluate the effectives of flooding and soil solarization or a combination of both practices.

Purple Blotch, *Alternaria porri*

Stemphylium Leaf Blight, *Stemphylium vesicarium*

Purple blotch and Stemphylium leaf blight 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 (Schwartz and Mohan, 1996) (UC IPM Pest Management Guidelines- Onion and Garlic 2002).

Chemical Controls

Purple blotch and Stemphylium leaf blight are controlled by the same fungicides.

Chlorothalonil

Chlorothalonil was applied to 3,149 acres in 2000, 3,233 acres in 2001 and 651 acres in 2002. Variation in amount of product used in a given year is driven by winter/spring weather patterns. Statewide use averages ~ 10%.

Mancozeb & maneb

These older fungicides still provide utility in disease management. Average acres treated during the 2000-2002 use seasons are 1,400 acres or ~ 5%.

Pyraclostrobin and boscalid

Pyraclostrobin is a new strobiluron fungicide with activity on purple blotch and stemphylium. The active ingredient pryraclostrobin is sold as Cabrio while the combination product Pristine contains both pyraclostrobin and boscalid. Boscalid is a new anilide fungicide. The single product Cabrio and the pre-mix Pristine have given excellent control in experimental trials.

Alternative Chemical Controls

Azadirachtin (Neem Oil)

This material is approved for use on organic acreage. It is relatively expensive, but provides some fungicidal efficacy if good plant coverage is achieved.

Biological Controls

There are no effective biological controls for foliar diseases on garlic.

Cultural Control Practices

Garlic growers typically rotate out of allium to keep foliar diseases out of their fields. The most effective means of reducing foliar infection is to switch from sprinkler irrigation to furrow irrigation as soon as a vegetative canopy has formed. Thisreduces leaf wetness and in turn lessens the opportunity for foliar disease infections.

Penicillium Decay, *Penicilliium hirsutum*

Penicillium decay is a fungal disease that infects the seed cloves, resulting in poor stands after planting. *Penicillium hirsutum* 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. The result in the field is poor stand after planting (Schwartz and Mohan, 1996).

Cloves most susceptible to Penicillium decay are those that have been wounded, typically during the "cracking" process (*i.e.,* separation of bulbs into individual cloves) in preparation for planting.

Chemical Controls

Benomyl

P. hirsutum have shown resistance to benomyl (Schwartz and Mohan).

Statewide Coverage was less than 5%. However, benomyl applied as a clove dip is not included in the 1997 acreage data. Instead, usage is reported to the agricultural commissioners in weight (lb) of cloves treated. Benomyl use was voluntarily removed from the market in 2001.

Thiophanate methyl

As part of the EPA coordinated arrangement to coordinate the voluntary removal of benomyl from the market place, thiophanate methyl registrants were allowed to add the use as a clove dip to their respective labels. Since this use is a seed (clove) treatment, minimum amounts of pesticide use are reported. However, this use can be important and the continued registration of thiophanate methyl must be protected.

Alternative Chemical Controls

Iprodione (Rovral) *See also White Rot*

This product is labeled for white rot, but it is also effective against *Penicillium.* The application method for *Penicillium* control is to spray the cloves during mechanical planting. About 500 acres are treated with iprodione annually.

Biological Controls

No biological control measures are practiced for control of *P. hirsutum*.

Cultural Control Practices

Growers, processors and handlers try to minimize clove wounding during cracking to minimize entry points for *P. hirsutum.*

Garlic Rust, *Puccinia porri*

Although garlic rust, *Puccinia porri*, is not a new disease, 1998 was the first year in recent history that it caused serious damage to California garlic production. In many fields, yield reduction of over 50% was observed. The disease was unexpected and growers were unprepared to respond in time to prevent heavy losses. Effective, registered fungicides were also not available at that time.

P. porri is a fungus that 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. 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.

Chemical Controls

Azoxystrobin (Quadris)

Azoxystrobin was registered for use on garlic in 2002. Prior to this registration, growers had relied upon a Section 18 Emergency Exemption for tebuconazole (Folicur 3.6F. During the 2002 crop year, over 28, 000 acres were treated with azoxystrobin. This use represents a 93% treatment rate assuming a single treatment per acre. In actuality, multiple treatments were made to those acres experiencing garlic rust infection. Because this is a preventative fungicide with minimal curative activity, early detection and treatment were mandatory to achieve control.

Tebuconazole (Folicur 3.6 F)

Tebuconazole had been labeled for use on grapes only, until it was issued a California Section 18 Emergency Exemption in November 1998 in response to a widespread infection of *P. porri* in garlic fields. The Section 18 was renewed in 1999, 2000 and 2001. With the registration of azoxystrobin, the Section 18 was not renewed in 2002. In 2003, the need to have both a preventative as well as a curative fungicide for rust control was presented to CA DPR and USEPA and a Section 18 was again granted to tebuconazole. Although 2003 use data are not yet available, growers and processors effectively utilized Quadris with Folicur to minimize rust as well as lessening the potential for resistance to both products.

Alternative Chemical Controls

Pyraclostrobin and boscalid

Pyraclostrobin is a new strobiluron fungicide with activity on purple blotch and stemphylium. The active ingredient pryraclostrobin is sold as Cabrio while the combination product Pristine contains both pyraclostrobin and boscalid. Boscalid is a new anilide fungicide. The single product Cabrio and the pre-mix Pristine have given excellent control in experimental trials.

Biological Controls

No biological controls have been identified for garlic rust.

Cultural Control Practices

No resistant cultivars have been identified, although research is ongoing.

Minor Diseases

Basal Rot, *Fusarium culmorum*

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 presence of *F. culmorum* does not necessarily generate symptomatic basal rot, seen in the field as decayed stem plate and storage leaves. Application of thiophanate methyl for the more serious disease *Penicillium* also controls *F. culmorum*. (Schwartz and Mohan, 1996). The primary cultural control of basal rot is curing bulbs properly before storage and storing the garlic at cool temperatures.

Damping Off, *Pythium* spp

This fungus is common to agricultural soils. It can infect newly planted garlic seed and seedlings, causing stand loss or stunted growth of the plant (Schwartz and Mohan, 1996). Some growers apply a soil treatment of metalaxyl (Ridomil) or its replacement, mefenoxam (Ridomil Gold), prior to or during planting to protect their plants from *Pythium*. However, in 1997, only 926 ac were treated with metalaxyl, for Statewide Coverage of only 3%.

Nematodes

Stem and Bulb Nematode, *Ditylenchus dipsaci*

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, *D. dipsaci* will move upwards and invade young foliage. It will also migrate from plant to plant if there is high moisture content in the soil (Schwartz and Mohan, 1996).

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 poor plant stand at mid season. By harvest, the cloves are shrunken and decayed. Although stem and bulb nematode has the potential to devastate a garlic crop, garlic growers' primary control strategy is to plant clean seed into clean ground (*cf*. Cultural Control Practices, below). As a result, usage of nematicides is minimal.

Chemical Controls

Soil fumigation can be used to control nematodes in cases where rotation or other non-chemical practices are not feasible.

<u>Metam-Sodium</u> See also Weed Control

This product is applied as a pre-plant soil fumigant. It controls weeds and some soil diseases, as well as nematodes. It is expensive to use, and not widely applied. Growers may use metam-sodium as a spot treatment when know infected areas are identified.

<u>Fenamiphos</u> (Nemacur 15 G)

This organophosphate is rarely used, although it is labeled for stem and bulb nematode control in garlic fields Nemacur is applied in-furrow with garlic cloves at planting. No usage of Nemacur has been reported during the last three years of pesticide use reporting. The use of fenamiphos is being discontinued by the manufacturer.

Oxamyl (Vydate L)

Oxamyl can be applied in-furrow, as a band, or in sprinker or furrow irrigation. In-furrow and band applications must be followed by irrigation. Oxamyl is the only product registered for use on garlic after plant emergence. Because growers and processors are very aware of the need to plant only clean seed, the appearance of bulb and stem nematode is usually unexpected The continued registration of oxamyl provides the only practical way to treat for bulb and stem nematode when it appears. Over the past three years (2000-2003), ~ 500 acres per year were treated with oxamyl. This represents less than 2% of the planted acres.

Alternative Chemical Controls

1,3-Dichloropropene (Telone II)

This product was not applied to garlic in 2003, but it has been an effective nematicide on other crops for many years. Cost of material and application are prohibitive in most production areas.

Biological Controls

Myrotheciun verrucaria (Ditera ES)

In some field situations, this reduced-risk product can be an alternative nematicide to metam-sodium. Current data on this product, including optimal usage patterns, is lacking.

Cultural Control Practices

Garlic growers in California take preventative steps to guard against nematode infestation. These steps include 1) a certification program to ensure that garlic seed is grown in nematode-free environments, 2) a crop rotation program to keep their fields free of this pest, and 3) treatment of garlic seed with hot water immediately prior to planting when bulb and stem nematode is suspected.

Discussion and Summary

California is the largest producing state in the U.S. of garlic producing 90%+ of the commercial garlic in the U.S. In Fresno County California, garlic was the 2002, ninth leading crop in dollar value with total production valued at $131,004,000. The value of garlic for Fresno county was comparable to those for plums, oranges, cattle and calves and almonds. Garlic represents a significant rotational crop for west side San Joaquin farmers. Critical issues facing garlic production today are:

1. White Rot: With almost 11,000 acres of west side San Joaquin Valley prime farming land infected with white rot, controlling the spread of this disease through cultural, biological and chemical control measures is of paramount importance. Considerable chemical control work has been done by Mike Davis, (UC Davis) and Fred Crowe (Oregon State). Shannon Mueller (UC Cooperative Extension) is now developing data to show the utility of these practices under San Joaquin Valley conditions. We have favorable results with two chemical compounds as well as with the biostimulant (diallyldisulfide) DADS. However, FQPA (Food Quality Protection Act) obstacles have delayed registration efforts with tebuconazole (Folicur). Additionally, although the biostimulant DADS is now registered in CA, the primary registrant elected not to pursue commercial production of the product due to economic constraints. A new company has acquired the registration of DADS and we are hopeful that they can produce and sell the product at a profit for them while still maintaining a reasonable cost to processors and growers. Continued work to identify potential biological controls as well as development of a model to predict white rot infection periods is critical to the continued production of garlic in CA.
2. Garlic Rust: The garlic rust epidemic during the 1998 production season reduced yields by over one-half causing major economic losses to both processors and growers. Since that time, we have been able to manage the garlic rust organism through the use of azoxystrobin (Quadris) plus Section 18 Emergency use of tebuconazole (Folicur). Should we lose the use of Folicur, we could again have serious disease problems if the infection levels reach a point where the preventative material Abound, cannot control the disease. Continued research on garlic rust control materials and a predictive model is needed.
3. Preemergence Herbicides: DCPA (Dacthal) and pendemethalin (Prowl) are the only preemergence herbicides registered for use on garlic. Neither product affords the weed spectrum control or crop safety desired.
4. Bulb and Stem Nematode: With the loss of Nemacur (fenamiphos) for use on garlic, the only available product for control is Vydate (oxamyl). New research on bulb and stem nematode management is needed.
5. Onion Thrips: Pyrethroids have been the predominant pesticide used to control onion thrips. As noted in the insecticide section, resistance to pyrethroids has not been documented. However, decreased susceptibility to pyrethroids by thrips is becoming more prevalent. A resistance management strategy needs to be developed as well as evaluation of new materials with novel target sites, such as Actara (thiamethoxam) and Spintor (spinosid), must be evaluated.

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References

1. National Agricultural Statistics Service (NASS). 2003. *Vegetables 2002 Summary*. United States Department of Agriculture.
2. California Department of Food and Agriculture (CDFA). 2003. *2002 California Agricultural Resource Directory*.
3. California League of Food Processors (CLFP) *Approved Pesticide List for Garlic, September 1, 2003.*
4. American Dehydrated Onion and Garlic Association (ADOGA). 1997. *Garlic Production Information, 1997*.
5. California Onion and Garlic Field Research Committee, *2003 Annual Research Report.*
6. California Department of Pesticide Regulation (DPR). 1999-2002. *Pesticide Use Report*, *Annual*, *Indexed by Commodity*. California Environmental Protection Agency
7. Economic Research Service (ERS). 1996. *Garlic: An Economic Assessment of the Feasibility of Providing Multiple-Peril Crop Insurance*. Office of Risk Management United States Department of Agriculture. http://www.rma.usda.gov/pilots/feasible/txt/garlic.txt
8. Caryl Saunders Associates (CSA). Accessed 11/17/1999. *Garlic: Good Taste and Good Health!* Christopher Ranch. http://www.christopher-ranch.com
9. California Agricultural Statistics Service (CASS). 2003. *2002 Agricultural Commissioners' Data*. California Department of Food and Agriculture.
10. University of California (UC IPM). 2002 8. UCIPM Pest Management Guidelines." Pub. 3453, January 2002... Division of Agriculture and Natural Resources
11. Metcalf, L., and R. A. Metcalf. 1993. *Destructive and Useful Insects: Their habits and control*. 5th ed. McGraw, New York.

12. Maynard, Donald N. and George J. Hochmuth. 1997. *Knott's Handbook for Vegetable Growers.* 4th ed. John Wiley & Sons, Inc. New York.
13. Schwartz, Howard F., and S. Krishna Mohan. 1996. *Compendium of Onion and Garlic Diseases.* APS Press, St. Paul, Minnesota.
14. Voss, RE, Vegetable Crops Department, UC Davis & Bob Ehn, CA Onion and Garlic Field Research Committee, *The Allium Industry in California and the History and Importance of White Rot*, 2002.

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Appendix 1

2002 Pesticide Usage: Fifteen most applied garlic pest control materials, based on 2002 usage data. Listing is in order of total Aggregate Treated Acreage (*cf.* Fig. 3). *See Appendix 2 for full listing of application data..*

Common Name	Trade Name	Class Chemistry	Activity	Total lb ai
azoxystrobin	Abound	Strobilurin	Fungicide	5,512
bromoxynil	Buctril	Nitrile	Herbicide	5,068
chlorothalonil	Bravo	Chloronitrile	Fungicide	864
clethodim	Prism	Cyclohexanedione	Herbicide	138
copper hydroxide	Various	Inorganic	Fungicide	354
cypermethrin	Ammo	Pyrethroid	Insecticide	86
fluazifop-P-butyl	Fusilade	Aryloxyphenoxy propionate	Herbicide	421
glyphosate	Roundup	None	Herbicide	3,243
iprodione	Rovral	Dicarboximide	Fungicide	306
malathion	Malathion	Organophosphate	Insecticide	774

mancozeb	Mancozeb	Dithiocarbamate	Fungicide	1,584
oxyfluorfen	Goal	Diphenylether	Herbicide	4,356
pendimethalin	Prowl	Dinitroaniline	Herbicide	10,456
sethoxydim	Poast	Cyclohexanedione	Herbicide	304
sulfur	Various	Inorganic	Fungicide	4,403

Appendix 2

2002 Total Pesticide Usage on California Garlic

	Number of:			
Common Name (active ingredient)	Applications	lb ai applied	Acres Treated	Ave. Rate
azoxystrobin	233	5,512	28,179	0.20
bromoxynil octanoate/ heptanoate	136	5,068	14,328	0.35
chlorothalonil	8	864	652	1.47
chlorthal-dimethyl	1	126	18	7.00
clethodim	13	138	1,083	0.13
(s) –cypermethrin	26	170	3,485	0.05
cypermethrin	8	86	1,245	0.07
fluazifop-p-butyl	22	421	1,679	0.19
glyphosate	16	3,242	1,599	2.02
iprodione	1	306	153	2.0
lambda cyhalothrin	19	50	1,607	0.03
malathion	6	774	492	1.50
maneb	1	20	10	2.0
mancozeb	2	1,584	766	2.25
metalaxyl/ mefanoxam	2	0	1	0.09
metam-sodium	1	397	1	317.5
oxyfluorfen	167	4,356	20,561	0.26

pendimethalin	111	10,456	11,331	0.83
permethrin	3	76	305	0.20
sethoxydim	10	304	1,063	0.26
sulfur	2	4,403	114	22.80

Appendix 3

Herbicide Susceptibility Charts

Chart 2. Susceptibility of Annual Grasses and Perennials to Herbicides Registered in Garlic and Onions in California

C = Control; P = Partial control; blank = No control or info.

	Before Planting			Pre-emergence			Post-emergence							
Annual Grasses	Glyphosate (Roundup Ultra®, etc.)	Metham sodium (Vapam®, etc.)	Paraquat (Gramoxone Max®)	Bensulide (Prefar®)	DCPA (Dacthal®)	Pendimethalin (Prowl®, etc.)	Bromoxynil (Buctril®)	Clethodim (Prism®)	Fluazifop - p (Fusilade DX®)	Glyphosate (Roundup UltraMax®)¹	Nitrogen fertilizer (Various names)	Oxyfluorfen (Goal®)	Sethoxydim (Poast®)	Buctril® followed by Goal®
Annual bluegrass	C	C	P	C	C	C		C		C	P	P		P
Barnyardgrass	C	C	P	C	C	C		C	C	P	P	P	C	P
Bromegrass	C	C	P	C	C	C		P	P	C	P		P	
Canarygrass	C	C	P	C	C	C		C	C	C	P	P	C	P
Cereals	C	C	P	P	P	P		C	C	P	P	P	C	P
Crabgrass	C	C	P	C	C	C		C	C	C	P		C	
Fall panicum	C	C	P	C	C	C		C	C	C	P		C	
Fescues	C	C	P	C	C	C		P	P	C	P		P	
Foxtail	C	C	P	C	C	C		C	C	P	P		C	
Goosegrass	C	C	P	C	C	C		C	C	P	P		C	
Junglerice	C	C	P	C	C	C		C	C	P	P	P	C	P
Lovegrass	C	C	P	C	C	C		C	C	C	P	P	C	P
Rabbitfootgrass	C	C	P	C	C	C		C	C	C	P		C	
Ripgut brome	C	C	P	C	C	C		P	P	C	P		P	
Ryegrass	C	C	P	C	C	C		C	C	C	P		C	
Sandbur	C	C	P	C	C	C		C	C	P	P		C	
Sprangletop	C	C	P	C	C	C		C	C	P	P		C	
Wild barley	C	C	P	C	C	C		C	C	P	P	P	C	P
Wild oats	C	C	P	P	P	P		C	C	P	P	P	C	P
Witchgrass	C	C	P	C	C	C		C	C	P	P		C	
Annual Grasses														
Bermudagrass - S	C	C	P	C	C	C		C	C	P	P		C	
Bermudagrass - E	C*	P						C*	C*	P			C*	
Dallisgrass - S	C	C		C	C	C		C	C	P	P		C	
Dallisgrass - E	C*	P						C*	C*	P			C*	

Annual Grasses														
Bermudagrass - S	C	C	P	C	C	C		C	C	P	P		C	
Bermudagrass - E	C*	P						C*	C*	P			C*	
Dallisgrass - S	C	C		C	C	C		C	C	P	P		C	
Dallisgrass - E	C*	P						C*	C*	P			C*	
Johnsongrass - S	C	C	C	C	C	C		C	C	P	P		C	
Johnsongrass - E	C*	P						C*	C*	P			C*	
Field bindweed - S	C	P	P			P	P			P	P			P
Field bindweed - E	P	P								P	P			
Nutsedge, purple	C	P	P							P	P			
Nutsedge, yellow	C	P	P							P	P			

S = seedling plant and E = established plant *May require multiple applications for control

[1]Registered for pre-harvest treatment in processing garlic under dry soil conditions

This chart is not a recommendation for the use of herbicides. Please refer to the label for specific uses and rates of application. Proper weed identification, timing, and accurate application is imperative for effective control. The information in this chart is tentative. Additional information may warrant changes. Kurt J. Hembree, Farm Advisor, Fresno County December 2002.

Table 1. Performance of Pre- and Post-emergence Herbicides in Garlic and Onions in California

Timing	Herbicide	Conditions resulting in effective weed control and crop safety
Before Planting	**Glyphosate** (Roundup Ultra®, etc.)	Used at 1 - 2 lb ai/acre. Planting occurs >3 days after treatment. Weeds are vigorous and <4" tall. Application made under minimal winds to prevent drift.
	Metham sodium (Vapam®, etc.)	Used at 50 - 75 gal/acre. Planting is 14 - 21 days after treatment. Beds are well prepared, ready for planting, of good tilth, free of large clods, at 50 - 75% field capacity, and between 50 - 90 F. A surface seal is made to prevent escape of the fumigant. Treated soil is not disturbed after planting.
	Paraquat (Gramoxone Max®)	Used at 0.625 - 0.9 lb ai/acre. Use a COC or NIS. Treatment is made >3 days before emergence. Weeds are <4" tall with thorough coverage. Application made under minimal winds to prevent drift. Treatment under warm, sunny days. It is a Restricted Use Pesticide, requiring a permit to purchase and use.
Pre-emergence	**Bensulide** (Prefar®)	Used at 4 lb ai/acre. Applied following planting before crop emergence. Incorporated with sprinkler irrigation to wet the soil to 2 - 4" deep within 36 hours of treatment. Not recommended for garlic.
	DCPA (Dacthal®)	Used at 4.5 - 10.5 lb ai/acre. Applied following planting before crop emergence. Incorporated within 3 days with 2" sprinkler irrigation. Effective under low to moderate levels of mustard species.
	Pendimethalin (Prowl®, etc.)	Used at 0.6 - 1.2 lb ai/acre. Applied after planting garlic, before emergence. Incorporated in <7 days with 1/2" sprinkler irrigation. Applied in onions with 2 - 6 true leaves before weed emergence. Applied in garlic with 1 - 5 true leaves before weed emergence. Mixed with Goal® in garlic under an SLN.
Post-emergence	**Bromoxynil** (Buctril®)	Used at 0.25 - 0.375 lb ai/acre. Used in oinios with 2 - 5 true leaves or in garlic <12" tall. Applied in a voulme of 60 gpa by ground or through sprinklers in onions. Applied under sunny, warm conditions.
	Clethodim (Prism®)	Used at 0.09 - 0.28 lb ai/acre. Use a COC or NIS. Grasses are actively growing, before tillering, and not moisture-stressed. It does not effectively control bromes or fescues. Annual bluegrass has <4 leaves. Repeat treatments made on perennials. Used in 30 gpa with good coverage.
	Fluazifop-p (Fusilade DX®)	Used at 0.094 - 0.28 lb ai/acre. Use a COC or NIS. Grasses are actively growing, before tillering, and not stressed for moisture. It is not effective on annual bluegrass, bromes, or fescues. Repeat treatments needed on perennials. Applied in 30 gpa with thorough coverage.
	Glyphosate (Roundup UltraMax®)	Used at 1 - 2 lb ai/acre. ***Used only in processing garlic under an SLN***. Applied following irrigation cutt-off, after plant tops have ***completely*** dried down. Applied in 5 or more gpa. Will control or suppress field bindweed, nutsedge, and nightshade.

		bromes, or fescues. Repeat treatments needed on perennials. Applied in 30 gpa with thorough coverage.
	Glyphosate (Roundup UltraMax®)	Used at 1 - 2 lb ai/acre. ***Used only in processing garlic under an SLN***. Applied following irrigation cutt-off, after plant tops have ***completely*** dried down. Applied in 5 or more gpa. Will control or suppress field bindweed, nutsedge, and nightshade. There is a 30 day PHI.
	Nitrogen fertilizers (N-Phuric, AN-20, etc.)	Used at 20 gpa (N-Phuric) and 40 gpa (AN-20 and others). Total spray volume is at least 60 gpa with thorough coverage. Onions have at least 1 true leaf and weeds are <2" tall. Does not effectivelly control grasses or weeds with waxy or hairy leaf surfaces.
	Oxyfluorfen (Goal®)	Used at 0.125 - 0.25 lb ai/acre. Onions have 2 - 5 true leaves and garlic is <12" tall. Used before final irrigation for nightshade control in garlic. Applied in sprinklers in onions to saften crop response.
	Sethoxydim (Poast®)	Used at 0.09 - 0.28 lb ai/acre. Use a COC. Grasses are emerged, actively growing, before tillering, and not stressed. It is not effective on annual bluegrass, bromes, or fescues. Repeat treatments needed on perennials. Applied in 30 gpa with thorough coverage.
	Buctril® followed by Goal®	Applied as a sequential treatment in onions. Applied through sprinklers when onions have at least 2 true leaves.

COC = crop oil concentrate and NIS = non-ionic surfactant

Numerous factors influence the performance of herbicides. The observations and comments in this table assume accurate and timely application and proper weed identification. Consult Chart 1 and 2 or the proper label(s) for the effectiveness of the registered herbicides to control specific weeds. This table is not a recommendation for the use of herbicides. Please refer to the proper label for recommendations. Kurt J. Hembree.

Chart 1. Susceptibility of Annual Broadleaf Weeds to Herbicides Registered in Garlic and Onions in California

C = Control; P = Partial control; blank = No control or info.

	Before Planting			Pre-emergence			Post-emergence							
A. Broadleaves	**Glyphosate** (Roundup Ultra®, etc.)	**Metham sodium** (Vapam®, etc.)	**Paraquat** (Gramoxone Max®)	**Bensulide** (Prefar®)	**DCPA** (Dacthal®)	**Pendimethalin** (Prowl®, etc.)	**Bromoxynil** (Buctril®)	**Clethodim** (Prism®)	**Fluazifop - p** (Fusilade DX®)	**Glyphosate** (Roundup UltraMax®)[1]	**Nitrogen fertilizer** (Various names)	**Oxyfluorfen** (Goal®)	**Sethoxydim** (Poast®)	**Buctril® followed by Goal®**
A. morningglory	P	P	C			P	C			P	P	C		C
Cheeseweed	P	P	C		P	P	P			P	P	C		C
Chickweed	C	C	P	P	C	C				C	C			
Clovers	P	P	P							P	P	P		P
Cocklebur	C	C	C				P			C	P	C		C
Cudweed	C	C					C			C	P			C
Dodder	C		C		C	P				C	P			
Fiddleneck	C	C	C		C	C	C			C	C	C		C
Filaree	P	C	C		P					P	C	C		C
Goosefoot	C	C	C	P	C	C	C			P	C	C		C
Groundcherry	C	C	C		C		C			P	C	C		C
Groundsel	C	C	C				C			C	C	C		C
Henbit	C	C	P		P	C	P			C	C	C		C
Knotweed	P	C	C	C	P	C	P			P	P	P		C
Lambsquarters	C	C	C	P	C	C	C			P	C	C		C
London rocket	C	C	C		P	P	C			C	C	C		C

Groundsel	C	C	C				C			C	C	C		C
Henbit	C	C	P		P	C	P			C	C	C		C
Knotweed	P	C	C	C	P	C	P			P	P	P		C
Lambsquarters	C	C	C	P	C	C	C			P	C	C		C
London rocket	C	C	C		P	P	C			C	C	C		C
Mustard	C	C	C		P	P	C			C	C	C		C
Nettle		C	C		P		C				C	C		C
Nightshade, black	C	C	C		P		P			P	C	C		C
Nightshade, hairy	C	C	C		P		C			P	C	C		C
Pigweed	C	C	C	C	C	C	C			P	C	C		C
Pineappleweed	C	C	C				C			C	P	C		C
Prickly lettuce	C	C	C				C			P	P	C		C
Puncturevine	C	C	C		P	P	C			P	C	C		C
Purslane	C	P	C	C	C	C				C		C		C
Red maids	C	C	C	P	C	C				C	C	C		C
Russian thistle	C	P	P			P	C			P	P	P		C
Shepherdspurse	C	C	C		P	P	C			C	C	P		C
Sowthistle	C	C	C		P		C			C	P	C		C
Spurge	C	C	C		P	P	C			C	C			C
Sunflower	C	C	C		P		C			P	P	C		C
Velvetleaf	C	P	C				P			P	P	P		P
Wild radish	C	C	C				C			C	C	C		C

[1]Registered for pre-harvest treatment in processing garlic under dry soil conditions

This chart is not a recommendation for the use of herbicides. Please refer to the label for specific uses and rates of application. Proper weed identification, timing, and accurate application is imperative for effective control. The information in this chart is tentative. Additional information may warrant changes. Kurt J. Hembree, Farm Advisor, Fresno County. December 2002.