UNIVERSITY OF MINNESOTA EXTENSION

AGRICULTURE, FOOD AND NATURAL RESOURCES

Growing garlic in Minnesota

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INTRODUCTION

Garlic (*Allium sativum* L.), a member of the onion family, has been cultivated for thousands of years and is widely used for both its culinary and medicinal attributes. As Americans have become more accustomed to garlic flavor and knowledgeable about the many health benefits of eating garlic, popularity of this crop has increased.

Most garlic in the U.S. is grown in the mild climate of northern California. Varieties adapted to mild climates and then grown in cold climates often do not perform well and usually develop a very "hot" flavor. Garlic is an adaptable species, however, and over thousands of years, varieties have been selected that grow well in cold climates, often with better garlic flavor than the varieties grown in mild climates.

Recent demand for high-quality garlic has prompted an interest in growing garlic for niche markets in the upper Midwest. With wholesale prices of fresh garlic between $2 and $4 per pound, and average yields of 8000 - 10,000 lbs. per acre, the potential for improving farm profitability is significant.

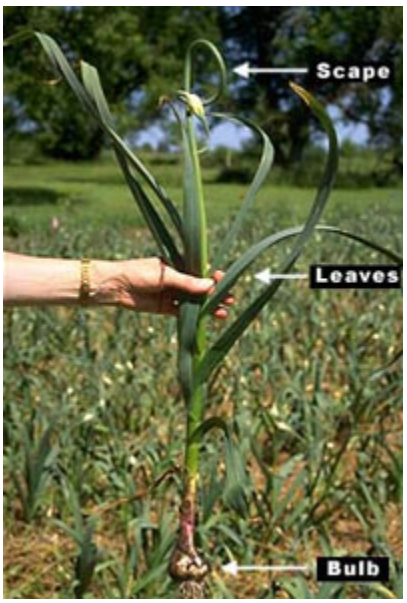
This publication provides guidelines for growing garlic in cold climates. The major areas addressed include variety selection, soils, cultural practices, pest management, harvesting, and storage.

VARIETIES

Over the many years of selection and cultivation, garlic has lost the ability to produce fertile seeds and, in some varieties, flower stalks and flowers are not even formed. Despite the fact that true garlic seeds cannot be easily produced, there are many different varieties from which to choose. These varieties have been selected over the years, presumably as the result of random mutations.

Garlic varieties are broadly classified into two main categories: **hardneck** and **softneck**.

Hardneck varieties (*Allium sativum* var. *ophioscorodon*) produce a flower stalk, or, technically, a scape, and are often termed "topsetting" or "bolting" varieties." The assumption is that they are most closely related to wild garlic. Flowers, if they are produced, usually abort and form "bulbils" instead. These are small, aerial cloves that have the same genetic make-up as the mother plant. They can be used for propagation, but the bulbs that are formed from bulbils are usually small the first year after planting. Two or three years are required before marketable bulbs are produced from bulbils. They are, however, an economical way to increase seed stock. Typically, hardneck garlic varieties have four to 12 cloves surrounding the flower stalk. Because of the hard flower stalk, they are difficult to braid. Another disadvantage of hardneck varieties is that they do not store well and may either start to form roots or start to dry out within a few months after harvest.



Hardneck garlic showing bulb, leaves, and scape plant parts.

Softneck varieties (*Allium sativum* var. *sativum*), sometimes referred to as "Artichoke" varieties, do not produce a seed stalk. These are among the varieties that are commonly used in California for commercial mass production. There are, however, some softneck varieties that are suitable for cold climates. Softneck varieties are considered to be the most domesticated varieties due to minimal flower stalk and bulbil production. They are generally more productive than hardnecks because all the energy goes to producing a bulb rather than a bulb and flower stalk. Each bulb generally contains between 10 to 40 cloves arranged in multiple layers somewhat like an artichoke. Softneck garlic generally has a much longer shelf life than hardneck garlic and typically can be stored for six to eight months without significant deterioration. They also are easy to braid.

Varietal characteristics can vary tremendously from one location to another, complicating variety selection. Climate can have a significant impact on garlic flower stalk formation as well as garlic taste. For example, a variety may be considered a softneck in one location, but in other locations it may produce a flower stalk. Occasionally, only a partial flower stalk is produced and bulbils will form directly above the bulb. Since there is no standardization, some garlic seed producers will rename particular varieties, leading to more confusion. It is best to try out several different varieties for a few years and select those that do best in your area. Characteristics of a few selected varieties when grown in colder climates are described below. For more information on varieties, refer to "Growing Great Garlic" and the "Supplement to Growing Great Garlic" by R. Engeland. Garlic seed may be purchased from various vendors listed at the end of this publication.

Softneck varieties

- **Inchellium Red** - Large bulbs and vigorous, mild garlic taste, difficult to peel.
- **New York White** - Often has purple streaks; may partially or completely bolt, when bolting occurs, bulb size is smaller.
- **Susanville** - Stores well; large size in mild climates, but is usually smaller than New York White under Minnesota conditions.

Hardneck varieties

- **German Red** - Often referred to as a "Rocambole" type, one of the most popular hardnecks for cold climates, large cloves usually 10 to 15 per bulb, prone to double cloves, flower stalk initially forms tight curls and then straightens out.
- **Merrifield Rocambole** - A New York selection that has performed well in Minnesota, similar to German Red except bulbs tend to be slightly larger, prone to double cloves.
- **Spanish Roja** - A northwest U.S. selection highly recommended by Filaree Farms, good garlic taste and yield.
- **Asian Tempest** - Genetically more similar to softnecks, but has characteristics of a hardneck; not quite as productive as German Red; usually four to eight large cloves per bulb; flower stalks do not curl; bulbils are much larger than those produced on German Red.

Note: Elephant garlic is not a true garlic, but is actually a type of leek, *Allium ampeloprasum*. It can grow much larger than true garlic with each bulb of five to six cloves weighing as much as one pound. The taste of elephant garlic is much milder than true garlic, and in cold climates can develop a sharp or bitter taste.

SOILS

Garlic grows best on well-drained soils high in organic matter. Sandy loam or loam soils have the most ideal texture for garlic. Drought or excessively wet conditions will reduce yields and marketable bulbs. Use of a green manure crop such as buckwheat tilled in a few weeks before planting is recommended to improve soil physical properties. Well-composted manure applied and incorporated at a rate of 20 tons to 30 tons per acre has also been shown to be ideal as a soil amendment, especially on low organic matter soils. The optimum soil pH for garlic is between 6 and 7. Liming is recommended if the pH is less than 5.8. Rates to apply should be based on soil

test recommendations. Prior to planting, soils should be well tilled to provide a loose growing bed for bulb growth.

FERTILIZER REQUIREMENTS

Nitrogen

Garlic has a moderate to high demand for nitrogen. Recommendations for nitrogen are based on previous crop and organic matter content (Table 1). Reduce recommended rates of nitrogen by: 70 lb. N/A if the previous crop is alfalfa, 40 lb. N/A if the previous crop is clover, and 20 lb. N/A if the previous crop is soybean or peas.

Nitrogen deficient garlic. Note symptoms of pale yellow leaves.

About one-quarter to one-third of the recommended N should be broadcast and incorporated in early fall before planting; suggested N sources at this time include either ammonium sulfate, urea, or blood meal. The remainder of the N should be topdressed as ammonium nitrate or blood meal in the spring after shoots are 4 inches to 6 inches tall. Avoid N applications after the first week in May since bulbing may be delayed. If manure or compost has been applied, be sure to take credit for the nutrient value of these amendments. Obtaining a nutrient analysis of these organic amendments before application is strongly recommended. Symptoms of nitrogen deficiency include a yellowing of older leaves and leaf tips, general yellowing of the plant, poor vigor, and low yields. Comparison of nitrogen deficient and nitrogen sufficient plants is shown in slides 2 and 3.

Nitrogen sufficient garlic. Note dark green leaves

Table 1: Nitrogen recommendations for garlic			
Soil organic matter level (O.M.)[1]			
Low	**Medium**	**High**	**Organic soil**
N to apply (lb/A)			
120	100	80	50
[1] Low = less than 3.1% O.M. Medium = 3.1 – 4.5% O.M. High = 4.6 -19% O.M. Organic soil = greater than 19% O.M.			

Phosphorous and potassium

Soil tests should be taken before planting to determine phosphorus and potassium needs. Recommendations for phosphorus based on a soil test are provided in Table 2. Use the Bray P1 test if soil pH is 7.4 or less and use the Olsen test if soil pH is greater than 7.4. Recommendations for potassium based on a soil test are provided in Table 3. All P and K fertilizers should be incorporated before planting. Symptoms of P deficiency include dark green to purple leaves and stunted growth. Symptoms of K deficiency include marginal scorching of the older leaves.

Table 2: Phosphorous recommendations for garlic						
Soil test P level (ppm)						
Bray P1	**0-10**	**11-20**	**21-30**	**31-40**	**41-50**	**51+**
Olsen P	**0-7**	**8-15**	**16-25**	**26-33**	**34-41**	**42+**
P_2O_5 to apply (lb/A)						
	200	80		50		

Table 3: Potassium recommendations for garlic					
Soil test K level (ppm)					
0-40	**41-80**	**81-120**	**121-160**	**161-200**	**200+**
K_2O to apply (lb/A)					
200	150	100	75	50	0

Calcium, magnesium and sulfur

Calcium and magnesium may be low in acid soils. The need for these elements usually can be met by following lime recommendations. Sulfur is a major constituent of compounds believed to be involved with the medicinal qualities of garlic. Yield responses to sulfur additions are not common in garlic, but there is active interest in determining how sulfur fertilizers may affect garlic flavor and medicinal compounds.

Micronutrients

Garlic response to micronutrients has not been reported in Minnesota. Addition of compost or other types of organic amendments will help to ensure that micronutrient supplies are adequate.

Use tissue analysis to help diagnose any suspected nutrient deficiencies and fine-tune a fertilizer program. Sufficiency ranges of the most recently matured leaf sampled at initial bulbing from high yielding garlic plants are presented in Table 4.

Table 4: Nutrient sufficiency ranges in the most recently matured leaf of garlic sampled at initial bulbing

N	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu	B	Mo
%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm
3.0 - 4.5	0.3 – 0.6	3.0 – 4.5	1.0 – 1.8	0.25 – 0.4	0.3 – 0.7	30 – 60	50 -70	13 -20	3 – 5	20 – 30	0.5 - 2

Many garlic varieties are susceptible to yellow tips. This disorder can occur even in the presence of adequate fertility. Unless the yellow tips occur early in the season (before bulbing), the disorder does not appear to have a drastic effect on yield. Yellow tips early in the season are usually a sign of water or nutrient stress or disease (see below).

PLANTING

Since true seeds are not produced by the garlic plant, cloves of the bulb are used for propagation. Garlic seedcloves for first time growers can be purchased as bulbs from local garlic growers or garlic seed producers who distribute nationally. Established growers usually save about 15 percent to 20 percent of their crop for planting the subsequent year. Depending on quantity ordered and variety, the price of garlic seedcloves can range from $3 to $20 per pound. Planting cloves from garlic purchased at the grocery store is not recommended; this garlic, primarily softneck varieties mainly adapted to mild climates, is usually stored at temperatures not conducive for proper bulb formation.

Time of planting is critical since both optimum shoot and bulb development require a cold treatment. **Garlic in Minnesota should be planted in the fall - usually within one to two weeks after the first killing frost (32 degrees Fahrenheit)**. In northern Minnesota, planting during the third to fourth week of September is recommended, while in southern Minnesota planting around the first or second week of October is recommended. Ideally, roots should be developing and shoots should be emerging from the clove but not above the soil at the time of the first hard freeze (28 degrees Fahrenheit). Garlic shoots will emerge from the ground in late March or early April. Unless given a proper cold treatment prior to planting, garlic planted in the spring will

often produce weak shoots and poorly developed bulbs. Lack of scape development in hardneck garlic and bulbing in all garlic is usually due to an inadequate cold treatment.

Spacing depends on a number of factors. Close spacing results in high yield but smaller bulbs, while spacing farther apart will result in lower total yields but larger bulbs. Generally, cloves planted in double row beds 30 inches apart on center and six inch spacing within and between rows in the beds results in good bulb size and yield (figure 1). Some growers will plant four to five row beds on 3 ft. to 4 ft. centers with six-inch spacing; however, plants in the middle of the bed will compete for light and nutrients, which may result in smaller bulbs than for those on the edge of the bed. Other options include single rows spaced 30 inches apart and cloves spaced six inches apart within the row. This wide spacing between rows allows for easy mechanical cultivation for weed control. Typically, yields of garlic planted in double rows 30 inches apart will range from three tons to five tons per acre. Higher yields can be attained with closer spacing and the use of herbicides to control weeds.

Fused garlic bulbs as a result of planting a double clove.

The amount of garlic to purchase will depend on the area to be planted, spacing, and variety. Some varieties have more plantable cloves per bulb than others. Generally, there are about 50 cloves per pound of cloves. Therefore, garlic spaced at six inches within a row 100 feet in length will require approximately four pounds of cloves or four to five pounds of bulbs. Generally, seedcloves from one pound of garlic bulbs will yield between four and eight pounds of harvestable bulbs. This will also vary, of course, with growing conditions and variety.

Individual cloves should be separated from the bulb the day of or up to two days before planting. Cloves separated for longer than two days tend to dry out. Generally, larger cloves from larger bulbs will produce the largest bulbs. In some varieties, large cloves may be actually two cloves fused together, known as a "double." These doubles will produce two bulbs that become flattened as they grow together. The result is less marketable, poorly shaped bulbs. Double cloves are more prevalent in certain hardneck varieties, such as German Red and other Rocambole types, compared to softneck varieties.

Garlic plant that results from a clove planted upside down.

Cloves should be planted with the pointed side up. Cloves planted upside down will develop a curved shoot that results in misshapen bulbs. The base of the clove should be planted two to three inches below the soil surface. For small acreage, cloves are generally planted by hand. Large commercial growers in California use mechanical planters.

MULCHING

Garlic roots and shoots can tolerate freezing conditions provided that sudden drops in temperature do not occur. Therefore, after planting, rows should be covered with a three-inch to four-inch layer of weed seed-free straw mulch to moderate soil temperatures and minimize excessively fluctuating temperatures in the winter and early spring. This mulch also will help control weeds during the growing season.

Severe cold injury in early spring.

Mulch should be removed in the spring after the threat of hard freezes is over, generally the second week of April. Garlic shoots can tolerate air temperatures as low as 20 degrees Fahrenheit without damage. Plant death, multiple shoots, and poor bulb development may occur if bulbs and shoots are exposed to temperatures below 10 degrees Fahrenheit. Some growers remove the mulch completely in the spring to allow the soil to warm faster, then return the mulch after the shoots are about six inches tall; others will leave the mulch in the between-row areas. In cool springs, complete removal of the mulch may be beneficial.

Symptoms of multiple shoots following cold damage in early spring.

Mulched garlic planting in early June.

Poor bulb development following cold damage in early spring.

IRRIGATION

Garlic has a relatively shallow root system and is sensitive to dry soil conditions. The amount of water to apply will depend on soil type. Irrigation is essential on sandy soils and may be beneficial in some years on finer textured soils. Enough irrigation should be provided so that the available water holding capacity does not drop below about 50 percent. The most critical stage for irrigation is during bulbing (end of May to mid July). Lack of irrigation or rainfall during this stage will result in smaller bulbs and earlier maturity. Irrigation should be stopped about two weeks before harvest to avoid stained bulb wrappers and diseases.

A soil's available water holding capacity (AWHC) can be obtained from the local Soil and Water Conservation District office or county soil survey. Table 5 shows AWHC estimations for some typical soil textures in Minnesota.

Table 5: Available water holding capacities for several Minnesota soils

Soil texture	Available water holding capacity	
	In. per inch of soil	In. per foot of soil
Loamy fine sand	.08 - .12	0.96 – 1.44
Sandy loam	.10 - .18	1.20 – 2.16
Loam	.14 - .22	1.68 – 2.64
Silt loam	.18 - .23	2.16 – 2.76
Clay loam	.16 - .18	1.92 – 2.16

Soil Water Monitoring. Two common ways of estimating soil water deficit to help schedule irrigation are: 1) soil water tension with soil moisture sensors and, (2) the feel and appearance method with the soil probe.

Soil water tension can be monitored at given point in the active root zone by electrical resistant moisture blocks or tensiometers. Soil tension or suction is a measurement usually expressed in centibars, and describes how tightly water is held to the soil particles.

The amount of soil water deficit for a given tension reading can be estimated by the use of Table 6 if the soil texture is known. Tensiometers directly read soil tension between 0 and 80 centibars, and work best in sandy loam or lighter textured soils. Resistance blocks, although slightly less accurate than tensiometers, work in a wider range of soil textures. Some types are as accurate in coarser textured soils as tensiometers.

To obtain representative soil tension readings with any sensor type, it should be installed and left throughout the irrigation season, preferably at two or more locations in the field. Two depths are generally desired at each location. These depths should be about one-third and two-thirds of the active root zone, or at around six-inch and 12-inch depths.

Table 6: Soil water deficit estimates for different soil textures and selected tensions							
Soil texture	**Soil tension in centibars**						
	10	**30**	**50**	**70**	**100**	**100**	**1500***
	Soil water deficit – inches per foot of soil						
Coarse sands	0	0.1	0.2	0.3	0.4	0.6	0.7
Fine sands	0	0.3	0.4	0.6	0.7	0.9	1.1
Loamy sands	0	0.4	0.5	0.8	0.9	1.1	1.4
Sandy loam	0	0.5	0.7	0.9	1.0	1.3	1.7
Loam	0	0.2	0.5	0.8	1.0	1.6	2.4
*1500 cbs refers to the permanent wilting point and the soil deficit value is equal to the soil's total available water capacity							

The feel/appearance method involves collecting soil samples in the root zone with a probe or a spade. The soil water depletion of each sample can be estimated by feeling the soil and comparing its appearance to data in Table 7. Soil samples should be taken from the top six inches to 12 inches in the root zone and at several locations in the field. Sum up the estimations from various depths for one location to estimate the total soil water depletion in the root zone. This method requires frequent use for an operator to develop the art of estimating soil water consistently.

More information on in-field soil moisture monitoring tools can be found in University of Minnesota Extension bulletins *Irrigation Scheduling: Checkbook Method*, FO-1322, and *Irrigation Water Management Considerations for Sandy Soils in Minnesota*, FO-3875, which are available at local county extension offices or can ordered online.

Table 7: Guide for judging soil water deficit based on soil feel and appearance for several soil textures

Moisture deficiency in. / ft.	Soil texture classification				Moisture deficiency in./ft.
	Coarse (loamy sand)	Sandy (sandy loam)	Medium (loam)	Fine (clay loam)	
	Field capacity				
0.0	Leaves wet outline on hand when squeezed.	Appears very dark, leaves wet outline on hand, makes a short ribbon	Appears very dark, leaves wet outline on hand, will ribbon out about one inch.	Appears very dark, leaves slight moisture on hands when squeezed, will ribbon out about two inches.	0.0
0.2	Appears moist, makes a weak ball.	Quite dark color, makes a hard ball	Dark color, forms a plastic ball, slicks when rubbed.	Dark color, will slick and ribbons easily.	0.2
0.4	Appears slightly moist, sticks together slightly.	Fairly dark color makes a good ball.	Quite dark, will make thick ribbon, may slick when rubbed.	Quite dark, forms a hard ball.	0.4
0.6	Appears to be dry, will not form a ball under pressure.	Slightly dark color, makes a weak ball.	Fairly dark, forms a good ball.	Fairly dark, makes a good ball.	0.6
0.8	Dry, loose, single-grained flows through fingers. (wilting point)	Lightly colored by moisture, will not ball.	Slightly dark, forms a weak ball.	With ball, small clods will flatten out rather than crumble.	0.8
1.0		Very slight color due to moisture, loose, flows through fingers. (wilting point)	Lightly colored, small clods crumble fairly easily.	Slightly dark, clods crumble.	1.0
1.2			Slight color due to moisture. Powdery, dry, sometimes slightly crusted but easily broken down in powdery condition. (wilting point)	Some darkness due to unavailable moisture, hard, baked, cracked sometimes has loose crumbs on surface. (wilting point)	1.2
1.4					1.4
1.6					1.6
1.8					1.8
2.0					2.0

REMOVAL OF SCAPES

For hardneck garlic, a decision needs to be made regarding scape removal. Research in Minnesota has shown that yields can be reduced by 20 percent to 30 percent if the scape is allowed to mature. Yields are most affected in poorly fertilized soil, and only minimally (< 5%) affected in high organic matter, well-fertilized soil. The time to remove the scape is just after the initiation of curling. There is some circumstantial evidence to suggest, however, that bulbs store better if the scape is left on until it turns woody. Scapes can be left on if a market for the bulbils is available to offset the loss in bulb yield.

WEED CONTROL

Garlic is a poor competitor with weeds. Unless weeds are controlled early, they can easily overtake young garlic plants, causing significant yield losses. For conventional (nonorganic) garlic production, application of RoundupTM in late August or early September, before planting garlic in the fall, is recommended if perennial weeds are a problem. Use of a green manure crop, such as buckwheat plowed down before going to seed, will reduce annual weed competition. A thorough, shallow cultivation before reapplying straw mulch in the spring also will keep down annual weed populations. Be sure to use straw free of weed seed as mulch. If desired, a few soil-applied and post-emergence herbicides are registered for use on garlic. Always read and follow herbicide label instructions for use.

INSECTS

Insects do not appear to be a major problem for garlic production in Minnesota. Over the last five years of growing garlic in Minnesota, no major outbreaks have been observed. Some potential insect pests include:

Onion thrips

These are small, sucking insects that are most prevalent during warm, dry weather. Symptoms include whitish specks on the leaves, which become blotchy in severe cases. Use of Safer soaps will help to control the pest and a few chemical pesticides are also available for control. Onion maggot. Maggots are white larvae, about one millimeter in length soon after hatching, growing to about five millimeters after about 15 to 20 days. They bore into the underground stem and cause young garlic plants to yellow and wilt. Yellowed plants should be removed immediately and discarded. Control this pest through proper rotation. Do not plant garlic after onions or other alliums. Although the maggot can complete two to three generations per year in the Midwest, maggot pressure and damage is highest in the spring.

Armyworms

Both the true and fall armyworm are common in the upper Midwest. True armyworm is active in June, while fall armyworm migrates from southern states in July and August. Eggs are laid in

large, fuzzy masses, and many larvae can feed on a given plant, often on the upper leaves. Once a plant is defoliated, larvae will move in mass to the next available plant. If high populations exist and damage occurs, the insect can be controlled by using Bt (*Bacillus thuringiensis*) sprays or other insecticides that are registered for leaf-eating caterpillars on garlic.

Wireworms

Wireworms are yellow/brown beetle larvae on-half inch to one and one-half inches long. The worms damage roots and bulbs and are most common if garlic is planted in fields following sod. Best control of this insect is to avoid planting garlic following sod. You should allow at least one year after sod is turned under before planting a garlic crop.

NEMATODES

The primary nematode of concern for garlic growers is the stem and bulb nematode. Invasion of the stem tissue occurs first, causing stunting, twisted, and pale leaves, usually followed by rotting of the lower stem and base of the bulb. In severely infested fields, young plants become enlarged and deformed and frequently die. The nematodes are primarily located in infected tissue, so to control this pest, infected plants should be removed by digging and then burned. Other control measures include planting clean seed stock, elimination of volunteer garlic and onions, and proper rotation. Do not plant garlic following any member of the onion family, or alternate hosts such as pea, parsley, celery, and salsify.

DISEASES

Most garlic diseases are either soil- or seed-borne and usually can be controlled with proper rotation and planting disease-free seed. The most common diseases include:

White rot

A major disease of commercial garlic grown in California and other areas of allium production. 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 ten years), destroying infected tissue, and planting disease-free seed stock.

Fusarium (basal or bottom rot)

The fungus is present in all soils and is usually considered a secondary invader because it attacks plants already weakened by insects, mechanical damage, or other diseases. Fusarium is most active at high temperatures. Symptoms are similar to white rot, except disease progression is much slower and death of the plant may not occur. 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.

Foliar symptoms of Fusarium

Basal rot of garlic caused by Fusarium

Pink root

Symptoms of this disease occur primarily in warm weather (>75 degrees Fahrenheit). The fungus infects the roots, causing them to turn pink, followed by root dieback. New roots are formed which also become infected. Aboveground symptoms include leaf tipburn. Control of this disease is by using at least a three- to four-year rotation without allium.

Botrytis

This fungus attacks garlic leaves following periods of warm, wet weather and bulbs in storage. Symptoms 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. 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 planting stock free of the disease.

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. When conditions are optimum for rapid 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

Until recently, this fungus was considered to be of minor importance in garlic production. However, recent outbreaks in California have reduced crop yields by up to 75 percent in some fields. The disease has not been reported in Minnesota. 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 and low rainfall and a temperature between 45 degrees and 55 degrees Fahrenheit. Disease incidence is highest in stressed plants. To reduce infection potential, use healthy seed in well-drained soil. Rotate with non-allium crops. Registered preventive fungicides may be the only method of control in situations where the disease potential/incidence is high. Varietal resistance has not been reported.

Viruses

Because garlic is clonally propagated, almost all planting stock is infected with some type of virus. The viruses are usually mild and do not seriously affect yield, and may even impart desirable characteristics in some varieties. One exception is onion yellow dwarf virus, which can cause severe mosaic in combination with other viruses. Any plants exhibiting severe mosaic symptoms should be rouged out. Tissue culture has been shown to be effective in producing "virus-free" garlic and is now used extensively for commercial plantings in California. Most of the garlic purchased from seed catalogs and other garlic growers contains some virus.

HARVESTING AND CURING

Knowing when to harvest has always been a tricky. In general, garlic harvest in Minnesota usually extends from the second week of July through the first week in August. Different varieties will often mature at different times. Harvesting too early will result in small bulbs that do not store well. Harvesting too late will force the cloves to pop out of the skins, making them susceptible to disease and resulting in unmarketable bulbs. There are a couple of procedures that can be used to determine when to harvest: 1) by early July the lower leaves will start to brown and harvest is usually optimum when half or slightly more than half of the leaves remain green, 2) pull a few bulbs and cut them in half; if the cloves fill the skins, then the bulbs are ready to harvest.

To harvest, the bulbs should be dug with the shoots and roots still attached. At this point there is some controversy about whether the bulbs should be washed. For most soils it is easiest to wash the bulbs the day of harvest and allow them to cure for a few weeks. Some growers feel that washing the bulbs may lead to more storage diseases, but this has not been observed in Minnesota. The alternative to washing the bulbs after harvest is to let the plants cure for three to four weeks and then brush the soil off after curing. This latter approach is less time-consuming in the short run, but more time-consuming in the long run.

After digging the plants, they should be tied in bundles of 10 to 15 and allowed to dry in a well-ventilated room. After about three to four weeks of curing, the shoots and roots should have dried down. The tops should then be cut about one-half to one inch above the main bulb and roots should be trimmed close to the base of the bulb. Clean bulbs by removing the outermost

skins, being careful not to expose any cloves. Any remaining soil should be brushed away. Bulbs can be graded into the following diameter sizes: < 2 inches, 2 to 2.5 inches, 2.5 to 3 inches, and > 3 inches. Premium bulbs are those 2.5 inches and larger.

STORAGE

Optimum storage conditions will depend on whether the garlic is to be used for table stock or planting stock.

Table stock garlic is best stored at 32 degrees to 40 degrees Fahrenheit and a relative humidity of 60 percent to 70 percent. Table stock garlic also can be stored at room temperature and 60 percent to-70 percent relative humidity, but will dehydrate faster than if stored at 32 degrees to 40 degrees Fahrenheit. Softneck garlic typically can be stored for six to eight months at room temperature, while hardneck garlic usually starts to deteriorate after about three to four months. At 32 degrees Fahrenheit, hardneck garlic can be stored for up to seven months without significant dehydration. Temperatures between 42 degrees and 52 degrees Fahrenheit will cause sprouting, and humidity greater than 70 percent tends to promote rooting.

Planting stock garlic should be stored at room temperature and 60 percent to 70 percent relative humidity. Garlic stored at 32 degrees to 40 degrees Fahrenheit and then used for planting will not bulb properly.

SOURCES FOR GARLIC SEED

Alice's Garlic Ranch
5550 Weatherstone Lane
Rochester, MN
507-529-8898
alicesgarlicranch.com

Filaree Farm
182 Conconully Hwy, Okanogan, WA 98840
509-422-6940

Harvest Moon Garlic, LLC
17437 Minnesota HWY 22, Litchfield, MN 55355
harvestmoongarlic@gmail.com
www.harvestmoongarlic.com

Hillside Prairie Gardens
47057 220th St. Brookings, SD 57006
605-695-0305 (cell)
605-693-3866 (home)
www.hillsideprairiegardens.com

Living Song Farm
7616 25th St. SW
Howard Lake, MN 55349
763-244-6659
www.livingsongfarm.com

Plum Creek Garlic
Chris R. Kudrna
3655 Plum Creek Drive, St. Cloud, MN 56301
www.plumcreekgarlic.com

Seed Savers Exchange
RR 3, Box 239
Decorah, Iowa 52101
319-382-5872

Sogn Valley Gardens, LLC
Dennison, MN 55108
612-701-2079
info@garlicmn.com

Sun Fresh Foods, certified organic
Paul and Karen Schmidt
19499 Killdeer Road, Preston, MN 55965
pschmidty@centurylink.net

Swede Lake Farms and Global Garlic
Deanna Stanchfield
10820 Swede Lake Road, Watertown, MN 55388
612-750-2553
SwedeLakeFarms@yahoo.com

Territorial Seed Company
P.O. Box 157, Cottage Grove, OR 97424
541-942-9547

Weavers Garlic Shedd
P.O. Box 67, Crabtree, OR 97335
541-491-3840

FURTHER READING

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Useful web pages

- http://www.garlicseedfoundation.info/classifieds.htm– More information about garlic
- http://www.garlicseedfoundation.info/bigNewsforGarlic.htm – Learn about a SARE study on garlic diversity