ONION/GARLIC

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PEST MANAGEMENT GUIDELINES FOR AGRICULTURE

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To be used with UC ANR Publication 3339PS3,
Color Photo Guide to Onion/Garlic Pests

The combined publications are available as
UC ANR Publication 3339PS3A,
UC IPM Pest Management Guidelines: Onion/Garlic with color photo supplement

An illustrated version of this guideline is available online at ipm.ucanr.edu/agriculture/onion-and-garlic/

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Updates: These guidelines are updated regularly. Check with your University of California Cooperative Extension Office or the UC IPM website for information on updates.

Note to readers: These guidelines represent the best information currently available to the authors and are intended to help you make the best choices for an IPM program. Not all formulations or registered pesticides are mentioned. Always read the label and check with local authorities for the most up-to-date information regarding registration and restrictions on pesticide use. Check with your agricultural commissioner for latest restricted entry intervals.

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General Information

RELATIVE TOXICITIES OF INSECTICIDES AND MITICIDES USED IN ONION AND GARLIC TO NATURAL ENEMIES AND HONEY BEES (6/23)

Common name (Example trade name)	Mode of action[1]	Selectivity[2] (affected groups)	Predatory mites[3]	General predators[4]	Parasites[4]	Honey bees[5]	Duration of impact to natural enemies[6]
abamectin (Agri-Mek)	6	moderate (leafminers, mites, thrips)	M	L	M/H	I	moderate to predatory mites and affected insects
azadirachtin (AzaGuard)	un	broad (insects, mites)	M	L/M	L/M	II	short
Beauveria bassiana (Mycotrol)	—	broad (insects)	L	L/M	L	II	—
clothianidin/imidacloprid (Sepresto 75 WS)	4A	broad (insects)	—	L/M	L/M	I	—
cyromazine (Trigard)	17	narrow (leafminers)	L	L	L	II	none
methomyl (Lannate)	1A	broad (insects, mites)	H	H	H	I	moderate
spinetoram (Radiant SC)	5	narrow (aphids, caterpillars, leafminers, scales, thrips, whiteflies)	M	M[8]	L/M	II	moderate[7]
spinosad (Entrust, Success)	5	narrow (leafminers, thrips)	M	M[8]	L/M	II	short to moderate
spinosad (Lumiverd)	5	—	—	—	—	—	—
spinosad/thiamethoxam (FarMore)	5/4A	broad (insects)	—	—	—	—	—
spirotetramat (Movento)	23	narrow (aphids, psyllids, scales, whiteflies)	L	L	L	II	short

H = high M = moderate L = low — = no information un = unknown or uncertain mode of action

1 Rotate insecticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers are assigned by IRAC (Insecticide Resistance Action Committee).

2 Selectivity: *Broad* means it affects most groups of insects and mites; *narrow* means it affects only a few specific groups.

3 Generally, toxicities are to western predatory mite, *Galendromus occidentalis.*

4 Toxicities are averages of reported effects and should be used only as a general guide. Actual toxicity of a specific insecticide depends on factors including the application rate, environmental conditions, and life stage and species of the parasite or predator.

5 Ratings are as follows: I–Do not apply or allow to drift to plants that are flowering; II–Do not apply or allow to drift to plants that are flowering, except when the application is made between sunset and midnight if allowed by the pesticide label and regulations; III–No bee precaution, except when required by the pesticide label or regulations. For more information about pesticide synergistic effects, see *Bee Precaution Pesticide Ratings*.

6 Duration: *Short* means hours to days; *moderate* means days to 2 weeks; and *long* means many weeks or months.

7 Residual is moderate if solution is between pH of 7 to 8.

8 Toxic against some natural enemies (predatory beetles, lacewing larvae, syrphid fly larvae, and predatory thrips) when sprayed and up to 5 to 7 days after, especially for syrphid fly larvae.

Acknowledgments: This table was compiled based on research data and experience of University of California scientists who work on a variety of crops and contribute to the Pest Management Guideline database, and from Flint, M.L. and S.H. Dreistadt. 1998. *Natural Enemies Handbook: An Illustrated Guide to Biological Pest Control*, ANR Publication 3386.

GENERAL PROPERTIES OF FUNGICIDES (2/19)

Common name (Example trade name)	Chemical class	Activity	Mode of action (FRAC[1])	Resistance potential
ametoctradin/ dimethomorph (Zampro)	QoSI[5]/carboxilic acid amides	locally systemic	single-site (45)/ single-site (40)	medium
azoxystrobin (Quadris)	QoI[2]	contact, systemic	single-site (11)	high
azoxystrobin/ difenoconazole (Quadris Top)	QoI[2]/DMI[3]	contact, systemic	single-site (11)/single-site (3)	medium
boscalid (Endura)	SDHI[4]	locally systemic	single-site (7)	medium to high
boscalid/pyraclostrobin (Pristine)	SDHI[4]/QoI[2]	contact, locally systemic	single-site (7)/single-site (11)	medium to high
chlorothalonil (Bravo, Echo)	aromatic chloronitriles	contact	multi-site (M5)	low
copper compounds (Basic Copper 53)	inorganic	contact	multi-site (M1)	low
difenoconazole/ cyprodinil (Inspire Super)	DMI[3]/anilino-pyrimidine	systemic/locally systemic	single-site (3)/single-site (9)	medium
dimethomorph (Forum)	carboxilic acid amides	locally systemic	single-site (40)	low to medium
fenamidone (Reason)	QoI[2]	contact, locally systemic	single-site (11)	high
fluazinam (Omega)	2,6-dinitro-alanines	contact, locally systemic	single-site (29)	low
fludioxonil (Cannonball)	phenylpyrroles	contact	single-site (12)	low to medium
fluopyram/tebuconazole (Luna Experience)	SDHI[4]/DMI[3]	locally systemic/systemic	single-site (7)/ single-site (3)	medium
iprodione (Rovral)	dicarboxamide	contact, locally systemic	single-site (2)	medium to high
mancozeb (Dithane)	dithiocarbamate (EBDC)	contact	multi-site (M3)	low
mancozeb/mefenoxam (Ridomil Gold MZ WG)	dithiocarbamate (EBDC)/ phenylamide	contact/systemic	multi-site (M3)/single-site (4)	medium to high
mefenoxam/ chlorothalonil (Ridomil Gold Bravo SC)	phenylamide/ aromatic nitrile	systemic/contact	single-site (4)/multi-site (M11)	medium to high
oxathiapiprolin/ mandipropamid (Orondis Ultra)	OSBPI[6]/ carboxylic acid amides	systemic/locally systemic	single-site (49)/single-site (40)	medium
penthiopyrad (Fontelis)	SDHI[4]	contact, locally systemic	single-site (7)	high
pyraclostrobin (Cabrio)	QoI[2]	contact, locally systemic	single-site (11)	high
pyraclostrobin/ fluxapyroxad (Merivon Xemium)	QoI[2]/SDHI[4]	locally systemic	single-site (11)/ single-site (7)	medium to high
pyrimethanil/fluopyram (Luna Tranquility)	anilino-pyrimidine/ SDHI[4]	locally systemic	single-site (9)/ single-site (7)	medium to high
tebuconazole (Orius)	DMI[3]-triazole	systemic	single-site (3)	high

[1] Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 7, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other group numbers, make no more than two consecutive applications before rotating to a fungicide with a different mode-of-action group number.

[2] QoI = quinone outside inhibitor (strobilurin).

[3] DMI = demethylation (sterol) inhibitor.

[4] SDHI = succinate dehydrogenase inhibitors.

[5] QoSI = quinone outside inhibitor, stigmatellin binding type.

[6] OSBPI = oxysterol binding protein inhibition.

Insects and Mites

BULB MITES (10/18)

Scientific Names: Acarid bulb mites: *Rhizoglyphus* spp., *Tyrophagus* spp.
Dry bulb mite: *Aceria tulipae*
Wheat curl mite: *Aceria tosichella*

DESCRIPTION OF THE PESTS

There are two groups of bulb mites that can infest onion and garlic:

1. Mites in the family Acaridae, which are round and look like tiny pearls.
2. Mites in the family Eriophyidae, called dry bulb mite and wheat curl mite. These mites are elongate and banana-shaped or wormlike.

Both groups of mites can infest onion and garlic both in the field and in storage. They can survive on decaying vegetation in the field until it is completely decomposed. These pests are not currently a problem in the low desert region.

Acarid Mites

Bulb mites in the family Acaridae are shiny, creamy-white, and bulb-shaped. They are between 0.02 to 0.04 inches (0.5–1 mm) long and have brown legs. These mites generally occur in clusters and inhabit damaged areas under the root plate of onion bulbs or garlic cloves.

Females lay eggs singly or in clusters of up to 100 eggs on damaged or decaying tissue on the bulb surface. Larvae have three pairs of legs, while nymphs and adults have four pairs of legs. All stages feed on the crop.

These mites have a wide host range, and feed on germinating seeds, bulbs, roots, and tubers of various plant species.

Eriophyid Mites: Dry Bulb Mite and Wheat Curl Mite

The dry bulb mite and wheat curl mite are smaller and more elongate than the other bulb mites, which are globular. These mites are microscopic, white, wormlike organisms of about 0.01 inch (0.25 mm). They have four legs that are located near the head.

In addition to onion and garlic, the dry bulb mite also feeds on liliaceous bulbs such as tulips. The wheat curl mite primarily feeds on cereal grains and wild grasses but occasionally feeds on onion and garlic as well.

DAMAGE

Bulb mites can stunt plant growth and reduce the onion or garlic stand. These mites also promote the rot of bulbs in storage by penetrating the outer layer of bulb tissue and allowing rot-causing pathogens to gain entry.

Acarid Mites

Bulb mites in this group are most damaging in cool, wet weather, when plant growth is slow. In direct-seeded onion, they can cut off the radicle before the plant becomes established, reducing the stand and creating gaps in the seed lines where weeds may grow.

Dry Bulb Mite and Wheat Curl Mite

Feeding by the dry bulb mite and wheat curl mite also causes stored onions and garlic to desiccate. Feeding injury during storage produces sunken brown spots and streaks on garlic cloves. Heavy field infestations in the field may also cause streaking and twisting of garlic leaves and reduce both the plant stand and yield. Damage from these mites on stored bulbs is rare in California, and the dry bulb mite more commonly infests onion and garlic than the wheat curl mite.

MANAGEMENT

Cultural Control

Culturally manage these mites with the following methods:

- Use only clean seed cloves when planting garlic.
- Avoid planting successive onion or garlic crops and rotate with crops that are less susceptible to bulb mite damage.
- Avoid planting onion or garlic immediately after *Brassica* species, corn, grain, sudangrass, or grass cover crops.
- Consider treating garlic seed cloves with hot water (130ºF for 10–20 minutes) before planting. **Note**: although this practice may reduce mite infestations, it can also decrease germination.
- Flood irrigation or heavy rains during the winter may also reduce mite numbers in the soil.
- The normal drying process before storage can destroy light to moderate infestations.
- In other states, soaking seeds in 2% soap (not detergent) and 2% mineral oil for 24 hours before planting has successfully reduced mite infestations; however, this method has not been evaluated in California.

Acarid Mites

In addition to the cultural methods listed above, allow complete decomposition of organic material by leaving fields unplanted (fallow) between the harvest of the previous crop and the start of the next crop. Rapid rotation from one crop to the next fosters survival of mites on the leftover vegetation in the soil from the previous crop. Decaying cole crops, especially cauliflower, may harbor very high numbers of Acarid mites.

Monitoring and Treatment Decisions

No specific monitoring methods or action thresholds are available. Use a microscope to examine fragments of undecayed vegetation in the soil or volunteer onions or garlic for the presence of the mites. For dry bulb mite and wheat curl mite, examine the surface of garlic seed cloves under a microscope to determine if these mites are present. See Identifying Pests of Onion and Garlic and Their Damage for mite photos and identification tips.

Pesticide applications for Acarid mites are generally preventive and should be considered for fields that are high in vegetative matter or that have had previous bulb mite problems. However, allowing complete decomposition of organic matter in the soil before planting is the key to managing these pests.

Pesticide applications are generally not necessary for dry bulb mite and wheat curl mite because damage from these mites rarely occurs in California.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

PREPLANT

A. METAM SODIUM*§

(Vapam HL)	37.5–75 gal	See label	NA

COMMENTS: Fumigants such as metam sodium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest.

In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

* Permit required from county agricultural commissioner for purchase or use.

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Materials Use Requirements, which may be lower than maximum label rates.

NA Not applicable

LEAFMINERS (10/18)

Scientific Name: *Liriomyza* spp.

DESCRIPTION OF THE PESTS

Adults are small black-and-yellow flies. Females puncture the leaf in a linear fashion to feed on plant sap and lay eggs within the leaf tissue. Both male and female leafminer flies feed on the sap from these punctures. The stippling of the puncture wounds becomes more visible over time as the damaged tissue dries and turns to white scar tissue. Eggs hatch within 2 to 4 days, and the small (less than 2.5 mm), white-to-yellow larvae tunnel within the leaf tissue. Larger larvae may feed inside the hollow leaves of onions or garlic, but still produce the characteristic "mines" visible from the outside of the leaf. Larvae exit the leaf upon completion of their development, and either pupate in the soil or in the leaf axils. Many generations occur each year, and the specific number of generations per year varies between growing regions. Leafminers may also overwinter as pupae in the soil and emerge the following spring.

DAMAGE

Damage caused by leafminers is primarily cosmetic; however, contamination by pupae and larvae is a marketing problem for green bunching onions. Damage in dry onions and garlic is rarely a concern unless leafminers become so numerous that they prematurely kill foliage.

Leafminers attack a wide variety of crops, including vegetables such as lettuce, celery, and spinach. The potential for damage to onion and garlic will be higher when other hosts are grown nearby.

MANAGEMENT

Biological Control

Natural enemies, especially parasitic wasps, can reduce leafminer numbers. However, these wasps are very susceptible to insecticide sprays, so they may not be reliable or effective in fields where insecticides have been used.

Cultural Control

To culturally control leafminers:

- Thoroughly work fields previously planted with susceptible crops before planting onion.
- Allow at least two weeks for leafminer flies to emerge from pupae in the soil before planting onion in a field that previously had a leafminer problem.

Organically Acceptable Methods

Biological control by naturally occurring predators and parasites is often effective in controlling this pest in organically grown onion and garlic crops. However, supplemental releases of commercially available natural enemies are rarely economically viable. Cultural controls as described above are critical. Azadirachtin products and the Entrust formulation of spinosad can also be used.

Monitoring and Treatment Decisions

There is no established threshold for leafminers in onions. Because large numbers of adults do not always lead to large larval infestations, make your management decisions based on the number of larvae on the crop and the type of onion crop.

See Identifying Pests of Onion and Garlic and Their Damage for leafminers photos and identification tips.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

A.	CYROMAZINE			
	(Trigard)	2.66 oz	12	7
	MODE-OF-ACTION GROUP NUMBER[1]: 17			
	COMMENTS: Do not make more than six applications per crop.			
B.	SPINOSAD			
	(Success)	3–6 fl oz	4	1
	(Entrust)#	1–2 oz	4	1
	MODE-OF-ACTION GROUP NUMBER[1]: 5			
C.	AZADIRACHTIN#			
	(AzaGuard)	10–16 fl oz	4	0
	MODE-OF-ACTION GROUP NUMBER[1]: un			
	COMMENTS: A restricted-use pesticide in an organically certified crop.			

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

* Permit required from county agricultural commissioner for purchase or use.

\# Acceptable for use on organically grown produce.

[1] Rotate insecticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers (un = unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee).

MAGGOTS (2/24)

Scientific Names: Seedcorn maggot: *Delia platura*
Onion maggot: *Delia antiqua*

DESCRIPTION OF THE PESTS

Adults of *Delia* species are small gray flies. When at rest, they keep their wings folded one over the other. Onion maggot flies are similar in size to house flies. Seedcorn maggot flies, however, are significantly smaller, ranging from between 1/2 to 2/3 the size of onion maggot flies.

Larvae (maggots) are creamy-white, legless maggots that are about 0.4 inch (10 mm) long. Microscopic examination is required to distinguish between species.

Female flies lay white, elongated eggs on or near the soil surface near the base of the onion plant. Maggots prefer cool, moist soils heavy in organic matter, where they can survive and move to seeds. Seedcorn maggots more commonly move to seeds than do onion maggots. Mature larvae pupate in the soil.

Maggots have several generations per year. Seedcorn maggots occur throughout California garlic and onion production areas, while onion maggots are more restricted to cooler coastal climates and the intermountain region. Maggots are generally not a problem to onion production in the low desert region.

DAMAGE

Larvae feed on the epicotyl (developing shoot) and young roots of the developing seedling. Seedcorn maggots feed on the seed and may damage onion plants as late as the 3- to 4-leaf stages.

The first generation of onion maggots primarily feeds on seedlings, up to the 3- to 5-leaf stages. The second and third generation of onion maggots will feed on the expanding bulb of the maturing plant, which can increase bulb rot during storage.

Maggots are serious pests of onions in California, but do not generally cause economic damage to garlic. Without proper planning and insecticide controls, these pests cause onion growers to lose more than 50% of their yields.

See Identifying Pests of Onion and Garlic and Their Damage for photos of maggots and their damage, as well as identification tips.

MANAGEMENT

Prevention is the key to avoiding damage from onion and seedcorn maggot, and insecticides should be applied when maggot infestations are expected.

Cultural Control

Delaying planting is an important cultural practice to reduce damage from maggots, though this may be less feasible in cooler climates with shorter growing seasons. The amount of time to delay planting differs for onion maggot and seedcorn maggot.

For onion maggot, wait to plant until later in the spring, after the first generation of adult flies has emerged. This will avoid the first generation of egg-laying by adult flies that overwintered in the soil during the previous year. Choose when to plant by calculating the accumulation of degree-days of average daily air temperature:

- Estimate the date when 50% of overwintering adult flies have emerged based on the accumulation of 792 to 812 degree-days, with a developmental threshold of 39.2°F.
- Plant after the estimated date.

For onion maggot, take the following cultural measures in addition to delayed planting:

- Remove and dispose of onion culls and volunteer onions.

- Avoid planting successive onion crops without rotating to other crops.
- Avoid planting onions near fields where onions were recently grown, or fields that are located near onion cull piles.
    - These fields most likely harbor overwintering onion maggot pupae.
    - If possible, plant onions no less than ¾ of a mile near fields that were previously planted to onion.

For seedcorn maggot, use degree-day accumulation to determine amount of time to delay planting after tilling or soil cultivation:

- Assume that adult seedcorn maggot flies will begin laying eggs in the field immediately after the soil is disturbed.
- Estimate the date of the first adult emergence by tracking the accumulation of 421 to 459 degree-days Fahrenheit (with a developmental threshold of 39.0°F) after tillage.

In the intermountain region, delaying planting 13 to 21 days after cultivation, tillage, or bed-shaping can reduce seedcorn maggot infestations. Soil conditions after tillage attract seedcorn maggot flies to lay eggs. Waiting at least 13 days will allow the first generation of seedcorn maggot to pupate and minimize their damage to onions. However, waiting as long as 21 days further reduces developmental time for onion bulbs, which may significantly reduce yields.

For seedcorn maggot, take the following measures in addition to delaying planting after disturbing the soil:

- Avoid planting onions after a rotation of legume crops, especially alfalfa. Adult seedcorn maggot flies are especially attracted to these decaying residues.
- Plant seeds at a shallow depth (but no less than ½ inch below the soil surface).
- Thoroughly incorporate organic matter such as manure, crop residue, weeds, and cover crops into the soil well in advance of planting (3–4 weeks prior).
    - In soils amended with animal manures, wait for the manure to break down completely before planting.

Cultural methods for both onion maggot and seedcorn maggot include the following:

- Use a press wheel, chain drag or similar implement behind the drill to cover the seed row when planting.
- Plant in conditions that favor rapid onion emergence, such as when the soil is warmer. This will allow onions to quickly grow to a stage that is harder for maggots to damage.
- Avoid fields that have high amounts of undecomposed organic matter, such as fields just coming out of pasture, alfalfa, or recently tilled or cultivated weeds.
- For direct-seeded crops, use a higher seeding rate.
- Consider no-till seeding.

Monitoring and Treatment Decisions

Monitor adult activity by placing yellow sticky traps around the field edges just above the growing onion foliage. Use degree-day models mentioned above in the Cultural Control section to determine when to plant.

Pesticides are ineffective or impossible to apply to maggots attacking a standing crop. The combination of cultural methods and insecticide-treated seed is critical to avoiding intolerable yield loss. Consider planting insecticide-treated seed, especially for fields that are likely to be infested with maggots (see the Cultural Control section) or fields that have previously had problems from maggots.

Common name (Example trade name)	Amount to use	REI‡ (hours)	PHI‡ (days)

UPDATED 6/23

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

Seed Treatment

A. SPINOSAD

(Lumiverd)# 5.29–6.89 lb a.i./100 lb seed 4 NA

MODE-OF-ACTION GROUP NUMBER[1]: 5

COMMENTS: Not registered for use in garlic. Contact your seed retailer for information and availability.

B. SPINOSAD/THIAMETHOXAM

(FarMore FI500) — — —

MODE-OF-ACTION GROUP NUMBER[1]: 5/4A

COMMENTS: **FarMore FI500 is not registered for use in California**, but seeds treated in and obtained from other states can be legally used in California, even for a chemical not registered for use on onion and garlic in California. In addition to spinosad and thiamethoxam, FarMore FI500 contains the fungicides azoxystrobin, fludioxonil, and mefenoxam. Contact your seed retailer for information and availability.

C. CLOTHIANIDIN/IMIDACLOPRID

(Sepresto 75 WS)	Bulb onion: 0.0074–0.011 oz/1,000 seed	NA	NA
	Bunching onion: 0.0056–0.0065 oz/1,000 seed	NA	NA
	Leek: 0.0126 oz/1,000 seed	NA	NA

MODE-OF-ACTION GROUP NUMBER[1]: 4A/4A

COMMENTS: Not registered for use in garlic. Avoid planting when pollinators are nearby; pesticide may become airborne.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

Acceptable for use in organically grown produce.

1 Rotate insecticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers (un = unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee).

NA Not applicable

THRIPS (10/18)

Scientific Names: Onion thrips: *Thrips tabaci*
Western flower thrips: *Frankliniella occidentalis*

DESCRIPTION OF THE PESTS

Thrips are very small, slender insects that can be easily seen with a hand lens. Mature onion thrips are about 0.05 inch (1.3 mm) while western flower thrips are slightly larger at 0.06 inch (1.5 mm). The most distinctive characteristic of thrips is two pairs of wings that are fringed with long hairs. Adults are pale yellow to light brown. The immature stages have the same body shape as the adult stage, but unlike adults, they are wingless and lighter in color.

When viewed under a microscope, western flower thrips can be distinguished from onion thrips by the hairs on the front of the thorax (the body segment after the head), as well as their 8-segmented antennae. In contrast, onion thrips lack these hairs, and their antennae are 7-segmented. These structures are best seen through a compound microscope at 400x.

Thrips are the most common insect pest of onion, causing widespread damage. They are found wherever onions are grown in California. Thrips are present every year, but infestations vary widely depending on weather conditions. Both onion thrips and western flower thrips have a wide host range that includes cereal crops, broadleaved crops, and many weed species. Both onion thrips and western flower thrips attack onion, but onion thrips are believed to be more prevalent and injurious than western flower thrips. Many areas have both onion thrips and western flower thrips, and their numbers can vary over the season.

Thrips thrive in hot and dry conditions and are usually more damaging in areas where these climatic conditions prevail for most of the production season. They may also transmit *iris yellow spot virus*, which is only vectored by onion thrips.

DAMAGE

High numbers of thrips can reduce both yield and storage quality of onions. Onion thrips also can be an occasional problem on garlic but are generally not as serious a pest as they are on onion.

Thrips are most damaging when they feed during the early bulbing stage of onion development. They feed under the leaf folds and in the protected inner leaves near the bulb but may also be found feeding on exposed leaf surfaces when their numbers are high. Their feeding may lead to leaf scarring, which is most serious on green onions. Severe scarring can reduce the effective photosynthetic area and creates an entry point for foliar diseases.

Both adults and nymphs cause damage. When foliage is severely damaged, the entire field takes on a silvery appearance.

MANAGEMENT

Biological Control

Natural enemies, including predaceous mites, minute pirate bugs, and lacewings, are often found feeding on thrips. However, natural enemies are susceptible to broad-spectrum insecticide sprays such as pyrethroids, and may not be reliable or effective in fields where broad-spectrum insecticides have been used.

Cultural Control

Avoid planting onions near grain or alfalfa fields if possible, because thrips often increase in those fields in the spring and migrate to onion fields when the grain senesces, or when the alfalfa is cut. Overhead irrigation and rainfall suppress thrips numbers, but pesticide applications are often still necessary.

Organically Acceptable Methods
Use biological and cultural controls in an organically certified crop. Sprays of the Entrust formulation of spinosad, azadirachtin, and entomopathogenic fungi such as *Beauveria bassiana* are also acceptable for use on organically certified crops.

Monitoring and Treatment Decisions
Thrips are most damaging to yields during the early bulbing stage. However, management should start before onions reach the bulbing stage, so that they do not reach levels that are difficult or impossible to control. Onions can tolerate higher numbers of thrips closer to harvest. However, in the case of hand-topped onions, applying pesticide closer to harvest may also be desirable because thrips can be a nuisance to harvest crews.

Evaluate thrips numbers in a field by randomly sampling entire onion plants (see Identifying Pests of Onion and Garlic and Their Damage for thrips photos and identification tips):

- Sample at least five plants from four separate areas of the field.
- Pull the leaves apart.
- Use a hand lens to count all the thrips on the inner leaves near the bulb as well as those under the leaf folds.
- Use a hand-held click counter for more efficient counting. Thrips are highly mobile and may disperse or hide before they can be counted.]
- Use the thrips monitoring form to record your results.

If you wish to make a cursory evaluation of thrips infestation, randomly sample leaves to evaluate thrips numbers and damage under leaf folds. Keep in mind that sampling only the leaves often fails to detect thrips hidden between leaves near the bulb.

An economic threshold has not yet been developed for thrips, but an action threshold of 30 thrips per plant mid-season (lower for very young plants and higher for larger, mature plants) has been used for making successful pesticide application decisions for dry bulb, fresh market, and drying onions. Other thresholds that use thrips per leaf (rather than thrips per plant) are used in New York and other states, in which all thrips are counted on a plant and then divided by the number of leaves. This method accounts for the size of the onion plant; however, the reliability of the method has not yet been evaluated in California.

Because the marketability of green onions (those marketed fresh with the leaves attached) is severely reduced by thrips scarring, apply insecticide at the first sign of thrips feeding. On onions grown for seed, thrips can reduce yield and quality of seed production during seed set, but no treatment thresholds have been established.

While resistance to organophosphate and pyrethroid insecticides has not been evaluated in California, it has been documented in other states and is suspected in California. For this reason, alternate insecticides with different modes of action when multiple pesticide applications are needed per season. A common practice for minimizing the risk of resistance development in thrips populations is to apply insecticides with the same mode of action for a maximum of two consecutive applications, and use an insecticide with a different mode of action to control the next generation of thrips if a third application is necessary. A total of three applications is often enough. Thorough coverage is essential for control, as most thrips feed in protected areas of the plant.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

A. SPIROTETRAMAT

(Movento)	5 fl oz	24	Garlic, bulb onion, bulb shallot: 3 Green onion, leek and shallot leaf: 7

MODE-OF-ACTION GROUP NUMBER[1]: 23
COMMENTS: For seed production, do not apply 4 months before the bloom, during bloom or before petal fall is complete. Two applications back-to back 7 to 10 days apart often greatly improves control.

B. SPINETORAM

(Radiant SC)	6–10 fl oz	4	1

MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Control may be improved with the addition of a spray adjuvant. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging. May be applied through sprinkler irrigation (see supplemental label), but level of pest control may be lower as a result.

C. SPINOSAD

(Entrust)#	1.25–2.5 oz	4	1
(Success)	4–8 fl oz	4	1

MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Provides suppression. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging. Do not rotate with spinetoram, as these insecticides have the same mode of action. Some thrips populations have developed resistance.

D. ABAMECTIN

(Agri-Mek SC)	1.75–3.5 fl oz	12	Garlic, bulb onion, bulb shallot: 30 Leek, green onion, shallot leaf: 7

MODE-OF-ACTION GROUP NUMBER[1]: 6
COMMENTS: Consider applying when thrips have reached 30 per plant; do not use as rescue treatment. Thorough coverage of crop canopy is essential for best results. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

E. AZADIRACHTIN

(AzaGuard)#	10–16 fl oz	4	0

MODE-OF-ACTION GROUP NUMBER[1]: un
COMMENTS: A restricted-use pesticide in an organically certified crop.

F. BEAUVERIA BASSIANA STRAIN GHA#

(Mycotrol ESO)#	0.25–1 qt	4	0

MODE-OF-ACTION GROUP NUMBER[1]: entomopathogenic fungi
COMMENTS: Multiple applications may be necessary for effective control. Efficacy for thrips control in onion and garlic in California is not known; however, this product has effectively reduced thrips in California strawberries.

G. METHOMYL*

(Lannate SP)	1 lb	48	7

(Lannate LV)	3 pt	48	7

MODE-OF-ACTION GROUP NUMBER[1]: 1A

COMMENTS: Registered for thrips control in green and dry bulb onion only. Add a wetting agent to improve coverage. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging. Best when used for resistance management purposes and when both caterpillars and thrips are causing damage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

* Permit required from county agricultural commissioner for purchase or use.

\# Acceptable for use on organically grown produce.

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Diseases

BACTERIAL BULB ROTS (2/24)

Burkholderia (=*Pseudomonas*) *cepacia*
Burkholderia gladioli pv. *allicola*
Dickeya (=*Erwinia) chrysanthemi*
Enterobacter cloacae
Pantoea agglomerans (formerly *Erwinia herbicola* or *Enterobacter agglomerans*)
Pectobacterium (=*Erwinia*) *carotovorum* ssp. *carotovorum*

SYMPTOMS AND SIGNS

Multiple bacterial pathogens can cause bulb rot in onion and garlic. It is impossible to determine which pathogen is causing the disease based only on visible symptoms. Bulb rot symptoms can develop any time between bulbing and harvest or even during storage. Common bulb rot symptoms include:

- softening and water-soaking of the bulb tissue
- yellow to brown discoloration
- progression of symptoms from the neck to the base of the bulb
- a neck that becomes soft when pressed.

Most of the bacterial bulb diseases also cause foliar symptoms. These symptoms distinctly differ from the natural senescence of the oldest leaves on healthy onions that occurs once plants reach mid-bulbing.

Most commonly, the earliest symptoms of bacterial infection appear as water-soaked lesions on one or more of the younger leaves. The subtle water-soaking develops to a more visible necrotic bleaching of the foliage, and affected leaves may wilt and die back. As lesions progress, they can extend down into the base of the leaves, and then potentially into the neck and the bulb. In the bulb, the bacteria can cause a yellow to brown discoloration of the onion scales or garlic bulb. The bacteria can rot only the center, only the outer scales, or only certain scales. Infected scales can be firm or completely rotten and broken down or mushy.

In garlic, narrow, water-soaked lesions form on older leaves while young leaves appear healthy. Leaf tips later die and turn white, and plants may be stunted.

Symptoms of various bacterial bulb rots can be confused with Fusarium basal rot; the difference is that with bacterial bulb rot diseases, the rot progresses from the neck down, while with Fusarium, the rot progresses from the basal plate up. Botrytis neck and bulb rot also rots from the top down, but produces mycelia and sclerotia when conditions are right.

COMMENTS ON THE DISEASE

Bacterial bulb rots are primarily a problem on onions. Water is essential for entry and spread of the bacteria. When bacteria enter through the neck, they cause internal rot; when bacteria enter the bulb through wounds and dying lower leaves, they cause external rot. The bacterial pathogens are soilborne and may spread through irrigation water or splashing water from rain or irrigation. Most of these pathogens are favored by warm temperatures (over 85°F) and wet conditions.

Overhead irrigation (especially late in the season), excessive nitrogen fertilization, and the poor or slow curing of the necks also favor the development of this disease.

MANAGEMENT

Cultural control is critical for preventing bacterial bulb rots. In field trials, chemical control has not been found to be effective in California.

Cultural Control

Use the following cultural methods to manage bacterial bulb rots:

- To reduce the amount of these bacteria in the soil, rotate out of onions or garlic for 2 or more years, and minimize volunteer onions and garlic, and weeds.
- Use drip or furrow irrigation instead of sprinkler irrigation, if feasible. If sprinklers are used, consider switching from sprinkler irrigation to furrow or drip irrigation once onions start to bulb (when the bulb is about twice the diameter of the neck). Sprinklers increase the movement of bacteria from the soil to the leaves, sometimes by splashing the crop with the soil and its pathogens, and increase the moisture in the neck area, which seems to be critical to development of bulb rot.
- When feasible, use water from cleaner sources (e.g., well water instead of surface water or reused water).
- Choose varieties with tight necks because they tend to be less susceptible to several bacterial bulb rots.
- Apply nitrogen fertilizer only as necessary; avoid excess nitrogen application, especially after bulb initiation.
- Harvest only after onion tops are well matured (meaning that more than 90% of the tops have lodged) and minimize injury to maturing or harvested bulbs.
- Store bulbs at 32 to 36ºF (or 32–34ºF if *Burkholderia* is detected) with good ventilation to prevent condensation from forming on the bulbs.
- Avoid wounding bulbs during cultivation or hand hoeing of weeds, and try to minimize bulb damage during harvest and handling as wounds can provide entry sites for bacterial rot pathogens.

BLACK MOLD (2/19)

Pathogen: *Aspergillus niger*

SYMPTOMS AND SIGNS

The fungus is first detected as an area covered with a black sooty mass (made up of microscopic spores) on the neck or outer scales, where injury, disease, or toppling of the foliage has caused an opening in the skin. Fungal spores may develop between dry, dead outer scales and the first inner fleshy scales of the bulb. Invaded scales initially become water-soaked, and spores often appear in a streaking pattern along veins. Occasionally, interior parts of the bulb may be affected with gray-to-black discoloration without showing external symptoms. Under dry conditions, diseased scales dry and shrivel, and black masses of spores are visible between outer scales. Affected parts may also be invaded by soft rot bacteria, causing the whole bulb to deteriorate into a watery soft rot.

COMMENTS ON THE DISEASE

Black mold is primarily a postharvest condition. It occurs on both onions and garlic, but is more of a concern in onion crops. Black mold occurs most commonly where onions or garlic are grown under warm conditions, such as the desert areas of California. Moisture must be present on the bulb for 6 to 12 hours for the disease to develop. This can occur if bulbs are damp when stored, or when they are going into and coming out of storage if condensation accumulates on the bulbs between the outer dry scales.

The fungus survives on decaying organic matter such as plant debris, and is a weak pathogen that generally does not affect uninjured bulbs. The fungus is widely distributed among soil environments.

MANAGEMENT

While some fungicide control programs used for foliar diseases may reduce the incidence of black mold (with the exception of many fungicides applied to control the pathogen that causes downy mildew), there are no fungicides for the direct control of black mold. Culturally manage black mold by doing the following:

- Store and transport bulbs at temperatures below 59°F and at low humidity to slow growth of the fungus.
- Reduce bruising and injury during harvest, handling, and transport to minimize the opening of invasion sites for the fungus.
- Harvest onions promptly and do not delay drying. Do not use heated air for drying.
- Maintain stable temperatures during transport, as well as when bulbs are going into and coming out of storage.
    - Wide temperature fluctuations can cause condensation on the bulbs and between the outer dry scales, which promotes the development of black mold.

BLUE MOLD (2/19)

Pathogens: *Penicillium* spp.

SYMPTOMS AND SIGNS

Initial symptoms include water-soaked or pale-yellow areas on the outer surface of scales. Later, a green to blue-green, powdery mold may develop on the surface of the lesions. Infected areas of fleshy scales are tan or gray when cut. In advanced stages, infected bulbs may disintegrate into a watery rot, often because of secondary infection by bacteria or yeasts.

COMMENTS ON THE DISEASE

Many species of *Penicillium* can cause blue mold. These fungi are common on plant debris and senescent plant tissue. The pathogens usually invade onion bulbs and garlic through wounds, bruises, or uncured neck tissue. Once inside the bulb, the mycelium grows through the fleshy scales, eventually sporulating profusely on the surface of lesions and wounds. For onions, secondary infections by other pathogens after an initial blue mold infection are more serious than blue mold alone.

Blue mold generally appears during harvest and storage. Germination of fungal spores is optimal at 70° to 77°F. High relative humidity favors the growth of the fungus.

MANAGEMENT

To reduce the risk of blue mold, promptly cure the bulbs so the necks are dry. Additionally, use the following other cultural practices:

- Minimize bruising or wounding bulbs during harvest and handling, as well as from insect damage.
- Store bulbs at a maximum temperature of 41°F and at low relative humidity.

BOTRYTIS LEAF BLIGHT (2/19)

Pathogen: *Botrytis squamosa*

SYMPTOMS AND SIGNS

Botrytis leaf blight, sometimes also referred to as Botrytis leaf spot, occurs on onions. White, sunken spots on leaves are usually the first sign of infection. Spots are small, oval-shaped, and range from 0.06 to 0.25 inch (0.5–6 mm) long. They sometimes have a light-green halo and may appear water-soaked. The epidermis around the spots may be silvery. When numerous spots are present, leaf tips die back and whole leaves may eventually die. In severely affected fields, plants appear blighted, with many dead and dried out leaves. When leaves are killed prematurely, bulb size is reduced, resulting in yield losses.

COMMENTS ON THE DISEASE

Botrytis squamosa spores are airborne, and land on leaf surfaces. In the presence of moisture, the spores germinate and produce enzymes that kill leaf tissue. The fungus damages the leaf by causing leaf spotting.

Leaf surfaces must be wet from dew or rain for long periods (20 or more hours) for leaf spots to develop. Optimal temperature for spore germination is 59°F, and optimal temperature for mycelial growth is in the mid-70s (°F). The fungus forms survival structures (sclerotia) on infected tissue, which can persist in soil for months to years.

Poor air circulation in the onion canopy also favors the disease. This may occur when onions are planted too closely together, or next to trees or other structures that block air movement.

MANAGEMENT

Cultural Control

Culturally manage *Botrytis* leaf blight with the following methods:

- Isolate seed fields from fresh-market or processing onion fields, since bulbs are a major source of airborne *Botrytis* spores.
- To reduce the amount of sclerotia in the soil, rotate away from *Allium* crops for three years.
    - Destroy volunteer and cull onions during this period.
- Plant with single row spacing at least 12 inches apart to speed up leaf drying and reduce severity of the disease.
- Time sprinkler irrigation to prevent extended leaf wetness and maximize leaf drying between irrigation events.

Chemical Control

Monitor fields and apply a fungicide at the first evidence of leaf spotting, when plants have at least five true leaves. Since *Botrytis*-specific fungicides are highly prone to resistance development, it is especially important to rotate fungicides with different modes of action. Fungicide efficacy can also be improved with the application of an adjuvant. The waxy surface of onion leaves helps to prevent crop injury from the adjuvant.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

A. BOSCALID/
PYRACLOSTROBIN

(Pristine)	14.5–18.5 oz	12	7

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate-dehydrogenase inhibitor (7)/quinone outside inhibitor (11)
COMMENTS: To limit the development of resistance, do not make more than two applications of Group 7 and Group 11 fungicides without alternating to a fungicide with a different mode of action.

B. FLUAZINAM

(Omega 500F)	1.0 pt	Hand weeding: 24 Other activities: 12	7

MODE-OF-ACTION GROUP NAME (NUMBER[1]): 2,6-dinitro anilines (29)
COMMENTS: Not registered for use on green onions.

C. PYRACLOSTROBIN/FLUXAPYROXAD

(Merivon Xemium)	8–11 fl oz	12	7

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11)/succinate-dehydrogenase inhibitor (7)
COMMENTS: To limit the potential for resistance development, do not make more than 3 applications per season or apply more than 33 fl oz product per acre per season. Do not make more than two applications of Group 7 and Group 11 fungicides without alternating to a fungicide with a different mode of action.

D. CHLOROTHALONIL

(Bravo Weather Stik, Echo 720)	Label rates	12	See label

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M5)

E. PENTHIOPYRAD

(Fontelis)	16–24 fl oz	12	3

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate-dehydrogenase inhibitors (7)

[1] Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 7, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other group numbers, make no more than two consecutive applications before rotating to fungicide with a different group number.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment until the harvest may take place. In some cases, the REI exceeds the PHI. The longer of these two intervals is the minimum time that must elapse before harvest.

BOTRYTIS NECK AND BULB ROT (2/19)

Pathogens: *Botrytis allii*, *Botrytis aclada*, and *Botrytis porri*

SYMPTOMS AND SIGNS

Botrytis neck and bulb rot is a disease of both onion and garlic, as well as leek and shallot.

In onions, Botrytis bulb rot generally appears during storage, although infection originates in the field. Initial symptoms usually begin at the neck, where affected tissue softens, becomes water-soaked, and turns brown. In a humid atmosphere, a gray and feltlike growth (where spores are produced) appears on rotting scales, and mycelia may develop between scales. Dark-brown-to-black sclerotia (the resting bodies of the pathogen) may eventually develop in the neck or between scales.

In garlic, symptoms appear either in the field towards the end of the season, or during storage. Plants infected in the field may be stunted, with dead and dying outer leaves. Affected tissue is initially water-soaked, but later turns dry and necrotic. Sclerotia form in the neck or adhere to the rotten outer scales of the bulb.

In both onion and garlic, initial infections may not be noticeable, and symptoms may develop only when leaves senesce and become necrotic.

COMMENTS ON THE DISEASE

Botrytis allii and *Botrytis aclada* cause this disease in onion, whereas *B. porri* causes it in garlic. These fungi persist on dead onion and garlic tissue and persist as sclerotia in the soil for long periods. The sclerotia germinate in moist weather and produce airborne conidia (spores), which land on tissue, germinate, and infect when conditions are favorable.

The greatest incidence of infection occurs in persistent cool (50° to 75°F) and moist weather. Infections are favored by excessive use of nitrogen fertilizer, applications of nitrogen after bulb initiation, and poor drying of the tops and curing of the necks.

The fungi are associated with garlic and onions wherever they are grown and are common colonizers of senescent tissue. Infection can also occur through wound sites on the bulb.

MANAGEMENT

Cultural control (especially methods that reduce crop injury) is the primary way to avoid damage from Botrytis neck and bulb rot. Healthy onions that are stored properly and harvested at the right time are seldom affected. To prevent infection:

- Harvest onions and garlic only when the crop is mature and necks are well cured.
- Minimize damage to bulbs from insects and diseases during the growing season.
- Avoid excessive or late applications of nitrogen fertilizer.
- Avoid late-season irrigation to allow the foliage and neck to dry before harvest. The neck tissue must be well cured before the crop is stored.
- Handle the crop to minimize bruising or wounding.
- Store bulbs at temperatures of 41°F or below.
- Minimize relative humidity and promote good air circulation during storage.
- Maintain stable temperatures when moving bulbs into and out of storage, as well as shipping to markets. Wide fluctuations in temperature can cause condensation on the bulbs, which favors the development of the disease.

Chemical Control

Seed and bulb treatment with fungicides prior to planting can reduce incidence of Botrytis neck rot. However, late in-season fungicide applications during the last month of harvest are the most effective at preventing infection of the necks, since late-season infection poses the greatest risk for bulb rot in storage. Chemical control may not be effective once the symptoms develop, and cultural control is the most reliable way to avoid infection.

Since *Botrytis*-specific fungicides are highly prone to resistance development, it is especially important to rotate fungicides with different modes of action.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

A. FLUXAPYROXAD/PYRACLOSTROBIN
(Merivon Xemium) 8–11 fl oz 12 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate-dehydrogenase inhibitors (7)/quinone outside inhibitors (11)
COMMENTS: To limit the development of resistance, do not make more than three applications per season, do not apply more than 33 fl oz per acre per year, and do not make more than two sequential applications before rotating to a fungicide with a different mode-of-action group number.

B. IPRODIONE
(Rovral Brand 4 Flowable) 1.5 pt 24 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Dicarboximide (2)
COMMENTS: Registered for control of Botrytis neck and bulb rot in dry bulb onion only. Apply as a foliar spray as soon as conditions become favorable for disease development.

C. CHLOROTHALONIL
(Bravo Weather Stik, Echo 720) Label rates 12 See label
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M5)
COMMENTS: See label for information on suppression of bulb neck rot during storage. Chlorothalonil is a contact-only fungicide; therefore coverage is critical for control of Botrytis neck and bulb rot.

[1] Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 7, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other group numbers, make no more than two consecutive applications before rotating to fungicide with a different group number.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment until the harvest may take place. In some cases, the REI exceeds the PHI. The longer of these two intervals is the minimum time that must elapse before harvest.

DOWNY MILDEW (2/19)

Pathogen: *Peronospora destructor*

SYMPTOMS AND SIGNS

At the field level, symptoms of downy mildew are first noticed as circular clumps of yellowed plants that are a few to many feet in diameter. As the disease progresses, the yellowing patterns often enlarge in the direction of prevailing winds.

On individual plants, leaf tissue becomes pale green, then tan to brown or yellow, and finally collapses. Lesions may exhibit a violet-to-purple color. When leaves are wet, or when humidity is very high, signs of *Peronospora destructor* are visible on the surface of older leaves as fine, furry, grayish-white growths. These growths may later turn purple or brown as a result of a secondary infection of the lesion by other fungi, such as those that cause PURPLE BLOTCH AND STEMPYLIUM LEAF BLIGHT, as these fungi can produce purple pigmentation and dark spores.

In addition to leaves, the downy mildew pathogen can infect seed stalks and flower parts and can infect bulbs systemically. After storage, systemically infected bulbs may become soft and watery. Symptoms of this disease are typically observed in the winter in California.

COMMENTS ON THE DISEASE

Peronospora destructor only infects species in the genus *Allium*, including garlic, onion, shallot, chives, and leek. The pathogen only grows and produces spores in live hosts but may survive in plant debris or soil. Initial sources of the pathogen can include infected bulbs, sets, seeds, and plant debris.

Downy mildew has complex environmental requirements, needing both cool temperatures and high humidity. Based on studies in Canada and Europe, spore production occurs at or above a relative humidity of 95% in the canopy. Spore production declines at temperatures above 75°F and may be suppressed completely if temperatures are sustained above 82°F for more than four hours, or above 84°F for more than two hours. Nightly rainfall can also suppress spore production.

Spores are airborne. After landing on healthy plants, they require leaf wetness for infection to occur. The length of leaf wetness required is directly proportional to air temperature. The research mentioned above assumes that for air temperatures of 43° to 61°F, only 2 to 3 hours of leaf wetness is necessary for infection, whereas infection requires 5 hours of leaf wetness at 61° to 68°F. The accuracy of these models for describing downy mildew in California, where it typically occurs during the winter, is unknown.

The time between infection and sporulation can range from 8 to 16 days, but spores produced during a given night can infect new plants the following morning, and up to 3 days later. Therefore, downy mildew can develop into a damaging epidemic very quickly under favorable conditions.

MANAGEMENT

Cultural Control

To reduce the incidence and severity of downy mildew:

- Minimize canopy leaf wetness:
    - Avoid sprinkler irrigation, especially when the canopy begins to fill.
    - If avoiding sprinkler irrigation is not feasible, adjust the irrigation schedule to maximize leaf drying and prevent extended leaf wetness between irrigation events.
    - Plant in fields where there is good air movement.
    - Select fields that are well drained.
    - Align rows with the prevailing winds.
    - Change planting date to avoid having a full canopy during conditions favorable for downy mildew.
- Use a 3-year rotation away from *Allium* crops in fields where the disease has occurred.
- Use disease-free bulbs, sets, and seed.

- Remove and destroy material of any *Allium* plants, including residue from the previous crop, volunteer plants, and culls from storage.
- Avoid entering fields when leaves are wet.
- Avoid injuring the crop with herbicides and other materials.

There are also currently a few red onion cultivars (for example, Calred) that are resistant to downy mildew, but this resistance is active only in the flower stalks and not the leaves.

Chemical Control
Spray at the first sign of the disease. After the first spray, scout fields and make subsequent applications when weather conditions are favorable for the disease. Rotate with fungicides from different mode-of-action groups to reduce the risk of fungicide resistance development. Fungicides may be applied on a 7-day schedule (only as consistent with the label), if necessary. For all fungicides, thorough coverage of foliage is important in the control of downy mildew.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

A. AMETOCTRADIN/ DIMETHOMORPH
(Zampro) 14 fl oz 12 0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone-outside inhibitor, stigmatellin binding type (45)/ carboxylic acid amide (40)
COMMENTS: For resistance management, no more than three applications per year or two sequential applications.

B. OXATHIAPIPROLIN/MANDIPROPAMID
(Orondis Ultra) 5.5–8.0 fl oz 4 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Oxysterol binding protein analogue inhibition (49)/carboxylic acid amide (40)
COMMENTS: See label for resistance management.

C. FENAMIDONE
(Reason 500 SC) 5.5 fl oz 12 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11)
COMMENTS: Do not make more than one application before alternating with a fungicide that has a different mode-of-action group number.

D. MEFENOXAM/MANCOZEB
(Ridomil Gold MZ WG) 2.5 lb 48 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Phenylamide (4) and multi-site contact (M3)
COMMENTS: Registered for use on garlic, bulb onions, and shallots (dry bulb). Do not apply to exposed bulb.

E. MEFENOXAM/CHLOROTHALONIL
(Ridomil Gold Bravo SC) 2.5 pt 48 Bulb onion, garlic: 7
Green onion, leek, shallot: 14
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Phenylamide (4) and multi-site contact (M5)
COMMENTS: Registered for use on garlic, bulb onions, leeks, green onions, and shallots (dry bulb).

F. DIMETHOMORPH
(Forum) 6 fl oz 12 0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Carboxylic acid amides (40)
COMMENTS: If spraying on the day of harvest, wait until spray dries to harvest the crop.

G. MANCOZEB
(Dithane F-45 Rainshield) 2.4 qt 24 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M3)
COMMENTS: Registered for use on dry bulb onion, garlic, and shallot. Do not apply to exposed bulb.

H. FLUAZINAM
(Omega 500F) 1 pt Hand weeding: 24 7
Other activities: 12
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Uncouplers of oxidative phosphorylation (29)
COMMENTS: Registered for use on bulb onion, garlic, and bulb shallot.

I. CHLOROTHALONIL
(Bravo Weatherstik, Echo 720) Label rates 12 See label
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M5)
COMMENTS: For suppression. See label regarding special instructions related to the 12-hour REI.

J. COPPER SULFATE
(Basic Copper 53)# 1.9 lb 48 0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M1)
COMMENTS: Not as effective as other pesticides, but some products are acceptable for use in an organically certified crop. Can cause phytotoxicity to leaves. Basic Copper 53 is allowed with restrictions in organically certified crop. OMRI certification expires December 31, 2019; after this date, check organic status before applying in organic onion or garlic production.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases the REI exceeds the PHI. The longer of two intervals is the minimum time that must elapse before harvest.

Acceptable for use on organically grown produce.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 7, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

FUSARIUM BASAL ROT (2/24)

Pathogens: *Fusarium oxysporum*, including *F. oxysporum* f. sp. *cepae*, *Fusarium proliferatum*

SYMPTOMS AND SIGNS

Fusarium basal rot (also known as FBR) is a fungal disease affecting onion and garlic, as well as other *Allium* crops such as leek. In field situations, Fusarium basal rot can cause damping-off of young plants, as well as foliar chlorosis, stunting, death of mature plants, and bulb rot. In garlic and onion, rot typically initiates in the basal plate (base of the bulb), then spreads into the bulb. In some cases, rot can start on the side of the bulb, potentially via wounds, or on the neck, necrotizing the bulb from the top down. When cut vertically, an infected bulb will show brown discoloration of the stem plate tissue. Later, the stem plate tissue becomes pitted and shows a dry rot. The stem plate and dry outer scales crack open under dry conditions. Bulb mites and maggots are commonly observed in rotten bulbs.

Bulb rot prevents water and nutrients from reaching the foliage, resulting in yellowing of the foliage and leaf dieback from the tips at early or intermediate stages of crop development. Affected roots can become dark brown to dark pink, and a white fungal growth is sometimes evident at the base of infected bulbs.

When bulbs are held under storage, Fusarium basal rot can cause rot of fresh market bulbs, mother bulbs used for seed production, and seed cloves.

Fusarium basal rot can be mistaken for white rot; white rot, however, can be distinguished by the spherical, black bodies (sclerotia) produced by the white rot fungus.

Bulbs rotted by Fusarium basal rot can also become secondarily colonized by bacteria, leading to a misdiagnosis of bacterial rot. To distinguish rots caused by Fusarium from those caused by bacterial pathogens, send samples of the plant at early stages of rot development to a diagnostic laboratory.

COMMENTS ON THE DISEASE

Fusarium basal rot is a disease complex caused primarily by the fungi *Fusarium oxysporum* and *F. proliferatum.* Although other Fusarium species have also been documented as pathogens in California and other regions, they are rare.

Post-harvest losses often have the largest economic impact in both onion and garlic production.

Infection can occur through wounds or in the vicinity of old root scars at the base of the bulb.

This disease progresses most rapidly in warmer soil temperatures, ranging from 77° to 82°F, but can occur when soil temperatures range from 59° to 90°F.

Co-occurrence of stem and bulb nematode *(Ditylenchus dipsaci)* and Fusarium basal rot may result in greater yield reductions and rot incidence.

Onion-Specific Comments

Fusarium oxysporum f. sp. *cepae* (also known as FOC) is the primary pathogen of onions. Although *Fusarium proliferatum* has also been documented causing onion bulb rot, it is thus far uncommon as a bulb rot pathogen in California.

Onion seed itself is not thought to become infected, but the mother bulbs used in seed production can harbor Fusarium basal rot, resulting in high levels of rot in seed-crop fields.

Garlic-Specific Comments

Fusarium proliferatum is the most virulent and common *Fusarium* pathogen of garlic in California.

Fusarium oxysporum is also common and can cause severe symptoms in some cases. While *F. oxysporum* f. sp. *cepae* has been documented to cause garlic disease, most *F. oxysporum* garlic pathogens in California are not *F. oxysporum* f. sp. *cepae;* work is ongoing to identify these strains in order to develop effective crop rotations and diagnostic tools.

Both pathogens have been documented to colonize garlic asymptomatically starting within 2 months of planting.

MANAGEMENT

Because the fungus can survive indefinitely in soil, preventing its introduction into new fields is one of the most effective strategies for management.

In cases where it is critical to prevent field contamination, such as in the production of foundation seed and mother bulbs, sanitize field equipment before entering the field to prevent introducing pathogens. Effective sanitation includes both physically removing soil and debris with air or by pressure-washing, together with the use of a sanitizer. Sanitizers with low corrosivity that are effective against Fusarium species include quaternary ammonium compounds.

To avoid favorable conditions for infection, store bulbs at temperatures below 39°F and at low relative humidity.

Onion-Specific Management

Long-day onions have partial resistance to *F. oxysporum* f. sp. *cepae*, although resistance gene efficacy is reduced under warm temperatures. There are no short-day cultivars resistant to *F. oxysporum* f. sp. *cepae*.

In seed production, have mother bulbs tested for the presence of Fusarium basal rot before planting. Avoid planting mother bulb lots with high rot levels.

Garlic-Specific Management

There are no established methods to eradicate Fusarium pathogens from garlic seed cloves. Managing seed clove infection is critical for mitigating Fusarium basal rot losses in both fresh market and processing garlic production since seedborne infections can be a significant driver of pathogen spread and primary infection into other fields. Even asymptomatic seed can be infected.

Use garlic seed that was tested for Fusarium basal rot pathogens. Avoid planting seed fields or production fields with seed lots that are heavily rotten, as Fusarium pathogens are likely present.

Clean garlic seed is produced in standardized clean-seed programs that test for Fusarium basal rot pathogens in foundation garlic and that are grown in pathogen-free fields.

GARLIC MOSAIC (2/19)

Pathogen: several viruses in the potyvirus group

SYMPTOMS AND SIGNS

Symptoms of garlic mosaic include:

- Small, angular, light-green-to-yellow discolored regions of tissue arranged in a mosaic pattern among darker tissue
- Irregularly shaped, light-green blotches among normally colored tissues
- Striping and streaking of leaves.

Symptoms are usually more pronounced in young leaves. Infected plants are stunted, and bulb size is reduced.

COMMENTS ON THE DISEASE

Because garlic is vegetatively propagated, several viruses are commonly present in all garlic. The label "garlic mosaic" has been applied to a number of different viruses in different countries and this has caused some confusion. However, there is a trend toward referring to garlic mosaic as a disease caused by one or more viruses belonging to the potyvirus group (*garlic yellow stripe virus*, *leek yellow stripe virus*, and several others). In addition to being spread by vegetative reproduction, these potyviruses can also be transmitted by various aphids.

MANAGEMENT

Purchase virus-free stocks produced from meristem tip culture and multiplied in areas free of commercial garlic to prevent reinfection by insects (aphids) that carry the viruses. Use of such stock can result in substantially higher yield.

IRIS YELLOW SPOT (2/19)

Pathogen: *Iris yellow spot virus*

SYMPTOMS AND SIGNS

Iris yellow spot is a disease of onions and other *Allium* species. Although garlic has not yet been found to be a host in the field, researchers have been able to infect it via inoculation.

Symptoms of iris yellow spot on onion include yellow to straw-colored lesions on leaves and scapes, and dry, elongated lesions or flecks that may resemble severe thrips feeding injury. Lesions may be diamond-shaped, but this occurs more commonly on scapes than on leaves. Severe disease on leaves may reduce bulb size.

Lesions on seed stalks may cause lodging (plant toppling) during seed set, when the weight of the umbel increases. Lodging at this stage reduces seed production.

COMMENTS ON THE DISEASE

The pathogen is a tospovirus that is transmitted by the onion thrips, *Thrips tabaci*. Onion thrips must acquire the virus when it is a nymph to be capable of transmitting the virus as an adult. Excessive nitrogen fertilization tends to increase the severity of iris yellow spot by attracting onion thrips.

Some ornamentals (iris, lisianthus) and weeds (jimsonweed, tobacco, redroot pigweed) are also hosts of *Iris yellow spot virus*.

The highest disease incidence is typically near field edges. Degree of susceptibility varies among onion cultivars, and susceptibility increases with plant stress.

MANAGEMENT

Cultural Control

The following cultural practices can reduce problems with iris yellow spot:

- Maintain good fertility and adequate soil moisture to reduce plant stress. Avoid excessive application of nitrogen fertilizer.
- Practice good sanitation. Remove and destroy infected plants along with cull piles.
- Eliminate weeds in and around onion fields, especially volunteer onions and wild *Allium* species.

Chemical Control

Disease severity is related to the presence of ONION THRIPS infected with the virus. Controlling onion thrips will reduce incidence of this disease; particularly spread within the field.

ONION YELLOW DWARF (2/19)

Pathogen: *Onion yellow dwarf virus*

SYMPTOMS AND SIGNS

The first symptom of onion yellow dwarf in young onions is the appearance of yellow streaks at the bases of the first true leaves. After this initial symptom, all developing leaves show symptoms ranging from yellow streaks to complete yellowing of the leaves. Leaves are sometimes crinkled and flattened and tend to fall over; bulb size is reduced.

In combination with other viruses, this virus probably contributes to GARLIC MOSAIC symptoms.

COMMENTS ON THE DISEASE

Onion yellow dwarf virus is a potyvirus that has a narrow host range (onions, garlic, shallots and a few ornamental *Alliums*). It survives in bulbs and sets, and therefore can be transmitted during vegetative reproduction. The green peach aphid, *Myzus persicae*, as well as other aphids, spreads the virus from plant to plant in a nonpersistent manner. The virus can also survive in volunteer onions.

Although the virus is not spread to the seed, seed from infected plants is of poor quality.

MANAGEMENT

Use true onion seed (rather than sets) and use virus-free planting stock. In garlic, indexing for the virus and meristem tip culture eliminates the virus. Rogue (remove) infected plants.

No pesticides control this disease. Controlling aphids also does not prevent the disease because they retain the virus for a very short period of time and quickly transmit the virus as they move through the crop in search of preferred hosts.

PINK ROOT (2/19)

Pathogen: *Phoma terrestris*

SYMPTOMS AND SIGNS

The most striking symptom of pink root is, as the name indicates, pink roots. Infected roots first turn light pink, then darken through red and purple, shrivel, and later turn black and die. The pinkish-red discoloration may extend up into the scales of the bulb. New roots also may become infected. The vascular tissue in the center of the root (stele) can turn very dark red to purple.

Plants become stunted if infection continues, but the disease seldom results in plant death. Infection is confined to roots and outer scales of the bulb.

Some *Fusarium* species can also cause pink roots, particularly on dead or old roots. Field diagnosis of pink root can only be accurately accomplished by observing pink roots on actively growing plants. The dark-red-to-purple stele combined with a collapsed outermost layer of root tissue distinguishes pink root from root rot caused by *Fusarium* species and other fungi.

COMMENTS ON THE DISEASE

Pink root is primarily a problem on onion. It can infect garlic, but rarely causes economically significant damage.

The fungus is a common soil inhabitant that penetrates onion roots directly. It can persist in soil indefinitely and may spread via water or dirty equipment. Optimal temperatures for disease development are 75° to 85°F.

Wounds are not necessary for infection, and weak plants are more susceptible. The more years onions are grown in the field, the more destructive the disease becomes.

MANAGEMENT

To prevent and control the disease:

- Avoid repeated cropping of onions on the same soil. Rotating to non-*Allium* crops for 3 to 6 years can reduce the incidence of pink root.
- Use resistant varieties.
- Maintain good soil tilth and fertility.
- Control insects and other diseases to maintain healthy plants.
- Fumigate the soil before planting.

Because some other plant species are hosts of this pathogen, rotation is only effective if the appropriate crops are grown in rotation with onion. Long-term rotations out of onion for 3 to 6 years are recommended, because the incidence of the disease increases with each crop of onions. Planting onions after cereals or sweet corn can also increase the risk of this disease because the inoculum potential generally becomes greater with these crops than with onions.

Disease-resistant varieties are available, but many popular varieties do not have this characteristic. Furthermore, depending on which strains of the fungus are present, many resistant varieties are resistant in some locations but not in others.

Solarization has proven effective in areas like the San Joaquin Valley, where onions are planted in fall after a summer fallow period.

Fumigation with metam sodium or chloropicrin can be effective against some strains of the fungus, but its effects can vary. Fumigation is also not always economical unless a high value seed crop is being grown.

Common name	Amount per acre	REI‡	PHI‡

(Example trade name)		(hours)	(days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

A. METAM SODIUM*§
(Vapam HL) Label rates See label NA
COMMENTS: Fumigants such as metam sodium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone.

B. CHLOROPICRIN*§
(Chloropicrin 100 Fumigant) Label rates See label NA
COMMENTS: Fumigants such as chloropicrin are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone.

[1] Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 7, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment until the harvest may take place. In some cases, the REI exceeds the PHI. The longer of these two intervals is the minimum time that must elapse before harvest.

* Permit required from county agricultural commissioner for purchase or use.

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Use Materials Requirements, which may be lower than maximum label rates.

NA Not applicable.

PURPLE BLOTCH AND STEMPHYLIUM LEAF BLIGHT (2/19)

Pathogens: Purple blotch: *Alternaria porri*
Stemphylium leaf blight: *Stemphylium vesicarium*

SYMPTOMS AND SIGNS

Purple blotch and Stemphylium leaf blight occur as oval-shaped, tan-to-brown lesions on leaf blades. Yellow streaks, which later turn brown, extend along the blade in both directions from the lesion. As it progresses, purple blotch lesions become deep purple and may develop dark-brown concentric circles within the lesion. Purple blotch lesions may expand, girdling and killing the leaf. Likewise, in advanced stages, Stemphylium leaf blight may exhibit multiple small lesions, which coalesce and cause blighted leaves. Both diseases can also attack and girdle seed stems.

COMMENTS ON THE DISEASES

Stemphylium leaf blight is more common than purple blotch in California, but symptoms and management are similar for both diseases. These fungi are often found infecting downy mildew lesions on onion but occur less commonly on garlic.

Stemphlyium leaf blight is a common late-season problem in processing onions grown in the Tulelake area. It commonly occurs in onions that are maturing and starting to lodge. Infection of seed stalks can reduce seed yield and quality.

Stemphylium vesicarium is a weak pathogen, so it often infects onion plants secondarily, after other diseases develop or when the plant is otherwise stressed. Stemphylium leaf blight develops in iris yellow spot lesions, as well as on dead onion leaf tips following severe heat stress. Both fungi are also commonly found infecting downy mildew lesions on onion but occur less commonly on garlic.

Moderate temperatures and increasing canopy humidity favor both diseases. Heavy dew favors their development in desert areas, but foggy and rainy weather promotes their development in other regions. The optimal temperature for disease development is in the mid-70s (°F). In most areas, these diseases are usually not a problem after the end of the rainy season. However, in the Imperial Valley and in Tulelake, they can cause damage in the absence of rain, when there are conditions of high humidity, nighttime dew, and moderate temperatures. The spores are airborne.

MANAGEMENT

Chemical Control

Because these diseases often occur after damage from onion DOWNY MILDEW, controlling downy mildew is a critical strategy for preventing problems with purple blotch and Stemphylium leaf blight. However, in some regions, such as in the Tulelake area, these diseases can also occur in the absence of downy mildew. In such cases, management must be focused specifically on fungicide applications for purple blotch and Stemphylium leaf blight.

The amount of time leaves are consecutively wet each night (leaf wetness) can be used to inform when to apply fungicides for control of purple blotch and Stemphylium leaf blight.

- When leaves are wet for less than 12 consecutive hours per night, the interval between fungicide applications can be increased by several days.
- When leaves are wet for more than 12 consecutive hours per night, fungicide application intervals for controlling these diseases can be shortened in a manner consistent with the pesticide labels.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a

pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

A. PYRIMETHANIL/
FLUOPYRAM
(Luna Tranquility) 16–27 fl oz 12 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Anilino-pyrimidine (9) and succinate-dehydrogenase inhibitor (7)
COMMENTS: Not registered for control of Stemphylium leaf blight in California. Do not make more than two sequential applications without alternating with a fungicide with a different mode of action.

B. AZOXYSTROBIN/
DIFENOCONAZOLE
(Quadris Top) 12–14 oz 12 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (7) and demethylation inhibitor (3)

C. DIFENOCONAZOLE/
CYPRODINIL
(Inspire Super) 16–20 fl oz 12 Bulbs: 7
Greens: 14
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Demethylation inhibitor (3) and anilino-pyrmidine (9)
COMMENTS: Make no more than two sequential applications without alternating with fungicides with different mode-of-action group numbers.

D. PYRACLOSTROBIN/FLUXAPYROXAD
(Merivon Xemium) 5.5–11 fl oz 12 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone-outside inhibitor (11)/succinate-dehydrogenase inhibitors (7)
COMMENTS: Make no more than two sequential applications before rotating to a fungicide with a different mode-of-action group number.

E. PENTHIOPYRAD
(Fontelis) 16–24 fl oz 12 3
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate-dehydrogenase inhibitor (7)
COMMENTS: Not registered for control of Stemphylium leaf blight in California. Make no more than two sequential applications before rotating to a fungicide with a different mode-of-action group number.

F. BOSCALID/
PYRACLOSTROBIN
(Pristine) 10.5–18.5 oz 12 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate-dehydrogenase inhibitor (7) and quinone outside inhibitor (11)
COMMENTS: Make no more than two sequential applications before rotating to fungicides with different mode-of-action group numbers.

G. PYRACLOSTROBIN
(Cabrio EG) 8–12 oz 12 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11)
COMMENTS: Do not exceed 72 oz/acre per season or make more than two sequential applications before rotating to a fungicide with a different mode-of-action group number.

H. BOSCALID

(Endura)	6.8 oz	12	7

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate-dehydrogenase inhibitors (7)
COMMENTS: Make no more than two applications before rotating to a fungicide with a different mode-of-action group number.

I. CHLOROTHALONIL

(Bravo Weatherstik, Echo 720)	Label rates	12	See label

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M5)

J. MANCOZEB

(Penncozeb 75DF)	2–3 lb	24	7
(Dithane M45)	3 lb	24	7

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M3)
COMMENTS: For use on bulb onions, garlic, and shallots only; do not apply to exposed bulb.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases the REI exceeds the PHI. The longer of two intervals is the minimum time that must elapse before harvest.

[1] Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 7, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

RUST (2/19)

Pathogen: *Puccinia allii*

SYMPTOMS AND SIGNS

Rust is primarily a disease of garlic, although onion, leeks, shallots, and wild species of *Allium* are also hosts. Symptoms begin as small (0.04 to 0.08 inch, or 1 to 2 mm) flecks, which expand into slightly larger (0.12 to 0.2 inch, or 3 to 5 mm), oval- to diamond-shaped, reddish- to dull-orange pustules that develop on leaf blades. Lesions typically form first on older leaves, and then spread to younger leaves. Reddish airborne spores (urediniospores) are produced copiously within the lesions. Later in the growing season, the lesions may appear dark because black survival spores (teliospores) develop within the pustules. Severely affected leaves can be completely covered with pustules, turn chlorotic (yellow) and then dry out and die. When infection is severe, bulb size and quality are reduced.

COMMENTS ON THE DISEASE

Previously, rust was a sporadic disease that caused little or no economic damage. Since 1998, however, rust has caused severe damage in some garlic-growing areas in California. In addition to garlic, onion and chives can be affected severely. However, the disease only damages onions when they are planted next to a heavily infected garlic field. Leek, elephant garlic, and shallot are more resistant.

Weedy *Allium*s can host the fungus, serving as a source of inoculum. The fungus probably overwinters on garlic and volunteer *Allium* crops.

The pathogen is active during cool weather conditions, between 57º and 75ºF (14º and 24ºC). Optimal conditions for infection occur around 59ºF (15ºC) with 100% relative humidity for at least 4 hours.

The pathogen that causes rust, *Puccinia allii*, is considered to be a complex of several species, and might elsewhere be referred to as *P. porri, P. mixta, P. blasdalei, Uromyces ambiguous* and *U. durus*.

MANAGEMENT

Rotate away from *Allium* crops for 2 to 3 years, keep *Allium* fields separated to prevent movement, and destroy volunteer *Allium* plants during this period. There are currently no industry garlic varieties that are completely resistant, but some California Early varieties exhibit disease tolerance. Plant seeds in well drained soils.

Fungicide sprays may be warranted if more than a few pustules develop on plants. Frequent fungicide applications are required to maintain effective control.

For optimal results, use a fungicide as a preventive application. Begin applications as soon as environmental conditions become favorable for disease development (see Comments on the Disease).

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

A. AZOXYSTROBIN
(Quadris) 6–12 fl oz 4 0
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone outside inhibitor (11)
COMMENTS: Begin applications before disease development and repeat every 7 to 14 days for up to three applications. Do not apply more than one application before alternating with a fungicide with a different mode-of-action group number.

B. MANCOZEB

(Penncozeb 75DF)	2–3 lb	24	7

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Multi-site contact (M3)
COMMENTS: Registered for use on garlic, dry bulb onion, and shallot. Applied as a protectant and in mixes, or used in rotation with systemic fungicides for disease resistance management.

C. TEBUCONAZOLE

(Orius 3.6 F)	4–6 fl oz	12	7

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Demethylation inhibitor (3)
COMMENTS: Product needs two to four hours drying time before rain or irrigation to move systemically into the plant. After this period, the fungicide will be resistant to weathering.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases the REI exceeds the PHI. The longer of two intervals is the minimum time that must elapse before harvest.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 7, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

SOUTHERN BLIGHT (2/19)

Pathogen: *Athelia rolfsii* (*Sclerotium rolfsii*)

SYMPTOMS AND SIGNS

At the initial stages of the disease, outer leaves turn yellow and wilt. The bulb and bases of the leaves are affected by a soft rot. White mycelium is present on bulbs and in soil. As the infection progresses, infected plants wilt and eventually die.

Accurate diagnosis is critical for effective control. Misdiagnosis as white rot is common, especially where southern blight has not previously occurred. Plants with southern blight can be diagnosed by the presence of small (0.04 to 0.08 inch, or 1 to 2 mm), extremely numerous, tan-to-reddish-brown sclerotia in and on bulbs, as well as in the soil. The sclerotia are white initially, but become brown as they mature. Fanlike growth of the white mycelium may also be apparent on the bulb and the surrounding soil surface. To diagnose this disease in the absence of these signs in the field, incubate the affected tissue in a moist chamber for 5 to 7 days and look for the rapid, fanlike growth of the white mycelium.

COMMENTS ON THE DISEASE

Southern blight is not a common disease of onions, but is a persistent problem in Kern County, and more recently has been detected in Lake County. The disease is often not noticed until it is widespread in a field. Within a season or two, it can become serious enough to cause the loss of an entire field. It can progress very rapidly under warm conditions (86–95°F) and is more common in unusually hot and wet years.

Disease incidence and severity depend on the number of sclerotia in the soil, which can be high if previous crops were affected, since each infected plant can produce tens of thousands of sclerotia. Sclerotia also survive for long periods (at least five years) in the soil. The pathogen has a host range of over 500 plant species, so rotation is not a very effective management tactic. However, avoiding highly susceptible hosts can be useful (see Cultural Control).

The fungus may spread via infected bulbs and infested soil. Although higher temperatures generally favor the development of the disease, the fungus cannot survive at extremely high temperatures (105–120°F).

MANAGEMENT

Cultural Control

Proper management should include the following actions:

- Keep the tops of the beds dry to reduce incidence of the disease.
    - Use subsurface drip irrigation if feasible.
    - Avoid alternating between wet and dry periods.
- In fields where subsurface irrigation is not used, deep plow to bury plant residue. Sclerotia buried more than 6 inches deep are usually parasitized by other microbes and are killed over time.
- Use good sanitation to prevent moving inoculum from infested fields into noninfested fields. Clean boots and equipment before moving from one field to another.
- Rotate to crops that are poor hosts of the pathogen, such as corn, sorghum, rice, or small grains (wheat, millet, or oats), for at least two years after detecting the disease. This will reduce the inoculum in the soil.
    - If fumigation is not an option, consider rotating with a mustard cover crop. Mustards can suppress southern blight.
    - Avoid highly susceptible rotation crops, such as tomatoes, potatoes, beans, peas, cucurbits, peppers, hairy vetch, alfalfa, and carrots.

Solarization can be used in combination with fungicides to manage the disease in inland areas, where temperatures are higher. To kill the sclerotia near the soil surface, the soil must reach temperatures

between 105°F to 120°F for 2 to 4 weeks. Solarization alone, as well as the combination of solarization and biological control, are not considered viable management strategies. Solarization is most effective when combined with a fungicide.

Biological Control
Biological control by other microbes reduces inoculum that is buried more than 6 inches deep. Fungi such as *Trichoderma harzianum* also have antagonistic effects on this pathogen and are available in organically certified pesticide products.

Organically Acceptable Methods
Use cultural controls and furrow application of *Trichoderma harzianum* in an organically certified crop.

Monitoring and Treatment Decisions
Scout the fields during the summer months to determine if southern blight is present. This will enable you to take action before the sclerotia become too numerous.

With their narrow, easily penetrated canopy, onion and garlic are some of the only crops where fungicide control is highly effective. Since the pathogen is only active in the top 3 to 4 inches of the soil, and only infects the neck and upper bulb from the soil line, the fungicide must completely cover the base of the plant and penetrate into the soil. Since thorough coverage of the neck is necessary, subsurface drip chemigation does not provide effective control.

Preplant fumigation with metam sodium can reduce the amount of sclerotia in the soil. However, this is unlikely to eliminate the inoculum completely unless applied through the sprinklers, which is restricted in many counties.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are listed at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties, and application timing, honey bees, and environmental impact. Always read the label of the product being used.

PREPLANT

A. METAM SODIUM*§
(Vapam HL) Label rates See label NA
COMMENTS: Fumigants such as metam sodium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Most effective when applied through sprinklers, which is not allowed in some counties. If sprinkler application is not allowed, shank in to apply. Shank applications are not as effective, and fields may still suffer losses when this type of application is used.

B. METAM POTASSIUM*§
(K-Pam HL) Label rates See label NA
COMMENTS: Fumigants such as metam potassium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Most effective when applied through sprinklers, which is not allowed in some counties. If sprinkler application is not allowed, shank in to apply. Shank applications are not as effective, and fields may still suffer losses when this type of application is used.

CROP ESTABLISHED

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
A. FLUOPYRAM/TEBUCONAZOLE (Luna Experience)	12.8 fl oz	12	7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate-dehydrogenase inhibitor (7) and demethylation inhibitor (3)			
B. TRICHODERMA HARZIANUM AND TRICHODERMA VIRENS (RootShield PLUS Granules)#	5–12 lb	See label	—
MODE-OF-ACTION GROUP NAME (NUMBER[1]): biological			
COMMENTS: Registered for use in onion, garlic, leek, and shallot. Apply from a granular applicator in-furrow at seeding, or to established crops as a sidedress, and incorporate into soil. Use prior to disease onset.			

[1] Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 7, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases the REI exceeds the PHI. The longer of two intervals is the minimum time that must elapse before harvest.

\# Acceptable for use on organically grown produce.

* Permit required from county agricultural commissioner for purchase or use.

§ Do not exceed the maximum rates allowed under the California Code of Regulations Restricted Use Materials Requirements, which may be lower than maximum label rates.

NA Not applicable.

— No information.

WHITE ROT (2/19)

Pathogen: *Stromatinia cepivora* (*Sclerotium cepivorum*)

SYMPTOMS AND SIGNS

Leaves of plants infected with the white rot pathogen show yellowing, leaf dieback, and wilting. Leaf decay begins at the base, with older leaves being the first to collapse. This results in a semi-watery decay of the bulb scales.

Roots also rot, and as a result, the plant can be pulled from the ground easily. At early stages of disease development, a fluffy white growth (the fungal mycelium) is associated with the rot, which develops around the base of the bulb. As the disease progresses, the mycelium becomes more compacted and less conspicuous, with numerous small, spherical black bodies (sclerotia) forming on this mycelial mat. These sclerotia are the resting bodies of the pathogen and are approximately the size of a pin head or poppy seed.

Plants can become infected at any stage of growth, but in California, symptoms usually appear from mid-season to harvest.

COMMENTS ON THE DISEASE

The pathogen persists as small, dormant structures (sclerotia) in the soil. Sclerotia remain dormant in the absence of a suitable host (garlic, onion, or other *Allium* crops), and can survive in the soil for over 20 years.

Sclerotia can spread throughout a field, or from field to field, via flood water, equipment, or plant material, such as wind-blown scales. *Allium* root exudates, which may seep ½ inch into the soil from the root, stimulates the germination of the sclerotia. Exudates from non-*Allium* plants do not stimulate or otherwise affect the germination of white rot sclerotia.

Disease severity depends on soil temperature and the amount of sclerotia in the soil at planting. As few as one sclerotium per 10 kilograms of soil can initiate disease. Only one sclerotium per kilogram of soil can cause measurable yield loss, and 10 to 20 sclerotia per kilogram cause essentially all plants to become infected.

Disease development is favored by cool, moist soil conditions. The soil temperature range for infection is 50° to 75°F, with an optimum of 60° to 65°F. At soil temperatures above 78°F, the disease is markedly inhibited. Soil moisture conditions that are favorable for onion and garlic growth are also ideal for white rot development.

MANAGEMENT

The most effective controls for white rot are avoidance and sanitation. Once a field is infested, fungicide applications are necessary to produce onion or garlic crops.

Because onion and garlic exudates stimulate the germination of white rot sclerotia, the use of such products to germinate and kill sclerotia are currently being investigated. At this time, however, this practice remains a challenge because most natural products (such as garlic juice) do not contain enough active ingredient to be effective and vary widely in the amount of the active ingredient they contain, and synthetic diallyl disulfide (or DADS, the main exudate that germinates sclerotia) products are not readily available on the market. Efforts are underway to increase the efficacy of natural onion and garlic products, but at this time they are not a reliable alternative.

Cultural Control

The most effective way to avoid introducing the white rot pathogen is to plant only clean stock from known origins that have no history of white rot. Onion seed is not likely to carry sclerotia since the pathogen is not seedborne in onion, but infected transplants and sets can carry sclerotia. On garlic, the disease is commonly introduced into the field on seed cloves. Therefore, do not move cull bulbs, litter,

and soil from infested to noninfested fields. Always clean the soil off of equipment before moving from one field to another.

In addition, follow a long-term rotation schedule, and do not follow *Allium* crops with other *Allium* crops. Rotation alone will not control white rot because sclerotia can survive in soil for more than two decades. However, rotation does help prevent an increase in the soilborne inoculum of the pathogen.

Because the fungus is vulnerable at temperatures above 115°F, dipping seed garlic in hot water is a good preventive measure that will greatly reduce the amount of pathogen, although it may not completely eradicate the fungus. Careful temperature control is essential when using this method, since temperatures above 120°F may kill the garlic.

If the disease is observed, ceasing irrigation will minimize damage but will not stop the spread of the disease.

Organically Acceptable Methods
Use cultural control in an organically certified crop.

Chemical Control
If white rot has been a recent problem in the field, apply a fungicide in a 6-inch band over the planting trench immediately before planting. This will provide effective control of white rot.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are listed at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

A. TEBUCONAZOLE
(Orius 3.6F, Tebu-crop 3.6F) — Bulb onion, garlic, shallot: 20.5 fl oz; Green onion and leek: 4–6 fl oz — 12 — 7

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Demethylation inhibitor (3)
COMMENTS: Must have two to four hours drying time before the product is resistant to weathering. In green onions and leeks, tebuconazole provides white rot suppression.

B. PENTHIOPYRAD
(Fontelis) — Label rates — 12 — 3
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate dehydrogenase inhibitor (7)

…*OR*…

BOSCALID
(Endura) — 6.8 oz — 12 — 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Succinate dehydrogenase inhibitor (7)

…*OR*…

PYRACLOSTROBIN/FLUXAPYROXAD
(Merivon Xemium) — 5.5–11 fl oz — 12 — 7

MODE-OF-ACTION GROUP NAME (NUMBER[1]): Quinone-outside inhibitor (11)/succinate dehydrogenase inhibitor (7)
COMMENTS: Do not make more than two applications without rotating to a fungicide with a different mode-of-action group number.

C. FLUDIOXONIL
(Cannonball WG) 7 oz 12 7
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Phenylpyrroles (12)

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases the REI exceeds the PHI. The longer of two intervals is the minimum time that must elapse before harvest.

Acceptable for use on organically grown produce.

1 Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with a different group number are suitable to alternate in a resistance management program. In California, make no more than one application of fungicides with mode-of-action group numbers 1, 4, 7, 9, 11, or 17 before rotating to a fungicide with a different mode-of-action group number; for fungicides with other group numbers, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number.

Nematodes (1/18)

Scientific Names: Stem and bulb nematode: *Ditylenchus dipsaci*
Root-knot nematode: *Meloidogyne hapla, M. incognita, M. javanica,* and *M. chitwoodi*
Stubby root nematode: *Paratrichodorus* sp.

DESCRIPTION OF THE PESTS

Soil-dwelling nematodes are typically elongated, unsegmented, microscopic roundworms that occur in virtually every terrestrial environment. The vast majority of these species feed on microorganisms and microfauna without harming plants. They are an important part of the soil food web and nutrient cycling processes. In contrast, plant-parasitic nematodes feed on plants by puncturing and sucking the cell contents, and can considerably reduce crop yield and quality. Most plant-parasitic nematodes have hollow, needlelike mouthparts called stylets. The stylet enables the nematode to puncture plant cells and inject various compounds, which support the feeding process and may influence host physiology and morphology. A nematode life cycle typically includes an egg, four juvenile stages, and the adult stages. The length of the life cycle depends on the nematode species and the temperature of its environment.

Stem and Bulb Nematode
Stem and bulb nematodes live mostly within the plant, feeding on cells in stems, leaves, and bulbs. The species has many biological races with different host ranges. The race that infects onions and garlic requires mating to reproduce; a female lays 200 to 500 eggs within the host tissue. Optimal egg development occurs between 59˚ and 70˚F. The life cycle takes approximately three weeks at 59˚F. Both juveniles and adults are able to infect plants. Under moist, mild conditions (59˚ to 68˚F), stem and bulb nematodes can move in a thin water film on the plant surface to enter their host through stomates. Multiple generations can occur during one season, potentially resulting in a huge increase in nematode numbers. They are capable of surviving drought for many years in or on dry plant material, only to become active again with rehydration.

Root-Knot Nematode
Root-knot nematodes live primarily within the roots of their hosts. Only the second-stage juveniles are motile, while the other stages are sedentary. At least four root-knot nematode species may cause damage in onions and garlic.

Root-knot nematodes have a large host range and complete their life cycle in 3 to 4 weeks under optimal conditions. Juveniles hatch from eggs in their second stage. They are able to infect host roots at soil temperatures exceeding 41˚F (*M. chitwoodi*), between 55 to 57˚F (*M. hapla*), or between 59 to 64˚F (*M. incognita*, and *M. javanica*). After initial penetration, the nematodes move to a site near the vascular cylinder, where they establish a permanent feeding site. Once they have established this site, they become sedentary. After three further molts, the nematodes develop into slender, wormlike males that can leave the roots, or into pear-shaped females that stay at the feeding site.

Most root-knot nematode species can reproduce asexually, with the exception of *M. hapla*. The females lay several hundreds of eggs in a gel sack that provides protection against desiccation and predation.

Stubby Root Nematode
These nematodes live exclusively in the soil and feed on host roots. In contrast to the previously mentioned nematodes with hollow stylets, stubby root nematodes have a curved, solid spear that is used to puncture cells. The nematode secretes saliva from its mouth that hardens into a hollow tube, allowing the nematode to feed on cell contents. A new tube is formed each time the nematode moves to a new cell. Males are rare, as the stubby root nematode reproduces asexually.

Lesion Nematode

Lesion nematodes spend large proportions of their life history inside of hosts' roots. These nematodes move through root tissues destructively while feeding on plant cells. When conditions become less suitable, they may leave the host to search for more suitable roots. While lesion nematodes have been shown to reduce growth and yield of onion and garlic crops in other states, they have not been reported to cause problems on onions or garlic in California.

SYMPTOMS AND DAMAGE

Field-level, aboveground symptoms of nematode problems often show as oval patches of stunted, thin plant stands. However, such symptoms may also be the result of other biotic and abiotic causes.

Stem and bulb nematodes can cause substantial crop damage and are of major concern in garlic and onion production worldwide. Migratory feeding by these nematodes creates cavities, leading to shortened, distorted or collapsing leaves and bloated tissues. The bulbs often soften at the neck. Cutting the bulb in half may reveal brown rings. Secondary invaders such as bacteria, fungi, and onion maggots may then cause soft rot and greatly accelerate the decay of the bulbs. Even during bulb storage at low temperatures, the nematodes may continue to develop, reproduce, and typically in combination with microbial contamination, damage the bulbs during storage.

Root-knot nematodes can also cause stunting and uneven stands of plants. The feeding process induces the characteristic knots or galls on the host's roots. Their size depends on the nematode species and the response of the host. Gall formation by root-knot nematodes impedes the uptake of nutrients and water that may lead to stunted growth. Nutrients produced by photosynthesis are diverted to sustain the nematodes instead of supporting plant growth. The feeding process also lowers the host's resistance to biotic and abiotic stress, such as the ability to deal with drought or microbial infections.

Stubby root nematodes feed primarily on the root tips of their host, which damages the meristematic tissues (growing root tissues). It causes the roots to remain very short. This impedes the ability of the host to take up nutrients and water, which reduces growth and bulb size.

Plants with lesion nematodes typically have fewer roots than noninfested plants, and may exhibit elongated, brown-to-black lesions along the roots.

FIELD EVALUATION

Because nematodes are tiny, colorless, and transparent, they are not easy to detect or identify. To make appropriate management decisions, it is critical to accurately diagnose the nematode species present and know how numerous they are. If a previous crop in the particular field had problems from nematodes that are also listed as pests of onions or garlic, their numbers may be high enough to damage sensitive young seedlings.

If nematode species in the field of interest have not previously been identified, consider taking soil samples and sending them to a diagnostic laboratory for identification.

1. Divide the field into sampling blocks measuring between 5 and 20 acres each. Each block should have similar cropping history, soil texture, or history of recent crop injury throughout.
2. Collect several subsamples randomly from a block, and mix them thoroughly to make a composite sample for laboratory analysis, which should be about 1 pint of soil for each block. Use soil from within the root zone (approximately 2 to 14 inches deep) and include samples of suspect plants.
3. Place samples from each block in separate plastic bags, seal them, and place a label on the outside with your name, address, location, and the current/previous crop and the crop you intend to grow.
4. Remove the samples from direct sun exposure, keep them cool (do not freeze), and transport as soon as possible to a diagnostic laboratory.

Contact your local cooperative extension advisor for more details about sampling, laboratories that identify nematodes in soil samples, and how to interpret sample results.

MANAGEMENT

Cultural Practices

Determine the cropping history of fields to be planted with seed garlic, onion transplants, or onion sets. The host range of the onion and garlic race of *D. dipsaci* (stem and bulb nematode) includes chives, leeks, certain lettuce cultivars, celery, hairy nightshade, and others. Growing nonhost and poor host crops such as corn in weed-free fields for at least three years will help reduce stem and bulb nematodes. However, such crops might be good hosts for other plant-parasitic nematodes.

Always use clean, noninfested cloves when planting garlic. Private laboratories or the California Department of Food and Agriculture can test garlic cloves to determine if they are infested with plant-parasitic nematodes.

Avoid infesting new fields by thoroughly cleaning machinery and equipment with water. Nematodes do not move far on their own; they are distributed mainly through infected planting material, irrigation or surface runoff water, contaminated equipment, and spread of infested soil.

There are currently no available onion or garlic cultivars with resistance to any nematode species.

Treatment Decisions

If noninfested seeds are not available, treating bulbs with hot water has been shown to reduce stem and bulb nematodes in garlic cloves. However, hot water treatment is unlikely to be 100% effective and may also predispose plants to other diseases.

Preplant fumigation can effectively reduce plant-parasitic nematode infestations in onion fields.

Common name (Example trade name)	Amount Per Acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. ***The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table.*** *When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.*

PREPLANT

A. 1,3-DICHLOROPROPENE*/ CHLOROPICRIN*
(Inline) Label rates See label NA
COMMENTS: This product is a soil fumigant used for preplant treatment of soil to control plant parasitic nematodes, symphylans, and certain weeds as well as to mitigate the impact of various soilborne fungal pathogens using low volume (drip) irrigation systems only. The use of a tarp seal is mandatory for all applications of this product to vegetable fields. Soil fumigants such as this product are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Its use amounts are restricted on a township basis.

B. 1,3-DICHLOROPROPENE*
(Telone EC) Label rates 120 (5 days) NA
COMMENTS: Fumigants such as 1,3-dichloropropene are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone. Use of a tarp seal is mandatory for all applications to vegetables in California

C. METAM SODIUM*
(Vapam HL) Label rates See label NA
COMMENTS: Fumigants such as metam sodium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone.

D. METAM POTASSIUM*
(K-Pam HL) Label rates See label NA
COMMENTS: Fumigants such as metam potassium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone.

PLANTING OR AFTER

A. OXAMYL
(Vydate L)* Label rates 48 See label
COMMENTS: Can be applied in-furrow, as a band, or in sprinkler or furrow irrigation. In-furrow and band applications must be followed by irrigation. See label for additional information. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases the REI exceeds the PHI. The longer of two intervals is the minimum time that must elapse before harvest.
* Permit required from county agricultural commissioner for purchase or use.
N Not applicable.
A

Weeds

INTEGRATED WEED MANAGEMENT (10/18)

An integrated weed management program is essential for onion and garlic production because of the unique challenges posed by their planting densities and susceptibility to weed competition. These crops are slow-growing and shallow-rooted, planted at high densities, and susceptible to severe yield loss from weed competition. Their narrow, upright leaves do not compete well with weeds, and their long growing season allows for successive flushes of weeds. Weed control is often challenging in these crops because few herbicides are registered, mechanical cultivation is often limited in high-density plantings, and handweeding can be costly. A good integrated weed management plan can increase the ease and effectiveness of these management tactics.

Planting densities for onion and garlic pose unique challenges to weed management. These crops are sown at high plant densities and are not thinned to produce the greatest possible yield per acre. Onions are planted with 4 to 10 seed lines on beds that are 40 to 80 inches wide (furrow to furrow), or 36 inches wide in the intermountain area. Garlic is typically planted with 2 to 4 seed lines on 40-inch beds. These planting configurations limit cultivation to the furrow and narrow row middles on the bed top.

Emphasis must be placed on techniques that reduce weed pressure before planting, such as the use of the stale seedbed method, weed-free seed, or soil solarization. Any method that reduces the amount of weed seed in the soil will reduce weeding costs during crop production. Another good way to prevent weed problems is to control existing weeds before they go to seed.

MONITORING

Monitor the fields and keep records of the weed species present in each field during the growing season. Pay special attention to weeds likely to be present at planting time. Not only are these records valuable in choosing the most suitable fields for growing onions and garlic, they also help track the occurrence of hard-to-control weeds.

Plant onion and garlic in the most weed-free fields available, and avoid fields with high amounts of difficult-to-control perennial weeds such as nutsedge, field bindweed, bermudagrass, johnsongrass, clovers, and Canada thistle. If weedy fields must be used, control weeds during fallow periods using stale seedbeds and herbicide application or shallow tillage. Fumigation with metam potassium or metam sodium can also be used to reduce the weed seed bank.

WEED MANAGEMENT BEFORE PLANTING

Nonchemical control options are primarily limited to the preplant period in onion and garlic production. For most weed control methods, timing is important because small weed seedlings are easier to kill than larger weeds.

Crop Rotation With Cover Crops

Cover crops are rarely used in onion and garlic production. However, they can provide a variety of benefits to the crop when used in crop rotations, especially if they are grown in the fall prior to planting *Alliums*.

Timing is the key to whether cover crops promote or inhibit weed growth. If cover crops become established quickly, they will suppress weeds. Adequate seeding rate of the cover crop is also an important factor in providing rapid ground cover and suppressing weeds. Vigorous cover crops that provide complete ground cover in the first 30 days of the cover crop cycle are very competitive with weeds and greatly limit weed growth. Competitive species include cereal rye (*Secale cereale*), white mustard (*Sinapis alba*), and Indian mustard (*Brassica juncea*). Avoid slow-growing winter cover crops, including legumes and many cereal-legume mixes, which allow substantial weed growth and set seed early in the growth cycle of the cover crop. Cover crop residues must have adequate time (at least 3 to 4 weeks) to break down in the soil before planting onion and garlic, which require shallow, precise seeding depth with good seed-to-soil contact.

Cover crop residues can increase pressure from certain diseases and insect pests. For example, cover crops can increase seedcorn maggot numbers. If a cover crop is used, incorporate the cover crop three to four weeks before planting onion or garlic to avoid tilling in green residues that attract this pest.

Cover crops also have the potential to increase weed pressure for the following reasons.

- Annual weeds frequently establish themselves at the time of the cover crop.
- Depending upon the species, weeds can grow in the cover crop and set seed unnoticed.
- Weeds often decompose before the end of the cover crop cycle, making their detection difficult. In such cases, the cover crops act as nurse crops to weeds, making substantial contribution to the weed seed bank.

It is important to monitor your cover crops, particularly in the first 40 days following seeding, to make sure that they are not creating a weed problem for subsequent plantings of onion and garlic.

Soil Solarization

Soil solarization traps the sun's heat beneath a layer of clear plastic and disinfests the soil with higher temperatures that kill weed seeds, vegetative structures, insects, and some disease-causing pathogens (such as the fungus that causes pink root).

Solarization effectively controls seedlings (but not mature plants) of bermudagrass, johnsongrass, and field bindweed, and is more effective on annual weeds than perennial weeds. It partially controls yellow nutsedge, but does not control purple nutsedge. Annual weeds with a harder seed coat such as little mallow and velvetleaf are often hard to kill with solarization.

Plan to solarize soil according to planting time: plastic must remain in place for a minimum of 4 weeks, and the best results occur when the crop is planted immediately after removing the plastic. For some crops, growers burn holes into the plastic mulch and transplant directly into them; however, this practice may be of limited value for high-density plantings of onion and garlic.

Because solarization requires a summer fallow, it works best with a fall-planted crop. In the desert and Central Valley, the plastic should be in place during June through August, and can remain in place until planting begins in the fall.

Solarization may not be practical in areas with short growing seasons, or in coastal areas, where it does not heat the soil as deep. In coastal areas, apply plastic in fall when there is less chance of fog (i.e. August and September). Cultivate solarized soil less than 3 inches deep to avoid bringing viable weed seeds to the surface, where they germinate.

For more details on how to effectively solarize soil, see *Soil Solarization: A Nonpesticidal Method for Controlling Diseases, Nematodes, and Weeds*, UC ANR Publication 21377.

Flaming

Flaming can be used to kill or suppress the flush of weeds anytime between seeding the crop and its emergence. This technique is particularly effective on crops that have slow seed germination like onion, where nonprimed seed is used. Timing is critical: flaming must occur just prior to the emergence of the onion plants, when a good number of weeds are emerged. Flaming is more effective on small (i.e., less than two true leaves) broadleaves than on grass weed species.

Propane-fueled flamers are the most common type of flamer used for this method. Other equipment without an open flame includes hot water or steam applicators and infrared devices. Flamers can be handheld or mounted on a handcart or tractor. Mechanized flamers have multiple burners, while small devices typically have a single flame source.

Typically, flaming can be done at 3 to 5 miles per hour through fields, although this depends on the heat output of the unit being used. Briefly touch the basal stem area with the tip of the flame to disrupt the cells; do not flame weeds to the point where they char and burn. Best results occur under windless

conditions, as winds can prevent the heat from reaching the target. Early morning or evening are the best times to observe the flame for adjustment.

Determine the correct working pace or travel speed by checking weeds after flaming a test area. Weeds are being killed if gently pressing their leaves between your thumb and index finger creates a water-soaked appearance, indicating that cell membranes have ruptured. Plants may wilt, change color, or appear unaffected soon after flaming. Even if no change in the weeds is evident immediately, proper flaming causes plants to yellow and die within several days.

Fire is a serious hazard when flaming weeds. Only an experienced operator with demonstrated skill and good judgment should be allowed to flame weeds. Wet conditions during the rainy season or after a thorough irrigation are often good times to flame. Work in the early morning or late evening when winds are lower and any open flame is more visible. Proper flaming should not create smoldering vegetation or air pollution other than fuel burning emissions.

Use good judgment to identify hazardous situations in which flaming should not be conducted due to the risk of starting a fire. Do not use flame weeders in dry areas or during the dry season. Be especially cautious around mulch and leaf litter. Keep fire suppression equipment (e.g., a fire extinguisher, shovel, water) handy in case of an accident.

Cultivation
To prevent the increase of weed seed in the soil, cultivate weeds before they set seed in cover or rotation crops. After incorporation of the cover crop (if a cover crop is used), clean cultivate the field before planting onions or garlic.

Deep Plowing
Deep plowing is a tillage technique that buries weed seed or propagules of perennial plants below the depth at which they can germinate. The viability of buried weed seed declines over time. A relatively long interval (3–5 years) is preferred between deep plowing and subsequent deep plowing, to avoid bringing up large numbers of viable weed seed back to the soil surface. In fields heavily infested with nutsedge, plow fields with a specialized moldboard plow that fully inverts the soil, to bury tubers 10 to 12 inches. This can reduce up to 95 to 98% of nutsedge in the field.

Stale Seedbeds
This method can provide substantial weed control. It involves controlling the final flush of weeds before planting, followed by minimal soil disturbance to reduce subsequent weed flushes. To do this, prepare a seedbed and preirrigate it to germinate weed seeds. Cultivate as shallow as possible to kill emerged seedlings and prevent bringing up weed seed from deeper soil layers. Other options for killing the flush of weeds include flaming and foliar herbicides. The crop can then be planted on these beds soon afterward. If an herbicide is used, be sure to follow label directions on plantback restrictions.

The time of year and the irrigation system used may also affect the efficacy of this technique. Irrigate and cultivate as close as possible to planting time to ensure that soil temperature and climatic conditions are similar to the crop germination period, and to maximize weed control. If the interval between irrigation-cultivation and planting is too long, the weed spectrum (seasonal variation in weed species) may change due to changes in season or weather. Using shallow tillage 14 days after irrigation can reduce up to 50% of weeds in the subsequent crop.

Herbicides
Herbicides, combined with good cultural practices, control most weed pests of onion and garlic. There are specific herbicides that are applied before planting or after planting.

Herbicide selection depends upon the weed species that are expected to occur. Plantback restrictions need to be considered when selecting herbicides—herbicide residues in soil can limit the growth of sensitive rotational crops. Herbicide labels are the best source of information on plantback restrictions.

Preplant treatments are used in fields with persistent perennial weed problems. Metam sodium will destroy most weeds present. Paraquat and glyphosate can be used before the crop is planted to control

emerged weeds. Glyphosate has been particularly helpful in controlling perennial weeds the season before planting.

Organically Acceptable Methods
Use the above-mentioned nonherbicidal methods in an organically certified crop. The stale seedbed method and cultivation are especially important preplant weed management tactics in organic onions and garlic.

WEED MANAGEMENT AFTER PLANTING

Cultivation
Cultivation is one of the most effective postplant cultural weed control practices. Because of the high-density plantings of onions and garlic where most of the bed top is occupied with the seedlings, cultivation is often limited to a narrow band on the bed and the shoulders of the bed and furrows. Not all planting configurations of onions allow for bedtop cultivation, but the middle of the bed can be cultivated in garlic production.

The goal of cultivation is to remove weed seedlings as close to the seed row as possible without disturbing the crop. Precision guidance systems for cultivation (e.g. EcoDan®) can help improve the accuracy of cultivation operations. More precise cultivation allows for reducing the width of the uncultivated band, thereby removing a higher percentage of the weeds. Uncontrolled weeds in the seed line can be removed by postemergence herbicides or by handweeding.

Handweeding
Handweeding, although effective, is costly. Handweeding is particularly difficult in onion due to close plant spacing and the placement of multiple seed lines in a single bed. Handweed carefully to avoid damaging or killing onion plants, especially those that are young. Preventive measures, precision cultivation, and herbicides can also make handweeding less time-consuming and more effective.

Flaming
Flaming can be used to kill the flush of weeds any time between seeding the crop and its emergence. This technique is particularly effective on crops that have slow seed germination. However, its use in onions is limited if the onions germinate too quickly. This is particularly true in fields where primed seed is used.

Herbicides
Foliar-applied herbicides may be used after crop emergence to control established weeds. Layby herbicides are applied to clean-cultivated soil, typically at the 4- to 5- leaf stage of crop development, to keep the crop weed-free until harvest. Most fields require one or more postplant preemergence applications and one layby application. Split applications are most common for controlling weeds throughout the season, and to prevent unacceptable crop injury from herbicides.

Herbicide application sequences in onion and garlic typically involve applying preemergence herbicides to control or slow the growth of weeds germinating shortly after planting, and applying postemergence herbicides during the 1- to 5-leaf stage to control any weeds that escape preemergence treatments. Layby herbicides can help prevent weed flushes after cultivation or weeds that tend to germinate later in the growing season.

Preemergence herbicides
Preemergence herbicides typically require activation through irrigation. In both onion and garlic, bensulide, ethofumesate, and pendimethalin can be used preemergence. However, preemergence use of pendimethalin is only registered for some areas and crops as directed by special labeling (see the Herbicide Treatment Table for more information regarding use at 75% radical emergence and the loop stage). In garlic, the above-mentioned materials can be used, as well as flumioxazin and oxyfluorfen. Pendimethalin controls many annual grasses and broadleaf weeds, and provides optimal weed control through sprinkler irrigation. In the southern San Joaquin Valley, a common practice is to combine application of flumioxazin or oxyfluorfen with pendimethalin to control weeds after planting garlic.

In both onion and garlic, occasionally postplant applications of glyphosate or paraquat are used to control germinated weeds before the crop emerges. The timing of this application is critical, because any emerged crop plants will be killed if contacted by these herbicides. If applied at more than 1% crop emergence, glyphosate may reduce the stand.

Postemergence herbicides
Several herbicides, including grass-selective herbicides, are available for postemergence use in both onion and garlic. Clethodim controls annual bluegrass, whereas other herbicides do not. See the Herbicide Treatment Table for more information.

Oxyfluorfen and bromoxynil can only be used on young onions (see the Herbicide Treatment Table for additional information). Oxyfluorfen is complimentary to bromoxynil in onion; together they control a wider spectrum of weeds than either do alone. They are usually used in sequence about 1 week apart depending on the crop growth rate and weeds present, and the order in which they are applied may vary according to experience. They can also be tank-mixed, or the sequence strategy can be combined with the tank mix method. If tank mixing these two chemicals, use a sufficient spray volume per acre and closely follow the label to avoid crop injury. Oxyfluorfen is commonly used when the crop has 1.5 fully developed true leaves, followed by an application of both oxyfluorfen and bromoxynil at the 2- and 3-leaf stages.

Ethofumesate can provide control of a variety of broadleaf and grass weeds. Dimethenamid controls yellow nutsedge if applied before nutsedge emerges.

Organically Acceptable Methods
After planting, use cultivation, flaming, and handweeding in an organically certified crop.

LAYBY

Cultivation
Cultivation will remove weeds from the furrow and sides of the bed. In the intermountain region, cultivate weeds between the 4- to 6- leaf stage. When drying out the field out for cultivation, avoid causing water stress to the crop. Take care to avoid injury to the root system on outside seed lines while cultivating.

Cultivation during the layby period can sometimes stimulate new flushes of weed species such as pigweed.

Herbicides
Pendimethalin is registered for use during the layby period in onion and garlic. It may be applied over the top of the crop and activated with irrigation. It does not control emerged weeds, and are used after cultivation of furrows. Some carryover can occur under certain conditions, creating a plantback problem. Consult the herbicide label before application.

Organically Acceptable Methods
During the layby period, use cultivation and handweeding in an organically certified crop.

PREHARVEST
Late-season weeds can be a problem in onion and garlic fields in the Central Valley, so it may be necessary to impose preharvest weed management efforts. Problematic weeds during this period include nightshade, nutsedge, and field bindweed. Weed growth during this time can increase the relative humidity within the field, increasing the risk of bulb rot. Harvest efficiency can also be hindered as weeds become entangled in the topping and harvest equipment, particularly with field bindweed.

If tall annual weeds (like nightshade) occur in patches in the field, using hand knives to sever the shoot from the roots can be effective. Controlled weeds should be layed in the furrow bottoms or removed from the field so they do not interfere with topping and harvest equipment.

When the weed infestation is widespread across the field, it is more efficient to apply glyphosate as a preharvest aid application. This is effective at drying down weeds like nightshade, nutsedge, and field bindweed, and allows for improved harvest of the crop. Application of glyphosate as a preharvest aid is available for onion and garlic grown for processing under a Special Local Needs [Section 24(c)] registration (see the Herbicide Treatment Table for more information).

SPECIAL WEED PROBLEMS (10/18)

YELLOW SWEETCLOVER AND WHITE SWEETCLOVER

Yellow sweetclover and white sweetclover are usually biennial but are occasionally summer annual or short-lived perennial weeds. They are difficult to control in onion and garlic because none of the registered herbicides will control them. Avoid growing onion or garlic crops in fields known to be heavily infested with these weeds.

NUTSEDGE

Yellow and purple nutsedge are perennial weeds that reproduce from underground tubers, which can survive for several years in the soil. Each tuber contains several buds that are capable of producing plants. Although only one bud germinates at a time to form a new plant, a new bud is activated if a germinated bud or plant is destroyed by cultivation or an herbicide. To best achieve control of nutsedge, use continuous cultivation during a summer fallow period, or rotate to crops where effective herbicide and cultural control methods can be used. Deep plowing with specialized moldboard plows will bury tubers 10 to 12 inches and can significantly reduce nutsedge numbers. Dimethenamid provides partial control of nutsedge if applied before its emergence. Fumigation with metam products does not control purple nutsedge and only partially controls yellow nutsedge.

ANNUAL BLUEGRASS

Annual bluegrass is mainly problematic in organic onion and garlic production. This weed can reach very high numbers in a field and become difficult to control, as cultivation and organic herbicides do not control it. While this weed was previously a problem in conventional production in the lower Colorado Desert, it has become less of an issue because clethodim controls it. In organic systems, management tactics include frequent handweeding or cultivation, preventing the weed from producing seed, using mulches that are several inches thick, and cleaning equipment before moving from infested fields to uninfested fields to prevent new infestations.

DODDER

Dodder is a parasitic weed that can build up in onion fields in the San Joaquin Valley and coastal valley growing areas. Avoid fields with a known history of this weed. Pendimethalin (onion and garlic) suppresses or controls this weed.

GREATER SWINECRESS

Greater swinecress is a winter or summer annual, and sometimes biennial, broadleaf weed. It is a major problem in onion and garlic production in the low desert. Most herbicides registered for onion and garlic do not control swinecress especially in the Imperial Valley. Bromoxynil partially controls swinecress.

LITTLESEED CANARYGRASS

Littleseed canarygrass is a winter annual grass weed has become more of a problem in the low desert in recent years. It has become resistant to many herbicides that are selective to grasses, including clethodim and fluazifop. Napropamide, pendimethalin, and glyphosate control canarygrass. Canarygrass can also be managed by rotating to a crop (such as broccoli) for which other registered herbicides (such as trifluralin) are effective options.

COMMON AND SCIENTIFIC NAMES OF WEEDS

(10/18)

Common Name	Scientific Name
barley, hare	*Hordeum murinum* ssp. *leporinum*
barnyardgrass	*Echinochloa crus-galli*
bermudagrass	*Cynodon dactylon*
bindweed, field	*Convolvulus arvensis*
bluegrass, annual	*Poa annua*
burclover, California	*Medicago polymorpha*
canarygrass	*Phalaris minor*
chickweed, common	*Stellaria media*
crabgrasses	*Digitaria* spp.
cudweeds	*Gnaphalium* spp.
docks	*Rumex* spp.
dodders	*Cuscuta* spp.
fiddlenecks	*Amsinckia* spp.
filarees	*Erodium* spp.
fleabane, hairy	*Conyza bonariensis*
foxtails	*Setaria* spp.
goosefoot	*Chenopodium* spp.
groundcherries	*Physalis* spp.
groundsels	*Senecio* spp.
henbit	*Lamium amplexicaule*
horseweed	*Conyza canadensis*
johnsongrass	*Sorghum halepense*
knotweed, common	*Polygonum arenastrum*
kochia	*Kochia scoparia*
lambsquarters, common	*Chenopodium album*
lettuce, prickly	*Lactuca serriola*
lettuce, prickly	*Eragrostis* spp.
mallow, little (cheeseweed)	*Malva parviflora*
morningglories	*Ipomoea* spp.
mustards	*Brassica* spp.
nettles	*Urtica* spp.
nightshade, black	*Solanum nigrum*
nightshade, hairy	*Solanum sarrachoides*
nutsedge, purple	*Cyperus rotundus*
nutsedge, yellow	*Cyperus esculentus*
oat, wild	*Avena fatua*
panicum, fall	*Panicum dichotomiflorum*
pigweeds	*Amaranthus* spp.
puncturevine	*Tribulus terrestris*
purslane, common	*Portulaca oleracea*
radish, wild	*Raphanus raphanistrum*
rocket, London	*Sisymbrium irio*
ryegrasses	*Lolium* spp.
shepherd's-purse	*Capsella bursa-pastoris*
sowthistles	*Sonchus* spp.
sunflowers	*Helianthus* spp.
sweetclovers	*Melilotus* spp.
swinecress, greater	*Lepidium coronopus*
thistle, Canada	*Cirsium arvense*
thistle, Russian	*Salsola tragus*

SUSCEPTIBILITY OF WEEDS TO HERBICIDE CONTROL (10/18)

	BEN	BRO	CLE	DIM	ETH	FLM	FLU	GLY	MET*	OXY	PAR*	PEN	SET
Mode of Action[1]	8	6	1	15	8	14	1	9	27	14	22	3	3
ANNUAL WEEDS													
barley, hare	P	N	—	C	C	P	C	C	C	P	P	P	C
barnyardgrass	C	N	C	C	P	C	C	C	C	P	P	C	C
bluegrass, annual	C	N	C	C	C	C	N	C	C	P	P	C	N
burclover, California	N	N	N	—	—	P	N	P	N	P	P	N	N
canarygrass	C	N	C	—	C	—	C	C	C	P	P	C	C
cereals	N	N	—	—	C	—	C	C	C	P	P	P	C
chickweed, common	P	N	N	C	C	C	N	C	C	N	C	C	N
crabgrasses	C	N	—	C	P	C	C	C	C	N	C	C	C
cudweeds	N	C	N	—	C	C	N	C	C	N	N	N	N
dodders	N	N	N	—	N	—	N	C	C	N	C	N	N
fiddlenecks	N	C	N	—	C	C	N	C	C	C	P	C	N
filarees	N	P	N	—	P	C	N	P	C	C	P	N	N
fleabane, hairy	N	C	N	—	P	P	N	C	C	P	C	N	N
foxtails	C	N	C	C	C	C	C	C	C	N	C	C	C
goosefoot	P	C	N	—	C	C	N	C	C	C	C	C	N
groundcherries	N	C	N	C	C	C	N	C	C	C	C	P	N
groundsel	N	C	N	—	P	C	N	C	C	C	C	N	N
henbit	N	C	N	—	P	C	N	C	C	C	C	C	N
horseweed	N	C	N	—	P	C	N	C	C	P	P	N	N
knotweed, common	C	P	N	—	C	C	N	C	C	P	P	C	N
kochia	—	C	N	N	C	—	N	C	C	P	P	C	N
lambsquarters, common	P	C	N	C	C	—	N	C	C	C	P	C	N
lettuce, prickly	N	C	N	—	C	P	N	C	C	C	P	N	N
lovegrasses	C	N	—	—	—	C	C	C	C	C	P	C	C
mallow, little (cheeseweed)	N	P	N	—	P	C	N	P	N	C	N	P	N
morningglories	N	C	N	—	C	C	N	C	P	C	P	N	N
mustards	N	C	N	—	N	C	N	C	C	C	C	N	N
nettles	N	C	N	C	P	C	N	N	C	C	P	N	N
nightshade, black	N	C	N	P	P	—	N	C	P	C	C	N	N
nightshade, hairy	N	C	N	P	C	—	N	C	C	C	C	N	N
oat, wild	N	N	C	—	C	C	C	C	C	P	P	P	C
panicum, fall	C	N	—	—	—	—	C	C	C	N	P	C	C
pigweeds	C	C	N	C	P	C	N	C	C	C	C	C	N
puncturevine	N	C	N	—	C	C	N	C	C	C	C	P	N
purslane, common	C	N	N	C	C	C	N	C	C	C	C	C	N
radish, wild	N	C	N	—	N	C	N	C	C	P	C	N	N
rocket, London	N	C	N	—	N	C	N	C	C	C	C	C	N
ryegrasses	P	N	—	C	N	P	C	C	C	N	P	C	C
shepherd's-purse	N	C	N	—	N	C	N	C	C	C	P	N	N
sowthistles	N	C	N	—	C	P	N	C	C	C	P	N	N
sunflowers	N	C	N	—	N	—	N	C	C	C	P	N	N
sweetclovers	N	N	N	—	—	C	N	P	N	P	P	N	N
swinecress, greater	N	N/P	N	—	—	—	C	C	C	C	N/P	—	N
thistle, Russian	N	C	N	—	P	C	N	C	C	P	C	P	N
PERENNIAL WEEDS													
bermudagrass (established)	N	N	P	—	N	N	P	C	P	N	N	N	P
bermudagrass (seedling)	N	N	C	—	—	N	C	C	C	N	P	C	C
bindweed, field (established)	N	N	N	N	N	N	N	P	P	N	N	N	N
bindweed, field (seedling)	N	P	N	—	N	N	N	C	P	N	P	P	N
dock, curly (established)	N	N	N	—	N	N	N	—	C	N	N	N	N
dock, curly (seedling)	P	C	N	—	—	—	N	C	C	C	C	C	N

	BEN	BRO	CLE	DIM	ETH	FLM	FLU	GLY	MET*	OXY	PAR*	PEN	SET
Mode of Action[1]	8	6	1	15	8	14	1	9	27	14	22	3	3
johnsongrass (established)	N	N	C	—	N	N	C	C	C	N	N	N	C
johnsongrass (seedling)	C	N	C	C	C	C	C	C	C	N	C	C	C
nutsedge, purple	N	N	N	—	P	N	N	P	N	N	N	N	N
nutsedge, yellow	N	N	N	P	P	P	N	P	P	N	N	N	N
thistle, Canada	—	—	N	N	—	—	N	P	N	—	N	N	N

C = control P = partial control N = no control — = no information

BEN = bensulide (Prefar)
BRO = bromoxynil (Brox)
CLE = clethodim (Select Max)
DIM = dimethenamid (Outlook)
ETH = ethofumesate (Ethofumesate)
FLM = flumioxazin (Chateau)
FLU = fluazifop-P-butyl (Fusilade)
GLY = glyphosate (Roundup)
MET = metam sodium or potassium* (Vapam, etc.)
OXY = oxyfluorfen (Goal, GoalTender)
PAR = paraquat* (Gramoxone)
PEN = pendimethalin (Prowl)
SET = sethoxydim (Poast)

* Permit required from county agricultural commissioner for purchase or use.

[1] Group numbers are assigned by the Weed Science Society of America (WSSA) according to different modes of action. Although weeds may exhibit multiple resistance across many groups, mode-of-action numbers are useful in planning mixtures or rotations of herbicides with different modes of action.

HERBICIDE TREATMENT TABLE (10/18)

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. **The following are listed alphabetically.** When choosing a pesticide, consider information relating to *environmental impact*, *resistance management*, the pesticide's properties, and application timing. Tank mixes may be necessary to achieve desired control; see *Susceptibility of Weeds to Herbicide Control* for information on specific weed control. Always read the label of the product being used.

PREPLANT

A. GLYPHOSATE
(Roundup PowerMAX) Label rates 4 14
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 9
TIMING: Can be used before planting or after planting, but before the crop emerges.
COMMENTS: **Registered for preplant use in onions (dry bulb and green), garlic, leek, and shallot.** A nonselective, foliar herbicide applied before planting to pre-made beds to kill emerged weeds. Consult the label for specific recommendations on particular weed species. Do not apply to weeds stressed for moisture or weeds with significant dust. For perennial weeds, allow 7 days after application before cultivating.

B. METAM POTASSIUM*§ 174–360 lb a.i.
(K-Pam HL) 30–62 gal See label NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 26
TIMING: Preplant only
COMMENTS: **Registered for use in onion, garlic, and leek.** This fumigant is effective against nightshade and many other weeds. Beds must be free of large clods and the soil should be moistened by rainfall or irrigation before application. Applications are made using a spray blade cutting 2 to 3 inches below the soil surface, depending on soil moisture. Disc hillers follow directly behind the spray blade to form a 3- to 6-inch soil cap over the treated area. Other methods of application include shank and drench application. Fumigants such as metam potassium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone.

C. METAM SODIUM*§ 159.75–319.5 lb a.i.
(Vapam HL) 37.5–75 gal See label NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 26
TIMING: Preplant only
COMMENTS: **Registered for preplant use in onion, garlic, and leek.** This fumigant is effective against nightshade and many other weeds. Beds must be free of large clods and the soil should be moistened by rainfall or irrigation before application. Applications are made using a spray blade cutting 2 to 3 inches below the soil surface, depending on soil moisture. Disc hillers follow directly behind the spray blade to form a 3- to 6-inch soil cap over the treated area. Other methods of application include shank and drench application. Fumigants such as metam sodium are a source of volatile organic compounds (VOCs) but are minimally reactive with other air contaminants that form ozone.

D. PARAQUAT* 0.625–1 lb a.i.
(Gramoxone SL 2.0) 2.5–4 pt 24 Garlic: 200
Onion: 60
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 22
TIMING: Either before planting or after planting, but before the crop emerges.
COMMENTS: **Registered for preplant use in garlic and direct-seeded onions.** A nonselective foliar herbicide that kills emerged weeds. Any crop plants exposed to the spray will be killed, even germinating seed in the crook stage. No residual soil activity. Faster acting on warm, sunny days.

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

POSTPLANT

Before crop and weeds emerge, loop stage (when specified)

A. BENSULIDE — 5–6 lb a.i.
(Prefar 4-E) — 5–6 qt — 12 — NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 8
TIMING: Either preplant or postplant, preemergence.
COMMENTS: **Registered for use on bulb onions, garlic, and shallot, but recommended only for onions in California.** Requires irrigation for activation. See label for optimal soil temperature and salinity conditions for preventing crop damage. Effective on annual grasses and on a broadleaf species such as knotweed, pigweed, and purslane.

B. ETHOFUMESATE — 0.5–1 lb a.i.
(Ethofumesate 4SC) — 16 fl oz (coarse soils) 32 fl oz (medium or fine soils) — 12 — NA
TIMING: General preemergence application.
COMMENTS: **Registered for use in garlic, dry bulb onions, and bulb shallot.** Requires rainfall, sprinkler or furrow irrigation for activation.

C. FLUMIOXAZIN — 3.06 oz a.i.
(Chateau SW) — 6 oz — 12 — NA
TIMING: Must be applied within 3 days after planting for preemergence use.
COMMENTS: **Registered for use in garlic only.** Weed control improves with rainfall or irrigation.

D. GLYPHOSATE
(Roundup PowerMAX) — Label rates — 4 — 14
TIMING: Can be used before planting or after planting, but before the crop emerges.
COMMENTS: **Registered for use in garlic, leek, onion (dry bulb and green), and shallot.** A nonselective, foliar herbicide applied to beds to kill emerged weeds. Consult the label for specific recommendations on particular weed species. Do not apply to weeds stressed for moisture or weeds with significant dust. For perennial weeds, allow 7 days after application before cultivating.

E. OXYFLUORFEN
(Goal 2XL) — Garlic: 1 pt Transplanted onion: 0.5–2 pt — 48 — 60
TIMING: For transplanted onions, apply immediately after transplanting before weeds emerge. For direct-seeded garlic, apply after planting and before crop emergence. For all other crops, do not apply until after crop emerges (see CROP ESTABLISHED).
COMMENTS: **Postplant, preemergence application registered for use in direct-seeded garlic and transplanted (NOT direct-seeded) dry bulb onions.** In a ground application, apply in a spray volume of 40 to 60 gallons per acre for thorough weed coverage. This will also help avoid injury to the crop. Activated by rainfall or irrigation.

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
F. PARAQUAT* (Gramoxone SL 2.0)	0.5 lb–1 lb a.i. Bulb onion: 2–4 pt Seeded onion and garlic: 2.5–4 pt	24	Onion: 60 Garlic: 200

TIMING: Either before planting or after planting, but before the crop emerges. Any crop plants exposed to the spray will be killed, even germinating seed in the crook stage.
COMMENTS: **Preemergence use registered for seeded onions, bulb onion, and garlic.** No residual soil activity. Faster acting on warm, sunny days.

G. PENDIMETHALIN (Prowl H2O)	0.475–1.52 lb a.i. Garlic: 1.5–3.2 pt Onion: 1–3 pt (see Special Labels)	24	60

WSSA MODE-OF-ACTION GROUP NUMBER: 3
TIMING: For dry bulb onions, registered as a delayed preemergence herbicide (75% onion radical emergence) for kochia control in Lassen, Modoc, Shasta, and Siskiyou counties under a special label (EPA SLN No. CA-150008, Exp. Oct. 31, 2020). For dry bulb, direct-seeded onions, also registered statewide for application at the loop stage under a special label (EPA SLN No. CA-060029). For garlic, general postplant, preemergence application.
COMMENTS: Preemergence application **registered for use in garlic and dry bulb onions (see onion specifications above).** Application rates depend on soil type. Requires rainfall or irrigation for activation.

Crop Established

A. BROMOXYNIL (Brox 2EC)	Onion: 0.25–0.375 lb a.i. Garlic: 0.375–0.5 lb a.i. Onion: 1–1.5 pt Garlic: 1.5–2 pt	24	Onion: 0 Garlic: 112 (60 in muck soils)

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 6
TIMING: For onion, chemigate or apply by ground when onions have 2 to 5 true leaves, and only apply it if the onion leaf cuticle has a waxy appearance. For garlic, may be applied any time after emergence before the crop is twelve inches tall. Weeds should not exceed the 4-leaf stage.
COMMENTS: **Postemergence use registered for garlic and dry bulb onions only.** Very good for control of shepherd's purse, mustard species and Russian thistle. Very effective for control of small broadleaf weeds. If applied to plants with thin cuticles, bromoxynil can cause severe crop injury. Foliage needs to be dry at the time of application. Other conditions can lead to crop injury; consult label before application. Can be used in sequence with oxyfluorfen; use lower rates than those listed in tank mixes.

B. CLETHODIM (Select Max)	0.068–0.2425 lb a.i. 9–32 fl oz	24	45

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 1
TIMING: Apply only after crop has 2 or more true leaves.
COMMENTS: **Labeled for use on dry bulb onion, garlic, and shallot.** Controls annual bluegrass in the 2- to 3-leaf stage as well as other annual grasses and some perennial grasses. Do not apply through any type of irrigation system. Always apply with a crop oil concentrate. Rate differs for annual and perennial grasses.

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
C. DIMETHENAMID	0.5625–0.9843 lb a.i.		
(Outlook)	12–21 fl oz	12	30

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 15
TIMING: Apply only after the crop has more than 2 true leaves. If applying to fields infested with yellow nutsedge, apply before nutsedge emerges.
COMMENTS: **Registered for use in garlic only.** Provides control of yellow nutsedge and broadleaf weeds. Most effective when activated by sprinkler irrigation, rainfall, or mechanical incorporation. Amount per acre may be split into two applications rather than one (see label for specifics), but do not exceed a total maximum of 21 fl oz per acre in a single growing season. Maximum rate per season also depends on soil type and organic matter (see label). Use lower rates on coarse-textured soils and higher rates on medium- and fine-textured soils.

D. ETHOFUMESATE	0.5 a.i.		
(Ethofumesate 4SC)	16 fl oz	12	30 (+/-2)

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 8
TIMING: General postemergence application.
COMMENTS: **Registered for use in garlic, dry bulb onion, and bulb shallot only.** Requires rainfall, sprinkler irrigation or furrow irrigation for activation. Controls a variety of broadleaf and grass weeds.

E. FLUAZIFOP-P-BUTYL			
(Fusilade DX)	Label rates	12	45

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 1
TIMING: General postemergence application. Safe to the crop.
COMMENTS: **A selective, foliar herbicide for control of grasses in dry bulb onions and garlic.** Effective at controlling small, annual grass seedlings and some perennial grasses. Later growth stages of annual grasses are more difficult to control. Not effective on drought-stressed grasses or on certain species (e.g., annual bluegrass, foxtail, sprangletop).

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
F. OXYFLUORFEN	0.12–0.25 lb a.i.		
(Goal 2XL)	Label rates	48	Onion: 45 Garlic and onion grown for seed: 60
(GoalTender)	Label rates	48	Onion: 45 Garlic and onion grown for seed: 60

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14
TIMING: In bulb onion only, GoalTender may be used at the 1st true leaf stage under a special local needs label (EPA SLN CA-070006); note that this use is not allowed on onions grown for seed. Otherwise, both Goaltender and Goal 2XL can be used after the onion crop (except crop grown for seed) has 2 fully developed true leaves under the regular label. On onions grown for seed, either product may only be applied when the crop has at least three true leaves. In garlic, either product may be applied when the crop is at least 12 inches tall. Apply when susceptible weeds are in the 2- to 4- leaf stage and actively growing.
COMMENTS: **Registered for use in garlic, dry bulb onions, and onions grown for seed (see above row for stage-specific uses allowed for each crop).** In a ground application, apply in a spray volume of 40 to 60 gallons per acre for thorough weed coverage. This will also help avoid injury to the crop. GoalTender is less active as a burndown herbicide, is most effective on young weeds, and causes less damage to crop foliage than the 2XL formulation. It will control some small annual grasses postemergence. In dry bulb onions, GoalTender may be tank-mixed with other pesticides such as bromoxynil, but such tank mixes must only be used on older onions with well-developed cuticles to avoid unacceptable crop injury. Unacceptable injury may occur if applied to small onions without adequate cuticle development, and in conditions such as after cloudy or rainy weather. Follow the label closely to avoid crop injury when tank mixing.

Oxyfluorfen has some residual soil activity after application. It controls small broadleaf weeds, some grasses, and nightshade, and controls little mallow (cheeseweed) well. **Will damage garlic foliage if it gets on the crop.** Activated by rainfall or irrigation.

G.	PENDIMETHALIN	0.71–1.52 lb a.i.		
	(Prowl 3.3 EC)	1.8–3.6 pt	24	60
	(Prowl H2O)	1.5–3.2 pt	24	60

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3
TIMING: Prowl H2O may be applied to onion and shallot between the 2- and 6- true leaf stages, and applied to garlic when the crop has 1 to 5 true leaves. Prowl 3.3EC may be applied when garlic, onion, and shallots have between 2 and 6 true leaves.
COMMENTS: **For use on garlic, shallot, and bulb onion.** Chemigate or incorporate with sprinklers or a heavy furrow irrigation. Controls many broadleaf weeds and annual grasses. Application rates depend on soil type, with lower rates for coarse-textured soils and higher rates for fine-textured soils; do not use on muck soils.

H.	SETHOXYDIM	0.19–0.28 lb a.i.		
	(Poast)	1.0–1.5 pt	12	30

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 1
TIMING: Postemergence, when grasses are actively growing. Safe to the crop.
COMMENTS: **Registered for use in garlic, leeks, both green and bulb onions, and shallots.** A selective, foliar herbicide for control of grasses. Effective in controlling small, annual grass seedlings and some perennial grasses. Later growth stages of annual grasses are more difficult to control. Not effective on drought-stressed grasses or on certain species (e.g., annual bluegrass, sprangletop).

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

LAYBY

A. PENDIMETHALIN
(Prowl H2O) — Coarse soil texture: 1.5 pt; Medium texture: 2.0 pt; Fine soil texture: 3.2 pt — REI‡: 24 hours — PHI‡: 60 days

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3
TIMING: May be applied to onion and shallot between the 2- and 6- leaf stages, and garlic between the 1st and 5- leaf stages.
COMMENTS: **Registered for use in garlic, bulb onion, and bulb shallot.** Controls many broadleaf weeds and annual grasses.

PREHARVEST

A. GLYPHOSATE
(Roundup PowerMAX) — 22–44 fl oz — REI‡: 4 hours — PHI‡: 30 days
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 9
TIMING: After the last irrigation and before removing the top of the crop.
COMMENTS: **Registered for preharvest use only in onions and garlic grown for processing (dehydration)**, for suppression of nutsedge and field bindweed, under a Special Local Needs label (SLN No. CA-170011, expires August 31, 2022). Apply by ground sprayer equipment only. In addition to nutsedge and bindweed, also effective at drying down nightshade. Avoid contact with the crop; otherwise severe damage may occur.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases the REI exceeds the PHI. The longer of two intervals is the minimum time that must elapse before harvest.

* Permit required from county agricultural commissioner for purchase or use.

1 Group numbers are assigned by the Weed Science Society of America (WSSA) according to different modes of action. Although weeds may exhibit multiple resistance across many groups, mode-of-action numbers are useful in planning mixtures or rotations of herbicides with different modes of action.

PRECAUTIONS FOR USING PESTICIDES

Pesticides are poisonous and must be used with caution. READ THE LABEL BEFORE OPENING A PESTICIDE CONTAINER. Follow all label precautions and directions, including requirements for protective equipment. Apply pesticides only on the crops or in the situations listed on the label. Apply pesticides at the rates specified on the label or at lower rates if suggested in this publication. In California, all agricultural uses of pesticides must be reported. Contact your county agricultural commissioner for further details. Laws, regulations, and information concerning pesticides change frequently. This publication reflects legal restrictions current on the date next to each pest's name.

Legal Responsibility

The user is legally responsible for any damage due to misuse of pesticides. Responsibility extends to effects caused by drift, runoff, or residues.

Transportation

Do not ship or carry pesticides together with food or feed in a way that allows contamination of the edible items. Never transport pesticides in a closed passenger vehicle or in a closed cab.

Storage. Keep pesticides in original containers until used. Store them in a locked cabinet, building, or fenced area where they are not accessible to children, unauthorized persons, pets, or livestock. DO NOT store pesticides with foods, feed, fertilizers, or other materials that may become contaminated by the pesticides.

Container Disposal

Dispose of empty containers carefully. Never reuse them. Make sure empty containers are not accessible to children or animals. Never dispose of containers where they may contaminate water supplies or natural waterways. Consult your county agricultural commissioner for correct procedures for handling and disposal of large quantities of empty containers.

Protection of Nonpest Animals and Plants

Many pesticides are toxic to useful or desirable animals, including honey bees, natural enemies, fish, domestic animals, and birds. Crops and other plants may also be damaged by misapplied pesticides. Take precautions to protect nonpest species from direct exposure to pesticides and from contamination due to drift, runoff, or residues. Certain rodenticides may pose a special hazard to animals that eat poisoned rodents.

Posting Treated Fields

For some materials, *restricted entry intervals* are established to protect field workers. Keep workers out of the field for the required time after application and, when required by regulations, post the treated areas with signs indicating the safe re-entry date. Check with your county agricultural commissioner for latest restricted entry intervals.

Preharvest Intervals

Some materials or rates cannot be used in certain crops within a specified time before harvest. Follow pesticide label instructions and allow the required time between application and harvest.

Permit Requirements

Many pesticides require a permit from the county agricultural commissioner before possession or use. When such materials are recommended, they are marked with an asterisk (*) in the treatment tables or chemical sections of this publication.

Maximum residue levels

Before applying pesticides to crops destined for export, check maximum residue levels (MRLs) of the importing country.

Processed Crops

Some processors will not accept a crop treated with certain chemicals. If your crop is going to a processor, be sure to check with the processor before applying a pesticide.

Crop Injury

Certain chemicals may cause injury to crops (phytotoxicity) under certain conditions. Always consult the label for limitations. Before applying any pesticide, take into account the stage of plant development, the soil type and condition, the temperature, moisture, and wind. Injury may also result from the use of incompatible materials.

Personal Safety

Follow label directions carefully. Avoid splashing, spilling, leaks, spray drift, and contamination of clothing. NEVER eat, smoke, drink, or chew while using pesticides. Provide for emergency medical care IN ADVANCE as required by regulation.

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