

Crop Profile for Garlic in Washington

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General Production Information



- Washington State ranks fourth in the United States in both the number of farms growing garlic and in harvested acres (1).
- Garlic acreage has increased substantially in Washington in recent years. Most of this increase has taken place in the eastern portion of the state.
- Approximately 90 farms in Washington grew garlic on a total of 414 acres in 1997 (1). Seventy-nine of these farms were irrigated.
- In addition to bulbs grown for the fresh market, garlic is also grown in Washington for seed and dehydration.
- Typical fresh market garlic yields range from 6,000 to 18,000 lbs. per acre.

Production Regions

Commercial garlic is produced in many Washington counties, much of it by small-scale growers. The leading counties are Klickitat, Okanogan, Thurston, and Yakima. Other counties where garlic is grown include Grant, King, Pierce, and Spokane.



General Information

Garlic (*Allium sativum* L.) is an ancient crop that originated in Central Asia. It has been grown for culinary, medicinal, and religious purposes for several millennia. Garlic is grown for its edible bulbs, which are composed of a number of cloves. The bulbs can be eaten fresh, cooked in various ways, processed into a dehydrated product, or

saved for seed to be planted later. Garlic leaves and flower stalks are also edible.

Garlic can be profitably produced in both large or small-scale commercial production systems in the temperate climate of the Pacific Northwest. Current garlic varieties respond to both the temperatures and photoperiod of the latitudes in Washington, and some clones are already adapted to these climates.

Types of Garlic

There are two general categories of garlic, softneck and hardneck. Both are produced commercially, but most of the garlic grown in Washington is softneck. While both types begin growth with leaf production, the hardneck types produce flower stalks, called scapes, by mid- to late-spring. The scapes extend, grow, and coil during early growth, then as the plant matures the scapes straighten out. Numerous classification schemes of the hardneck types have been proposed in the scientific literature and/or popular press based on clove configuration, clove size, and bulb wrapper skin coloration.



Cross-section of Korean Six-Piece garlic variety.

Hardneck garlics are represented by varieties that may be red, purple, purple-striped, or white. With some of these varieties, the scapes are often topped with a cluster of small round propagules called bulbils, which are also referred to as topsets. In general, hardneck garlic bulbs contain fewer, but considerably larger, cloves than bulbs of the softneck types.



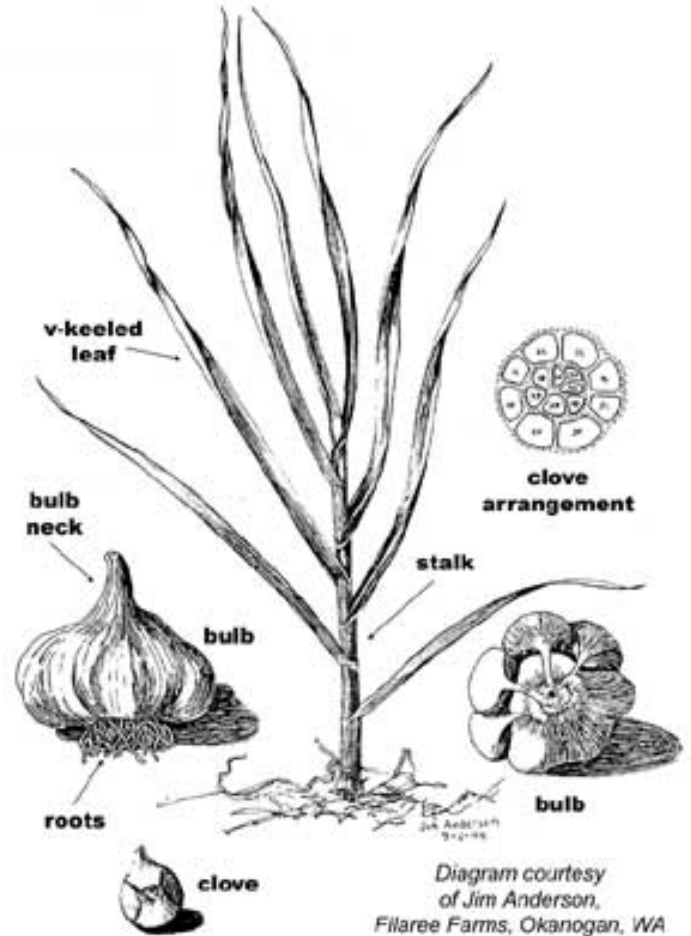
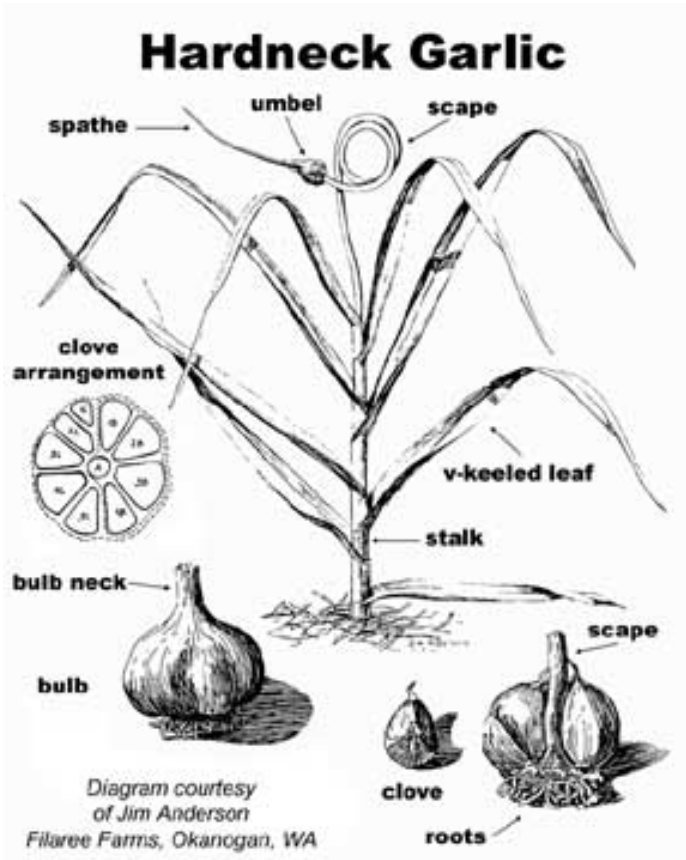
Garlic stalks or “scapes” with topsets.

The softneck garlics are often referred to as silverskin or artichoke garlic, and are most commonly represented by the varieties “California Early” and “California Late.” Silverskin garlic may also be differentiated into many-cloved or few-cloved varieties. The bulbs are usually all white, but can be purple-tinged. Numerous strains of these exist, having been selected over the years by the various companies that produce them for dehydration or growers producing them for fresh market.

It should be noted that a garlic relative, elephant garlic, is often grown for commercial production. Elephant garlic is a different species, *Allium ampeloprasum*, than garlic, and is not true garlic, but a type of leek that produces very large cloves, often only three or four per bulb. Several small bulblets may also develop on the bulb. It produces a large scape and umbel (flower head) that may be cut and sold to florists. In the spring, the tender lower portion of the scape is also used for fresh vegetable dishes.

Garlic is relatively easy to grow and can be a profitable crop for large- and small-scale growers. However, profitability in garlic requires good yields and high quality. Because of the cost of seed and labor, garlic is a relatively expensive crop to grow. Garlic weed control is largely manual, therefore labor-intensive, and many small-scale growers use hand labor for planting and harvesting as well.

Softneck Garlic



Planting stock

Many garlic cultivars are grown commercially in Washington State. Some large-scale growers grow “California Early” and “California Late.” While both are considered softneck, “California Late” often produces scapes under Washington State growing conditions. Small-scale growers often prefer hardneck types. “Asian Tempest,” “Chet’s Italian Red,” and “Music” are among the cultivars planted by small-scale growers.

Garlic is responsive to temperature and photoperiod for proper clove and bulb formation, and subsequent scape development of some varieties. Because of this, significant differences in yield can occur, even with plantings of the same variety.

Growers emphasize selection of clean, disease-free garlic lines adapted to the area of production. Bulbs and cloves used for planting can carry and transmit diseases such as white rot, basal rot, and possibly gray mold. *Penicillium* is a fungus that can cause a decay of the seed cloves and reduction of the stand. Other important pests that can be carried on the seed cloves include several species of nematodes, such as the stem and bulb nematode. Some of these diseases and pests may contaminate the soil and make the fields unusable for future garlic and onion production.

Garlic for seed purposes is stored at 50°F with a relative humidity (RH) of 55 to 65%. Garlic cloves break dormancy

and sprout most rapidly at 40 to 50°F; hence prolonged storage at this temperature range is avoided. Storage of planting stock at temperatures below 40°F may result in rough bulbs, side-shoot sprouting, and early maturity. Storage above 65°F may result in delayed sprouting, late maturity, or accelerated desiccation of bulbs.

Cultural Practices

Soil Preparation

Garlic will grow in almost any well-drained, friable soil. Friable soils with good organic content allow the bulbs to expand without becoming misshapen and aid in the soil's water-holding capacity, which is important due to the relatively restricted rooting characteristic of garlic. Soils must have a pH above 6.0. The ideal pH for garlic is between 6.5 and 7.0.

Growers have the soil tested for nutrients for each field planted in order to best determine the fertility needs. The amount of nitrogen and irrigation used will directly affect not only the yield, in terms of bulb size, but also can affect disease susceptibility and post-harvest storability. A baseline recommendation for production in Washington is 150 lbs. nitrogen per acre (N/A) and 15 lbs. sulfur per acre (S/A), plus potassium and/or phosphate as needed. Growers apply 50 lbs. N/A and 5 lbs. S/A at planting in the fall. They make a second nitrogen application in early spring when the garlic begins to grow again, then a final application in early to mid-June. Some growers successfully combine the last two fertilizer applications into one, but it is recommended to split the last 100 lb. N/A into at least two applications. It has been reported that witches brooming can result from using too much manure or high levels of nitrogen during the winter.

Planting

For maximum yield of fresh market garlic, growers plant in the fall, from mid-September to mid-October. Both softneck and hardneck varieties generally survive the harsh winters of eastern Washington, when the planting is done at least four to six weeks before the ground freezes. Planting can also be done in early spring, albeit with some loss of yield potential. In western Washington, garlic is planted in late fall (e.g., November) or very early spring (e.g., March) (2). Some cultivars may produce a high percentage of unmarketable "rounds," bulbs composed of a single clove, when planted in the spring (3).

Optimally, the seed bulbs should be "cracked" or broken into cloves no more than a few days before planting, although this can be done up to ten days before planting without any real adverse affect. Cracking in Washington State is generally done by hand, however, in the case of large-scale operations, machines with rubber-faced rollers are used to speed up the process. Regardless of the method used, it is important to avoid doubles and not to damage the cloves when cracking the bulbs. Doubles produce misshapen bulbs. Injured cloves are more prone to infection by disease organisms. Cloves, regardless of size, will produce garlic plants, but there is a definite correlation between the size of the clove and, under proper growing conditions, the size of the bulb harvested. It is common for growers to select the largest, most healthy cloves from large, healthy bulbs for planting.

It has been shown that there is a definite effect of clove orientation at planting on the total yield and quality of bulbs harvested. Cloves should be planted vertically, with the basal root plate down. This is optimum, but if cloves are planted with a mechanical planter, like a cone drill, and do end up lying horizontal, the emerging plants will often right themselves in the early growth stages. Studies conducted with three cultivars in the Columbia Basin showed that planting garlic cloves upright or sideways resulted in the highest plant stand and the greatest yield (3). When planting by hand, growers find it is worthwhile to take care to plant cloves upright. Cloves planted upside-down were found to be slower to emerge and produced bulbs that were smaller and tended to be deformed.



Upright (left) and inverted (right) garlic bulbs



Cloves are planted two to three inches deep on a 2- to 4-inch spacing in the row. The size of the field, irrigation system, and cultivation equipment and practices dictate the row configuration. Garlic can be successfully planted and grown on double plant-row raised beds, in single rows on the flat, or in a dense planting matrix. In central Washington, raised beds, 36-40 inches from center to center, with two rows per bed are commonly used. The rows are spaced about 12 inches apart.



Garlic planted in double rows on raised beds

Irrigation

Garlic can be successfully grown using furrow, sprinkler, or drip irrigation. Because garlic has a relatively shallow root system, it is sensitive to moisture stress throughout the growing season. A straw mulch can help retain soil moisture. Garlic growers typically plant into moist soil. For fall-seeded garlic in eastern Washington, one watering may be necessary before winter if the soil becomes dry. Irrigation resumes in the spring. In western Washington, irrigation may be required in May, June, and July (2). Irrigation is continued until the bulbs reach the desired size and have two to three matured scales surrounding the bulb. Garlic should not be irrigated once the tops dry and begin to fall to the ground.

Scape Removal

Although most garlic growers do not remove scapes, some data suggests a positive yield response to scape removal with hardneck types. In trials conducted by WSU Cooperative Extension in the Columbia Basin, scape removal, or “topping” as it is sometimes called, was useful in increasing bulb size and hastening maturity (4). If removing the scapes is planned, the best results come from cutting the scapes just above the top leaf whorl when they reach the full-coil stage. If growers wait until the scapes have fully elongated and are straight, the increase in yield is negligible. If an early harvest is desired, the removal of scapes will hasten the senescence or death of the leaves. Additionally, tender scapes can be used as a high-value, seasonal fresh market produce product.



Removing garlic scapes.

Harvest

Depending on the type of garlic being produced and growing conditions, yields can range up to 18,000 lbs. per acre. Typical harvest dates in central Washington range from early July through mid-September, although harvest can occur slightly earlier or much later. Garlic is harvested when the lower leaves are half to three-quarters brown, and there are still some partially green upper leaves. If a grower waits until all of the leaves are brown, the wrapper leaves of the bulb will deteriorate, leaving a naked bulb. This is especially true of the hardneck types, where the cloves will also pull away from the scape, thus resulting in an unmarketable product. In general, spring-planted garlic

must be harvested later in the year than fall planted crops.

Garlic is lifted from the soil without bruising or cutting the bulbs. In medium to small-scale production operations, gathering the plants from the field is done by hand. During this process, workers do not bang the soil off the roots, but give the bulb a quick hand rub or a shake to get the soil off, leaving an uninjured bulb and one to two inches of roots. Although some growers wash the bulbs soon after digging the crop, this not necessary. Bulbs cannot be left in the field under the sun to dry out as they will get sun scald or may exhibit greening from excessive sunlight. The crop is removed from the field and cured in a shady, well-ventilated location. Plants can be bundled and hung, put loosely in net bags and hung, or laid out on screen shelving to dry.

Most growers wait until the crop has cured and dried adequately before cutting the tops and roots, generally by hand. About one inch of stem and a half inch or so of roots are left on the bulb, which helps prevent infestation by a number of storage diseases.

Garlic grown on a large scale or for dehydration is typically harvested by machine. The dried tops may be burned off using propane flaming. Flailing is also used to remove the tops after which the bulbs are lifted using equipment such as potato diggers. As with hand- harvested garlic, the bulbs are generally allowed to cure in the field for one to two days. The bulbs are then harvested into trucks and loaded into bins for storage and shipping to intended markets.



**Mechanized garlic harvest
for dehydration.**

Storage

Depending upon the type, well-cured and well-cleaned garlic bulbs can be kept in storage for up to 12 months. For long-term storage of clean, dry bulbs, most references recommend temperatures between 30-32°F and low (60-70%) RH. If freezing storage facilities are not available, it has been shown that many cultivars of garlic will store seven months or more at 55- 58°F and 55-60% RH in conditions with good air circulation. When garlic is chilled at temperatures between 35-50°F, dormancy is broken and the cloves begin to sprout, especially under high RH conditions. High humidity conditions also promote the growth of storage pathogens and promote post-harvest diseases.

Weeds

Weeds are a major concern for farmers wherever garlic is grown. Garlic requires nearly perfect weed control since it emerges slowly and never forms a canopy with its short, vertical leaf arrangement (8). The long growing season required for garlic production subjects garlic to competition from successive flushes of weed growth. When planted in the fall, garlic must compete with winter annuals in the fall and winter and with spring and summer annuals in the following year.

Numerous weed species are troublesome in eastern and western Washington. Among the common annual broadleaf weeds are lambsquarters (*Chenopodium album*), Russian thistle (*Salsola iberica*), kochia (*Kochia scoparia*), mustards (*Brassica* spp.), shepherdspurse (*Capsella bursa-pastoris*), and pigweeds (*Amaranthus* spp.). The most important annual grass weeds are annual bluegrass (*Poa annua*) and barnyard grass (*Echinochloa crus-galli*). Canada thistle (*Cirsium arvense*), field bindweed (*Convolvulus arvensis*), and quackgrass (*Agropyron repens*) are widespread perennial weeds. Volunteer potato and cereal crops can be troublesome weeds in fields where these crops are grown in rotation with garlic.

Weeds reduce yields of garlic by direct competition for nutrients, water, and space. Large weeds can reduce air movement in garlic fields, increasing the risk of diseases such as neck rot. Heavy weed growth also slows the drying down of foliage prior to harvest. In general, harvesting operations are more difficult in fields where weeds have not been properly controlled.

Cultural Control

Cultivation is a key component of weed control in all garlic fields in Washington State. Most garlic growers cultivate at least once during the growing season in addition to the cultivation that takes place when the field is prepared for planting. Mechanical cultivation is the preferred method on large fields. Typical cultivation equipment includes cultivators with knives or small disks. Finger weeders are also used where garlic is planted in single rows. This piece of equipment works best when the ground is relatively soft and the garlic has established an adequate root system. Shallow cultivation is preferred, both to avoid disturbing the root system of the garlic plants and to prevent weed seeds that are buried deeply from being brought to the surface. On small fields, growers often rely on hand weeding. Hand weeding is used sparingly on large fields, primarily to control large weeds that have escaped other methods of control.

Some small-scale growers use mulch as a component of their weed control program. In addition to suppressing weeds, mulch can also serve to conserve soil moisture and provides some degree of protection from severe cold in the winter.



Some small-scale growers use mulch to help control weeds

Flaming is also used on a limited scale for weed control in garlic. In organic production, flaming is done pre-emergence to reduce the need for hand weeding. Organic growers prepare the field so that as many weeds as possible emerge before the crop. Successful weed control in garlic requires an integrated approach utilizing a variety of techniques.

Chemical Control

Relatively few herbicides are registered for use on garlic. In general, growers recognize that weeds are easier to control when small. Cool soil and air temperatures in the fall can reduce the efficacy of some herbicides. A common herbicide combination is a broadleaf herbicide, such as bromoxynil, plus a grass herbicide, such as sethoxydim or fluazifop. Mechanical cultivation and hand weeding are almost always used in conjunction with herbicides for control of weeds in garlic.

Chemical	Target Weeds	Application Rate	Timing
glyphosate (Roundup and others)	Annual grasses and broadleaves and some perennials	Rate depends on target weed	Pre-emergence
pendimethalin (Prowl)	Annual grasses and broadleaves	0.75 to 1.5 pounds AI per acre, rate depends on soil texture, lower rates are used on coarse textured soils	Pre-emergence or post-emergence

bromoxynil (Buctril and others)	Broadleaf weeds	0.25-0.38 pounds AI per acre, applied when weeds <4" tall and garlic <12" tall	Post-emergence
fluazifop (Fusilade DX)	Annual grasses and some perennial grasses	Rate depends on target weed	Post-emergence
sethoxydim (Poast)	Annual grasses and some perennial grasses	0.19 to 0.2 pounds AI per acre	Post-emergence

Diseases

White Rot

Sclerotium cepivorum

White rot, caused by *Sclerotium cepivorum*, is a key disease of garlic in Washington. Although not currently present in all parts of the state, the seriousness of white rot makes it a concern for the entire industry. Once introduced into a field, the sclerotia may survive for 20 to 30 years without the presence of an *Allium* host. Fungal activity is favored by cool soils and is restricted above 75°F. Only *Allium* spp. are attacked.

Leaves decay at the base, turn yellow, wilt, and topple over (5). Older leaves collapse first. Roots are rotted, and the top of the plant can be pulled out of the ground easily. Roots and bulb may be covered with a fluffy white mycelium. Affected bulbs may become watery, and the outer scales crack as the bulb dries and shrinks. Small black sclerotia form on and in affected bulb parts.

Cultural Control

Growers plant only disease-free cloves and plant in only disease-free soil. They use sanitation to avoid introducing white rot via contaminated soil carried in on equipment or shoes.

A white rot quarantine area exists in Adams, Franklin, and Grant counties. This regulation prohibits the importation of vegetative planting material of onion, garlic, leek, chives, shallots, and other *Allium* spp. except those produced in and shipped from a white-rot-free area and certified to be free of white rot.

Chemical Control

Chemicals are not used by growers to control white rot. Under most conditions, even the best chemicals control only a portion of the disease, and soils become useless for the production of garlic and other *Allium* spp. Exclusion is the best way to control white rot. Once this disease is established in a field, it is very difficult to grow any *Allium* spp. successfully.

Basal Rot

Fusarium culmorum

Basal rot of garlic is caused by *Fusarium culmorum*. Soilborne inoculum infects garlic through the stem plate rather than through roots or storage leaves (5). Leaves of infected plants may not produce disease symptoms, but can be a source of the disease. Transmission can occur when infested soil or debris is transported on equipment, seed, or runoff water. The fungus can survive indefinitely in the soil. *Fusarium culmorum* can also infect elephant garlic, but not to the same degree as garlic. Onion is not a host.

Symptoms include pre-emergence decay of cloves and seedlings. Stem plates and storage leaves may decay in the field during the growing season. Lesions may have a reddish fringe. Disease expression is erratic from year to year and field to field. Post-harvest decay may involve a single clove or the entire bulb.

Cultural Control

Growers commonly rotate garlic with non-host plants to reduce disease pressure. Cereals are a host of strains of *F. culmorum*. Growers also avoid planting in fields with a history of basal rot problems.

The primary cultural control of basal rot is curing bulbs properly before storage and storing the garlic at cool temperatures, as *Fusarium culmorum* is favored by warm conditions.

Chemical Control

Garlic growers in Washington seldom use chemicals to control basal rot.

Blue Mold Rot

Penicillium spp.

Several species of *Penicillium* can cause blue mold rot in garlic. Infected bulbs are covered with characteristic blue-green spores and entire cloves may be filled with spores (5). Infected cloves fail to emerge after planting. Blue mold rot can also infect elephant garlic and, occasionally, onions.

The fungus does not survive long in the soil and is generally transmitted on seed cloves. Infection first occurs on wounds sustained when cloves are separated from the parent bulb. Blue mold is one of the most common storage diseases of garlic.

Cultural Control

Bulbs are harvested carefully to avoid wounds and bruising, then promptly dried or cured. Growers plant cloves promptly after cracking to minimize blue mold infection.

Chemical Control

Growers do not use chemical control for blue mold rot as cultural controls are sufficient at present.



Blue mold rot in garlic is caused by various *Penicillium* species

Leaf Blight

Botrytis squamosa

Several different *Botrytis* diseases occur in Washington State garlic. *Botrytis squamosa* causes leaf blight on garlic. Onions are also susceptible. This disease is generally a problem only late in the season under conditions of high humidity, excessive rain, or irrigation (5). The fungus can overwinter in cull piles or in the soil and spores are spread by the wind.

Leaf spots appear as small circular-to-elliptical, grayish-to-white lesions with a green halo. Under conditions of high humidity, the spots may enlarge, blighting the leaves.

Cultural Control

Growers generally rotate garlic with non-host crops, avoid excessive irrigation, and destroy garlic and onion cull piles.

Chemical Control

Several chemicals are registered for use on garlic, but growers seldom use fungicides to control leaf blight. Damage is generally not severe enough to warrant the use of chemical sprays.

Neck Rot

Various species including *Botrytis porri* and *B. aclada*

The fungus organisms that cause neck rot, including *Botrytis porri* and *B. aclada*, survive the winter as sclerotia on dead plant parts in the soil and on infected bulbs. Infection occurs through neck tissue or through wounds. In garlic, neck rot is generally a more serious problem than is leaf blight.

Symptoms may first appear on the neck of the plant near the soil line in the spring. The fungus moves rapidly into the neck region of the bulbs causing a water-soaked appearance. A gray mold develops on the surface, later producing black sclerotia. Before bulbing, plants may die or recover depending on weather conditions. Bulbs infected late in the season break down and are often infected by other disease organisms.

Cultural Control

Growers avoid excessive nitrogen and irrigation, especially late in the season. They practice good weed control to aid air movement through field and to keep relative humidity low. When harvesting, growers allow tops to mature, then lift or undercut plants to avoid bruising and mechanical injury. Finally, they make sure that the garlic is properly cured before storing.

Chemical Control

Fungicides are not generally used by growers against neck rot, as cultural methods control the disease at this time.

Stem and Bulb Nematode

Ditylenchus dipsaci

A race of the stem and bulb nematode, *Ditylenchus dipsaci*, has been recently found in Washington State. They are spread primarily through infected planting material. The nematode can live in stored plant tissue for at least nine years, but they decline rapidly in soil (5). Hosts for the garlic strain of stem and bulb nematode include garlic, onion, leek, and chive.

Diseased cloves generally show no symptoms, but the presence of nematodes can be detected by examining tissue with a microscope. In the field, leaves become yellow and dry prematurely. Plants can be stunted. The whole bulb may separate from the basal plate. High temperatures bring on symptoms quickly.

Cultural Control

Growers strive to plant only nematode-free cloves. They rotate garlic with non-host crops and eradicate volunteer garlic plants from fields by cultivation or application of glyphosate (see [Weeds](#) section, above).

Planting seed that has been treated with hot water (a treatment also useful for control of bulb mites) has proven effective for some growers.

Chemical Control

There is a Section 18 special local needs label (WA-000018) for oxamyl (Vydate) for control of stem and bulb nematodes on garlic in Washington State, valid through 12/31/05.

Chemical	Application Rate	Preharvest Interval
oxamyl (Vydate L)	2 to 4 quarts per acre at planting as in-furrow spray or post-emergence at 2 to 4 quarts in 20-40 gallons of water per acre in a 1-2" band	14 days

Viruses

Viruses, which can reduce yield and quality, are a widespread problem on garlic grown in Washington State. Numerous viruses infect garlic, such as onion yellow dwarf virus and garlic mosaic, but few have been studied to any great extent, and there are no assay methods currently available. Although virtually all planting material contains virus, infections are usually mild. Virus-free planting stock can be obtained only through tissue culture. In the field, aphids and thrips are possible vectors, transmitting virus from infected to healthy plants.

Symptoms include changes in color, mosaic, striping, streaking, and leaf distortion. Infections may not produce visible symptoms or yield loss unless the plants are stressed. Plants may become stunted and bulb size reduced, especially when under stress from soil moisture or low fertility.

Cultural Control

Only large, healthy cloves are planted. Plants exhibiting severe virus symptoms in the field are rogued out. Good soil fertility and proper soil moisture are maintained during the growing season to avoid plant stress.

Chemical Control

Growers do not treat with chemicals to control viruses; they rely on cultural controls to keep the plants healthy.



Garlic plants showing virus symptoms (leaf striping)

Insects and Related Pests

Bulb Mites

Rhizoglyphus spp. and *Tyrophogus* spp.

Bulb mites are shiny, cream-colored creatures with four pairs of short brown legs. They have a wide host range that includes onions. Bulb mites can be introduced into a field on infested cloves and can survive on decaying vegetation in the field after harvest.

Damage results from bulb mites penetrating the outer layer of bulb tissue allowing the entry of disease organisms. Bulb mites can reduce stands of garlic, stunt plant growth, and promote rot in stored bulbs.

Cultural Control

Growers plant only mite-free cloves. Hot water treatment is occasionally employed to reduce chances of infestation. They also allow the fields to lie fallow for natural breakdown and decomposition of crop residue. Mite numbers can increase on green manure crops. Avoid planting successive onion or garlic crops.

Chemical Control

Soil fumigation with metam sodium (Vapam or Sectagon) can reduce bulb mite numbers, however, soil fumigation is rarely used for garlic. Some growers plant garlic following a crop such as potatoes or carrots that was fumigated.

Thrips

Frankliniella occidentalis and *Thrips tabaci*

Thrips are small, slender insects. Western flower thrips, *Frankliniella occidentalis*, are typically more abundant in fields than onion thrips, *Thrips tabaci*. Adults are pale yellow to light brown in color, with feathery wings (7). It is very difficult to distinguish between these two pests without using a dissecting microscope. Young thrips, called nymphs, are pale yellowish-green and wingless. Thrips thrive in hot, dry conditions and are more damaging when such conditions persist for much of the growing season. These insects have a wide host range, including cereals and broadleaf crops. Generally thrips are a more serious pest of onions than of garlic. Both adults and nymphs feed on foliage. When foliage is severely damaged, it becomes scarred and silvery in color. Yields can be reduced.

Cultural Control

Growers avoid planting garlic near cereals, as thrip populations build up in cereals in the spring and migrate to nearby fields. Some growers find that overhead irrigation provides a measure of suppression.

Chemical Control

Insecticides, such as lambda-cyhalothrin (Warrior T, applied at 0.02 to 0.03 lbs. ai/A) and zeta- cypermethrin (Mustang, applied at 0.0375 to 0.05 lbs. ai/A), are used only when thrip populations are high and damage is evident. Resistance to organophosphate and pyrethroid insecticides has been noted in Western flower thrips.

Wireworms

Limoni spp.

Wireworm is a pest of many crops in Washington, including garlic. The larvae, which can live in the soil for two to

six years, are jointed, light brown in color, and about one inch in length when fully grown (7). They feed on bulbs and can destroy the crop. The adults, known as click beetles, do no direct damage.

Cultural Control

Crop rotation is an important practice in controlling wireworms (7). Populations tend to build up in fields where grains or vegetable crops are grown. Weedy conditions also favor wireworms. When possible, growers select fields with no history of wireworm problems.

Chemical Control

Soil fumigation with dichloropropene (Telone II) can reduce wireworm numbers, however fumigation is seldom used for garlic. Some growers plant garlic following a crop that was fumigated, such as potatoes or carrots.

Pest Control Issues

Garlic growers in Washington State integrate a wide variety of cultural methods into their pest management systems. Field selection, crop rotation, and the use of vigorous, pest-free planting material are critical components for a successful garlic crop. The chemical methods mentioned are important for situations where disease pressure is great. Generally speaking, large-scale growers rely on chemicals to a greater degree than do small-scale growers.

While many growers do not treat for diseases or insect pests, herbicides are widely used in conjunction with mechanical cultivation and hand weeding. The most common and successful herbicide application combines a broadleaf herbicide with a grass herbicide. With very few herbicide choices registered for garlic, it is important that growers have glyphosate, pendimethalin, bromoxynil, fluazifop, and sethoxydim available to them.

Diseases play a role in Washington garlic production as well. More pressure exists on the west side of the state where conditions are wetter and in garlic grown for planting stock. These segments of the industry need fungicides they can rely on. Planting stock garlic undergoes more intensive disease management than garlic for the fresh or processing markets, as it is important to ensure clean seed (9). Oxamyl for stem and bulb nematode control is generally used only on garlic grown for seed, and is therefore a critical component of this segment of the industry.

At present, white rot is not a widespread problem, but this disease can be devastating to the prospects of growing any *Allium* spp. Resistant cultivars and/or a fungicide effective against white rot would be a useful addition to future pest control tools.

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