Garlic: Organic Production

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Contents

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Garlic is a cool-season crop grown in most regions of the U.S. This publication addresses most aspects of organic garlic production, including seed sources, organic fertility management, pest management and harvesting and storage. Marketing and economic considerations, including enterprise budgets for organic garlic production, are also addressed in this publication. A resource and reference section follows the publication.

Introduction

Cultivated garlic, *Allium sativum*, is a member of the lily family. It may be divided into two subspecies: *Allium ophioscorodon* (bolting or hard-neck cultivars) and Allium sativum (non-bolting or soft-neck cultivars). *Allium ophioscorodon* produces elongated flower stalks, often referred to as scapes, and flower-like bulbils at the top of the stalk. Soft-neck garlic does not produce bulbils except in times of stress. While both bulbils and individual cloves can be propagated vegetatively, bulbils take longer—up to two seasons—to produce mature bulbs, and require special care because the young plants are very small and fragile.

Elephant Garlic

Even though elephant garlic, *Allium ampeloprasum,* is not considered a true garlic, we will address its production in this publication. Closely related to the leek, elephant garlic produces a very large bulb of cloves with a mild garlic flavor (Engeland, 1991).

Elephant garlic usually is grown the same way as a hard-neck/ bolting garlic, except that these big bulbs are planted farther apart. It is a specialty for people who want a milder garlic or who need a larger clove due to reduced dexterity or arthritis. This allium is much less productive (an in:out ratio of 1:3) than true garlics and must be sold at a higher price. Also the plant is less winter hardy than all common garlic cultivars and the bulbs will not keep as long, so it is not recommended in climates with very cold winters. (Gough, 1999)

Hard-neck cultivars like Rocambole and Porcelain usually do better in colder climates. The cloves are larger and easier to peel. A few of these variety names are 'Spanish Roja,' 'German Red,' 'Carpathian,' and 'Music.'

Soft-neck garlic cultivars (Silverskin or Artichoke) are not recommended for northern climates. Numerous strains exist, having been selected over the years by the various companies that produce them for dehydration, or by growers producing them for the fresh market. Mechanized farms grow and develop cultivars of soft-neck garlic because the planting process can be mechanized. Since they don't produce a scape (flower stalk), the cloves can be planted upside down. Topsetting (hard-neck) garlic cloves must be set upright. There are fewer

cultivars of soft-neck garlic, compared to topsetting. The varieties 'California Early' and 'California Late' comprise 90 percent of the soft-neck types grown commercially.

Organic Garlic Production

Garlic is well adapted for production in most parts of the temperate U.S. Yield and quality vary with climate, region, altitude, soil and pH, cultural practices, and variety of garlic. The term "biological elasticity" describes garlic's ability to acclimatize to these factors over time. That is, the same variety can look, taste, or produce differently depending on its geography, altitude, etc. No one practice is best suited for every situation. You will want to talk with other garlic growers in your area and experiment with different cultural practices and varieties to discover the best combination for your operation.

Related ATTRA Publications

Organic Allium Production

Overview of Organic Crop Production

Sources of Organic Fertilizers and Amendments

Sustainable Soil Management

Certain considerations and practices in garlic production will be the same for both organic growers and conventional growers within a given region. For instance, site selection and planting techniques are similar for both conventional and organic garlic culture. Information on these topics is available through the Cooperative Extension Service, the garlic growers associations, and common vegetable and herb texts, bulletins, and trade magazines. See the **Further Resources** section for a list of these. Accordingly, this publication focuses primarily on organic management practices for pests, diseases, and weeds, and fertility, and seed sources specific for organic production.

Seed Sources

Although garlic is listed in many commercial seed catalogs, "Buy local!" is the advice from David Stern of the Garlic Seed Foundation. (Stern, 2001) If you buy from out of state, it will take a couple of years for the garlic to acclimatize itself, due to the biological elasticity mentioned above. David says there is an ongoing debate about varieties, and recent research with a northeastern SARE project is working to clarify this. See "Genetic Diversity of Garlic" by Stern and Volk for more information on this project. It wasn't until 2003 that Dr. Gayle Volk of the USDA Agricultural Service ran DNA analysis on several large garlic collections and determined that there are 10 separate garlic types. Growers throughout the U.S. are now participating in a national project by growing each of these cultivars in different regions to determine which varieties perform well under their growing conditions, and to come up with descriptors to publicize these types of garlic to their customers (Stern and Volk, 2007). While many producers are concerned with yields, other factors such as consistency, growth characteristics, and market preference are equally important. David advises that growers experiment to find which varieties work best in their particular climates and soils.

We do not recommend buying garlic for planting from the produce section of a grocery store. It has often been treated to prevent sprouting and is not grown regionally.

You can find garlic planting stock at the following sources.

1) Local farmers at farmers' markets or roadside and farm stands. Select only large, disease-free bulbs for planting.
2) Garlic Seed Foundation list, sent on request if you furnish a stamped self-addressed envelope. See "Further Resources" section below for contact information.
3) Other seed-saver organizations, such as Seed Savers Exchange, Southern Exposure Seed Exchange, and Native Seed Search. See "Further Resources."
4) Commercial seed catalogs.
5) Internet.

Many farmers will initially source their garlic seed from one of the sources listed above and then sell only what they do not intend to plant for the following season. This assures that the garlic seed will become adapted to their particular climatic and soil conditions. Other growers prefer to purchase new seed every year, as they are able to obtain high

prices for their garlic and it is much cheaper to just buy the seed.

The USDA National Organic Program requires Certified Organic planting stock.

USDA National Organic Program Rule

§ 205.204 Seeds and planting stock practice standard.

(a) The producer must use organically grown seeds, annual seedlings, and planting stock: Except, That,

(1) Non-organically produced, untreated seeds and planting stock may be used to produce an organic crop when an equivalent organically produced variety is not commercially available, Except, That, organically produced seed must be used for the production of edible sprouts;

(2) Non-organically produced seeds and planting stock that have been treated with a substance included on the National List of synthetic substances allowed for use in organic crop production may be used to produce an organic crop when an equivalent organically produced or untreated variety is not commercially available;

(5) Seeds, annual seedlings, and planting stock treated with prohibited substances may be used to produce an organic crop when the application of the materials is a requirement of Federal or State phytosanitary regulations.

For regional sources of organic garlic seed see ATTRA's Organic Seed Suppliers database, available on our Web site, *www.attra.ncat.org*. If you do not have Internet access, call 1-800-346-9140 for a printed list.

Soil Fertility

We recommend getting a soil test before you begin field preparation. Request recommendations for nutrient requirements for onions when you send a soil sample to a soil-testing laboratory. Many soil testing laboratories only include the conventional NPK recommendations. See the ATTRA publication IP105, *Alternative Soil Testing Laboratories*, for a listing of laboratories that include information on organic matter, humus, mineral analysis, and alternative fertility recommendations. For additional information on organic fertility management in vegetable crops see the ATTRA Publication *Sustainable Soil Management*.

Since garlic is a high-value crop and a heavy feeder, it deserves your best ground. It needs full sun and a full range of available nutrients. A pH of 6.8 to 7.2 is ideal; many nutrients are tied up in soils that are more alkaline or more acidic than this. Garlic will grow in almost any well-drained, friable (easily crumbled in the hand) soil, preferably with high organic matter content. High organic matter aids in soil water-holding capacity and drainage. If possible, begin soil preparation the year before planting. In his book *Growing Great Garlic*, Ron Engeland recommends building up the soil over a period of 1-2 years using animal and green manures before the garlic is planted (Engeland, 1991). See the ATTRA publication *Overview of Cover Crops and Green Manures* for information on building soils with cover crops.

Provide additional nitrogen, if needed, through supplemental use of organic fertilizers. Nitrogen can be applied in the fall at planting if a slow-release fertilizer such as soybean meal is used. Avoid applying any form of soluble nitrogen fertilizer in the fall to prevent contamination of ground water as well as loss of nitrogen to leaching. Do not apply nitrogen when the bulbs are beginning to enlarge, since it will encourage excessive leaf growth and reduce bulb size. Another way to add fertility is to side-dress with compost after leaf emergence in the fall, then apply fertilizer again in the spring. Avoid fertilizing beyond May, since high nitrogen levels at this stage may actually decrease bulb size. Some organic growers apply foliar sprays of liquid fish and seaweed fertilizer, several times in the spring (Rosen et al., 1999); (The Garlic Store, 2006).

If foliar feeding is used to supply nutrients, it should be done prior to the 4th or 5th leaf stage. A good surfactant (or spreader-sticker) is essential to hold the solution on the garlic's waxy leaves. There are a limited number of spreader-stickers that are

Tips for purchasing garlic seed:

- Find a local source, so that your garlic does not have to go through a 2-3 year period of adaption to your climate.
- Buy your seed from a reputable source—ask other garlic growers where they get their seed.
- Do not purchase your garlic seed from a store, as is it has most likely been sprayed with an anti-sprouting agent.
- Carefully inspect your garlic seed for disease. If there is any sign of disease, do not plant it. Once you introduce certain diseases to the soil, it can be very difficult to get rid of them.

approved by the National Organic Program. If you are certified organic, see the OMRI list of approved products or check with your certification agency to ensure that you are using a permissible product.

When to Plant

Fall/early winter planting is recommended in all parts of the U.S. A cold period is required in order for the mother bulb to split into cloves. The bolting cultivars of garlic require a cold period to trigger cellular division. For spring planting, which is not recommended, the bulbs need to be refrigerated at 40°F for 40 days. By planting garlic in the fall, the plants obtain significant root growth before the ground freezes. Then in the spring the plant focuses its energy on sprouting, leaf growth, and ultimately bulb development. If the garlic is planted too late in the fall to obtain significant root growth, this will ultimately detract from bulb size the following summer. Fall-planted garlic grows rapidly when the weather warms in spring.

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Bulb growth in garlic, like many alliums, is dependent on the lengthening of the day and the accumulation of degree days (heat units). In northern latitudes, most growers plant garlic in October before the ground freezes. This gives the plant time to make good root development but not enough time to make leaf growth. Where winter sets in earlier, growers are recommended to plant garlic two to three weeks after the first frost (below 32°F) (Rosen et al., 1999). Where winters are milder, garlic can be planted as late as mid-December. In some parts of California, it can be planted as late as February or March. We recommend talking with local producers and your county Cooperative Extension to determine the best time to plant garlic in your region.

How to Plant

Garlic is propagated vegetatively from the clove. One clove produces one bulb. The size of both the clove and the bulb is an important consideration when selecting planting stock. Grade your garlic for both size and quality. Bulbs should be firm without soft spots or defects and the cloves

These popped cloves are free of defects and ready to plant. Photo courtesy of Hood River Garlic.

creamy white without any discolorations. Discard anything that appears diseased, small, soft, damaged, or discolored. This is time-consuming, but important.

Crack each bulb into individual cloves (referred to as "popping"). Plant cloves with the root end down. Where winters are mild, plant cloves one inch deep; where winters are severe, put them two to four inches deep. In general, plant the biggest and best cloves from the best bulbs. They will generate the biggest bulbs. This will also build up bigger seed stock over time. Keith Stewart of Keith's Farm plants the medium to large bulbs, refraining from the largest. "It should also be said that planting the biggest cloves does not necessarily assure the best garlic, in terms of flavor and hardiness." (Gough, 1999)

Mulch is used frequently in organic garlic production. It helps improve winter survival, suppress weeds, conserve soil moisture, and prevent soil erosion. It can also increase yields by keeping the soil cooler. Garlic quits growing when the soil temperature increases to above 90°F. David Stern establishes a winter cover crop/ mulch on his New York state farm by planting oats in late August or early September. The oats are six inches tall when he plants garlic. He uses a disc-furrower on a tool bar behind his tractor to cut slices through the oats. Garlic is set into the furrows. The oats continue to grow until killed by winter frost (Stern, 2001). This system works well in areas with deep freezes, however, in milder climates, the oats will become a problem the

Garlic can also be mulched with clean straw or other organic material immediately after planting in climates with very hard frosts. If you live in warmer areas, it is good to mulch after the ground gets cold, so that the cloves will experience their required chilling vernalization period. Photo courtesy of Hood River Garlic.

subsequent spring if they are not winterkilled. The oats go from a living mulch in the field to a dead mulch in the winter, when the erosion potential is strong. No "living-mulch" crop combinations have been identified that do not compromise yields in garlic (Stern 2007).

The garlic will have no trouble pushing through an inch or more of mulch. Mulch is typically used by operations without mechanical harvest, as it will make harvesting by machine difficult or impossible.

Garlic is often planted in raised beds for ease of digging, good soil drainage, and reduction of soil compaction. Hood River Garlic uses a bed maker that is attached to their tractor. Terry Browne Hixson, co-owner of Hood River Garlic, claims that "the most vital piece of equipment that we own is our John Deer Tractor. Without the tractor, tiller and raised-bed maker our crop yields could not be so successful."

Raised beds at Hood River Garlic farm. Photo courtesy of Hood River Garlic.

Clove spacing of 6 inches by 12 inches is best, except for some varieties of the Porcelain cultivars and elephant garlic, which require a spacing of 12 inches by 12 inches to produce the largest bulbs.

Seed Stalks

Hard-neck varieties put up a tall, woody, round, flowering stalk, or scape, that grows bulbils at the top. If the plant is allowed to put its energy into these bulbils, the bulb forming below the ground can be 1/3 smaller than if the scape is removed. Many farmers cut the scapes when they are young and tender, to eat or sell them. They can be used for pickles, pesto, or stir-fry. "Depending on the planting density, 300 – 800 pounds of scapes per acre can be harvested, which sell for between $1.00 and $3.00 per pound," says Stern. He advises cutting or snapping off the scapes on a sunny day so that the wound will heal/ dry quickly. If you are not selling the scapes, they should still be removed from the field as a sanitary measure to lessen the potential for disease.

Many farmers cut the scapes when they are young and tender, to eat or sell them. Photo courtesy of MaryJanesFarm, www.maryjanesfarm.org

Irrigation

Garlic needs a continuous supply of moisture when it is actively growing. If the ground is dry, one inch of rainfall per week or the equivalent in irrigation is needed for best garlic growth. Drip or trickle irrigation is recommended. If you are using mulch, lay the drip irrigation lines after planting and before mulching in the fall. Stop irrigating at least two weeks prior to harvest.

Labor

Labor needs vary seasonally. David Stern notes that 20 to 25 "human interventions" are needed between the time he starts and the time he sells bulbs (Stern, 2001). Planting and harvest are critical times. If you do not use mulch, hand cultivation should also be a consideration in labor. You should keep this in mind if you are considering expansion of your garlic planting. If you double your acreage, you will also double the time spent on each process, such as cracking the "seed" bulbs into cloves, digging, bunching, and cleaning. Storage space needs are also doubled. Mr. Stern cautions that a garlic grower makes a large investment in this crop: tasks must be done on time or the crop and the investment will be lost.

If you are planning to significantly expand your acreage, mechanizing the planting and harvesting can alleviate some of the labor requirements associated with the expansion. Erme, a Dutch company, manufactures bulb planters. A typical 12-row planter can plant 25 acres of bulbs in a day. There are also 3-, 4-, and 8-row configured planters (Dutch Valley Growers, 2006). Erme also manufactures single-row garlic harvesters.

Pest Management

Healthy soil builds healthy plants and is a foundation of ecological pest management. Practices such as crop rotation and the creation of habitat for beneficial organisms work to manage pests by increasing the biological diversity on the farm. The following is an excerpt from the ATTRA publication *Biointensive Integrated Pest Management.*

"When we kill off the natural enemies of a pest, we inherit their work." —Carl Huffaker, Biological Control Pioneer, UC Berkeley

Maintaining and increasing biological diversity of the farm system is a primary strategy of cultural control. Decreased biodiversity tends to result in agroecosystems that are unstable and prone to recurrent pest outbreaks and many other problems. Systems high in biodiversity tend to be more dynamically stable. The variety of organisms provides more checks and balances on each other, which helps prevent one species from overwhelming the system and becoming a pest.

Factors influencing the health and biodiversity of soils include the amount of soil organic matter, soil pH, nutrient balance, moisture, and parent material of the soil. Healthy soils with a diverse community of organisms support plant health and nutrition better than soils deficient in organic matter and low in species diversity.

Research has shown that excess nutrients as well as relative nutrient balance in soils will affect insect pest response to plants. Imbalances in the soil can make a plant more attractive to insect pests, less able to recover from pest damage, or more susceptible to secondary infections by plant pathogens. Soils rich in organic matter tend to suppress plant pathogens. In addition, it is estimated that 75 percent of all insect pests spend part of their life cycle in the soil, and many of their natural enemies occur there as well. Overall, a healthy soil with a diversity of beneficial organisms and high organic matter helps maintain pest populations below their economic thresholds.

For more information on ecological pest management, see the ATTRA publications, *Biointensive Integrated Pest Management* and *Farmscaping to Enhance Biological Control.*

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Most pests that attack onions will also attack garlic. These include onion thrips, onion maggots, grasshoppers, and gophers. Diseases are caused by a number of fungi, bacteria, nematodes, and viruses. Learning to identify the symptoms is the first step in management. *Growing Great Garlic* (Engeland, 1991) has a section on pests and diseases that gives good descriptions and management techniques. Two other

excellent resources are *Compendium of Onion and Garlic Diseases* (Schwartz and Mohan, 2007) and *Integrated Pest Management for Onions* (Hoffman, et al., 1996). The Cooperative Extension Service can also help in pest identification. Once you identify a pest, refer to ATTRA's *Biorationals: Ecological Pest Management Database* as a source of information on different control mechanisms for the pests that are listed below.

Soil solarization is a process that uses heat from the sun for controlling many soil-borne plant pathogens, weeds, and nematodes. Basically, when clean-tilled soil is covered with clear plastic for several weeks during the hottest part of the summer, solar heat builds up under the plastic, killing many weed seeds and disease-causing organisms. This timing corresponds particularly well as a pre-planting technique for fall-planted garlic. The bulletin *Soil Solarization: A Non-Chemical Method for Controlling Diseases and Pests* gives more specific details and is available from the University of California Department of Agriculture and Natural Resources. Information on how to obtain this is available under **Further Resources.**

Terry Browne Hixson from Hood River Organic Garlic suggests scouting as a pest management tool. Her partner Eric spends countless hours out in his fields, especially during the summer months, when he spends many hours daily inspecting the crops.

Insects

Onion thrips begin to migrate when weeds in surrounding fields begin to dry up. Monitoring thrips with hot pink sticky traps should start before this migration begins. Since adults and nymphs will inhabit weedy areas surrounding the field, keep these areas weed-free to reduce thrips infestations. After the crop is harvested, the tops should be raked together and burned to reduce overwintering populations.

Several species of lady beetles, as well as the minute pirate bug, are predators of onion thrips (Davidson and Lyon, 1987). The predatory mites *Amblyseius cucumeris* and *A. barkeri* are also reported to attack onion thrips. Adult female predatory mites *(Neoseiulus)* consume from 1 to 10 young thrips per day and have a 30-day lifespan. They can also survive on pollen and other spider mites in the absence of thrips. Repeat applications of predators must be made to establish a 1:2 ratio of predators to prey. *Neoseiulus* attacks first instar (very young) thrips only and does not move long distances from where it is first placed. They are most often applied in small piles at the base of plants, or in paper bags. Usually, a small hole is made in the bag, and mites move out of the bag slowly.

Thrips nymphs and adults rasp the leaves and other plant tissue to encourage the release of sap, which is then consumed. When damage is severe, the entire plant may wilt and die (Davidson and Lyon, 1987). Photos courtesy of InsectImages.org.

Carol Glenister of IPM Laboratories in Locke, New York, has researched the use of predatory mites for control of onion thrips in the field. She says the results were not encouraging (Glenister, 2006). Thrips are hard to control through biological controls because of their mobility and numbers. They migrate in large numbers (in the billions) from neighboring areas that are drying up, and the mites find it difficult to prey on them all at once. Glenister suggests that release of beneficial insects is not the answer, but ensuring natural habitats, and providing crop diversity would be more effective. Habitat enhancement for natural predators and parasites is discussed in the ATTRA publication *Farmscaping to Enhance Biological Control.*

There are several "least-toxic," or biorational, pesticides that may reduce thrips populations. According to Dr. Richard Lindquist, entomologist at Ohio State University, a mixture of M-Pede® (insecticidal soap) and SunSpray Ultra-Fine Spray Oil® controlled western flower thrips—a closely related thrips species—in a greenhouse trial (Lindquist, 2001). Sunspray is no longer available from the manufacturer; however Safe-T-Side horticultural oil may be an apt substitute.

Neem oil, a botanical pesticide extracted from the neem tree, *Azadirachta indica*, has shown good control of a variety of agricultural pests. Dr. Lindquist indicates that it provided control of flower thrips in the greenhouse after a series of four weekly applications. (Note: Neem is not a good rescue treatment, but works as an insect growth regulator and should be applied early in the crop cycle.) Before spraying a new biorational pesticide, always check with your certifier to confirm that the product is approved for organic production.

Onion Maggot

Beneficial nematodes have shown to be effective with onion maggots. *Steinernema carposporae* and *Steinernema feltiae* are the most effective species for maggot control, with the latter being more tolerant of cool soil. For the most effective nematode biological control, spray in the morning and evening and keep soil moist. Beneficials such as ground and rove beetles, birds, and braconid wasps prey on all life stages of the maggot (Davis et al., 2007).

Onion Maggots,* Delia antigua, *will also become a pest on garlic. Adults of* Delia *species are small gray flies that are somewhat smaller than house flies. When at rest, they keep their wings folded one over the other. Larvae are creamy white, legless maggots about 0.4 inch (10 mm) long (Coviello, 2007). Photo courtesy of J. Ogrodnick, Cornell University; NYSAES.

Diatomaceous earth spread around early transplants has also shown effectiveness in treating the maggots. The fine fossilized shell material has microscopic sharp edges that pierce soft bodies and causes them to dehydrate. Apply after a light rain for better effectiveness (Coviello, 2007).

Good cultural practices are essential in controlling this pest. Start by rotating your crops. Don't plant garlic in the same place two years in a row. Once the pest's breeding cycle is broken by planting its host (garlic and onions) in a different spot, you can use a floating row cover to keep the flies from laying eggs on your fresh plants (Rodale Press, 2006). Use the cover immediately after planting cloves, and insure it extends at least six inches beyond each side of the planted bed. Remove and destroy garlic debris at the end of the season (Davis et al., 2007).

Bulb mites and leafminers can also be significant garlic pests in California. Bulb mites damage bulbs by penetrating the outer layer of tissue and allowing rotting organisms to gain entry. This pest is most damaging when plant growth is slowed by cool, wet weather. Bulb mites can reduce plant stands, stunt plant growth, and promote rot of bulbs in storage. (Coviello, 2007). Management includes rotating garlic and onions with other crops, avoiding rapid rotation of garlic into areas with high residue, and insisting on clean garlic seed. Hot water treatment of seed garlic before planting may reduce mite infestation.

Damage by leafminers in garlic is of little concern unless populations become so high as to prematurely kill foliage. Close proximity to crops such as lettuce, celery, or spinach will increase the potential for damage by leafminers in garlic. Natural enemies, especially parasitic wasps, are effective at managing leafminer populations.

Diseases

Most garlic diseases are either soil- or seedborne and usually can be controlled with proper rotation and by planting disease-free seed. Certain cultural practices can help to reduce the incidence of diseases in garlic. Crop rotations away from other species of

alliums and from fields with a history of disease problems are recommended. Sanitation is another important aspect of disease control. If you see any yellowing or misshapen leaves in the field, they should be removed and destroyed. Culls and diseased foliage should also be removed and either burned or buried away from the field after harvest. Purchasing disease-free stock is essential in avoiding disease problems.

The most common diseases in garlic include:

White Rot

Sclerotium cepivorum is a major disease of commercial garlic grown in California and the Pacific Northwest. The organism is most active when the temperature is cool (less than 75°F). In northern climates it usually attacks in the spring. Symptoms include premature yellowing and dying of older leaves, stunting, and leaf tipburn, followed by destruction of the root system, shoot dieback, and rotting of the bulb. Control by rotating out of allium crops for many years (white rot has been known to persist in soil for 10 years), destroying infected tissue, and planting disease-free seed stock (Coviello, 2007). Spraying garlic extract in the absence of the allium crop may stimulate the fungal mycelium to grow and exhaust itself several weeks before planting (soil temperature needs to be between 60 and 70°F) resulting in a successful subsequent garlic crop. Apply the garlic extract in 10 to 150 gallons of water per acre. Use of this product before planting causes sclerotia in soil to germinate and die before the crop is planted (Jepson, 2006).

Fusarium (Basal or Bottom Rot)

Fusarium oxysporum and *F. cepae* are the causal organisms of this fungus, which is present in all soils and is usually considered a secondary invader because it attacks plants that have been weakened by insects, mechanical damage, or other diseases. It is the most common disease found on planting stock. *Fusarium* is most active at high temperatures. Symptoms are similar to white rot, except disease progression

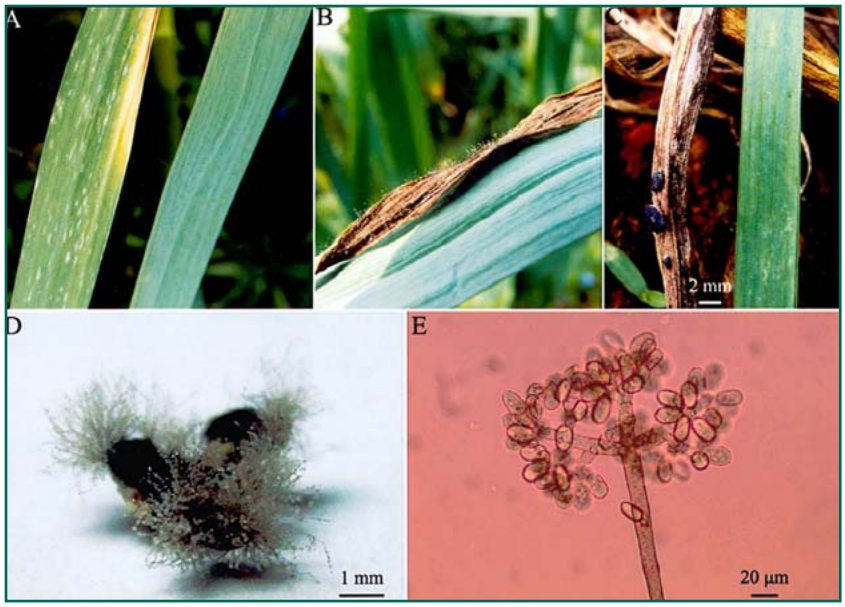
Foliar Symptoms of* Fusarium *show yellowing and/or browning (necrosis) of leaves beginning at tips. The discoloration will move toward the base of the leaf, which will eventually wither and die. Photo from http://www.extension.umn.edu.

Fusarium sp. ***in garlic head. Photo copyright held by Melodie Putnam, Oregon State University.***

is much slower and death of the plant may not occur. In the field, affected plants may show reduced emergence, yellowing and/or browning (necrosis) of leaves beginning at tips. The discoloration will move toward the base of the leaf, which will eventually wither and die. (Jepson, 2006) Bulbs infected with *Fusarium* may decay further in storage. This disease is controlled by proper crop rotation with non-susceptible crops for four years, removal of infected plants, and planting disease-free seed (Coviello, 2007).

Botrytis

Symptoms of *Botrytis* include water-soaked stems, which is why the disease is often called "neckrot." In severe infections, the bulbs may rot. In mild infections, the disease may not be noticed during the season, but may attack the bulb during storage



Botrytis squamosa ***is a fungus that attacks garlic leaves following periods of warm, wet weather as well as bulbs in storage. Photo courtesy of M. D. Wu and G. Q. Li. Copyright The American Phytopathological Society.***

Post-harvest* Botrytis *neck rot in garlic cloves. Photo courtesy of the WSU IMPACT Center.

(Schwartz and Mohan, 2007). Control this disease by promoting air movement through the field so that foliage does not remain wet. Rapid drying during harvest, followed by good aeration during storage, will also minimize the problem. Use disease-free planting stock.

Penicillium Molds

Penicillium is both a field and storage disease. Plants from infected cloves planted in the fall will often emerge in the spring, turn yellow, and then die. A blue-green color is observed on cloves in soil and in storage, thus its common name, "Blue Mold." (Schwartz and Mohan, 2007) When conditions are optimum for rapid garlic bulb emergence, the plant may outgrow the disease. Air-borne spores spread the disease. If a bulb is infected, do not use the cloves for planting stock. Wash hands after touching the bulb and avoid bruising or wounding stored bulbs. Prevent the disease by planting clean stock.

Rust

Puccinia allii, also called *Puccinia porri*, is the fungus that causes rust. Until recently, this fungus was considered to be of minor importance in garlic production. However, outbreaks in California in the late 1990s reduced crop yields by up to 75 percent in some fields. Initial symptoms occur on the foliage and stem as small white flecks that develop into orange spots (spores) or pustules. The bulbs become shrunken and deformed. Heavily infected plants may turn yellow and die. Conditions favorable for disease development include high humidity, low light, and low rainfall and a temperature between 45 degrees and 55°F (Schwartz and Mohan, 2007). Disease incidence is highest in stressed plants. To reduce infection potential, use healthy seed in well-drained soil. Rotate with non-allium crops.

Other Diseases

Bacterial soft rots are characterized by softening and water soaking of one or more of the inner fleshy scales of the bulb. Affected tissue is yellow initially, turning brown as the disease progresses lengthwise in the bulb. The neck of infected bulbs may be soft when pressed. These organisms generally appear just before or at the time of harvest or in storage. This organism is more common in onion than in garlic. Wounds and senescent leaves are the means by which bacteria gain entrance into the bulb. It is spread through direct contact with water. Avoid overhead irrigation once garlic begins to bulb.

Black mold is first evident at the top or sides of the bulb where disease or injury has caused an opening in the skin. The fungus develops between dry, dead outer scales and the first inner fleshy scales of the bulb. Invaded scales initially become water soaked. Under dry conditions diseased scales dry and shrivel, and black masses of spores are visible between outer scales. Gentle handling of the bulbs post-harvest is a preventive measure for this disease. (Davis et al., 2007)

Nematodes

Ditylenchus dipsaci is a stem and bulb species of nematode. Plant parasitic nematodes are microscopic roundworms that live in soil and plant tissue and feed on plants by puncturing and sucking the cell contents with a needlelike mouthpart called a stylet. The stem and bulb nematode lives within the plant, feeding in stems, leaves, and bulbs (Westerdahl, 2007). The only known hosts for the garlic strain belong to the onion family: garlic, onion, leek, and chive (Ocamb, 2007). The stem and bulb nematode penetrates the germinating clove and destroys tissue as it moves through, seeking food. Nematodes suck the cell contents and their salivary secretions cause the cells to collapse. Root knot nematodes can cause stunting and reduce a stand of garlic. Stubby root nematode causes stunting of plants.

Plants infested with the stem and bulb nematode have distorted and bloated tissue with a spongy appearance; the plants are stunted with shortened and thickened leaves, often with brown or yellowish spots. In the field, top growth will yellow and ripen prematurely. The whole bulb may separate from the basal plate.

Management options include:

- Eradicate volunteer garlic plants from fields having a history of stem and bulb nematode.
- Avoid other hosts of the nematode in your rotation if possible. To reduce reintroduction and spread of this pest, it is necessary to implement a three-year crop rotation with a non-host crop and to bury or burn infested or contaminated seed and plant debris.
- Plant only nematode-free cloves.
- Soak cloves at 100°F for 30 minutes in water containing 0.1 percent surfactant; then soak at 120°F for 20 minutes in the same kind of solution. Cool cloves in tap water for 10 to 20 minutes before drying for 2 hours at 100°F, or plant if possible. This helps eradicate the bulb or stem nematode from loose (cracked) cloves but not from intact bulbs.

Viruses

There has been a high incidence of multiple viruses found in garlic fields in Canada and throughout the United States in recent years. However, there are only rare situations where these have had economic consequences. The most obvious symptoms are "radical abnormal leaf expression, such as extreme curling, stunting, swollen veins and unusual protrusions." (Brunt et al., 1996) If your garlic crop shows these symptoms, it may grow out of it, but will still have the virus. It is important not to use seed from that crop for the following year.

Weeds

Good weed control is *essential* in garlic production. Alliums are slow-growing, shallow-rooted crops that can suffer severe yield loss from weed competition (Smith et al., 2007). Planted in the fall and harvested in the mid-summer of the next year, garlic will be in the ground nine months. It is therefore vulnerable to competition from winter and summer annual weeds. Weed competition, even early in the growth of the crop, can reduce yields. In addition to reducing yield and quality, weeds also interfere with mechanical harvesting equipment.

Hood River Garlic Farm uses a smother cover-crop of buckwheat in the summer, before the garlic is planted. Buckwheat is easily broken down and its large cotyledons (first leaves) and fast growing habit are quite effective at smothering summer weeds. Photo courtesy of Hood River Garlic.

If possible, advance field preparation with a weed-suppressing cover crop such as rye or sorghum-sudan grass can significantly reduce weeds as well as build up soil organic matter. Mulching new plantings has already been mentioned as a way to control weeds. If mulch is used, it should be thick enough to last until harvest. Avoid spent hay and inspect straw for weed seeds. If mulch is used, garlic will have to be dug by hand rather than machine harvested. Garlic can also follow any well-cultivated crop, like carrots.

Cultivation is another method of weed control. If the soil is not mulched, various types of cultivators or tillers can be used to control weeds between rows and wheel tracks on the sides of the beds. The weeds within the plant rows may be removed by hand cultivation. David Stern has adapted his tractor equipment for cultivation with small discs that throw dirt between the plants. The garlic leaves are not covered, but small weeds are eliminated.

Gauging the right time to harvest is very important. Garlic will double in size during its last stage of growth.

Flame weeding works with garlic, as well as with onions. At six commercial organic farms in Europe, flaming was tried on onions before the four-leaf stage and also later in their development (Desvaux and Ott, 1988). Flaming the younger plants resulted in damage to the onions. However, flaming at a later stage was successful, though too much heat damaged the onions. Flaming also works best with more mature garlic plants, particularly with the Porcelain cultivars, because they have vertical leaf structure. Field conditions such as uneven ground, inconsistent tractor speed, or high winds can affect the degree of success with this technique. For small-scale plantings, backpack flamers from construction supply outlets should work well. The ATTRA Publication *Flame Weeding for Vegetable Crops* has more detail on this form of cultivation.

A SARE farm-based research grant in 2003 studied the affects of acetic acid (vinegar-based) herbicide for control of broadleaf leaves and grasses in garlic. The outcomes demonstrated that 10 percent acetic acid vinegar was very useful in controlling broadleaf weeds in the test plots. The vinegar provided minimal to no control on grasses, however. Test plots sprayed from both sides of the row had virtually no broadleaf weeds at the end of the trial. There was no difference in plant size, maturity date, quality, yield, bulb size, appearance, or keeping ability between the test plots and the control plots. Despite the unusually cold and wet spring during which this trial was conducted (which impacted the ability to make timely applications), they found that there was a 94 percent reduction in labor (associated with weed management) by using vinegar rather than in-row weeding. (Forsburg, 2004) It is important to use a mask and gloves when handling and spraying acetic acid-based herbicides, as they can be caustic to your skin and lungs.

Harvest and Storage

Gauging the right time to harvest is very important. Garlic will double in size during its last stage of growth. If dug too soon, the cloves will not have grown to their maximum size. If bulbs are dug too late, they may have begun to split apart in the soil. David Stern often begins harvesting when the leaf tips start to brown. Ron Engeland uses the number of green leaves left on the plant to judge if the bulb is ready for harvest. On an average, he harvests when about six plant leaves are still green (Engeland, 1991). Some growers harvest when plants are 40 percent browned and 60 percent green. Mr. Stern notes that leaf conditions cannot always be an accurate indicator that it is time to harvest. Browning of leaves may be the result of drought, damage, or disease. He recommends digging some plants up to determine the correct time to harvest (Stern, 2001). The outer skin should be tight, the bulbs fully developed and well formed. Mr. Stern recommends digging sooner rather than later. If garlic becomes too mature before harvest, the cloves will begin to crack apart while still in the ground. However, if the garlic is pulled at a slightly immature stage, the leaves, which serve as wrappers for the cloves, will continue to translocate nutrients to the cloves, making the crop easier to prepare for sale.

Some growers harvest when plants are 40 percent browned and 60 percent green. Photo courtesy of Hood River Garlic.

In small-scale plantings, garlic can be dug with a garden fork. For larger acreages, several tools are available for undercutting and harvesting garlic. Bed lifters, potato diggers, or subsoilers can be used to loosen garlic from the soil. (These will not work if heavy mulch remains.) Erme, a small farm implement manufacturer from France, has single- and double-row garlic harvesters and binders. The company's contact information is listed below under **Further Resources.**

The Garlic Seed Foundation can also provide information on building your own harvesting equipment, or referrals to manufacturers.

After mechanical digging, the garlic still needs to be removed from the field by hand. Field grading should be done immediately to remove any damaged or diseased plants, a standard practice for disease prevention.

Sort garlic into three categories:

- Small bulbs can be cleaned for sale or your own kitchen.
- Medium-sized bulbs are cleaned in preparation for sale. One harvesting debate involves whether or not to wash bulbs. Ron Engeland states in *Growing Great Garlic* that he doesn't want to invite mold and decay that might result from having wet bulbs as a result of washing, and bulbs grown in light soils with lots of humus clean up fairly easily. Garlic grown in heavier soils is more difficult to clean. David Stern's method for cleaning garlic begins by holding a bunch of six to eight bulbs in one hand and spraying them with the garden hose while rotating his wrist so that all sides are washed. He then lays the garlic—not bunched—on racks in the greenhouse and off the ground to dry overnight. The plants are bunched the next day, and stay bunched until he is ready to braid. David Stern digs in the morning and cleans in the afternoon, taking care not to dig more than he can clean that day. Cull any diseased bulbs right away.
- Large bulbs are saved for planting stock. These should not be washed, but hung in a covered barn or shed to dry. Fans may be used to increase air movement in wet years. (California is the only place where garlic is dried in the field. Growers commonly lay the bulbs in the field for a few days to dry, covering the bulbs of one row with the leaves of the next to prevent direct exposure to sunlight.)

Before garlic is stored, it must be properly cured or dried. According to David Stern, the garlic needs to cure/dry for at least 10 to 14 days. The neck cells constrict and hold the juice in the bulb. He suggests this be done with the stem and roots still on, but there are many theories on this which can vary by region and year. After a couple of weeks they may be clipped off, leaving ¼ to ½ inch of the stem and roots. When the outer skins are dry and crispy, the garlic is ready for storage or sale. It can be stored in *clean* onion bags. Garlic will lose up to 20 percent of its weight in the curing process.

According to the publication *Commercial Storage of Fruits and Vegetables*, garlic will keep for 6 to 7 months if it is stored at 32° F and at 65 to 70 percent relative humidity (Hardenburg et al., 1986). It is important to keep temperature and humidity constant. High humidity will keep the bulbs from dehydrating. A walk-in cooler should make a suitable storage facility; however many farms shut their coolers down in the winter. Also, any variation or fluctuation in

Hood River Garlic Farm cures their garlic by hanging it in bunches in their barn after the harvest. Photo courtesy of Hood River Garlic.

these conditions will initiate sprouting. This can make it difficult to store garlic for long periods of time without sprout inhibitors. A 25-watt light bulb and a thermostat can be used to provide heat when needed. A fan will keep air circulating. Most farmers sell their garlic as a fresh crop at farmers' markets; very few sell over the winter, because of the difficulty associated with sprout prevention (Stern, 2007).

Stored garlic should be checked monthly. *Penicillium*, or white or blue mold, is a post-harvest disease that may show up in stored garlic. The fungus will sporulate and spread within the confined conditions of storage. For more on prevention of *Penicillium* see the **Disease** section of this publication.

Marketing and Economics

U.S. garlic production has doubled over each of the last two decades. No other vegetable, including high flyers like onions, broccoli, and carrots, has exhibited such strong sustained growth. (Lucie and Lin, 2000). Despite this sustained growth, there has been significant global competition, mostly from the People's Republic of China. As of 2004, China was the dominant source of imported garlic in the United States, despite the imposition of a hefty duty tax against fresh Chinese garlic imports imposed in 1994. Prior to imposition of the anti-dumping duties China was a major exporter of garlic to the United States (Boriss, 2006), which had a significant impact on U.S. growers. International competition should be a serious consideration for farmers considering developing larger international markets for their garlic.

The cost of seed cloves plus the hand labor for planting and harvest makes the initial investment for garlic production high in comparison to some other vegetable crops. Additional costs include land preparation and installing an irrigation system. The enterprise budgets in **Appendix 2** will help growers gauge what their costs and returns will be. Garlic returns are very dependent on how the crop is marketed. The University of Kentucky Cooperative Extension bulletin on garlic production suggests that wholesale marketing of well-managed garlic at prices from $2.00 to $4.00 per pound could easily return (net) from $1,400 to $3,200 per acre (see *Table 1*). An acre of well managed conventional or organic garlic that is direct marketed at prime locations by the producer (perhaps in braids and other forms) could return in excess of $5,000 per acre (CES, 2006). In producing value-added products such as braids, labor needs to be accounted for in your enterprise budget.

Of the total garlic harvested in the U.S., 75 percent is sold wholesale for dehydration; however, garlic is an excellent crop to direct market as a local specialty (Boriss, 2006). It can be sold in a number of forms for a number of uses. Some fresh-market options for garlic include wholesale markets, farmers' markets, and roadside stands. Sales to local retail markets, such as supermarkets and specialty produce and health food stores, are also an option.

Retail garlic prices vary considerably. Supermarkets generally sell garlic at around $2.00 per pound, while some natural foods grocers sell garlic for as high as $4 to $5

Table 1. Net Returns for five different yields and prices of garlic

	Yield (lbs./ acre)				
Price ($/lb.)	2,000	3,000	4,000	5,000	6,000
$0.80	($5,815)	($5,313)	($4,810)	($4,308)	($3,805)
$1.60	($4,215)	(2,913)	(1,610)	(308)	995
$2.40	($2,615)	(513)	1,590	3,692	5,795
$3.20	($1,015)	1,887	4,790	7,692	10,595
$4.00	$585	4,287	7,990	11,692	15,395

Taken from: Garlic Production *(Thomas Ford, et al., 2006). Penn State Agriculture Alternatives.*

per pound. Direct market prices can go as high as $1.00 per bulb for specialty varieties. At the wholesale level, garlic is normally traded as 5-, 22-, and 30-pound boxes, and 3-pound ropes and braids. To view recent information on organic garlic wholesale prices see the New Farm Organic Price Index. This information is available under **Further Resources** below.

In addition to the whole bulbs, garlic can be sold in a number of additional forms:

Garlic greens are the leaves of the tender, immature garlic plant grown from small whole bulbs planted four inches apart in the fall. They are harvested at ground level, bunched (2" across at base), banded, and rinsed. The leaves need to be tender, and approximately 8-10" tall. New leaves will re-grow up to two additional times. Harvest season is approximately late March to late April in most temperate climates. In warmer climates this may be earlier. You can create a value-added product by making garlic greens pesto.

Garlic scapes (or flower stalks) should be cut from the plant when tender, curled, and no longer than 16" total and/or 1/4" in diameter. Harvesting in mid-day sun is a good cultural practice. They should be rinsed, drained, bagged, and refrigerated. These are living vegetable matter and must not dry out or mold. Monitoring in storage is necessary, and yellowing scapes must be removed.

Garlic Scallions are immature plants. They can be grown from small cloves planted in either fall or spring. They should be harvested when the plant is 12" above ground and 14" total. The entire plant is dug, outer leaf or two peeled down and off, and rinsed clean. The roots should be left on and free of dirt. Pack the "scallions" for market in banded bunches of 6 with 12 bunches per poly bag or waxed and lined box. No bulbing at the base is acceptable, since this will be tough and inedible. No scallion should be less than 3/8" in diameter.

Bulbs with leaves attached may be braided, with or without dried flowers or herbs, and sold as ornamental edibles. Instructions for making garlic braids are available in the informational pamphlet titled *How to Make a Garlic Braid*, by Diane Trenhaile, listed below under **Further Resources**.

Braiding garlic can help increase the value of your garlic crop. Photo by Yuki Yanagimoto, courtesy of Arcosanti.

Many farmers sell garlic for planting stock. Planting stock can be sold to gardeners, local farmers, and through the Internet or mail order. Terry Browne Hixson, from Hood River Garlic, describes their decision to grow organic garlic for planting stock. "Seed was not our original goal. Our goal was to just grow garlic. But after years of experience and hard work, we started growing garlic of superior quality. Our markets are people who want to buy premium quality, certified organic seed garlic. We are low-volume, high-quality seed growers. We love to grow our garlic and practice good stewardship for the land. There are easier and less expensive ways to grow garlic, however, we choose to grow organically and promote sustainable agriculture to help our planet." They mainly sell their garlic via the Internet, and use advertisements in selected magazines.

Terry also suggests a Garlic of the Month club for those who are direct marketing. "The Garlic of the Month Club has been a great market for us. It's a great gift idea for anyone who loves to cook, as well as the kitchen gardener."

Garlic festivals provide an excellent opportunity to market and increase consumer awareness. Almost every state has a garlic festival, check out the Garlic Seed Foundation Web site to find one near your location.

Further Resources

Organizations

Garlic Seed Foundation
David Stern, Director
Rose Valley Farm
P.O. Box 149
Rose, NY 14542-0149
315-587-9787
www.garlicseedfoundation.info

Created in 1984 over a love of garlic potluck suppers, the Garlic Seed Foundation has grown to an international organization of over 1,000 members, primarily centered in the Northeast U.S. Objectives have been to educate, promote, and have some fun. GSF acts as a clearinghouse for information and research data. Its newsletter, The Garlic Press, is published about four times per year. Yearly membership fee is $15.00 and includes a copy of Garlic, a cooperative report written by Cornell University and the GSF. Also available from the Foundation are a number of reports, fact sheets, videos, books, a garlic bibliography, and an annual listing of available planting stock. Mr. Stern is willing to accept calls with specific questions.

The Cooperative Extension Service (CES)
www.csrees.usda.gov/Extension/index.html

CES in many states has bulletins on conventional, and occasionally on organic, production of horticultural crops. To find the Cooperative Extension Office closest to you go to their Web site and click on your state. If you are unable to access the Internet, call the ATTRA information line at 1-800-346-9140 and we will provide this information for you.

Publications

Compendium of Onion and Garlic Diseases and Pests. 2007. Edited by H. F. Schwartz and S. K. Mohan. APS Press, St. Paul, MN.

A comprehensive compendium on garlic and onion diseases.

Diseases of Vegetable Crops. 1952. By John C. Walker. McGraw-Hill Book Co., New York, NY. 529 p. Library of Congress card # 51-12826.

Contains a 37-page chapter on allium diseases. Suggests many organically acceptable cultural control options.

Garlic. Report # 387. 1990. By Roger Kline and the Garlic Seed Foundation. Cornell University and the Garlic Seed Foundation, Rose, NY. 10 p.

Covers a broad range of garlic production information including history, varieties, soil and fertility, planting, mulching, cultivation, pests, scape removal, harvesting and handling, and markets. Available from the Garlic Seed Foundation for $3.00 (free with membership).

The Garlic Press. Newsletter of the Garlic Seed Foundation.

Covers tours, festivals and other events, trial planting results, drying and production information, equipment, and other topics.

Growing for Market. Edited by Lynn Byczynski.
P.O. Box 3747
Lawrence, KS 66046
785-748-0605, 800-307-8949
www.growingformarket.com

Since 1992 this informative and practical monthly magazine has published the experience of the nation's direct-market farmers. All the articles are written by farmers, farmers' market managers, and others directly involved in the business of growing and selling local food and flowers. Available in print and online.

Growing Great Garlic: The Definitive Guide for Organic Gardeners and Small Farmers. 1991. By Ron L. Engeland. Filaree Farms, Okanogan, WA. 226 p. ISBN # 0-9630850-1-8. Available from:
Filaree Farms
182 Conconully Hwy.
Okanogan, WA 98840
509-422-6940
E-mail: *info@filareefarm.com*
www.filareefarm.com

This book covers the history and evolution of garlic, site and soil preparation, harvest, curing, and storage. It tells which strains to plant, when and how to plant, when to fertilize (and when not to fertilize), when to prune flower stalks, when to harvest, plus how to store, market and process the crop. The author provides updated information on varieties in a 1995 supplement.

How to Make A Garlic Braid. 1995.
By Diane Trenhaile. Clove Publications, Inc.
Available from Filaree Farms, above.

This 12-page booklet, complete with clear photographs and drawings and detailed instructions, leads the reader step-by-step through the braiding process.

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University of California
6701 San Pablo Avenue
Oakland, CA 94608-1239
510-642-2431
http://ANRcatalog.ucdavis.edu

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Equipment

Erme Farm Machinery
Dutch Valley Growers, Inc
E-Mail : *info@dutchvalleygrowers.com*
4067 E. 4000 N. Rd.
Bourbonnais, IL 60914
www.dutchvalleygrowers.com/harvesters.html

Organic Garlic Pricing

The New Farm Organic Price Index
http://newfarm.org/opx

An online tool that helps you price competitively. The tool tracks selected prices from the fruit, vegetable, herbs and grain sectors, comparing organic prices to conventional prices in markets across the country.

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Appendix 1 :
Farmer Profile: Keith Stewart, Keith's Farm

A Garlic Affair: How the "Stinking Rose" Became a Major Crop on One Farm

By Keith Stewart
Excerpted with permission from Keith Stewart's book, It's a Long Road to a Tomato

Of the approximately 100 varieties of vegetable and herbs we grow on our farm, garlic reigns as the sovereign queen. I would give up the 99 others, albeit reluctantly, before I would give up my garlic. Garlic is our biggest crop and the one that has brought us major press coverage, both in New York City and nationally. Finally and, perhaps most endearingly, garlic is the crop that brings in the most cash.

Most growers of garlic, be they weekend dabblers or for-profit players like myself, soon learn that they have entered into a relationship with a plant that will not be easily cast off. Garlic's attributes are such that, once smitten by the garlic bug, many growers develop a lifelong attachment. Often, our passion for *Allium sativum* goes well beyond its wondrous culinary, medicinal and curative properties. For me, it is the plant itself that is most remarkable: its stately appearance in the field, its fascinating life cycle and growth habit, its hardiness, its ancient lineage, the way it comports itself in this world.

The Northeast, with its cold winters, is suited to growing the hard-neck garlic, a different subspecies that is closer to the original wild garlic from south-central Asia and not as domesticated as the soft-neck varieties. Hard-neck garlic (sometimes called topset garlic) has larger cloves that radiate out from a hard central stem. They peel easily and their flavor, while it ranges widely from one hard-neck variety to another, is often outstanding. Hard-neck garlic is more demanding to grow than soft-neck. It tends to yield less per acre, and often has a shorter shelf life, but among real garlic lovers, it is the only stuff to eat.

On our farm we grow Rocambole, a variety of hard-neck garlic that arrived in my hands seventeen years ago through good fortune and the generosity of a neighbor. Andy Burigo, an old Italian American who lives down the road from us, befriended my wife, Flavia (also of Italian ancestry), while she was out on one of her landscape-painting excursions. After Mr. Burigo learned that I was running an organic farm, he presented my wife with a brown paper bag containing about 30 bulbs of garlic and suggested to her that I try to grow them. He told her the original planting stock came from Calabria, Italy, and that it had entered the U.S. many years earlier in the pocket of a friend, unbeknownst to customs officials. Ever since then he had given it pride of place in his extensive and well tended garden.

...I sold a few dozen bulbs at my farmer's market stand. The following week almost every customer who had purchased one came back smiling, asking for more. It occurred to me then that I might be onto a good thing. I didn't sell any more garlic that year and was reluctant even to give an occasional bulb to my wife. Instead, I squirreled away the 100-odd bulbs that were left. That fall I divided them into about 800 cloves and planted them with great care.

The following year we sold a few hundred at market, again to rave reviews, and saved the rest for planting. I continued like that for a while, parceling out my trove in quite parsimonious fashion, but within a few years I had built up planting stock of 20,000 cloves and an eager pool of customers. I was ready to do some serious business.

With each subsequent year, aided by good press (on TV, radio, and in print media), the demand for our garlic has increased. And each year, to keep pace with this demand, I have allotted more acreage and labor to the cultivation of this exceptional plant.

Now we are planting approximately 50,000 cloves—each and every one by hand. It

may be that we have reached a natural ceiling in garlic production, if not in terms of how much we can sell at market, then in terms of the resources we have available to grow the stuff. These days I often feel overwhelmed by the vast sea of garlic growing in my fields and the substantial effort required to plant it, mulch it, weed it, water it, harvest it, cure it, grade it, and sell it. But I still dearly love my garlic and regard it more than ever as the plant that defined the essence of our farm.

Growing 50,000 garlic plants on a small, diversified, organic farm is no small task. It must be approached in a highly organized, almost military fashion. At each stage, timing is critical. First, we select the planting stock—some 8 or 9,000 of our best bulbs from the summer harvest. We prefer large bulbs, but not the very biggest—these have a high proportion of split cloves that grow two or three small plants instead of one large one.

In early October we look for a warm and comfortable spot and sit down to separate the chosen bulbs into their constituent cloves. This phase of garlic planting is known as "garlic popping." We grade the cloves into several categories (tiny, small, medium, large, questionable, and "bad stuff") depending on their size and quality. The few cloves that are soft, moldy, damaged, or exhibit even the slightest sign of disease go straight into the "bad stuff" box and are later burned in a 55-gallon drum. I regard it as imperative that our planting stock be clean and well-screened. The whole process usually takes two weeks and is quite taxing on the hands, especially the thumbs. By the time all the cloves are "popped" and ready to plant, my helpers are wondering if our workers' compensation insurance covers thumb replacement surgery. (It does not.)

Next, I use a tractor to cut furrows 18 inches apart in well-rested ground. We then set about on our hands and knees, planting the cloves one at a time at a spacing of three to six inches. Each clove is pushed a few inches into the soil and must be oriented correctly, so that its first shoot in the spring will head toward the sun, not the earth's molten core. The smallest cloves are planted more closely (they receive the three-inch spacing) and will be dug up and sold as green garlic in the early summer. The entire plant is sold, leaves and all, to the surprise and bemusement of newer customers. The larger cloves receive five or six inches of spacing and will be allowed to grow to maturity.

After planting is completed (it usually takes two to three weeks), the cloves are mulched a few inches thick with 100-odd tons of well-aged bedding material from a nearby horse farm. Through the winter, they rest in the cold ground, nursing their store of energy, awaiting the transformation to come. For a farmer it is a good thing to know that the garlic is in the ground, that the next generation of this most special plant is waiting under the snow to be born.

The first green shoots break ground in late March or early April, and that's when I know for sure that I'm back in the garlic business. By mid-April all the plants should be up. May and June are the months of intensive weeding, much of which is done by hand. If the rains fail, water will have to be provided via irrigation.

The garlic carries on its above-ground growth rapidly until the summer solstice, when the longest day of the year is reached. As the days begin to shorten, the plant slows down its photosynthetic processes and begins to focus on its underground parts—the energy captured in the leaves is directed downward to form the new bulb.

Toward the end of June our garlic sends up a flower stalk, though it's more correctly referred to as a false flower stalk, since garlic rarely, if ever, reproduces sexually (via the coming together of male and female parts), like most other plants do. Instead, its strategy for self-perpetuation relies on clonal division: each new bulb is a clone of an earlier bulb, going all the way back, you might say, to an ancient mother bulb from some distant time and place.

The false flower stalk of our Rocambole garlic, if left on the plant, can grow two to three feet high. It goes through some wonderful loops and whorls and eventually straightens up and swells at the top to form a capsule that contains several miniature bulbs of garlic known as bulbils. Most growers believe that early removal of the false flower stalk—the scape or top, as it is often called—will lead to a larger bulb. We subscribe to this belief, too, but we usually leave some tops on anyway, since they make such a sight in the field and can present a stunning arrangement in a vase.

The growth of the false flower stalk, the development of the capsule, and the formation of the bulbils are all part of what makes hard-neck garlic such an extraordinary plant. Visually, the tops are striking. They are also excellent to eat.

We harvest our garlic when about half the leaves have turned brown, usually over a two-week period from the last week of July to the first week of August. This calls for major effort on the part of all hands present and generates a copious amount of human sweat. A tractor with cultivator tines loosens the soil on either side of the bulbs so that most of them can be pulled by hand, without additional digging. But the numbers are great, the sun is hot, and the total harvested plant weight, along with a little residual soil around the roots, is several tons.

With their leafy tops still attached, the bulbs are hung in clusters of 10 or 12 in every available space in the barn and tractor or implement sheds. Strategically placed fans assist in the curing process. Access into these large enclaves of hanging plant matter is severely limited, and everywhere the air is redolent with the smell of fresh garlic. If the weather is not too humid, within a month the stems of the plants will be sufficiently dry and hard that the leafy tops can be cut off without the risk of bacteria entering the bulbs. Once the leaves are removed (this is typically carried out over several weeks), the bulbs are graded according to size and quality. The largest bulbs are usually sold first. They are prized by our customers but do not store quite as well as the smaller and medium-sized bulbs. If all goes according to plan, by December we are taking our last bulbs to market (with the exception, of course, of a personal stash) and our customers are stocking up for the winter. Meanwhile, dormant in the frozen ground, the next generation of garlic is waiting to fulfill its ancient destiny and, at the same time, keep its promise to help a small farm stay afloat. It's not a bad deal, on both sides.

A few years back Andy Burigo, gardener extraordinaire and father of our garlic, died at age 86. In his later years, he and his wife Ida visited our farm once a year or so to have coffee with Flavia and evaluate the condition of my crops. On their last visit—by which time I had transformed his original gift into some 35,000 healthy plants glistening in the morning sun—Andy called my wife over to him, saying that he had something for her. With a sober look in his eyes, he reached out and pressed into her hand a half-dozen newly minted pennies. "See what your husband can do with these," he said, and broke into his customary twinkle-eyed laughter.

At his well-attended funeral on a Saturday morning, while I was selling garlic in New York City, Flavia reached in to her handbag and took out a very large bulb I had given her the night before. Quietly she made her way through the crowd of mourners and placed the bulb on Andy's coffin just before it was lowered into the ground.

Appendix 2

Sample Garlic Budget 1:

Excerpted from: Ford, T. et al. 2006. Agricultural Alternatives: Garlic Production. The Pennsylvania State University. Page 4. *http://agalternatives.aers.psu.edu/crops/garlic/garlic_prod.pdf*

Table 2. Sample Garlic Budget. *Summary of estimated costs and returns per acre.*

Items	Quantity or Number of Operations	Units	Price	Total	Your Estimate
Variable costs					
Seeding costs:					
Seed (cloves, including freight)	1,000	lbs	$4.90	$4,900.00	
Lime	2	tons	$25.00	$50.00	
Nitrogen	75	lbs	$0.38	$28.50	
Phosphorus	138	lbs	$0.32	$44.16	
Potassium	138	lbs	$0.23	$31.74	
Planting labor	20	hrs	$10.00	$200.00	
Herbicides:					
Buctril 4EC	0.25	pint	$13.34	$3.34	
Gramoxone Extra	0.375	gallon	$33.92	$12.72	
Harvesting:					
Harvest labor	40	hrs	$10.00	$400.00	
Grading and packaging (*)	200	bags	$0.95	$190.00	
Hauling (*)	4,000	lbs	$0.15	$600.00	
Machinery:					
Machinery rental (mulch layer)	1	day	$40.00	$40.00	
Diesel fuel	10.573	gallon	$2.00	$21.15	
Tractor repairs and maint.	1	acre	$6.30	$6.30	
Implement repairs and maint.	1	acre	$7.62	$7.62	
Other variable expenses:					
Plastic mulch	1	acre	$250.00	$250.00	
Drip irrigation (tape and labor)	1	acre	$330.00	$330.00	
Interest expense:					
Operating interest				$217.27	
Total variable costs				*$7,332.79*	
Fixed costs					
Tractors	1	acre	$12.75	$12.75	
Implements	1	acre	$14.76	$14.76	
Drip irrigation system	1	acre	$500.00	$500.00	
Land charge	1	acre	$150.00	$150.00	
Total fixed costs				*$677.51*	
Total Costs				**$8,010.30**	

* Based on 4,000 lbs/A production
It is customary for producers to keep enough cloves for replanting for the following season.
This should be factored into subsequent budgets.

Sample Garlic Budget 2:

Excerpted from: Klonsky, K. et al. (no date) Cultural Practices and Sample Costs for Organic Vegetable Production in the Central Coast of California. University of California Vegetable Research and Information Center. *http://vric.ucdavis.edu/veginfo/topics/prodcosts/organic/table4-garlic.pdf*

Table 3a. Costs to Produce Organic Garlic

	Operation Time (Hrs/A)	Cash and Labor Costs per Acre: Labor Cost	Fuel & Repairs	Material Cost	Custom/ Rent	Total Cost	Your Cost
Cultural:							
Disc 4X	1.03	10.77	6.32			17.08	_____
Chisel 2X	1.00	10.45	5.44			15.89	_____
Compost Application				212.40	24.00	236.40	_____
List Beds	0.75	7.84	3.21			11.05	_____
Preirrigate	1.40	11.54		16.10		27.64	_____
Preplant Cultivation	0.20	2.09	1.17			3.26	_____
Shape Beds	0.25	2.61	1.37			3.98	_____
Open Planting Furrow	0.33	3.48	1.43			4.91	_____
Hand Plant Garlic	50.00	412.00		970.00		1,382.00	_____
Close Planting Furrow	0.33	3.48	1.43			4.91	_____
Roll Beds	0.25	2.61	0.97			3.59	_____
Irrigate	7.00	57.68		50.60		108.28	_____
Preemergence Flame Weed Control	0.50	10.45	9.30	15.00		34.75	_____
Cultivate 7X	3.50	36.58	17.75			54.33	_____
Postemergence Flame Weed Control	0.50	10.45	9.30	15.00		34.75	_____
Hand Weed	18.50	152.44				152.44	_____
Foliar Feed	0.60	6.27	2.74	48.69		57.70	_____
Rodent Control (Trap)	2.00	16.48				16.48	_____
Pickup Use	1.75	18.29	8.94			27.23	_____
TOTAL CULTURAL COSTS	89.90	775.52	69.36	1,327.79	24.00	2,196.67	_____
Harvest:							
Windrow Garlic					495.00	495.00	_____
Top/Trim Roots & Bag Garlic	120.00	988.80		3.30		992.10	_____
Grade & Pack	325.00	2,678.00		231.00		2,909.00	_____
Transport to Broker	1.75	31.89	15.20			47.09	_____
TOTAL HARVEST COSTS	446.75	3,698.69	15.20	234.30	495.00	4,443.19	_____
Assessments:							
CA State Organic Reg. Fees				6.25		6.25	_____
CCOF Inspection Fees				0.78		0.78	_____
CCOF Membership Fees				0.78		0.78	_____
CCOF .5% of Gross Sales				82.50		82.50	_____
TOTAL ASSESSMENT COSTS				90.31		90.31	_____
Interest on operating capital @ 9.00%						171.97	_____
TOTAL OPERATING COSTS/ACRE		4,474.21	84.56	1,652.40	519.00	6,902.14	_____
TOTAL OPERATING COSTS/BOX						20.92	_____

Table 3a continued

	Total Cost	Your Cost
Cash Overhead:		
Land Rent	359.38	_____
Office Expense	61.09	_____
Liability Insurance	1.88	_____
Sanitation Services	6.19	_____
Property Taxes	11.23	_____
Property Insurance	5.61	_____
Investment Repairs	6.25	_____
TOTAL CASH OVERHEAD COSTS	451.63	_____
TOTAL CASH COSTS/ACRE	7,353.77	_____
TOTAL CASH COSTS/BOX	22.28	_____

Non-Cash Overhead:

Investment	Per Producing Acre	Annual Cost: Depreciation	Annual Cost: Interest @ 4.00%		
Buildings	62.50	1.88	1.38	3.25	_____
Fuel Tanks & Pumps	50.63	2.28	1.11	3.39	_____
Shop Tools	68.75	4.13	1.51	5.64	_____
Tool Carrier	76.25	3.43	1.68	5.11	_____
Irrigation Pipe	185.63	16.71	4.08	20.79	_____
Harvest Bins	117.50	10.57	2.58	13.16	_____
Irrigation Pipe Trailers	6.25	0.28	0.14	0.42	_____
Cover Crop	20.35	18.31	0.45	18.76	_____
Equipment	1,453.84	122.64	31.98	154.63	_____
TOTAL NON-CASH OVERHEAD COSTS	2,041.69	180.23	44.92	225.14	_____
TOTAL COSTS/ACRE				7,578.91	_____
TOTAL COSTS/BOX				22.97	_____

Table 3b. Operating Inputs Costs to Produce Organic Garlic

	Quantity/Acre	Unit	Price or Cost/Unit	Value or Cost/Acre	Your Cost
Soil Amendments:					
Compost w/Gypsum	6.00	ton	35.40	212.40	_____
Custom:					_____
Spread Compost	6.00	ton	4.00	24.00	_____
Water:					_____
Pumped	14.50	acre inch	4.60	66.70	_____
Seed:					_____
Garlic	1,000.00	lb	0.97	970.00	_____
Miscellaneous:					
Propane	24.00	gal	1.25	30.00	_____
Foliar Nutrients:					
Fish Fertilizer	9.00	lb	2.07	18.63	_____
Corn Calcium	3.00	qt	1.45	4.35	_____
Kelp Extract	2.25	lb	5.96	13.41	_____
Omega 2-7-7	3.00	pint	3.22	9.66	_____
Spreader/Sticker:					
Thern X (Yucca Extract)	6.00	oz	0.44	2.64	_____
Contract:					
Windrow Garlic	330.00	box	1.50	495.00	_____
Harvest Materials:					
Bag - Cure Garlic	330.00	each	0.01	3.30	_____
Packing Materials:					
Box - Garlic	330.00	each	0.70	231.00	_____
Assessments:					
CA State Organic Reg. Fees	1.00	acre	6.25	6.25	_____
CCOF Inspection Fees	1.00	acre	0.78	0.78	_____
CCOF Membership Fees	1.00	acre	0.78	0.78	_____
CCOF - .5% of Gross Sales	1.00	acre	82.50	82.50	_____
Labor (machine)	12.30	hrs	8.71	143.67	_____
Labor (non-machine)	525.55	hrs	8.24	4,330.53	_____
Fuel - Gas	24.86	gal	0.98	24.36	_____
Fuel - Diesel	36.10	gal	0.71	25.63	_____
Lube				7.51	_____
Machinery repair				27.01	_____
Interest on operating capital @ 9.00%				171.97	_____
TOTAL OPERATING COSTS/ACRE				6,902.14	_____
TOTAL OPERATING COSTS/BOX				20.92	_____

Table 3c. Monthly Cash Costs to Produce Organic Garlic

	OCT 92	NOV 92	DEC 92	JAN 93	FEB 93	MAR 93	APR 93	MAY 93	JUN 93	JUL 93	TOTAL
Cultural:											
Disc 4X	17.08										17.08
Chisel 2X	15.89										15.89
Compost App.	236.40										236.40
List Beds	11.05										11.05
Pre-irrigate	27.64										27.64
Preplant Cult.		3.26									3.26
Shape Beds		3.98									3.98
Open Planting Furrow		4.91									4.91
Hand Plant Garlic		1,382.00									1,382.00
Close Planting Furrow		4.91									4.91
Roll Beds		3.59									3.59
Irrigate		25.34	20.74				20.74	20.74	20.74		108.28
Preemergence Flame Weed Control		34.75									34.75
Cultivate 7X			15.52	15.52			7.76	7.76	7.76		54.33
Postemergence Flame Weed Control			34.75								34.75
Hand Weed				70.04	41.20	41.20					152.44
Foliar Feed						19.23	19.23	19.23			57.70
Rodent Ctrl										16.48	16.48
Pickup Use										27.23	27.23
TOTAL CULTURAL COSTS	308.06	1,462.73	71.01	85.56	41.20	60.43	47.73	47.73	28.50	47.71	2,196.67
Harvest:											
Windrow Garlic										495.00	495.00
Top/Trim Roots & Bag Garlic										992.10	992.10
Grade & Pack										2,909.00	2,909.00
Transport to Broker										47.09	47.09
TOTAL HARVEST COSTS										4,443.19	4,443.19
Assessments:											
CA State Organic Reg. Fees										6.25	6.25
CCOF Insp. Fees										0.78	0.78
CCOF Membership Fees										0.78	0.78
CCOF .5% of Gross Sales										82.50	82.50
TOTAL ASSESSMENT COSTS										90.31	90.31
Interest	2.31	13.28	13.81	14.46	14.76	15.22	15.58	15.93	16.15	50.48	171.97
TOTAL OPERATING COSTS/ACRE	310.37	1,476.01	84.82	100.02	55.96	75.65	63.31	63.67	44.64	4,627.69	6,902.14
TOTAL OPERATING COSTS/BOX	0.94	4.47	0.26	0.30	0.17	0.23	0.19	0.19	0.14	14.02	20.92
Cash Overhead:											
Land Rent										359.38	359.38
Office Expense	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	61.09
Liability Ins.										1.88	1.88
Sanitation Services										6.19	6.19
Property Taxes			11.23								11.23
Property Ins.			5.61								5.61
Invstmnt. Rep.	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	6.25
TOTAL CASH OVERHEAD	6.73	6.73	23.58	6.73	6.73	6.73	6.73	6.73	6.73	374.17	4,51.63
TOTAL CASH COSTS/ ACRE	317.10	1,482.75	108.40	106.75	62.70	82.39	70.04	70.40	51.38	5,001.86	7,353.77
TOTAL CASH COSTS/ BOX	0.96	4.49	0.33	0.32	0.19	0.25	0.21	0.21	0.16	15.16	22.28

Notes

Garlic: Organic Production

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