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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. Popularity of this crop has increased in recent years as Americans have become more accustomed to garlic flavor and knowledgeable about the many health benefits of eating garlic.

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 this crop for niche markets in the upper Midwest. With average yields of 8000 - 10,000 lbs. per acre and prices between $5.00 and $10.00 per pound at farmer's markets, 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. Recent research has shown that it is possible to produce true garlic seed, which eventually will improve genetic diversity in the crop. Despite the fact that true garlic seeds cannot be easily produced, there are still many different varieties from which to choose. These varieties have been selected over the years, presumably as the result of random mutations.

Garlic varieties can be broadly classified into two main categories: **hardneck** and **softneck**. Hardneck varieties produce a flower stalk while soft neck varieties do not. Based on genetic DNA analysis there are 10 major garlic varieties or types within these two categories (described below); however, 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. Within each variety are named selections or strains. Since there is no standardization, some garlic seed producers will occasionally rename a particular selection, leading to more confusion. **It is best to try out several different varieties/selections for a few years and select those that do best in your area.**

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 is that some hardneck varieties do not store well and may either start to form roots or start to dry out within a few months after harvest. Typical hardneck varieties are: "Rocambole", "Purple Stripe", "Glazed Purple Stripe", "Marbled Purple Stripe", and "Porcelain". Other unique varieties that often produce a scape are “Asiatic”, “Creole”, and “Turban”.

***Slide 1**. Hardneck garlic showing bulb, leaves, and scape plant parts.*

Softneck varieties (*Allium sativum* var. *sativum*) 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. In cold climates, however, hardneck varieties can be just as productive as or more productive than softneck varieties. In some softneck varieties a partial flower stalk may be produced and bulbils will form directly above the bulb. This will often occur in Artichoke varieties following winters

with poor snow cover and below average temperatures. Each bulb of a softneck variety 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. Typical softneck varieties are “Artichoke” and “Silverskin”.

Characteristics of the 10 major garlic types or varieties are described below. Some perform better in cold climates than others. For more information on varieties, refer to "Growing Great Garlic" and the "Supplement to Growing Great Garlic" by R. Engeland. For more technical information refer to the Volk et al. (2004) reference listed in the further reading section. Garlic seed may be purchased from various vendors listed at the end of this publication.

Major garlic types and varietal descriptions:

Rocambole – Moderately sized plant (3 to 4 ft tall with scape uncurled), characterized by a scape that coils 2-3 times before straightening out. Bulbils are numerous and generally a purple color. Bulbs are off-white with purple streaks. Clove skins are brownish and easy to peel. Bulbs store for about 4-5 months. Generally performs well in cold climates. Prone to double cloves.

- Typical named selections include: German Red, German Brown, Spanish Roja, Russian Red, Killarney Red, Montana Giant

Purple stripe – Moderately sized plant (3 to 5 ft tall with scape uncurled), characterized by a scape with ¾ of a coil and others just form a downwards U before straightening out. Bulbils are numerous and generally a purple color. Bulbs have purple streaks. Clove skins are brownish and more difficult to peel than rocamboles. Bulbs store for about 5-7 months. Generally performs well in cold climates. A typical bulb has 8 to 12 cloves and one pound of garlic will supply about 60 cloves. Double cloves rarely occur.

- Typical named selections include: Chesnok Red, Persian Star

Glazed Purple Stripe – Similar to Purple Stripe except clove color is more intensely purple and fewer cloves per bulb. One pound of garlic will supply about 60 cloves. Scape tends to form a full coil before straightening out.

- Typical named selections include: Purple Glazer, Red Rezan

Marbled Purple Stripe – Bulbs actually look more similar to Rocamboles than Purple Stripes, but genetic analysis places them closer to Purple Stripes. Scapes tend to be weak in some strains and form somewhat random coils. A typical bulb has 4 to 7 cloves and one pound of garlic will supply about 50 cloves. Plants are very vigorous in cold climates.

- Typical named selections include: Siberian, Brown Tempest, Krasnodar Red

Porcelain – Large and vigorous plants (4 to 6 ft tall with scape uncurled). They are characterized by a scape with loose and somewhat random coils before straightening out.

Bulbils are numerous, small, and generally a white color. Bulbs are large and typically contain 4 to 6 cloves. This characteristic is great for cooks, but growers need to save more of their crop for seed. Clove skins smooth and white. They tend to be more difficult to peel than Rocamboles. Double cloves are rare. Bulbs store for about 5-7 months. Generally performs well in cold climates. One pound of garlic will supply about 35 cloves.

- Typical named selections include: Romanian Red, Georgian Crystal, Music, Polish Hardneck, Zemo, Georgian Fire, Northern White, German White, Krasnodar White

Artichoke – This garlic type is usually a softneck but may partially bolt following cold winters. In some cases the bulbils form just above the bulb making the bulb unmarketable. In a mild winter only 1-2% will bolt. In a cold winter without snow cover, 70 to 100% will bolt. Bulbils that do appear are usually purple. Bulb color is whitish to purple blush. Bulbs typically contain12 to 20 cloves and one pound of bulbs will supply about 80 cloves. This is usually the most productive softneck type in cold climates. Cloves are difficult to peel. Bulbs store for 6 to 9 months.

- Typical named selections include: Inchellium Red, California Early, Susanville, California Late, Early Red Italian, Machashi, Red Toch

Asiatic – A shorter garlic plant that is about 3 ft tall when the scape is mature. Originally thought to be closely related to artichoke varieties, but further genetic analysis suggests it is a hardneck type. A flower stalk almost always forms under Minnesota conditions. Scapes generally do not curl and may be somewhat drooping with a long characteristic bulbil capsule. Bulbils are much larger than those produced on other garlic types and are usually dark purple. There are usually four to eight large cloves per bulb and one pound of bulbs will provide about 50 cloves. Double cloves do occur in this type. Cloves are brownish and bulb color varies from white to pink to purple striped. Clove skins are somewhat tight making it difficult to peel. Generally they perform well in cold climates. Cloves are very prone to splitting through the bulb skins if harvested too late. Bulbs typically can be stored for 5 to 7 months.

- Typical named selections include: Asian Tempest, Japanese, Wonha, Sakura, Pyong Vang

Turban – Genetically related to softneck types, but often forms a flower stalk under Minnesota conditions. Scapes are weak and tend to form a downwards U. The purple bulbils are numerous and small. There are usually 7 to 11 cloves per bulb and one pound of bulbs will supply about 60 cloves. Double cloves are not common in this type. Cloves are brownish and bulb color is usually dark purple striped. Clove skins are loose making it easy to peel. This type does not store well and typically only lasts 3 to 5 months. The advantage of this type is that it matures 1 to 3 weeks earlier than most other garlic types.

- Typical named selections include: Red Janice, Blossom, Xian, Tzan, Chinese Stripe

Creole – Genetically related to softneck types, but often forms a flower stalk under Minnesota conditions. Scapes that do form are weak and curl randomly sometimes just

forming a downwards U. Bulbils are small and usually white to pink. There are usually 8 to 12 cloves per bulb and one pound of bulbs will supply about 80 cloves. Creole garlic is most suited for warm climates and mild winters. For this reason, bulb size is small (usually less than 2 inches) under Minnesota conditions, especially after a cold open winter. However, the dark purple clove skins and generally sweeter taste make this garlic type unique and desirable. Bulb size can sometimes be improved by planting early in the spring as soon as the ground thaws. Clove skins are somewhat tight making peeling difficult. Bulbs typically can be stored for 6 to 8 months.

- Typical named selections include: Ajo Rojo, Burgundy, Creole Red

Silverskin – A true softneck type even under Minnesota conditions most years. The lack of a flower stalk makes this garlic type the best for braiding. Occasionally flower stalks will form following a cold winter. Clove number per bulb ranges from 8 to 40 and one pound of bulbs will supply about 90 cloves. Silverskin garlic is most suited for warm climates and mild winters. For this reason, bulb size is small (usually less than 2 inches) under Minnesota conditions, especially after a cold open winter. Bulb size can be larger than 2 inches following a mild winter. Because of their weak necks, the plants will lay down (lodge) about one week before harvest. Bulb size can sometimes be improved by planting early in the spring as soon as the ground thaws. Clove skins are somewhat tight making peeling difficult. Bulbs typically can be stored for up to one year.

- Typical named selections include: Silver White, Nookota Rose, Mild French, S&H Silver, Idaho Silver

Note: Elephant garlic is not 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, but 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 (N). Recommendations for nitrogen are based on previous crop and organic matter content (Table 1). Reduce recommended rates of nitrogen by: 70 lb. nitrogen per acre (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. Up to 20-30 lbs of N can be broadcast and incorporated in the planting beds in early fall before planting; suggested N sources at this time include ammonium sulfate, urea, or blood meal. The remainder of the N can be split applied in the spring as a topdress after shoots emerge and then again 2-3 weeks later. Avoid N applications after the first week in May as bulbing may be delayed. If manure or compost has been applied, be sure to take credit for the nutrient value of these amendments. Knowing the nutrient analysis of these organic amendments before application is strongly recommended. Additional N may not be needed in the spring if adequate amounts of compost have been applied in the fall. Symptoms of nitrogen deficiency include a yellowing of older leaves and leaf tips, general yellowing of the plant, poor vigor, thin stems, and low yields. Comparison of nitrogen deficient and nitrogen sufficient plants is shown in Slides 2 and 3.

***Slide 2**. Nitrogen deficient garlic. Note symptoms of pale yellow leaves.*

***Slide 3**. Nitrogen sufficient garlic. Note dark green leaves.*

Table 1. Nitrogen recommendations for garlic.

Soil Organic Matter	N to apply (lb/A)
Low (< 3.1%)	120
Medium (3.1-4.5%)	100
High (4.6-19%)	80
Organic Soil (>19%)	50

Phosphorus and potassium

Soil tests should be taken before planting to determine phosphorus (P) and potassium (K) 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. Phosphorus recommendations for garlic.

Soil Test P Level (ppm)		**P_2O_5 to apply (lb/A)**
Bray P1	Olsen P	
0-10	0-7	200
11-20	8-15	150
21-30	16-25	100
31-40	26-33	75
41-50	34-41	50
51+	42+	25

Table 3. Potassium recommendations for garlic.

Soil Test K Level (ppm)	**K_2O to apply (lb/A)**
0-40	200
41-80	150
81-120	100
121-160	75
161-200	50
200+	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 nutrition affects 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.

Tissue analysis

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.

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).

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

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

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

Slide 4. *Fused garlic bulbs as a result of planting a double clove.*

producers who distribute nationally. Refer to the section on Sources for Garlic Seed for a list of garlic vendors. 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 $4 to $24 per pound. Planting cloves from garlic purchased at the grocery store is not recommended. This garlic, primarily softneck varieties, is mainly adapted to mild climates, and generally does not store well under Minnesota conditions.

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°F).** 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°F). 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. 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.

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 with softneck varieties.

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 the U.S. use mechanical planters.

Slide 5. *Garlic plant that results from a clove planted upside down.*

Mulching

Garlic roots and shoots can tolerate freezing conditions provided that sudden drops in temperature do not occur. Therefore, within three to five weeks 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.

Mulch can 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 and then return the mulch after the shoots are about six inches tall; others will leave the mulch in place to minimize weed pressure and conserve moisture. In cool springs and in northern zone 3 growing areas, complete removal of the mulch may be beneficial.

Slide 6*. Severe cold injury in early spring.*

Slide 7*. Symptoms of multiple shoots following cold damage in early spring.*

***Slide 8**. Poor bulb development following cold damage in early spring.*

***Slide 9**. Mulched garlic planting in early June.*

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 (mid-May to late June or early 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	
	Inches per inch of soil	*Inches. per foot of soil*
Loamy fine sand	0.08 - 0.12	0.96 - 1.44
Sandy loam	0.10 - 0.18	1.20 - 2.16
Loam	0.14 - 0.22	1.68 - 2.64
Silt loam	0.18 - 0.23	2.16 - 2.76
Clay loam	0.16 - 0.18	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**	**200**	**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 6 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.

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

Soil Texture Classification					
Soil Water Deficit (in/ft)	**Coarse (loamy sand)**	**Sandy (sandy loam)**	**Medium (loam)**	**Fine (clay loam)**	**Soil Water Deficit (in/ft)**
.0	(field capacity) Leaves wet outline on hand when squeezed.	(field capacity) Appears very dark, leaves wet outline on hand, makes a short ribbon.	(field capacity) Appears very dark, leaves wet outline on hand, will ribbon about 1".	(field capacity) Leaves wet outline on hand when squeezed.	.0
.2	Appears moist, makes a weak ball.				.2
.4	Appears lightly moist, sticks together slightly.	Quite dark color, makes a hard ball.	Dark color, forms a plastic ball, slicks when rubbed.	Dark color, will slick and ribbons easily.	.4
.6	Appears to be dry, will not form a ball under pressure.	Fairly dark color, makes a good ball.	Quite dark, forms a hard ball.	Quite dark, will make thick ribbon, may slick when rubbed.	.6
.8		Slightly dark color, makes a weak ball.	Fairly dark, forms a good ball.	Fairly dark, makes a good ball.	.8
1.0	Dry, loose, single-grained. Flows through fingers. (wilting point)	Lightly colored by moisture, will not ball.	Slightly dark, forms a weak ball.		1.0
1.2		Very slight color due to moisture, loose, flows through fingers. (wilting point)	Lightly colored, small clods crumble fairly easily.	Will ball, small clods will flatten out rather than crumble.	1.2
1.4				Slightly dark, clods crumble.	1.4
1.6			Slight color due to moisture, dry, sometimes slightly crusted but easily broken down in powdery condition. (wilting point)		1.6
1.8				Some darkness due to unavailable moisture, hard, baked, cracked sometimes has loose crumbs on surface. (wilting point)	1.8
2.0					2.0

More information on in-field soil moisture monitoring tools can be found in University of Minnesota Extension Service 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.

Removal of Scapes

***Slide 10**. 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% to 30% 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. The immature scapes are edible and considered a delicacy in some countries. They can be sold at farmers markets as a green and used in stir fries, salads, or steamed vegetables. 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. More mature scapes are sometimes used in flower arrangements.

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 Roundup™ 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. Leaving the straw mulch in place will greatly reduce weed pressure. If mulch is removed in the spring to allow the soil to warm up, a thorough, shallow cultivation before reapplying straw mulch 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.

For information on registered herbicides for garlic see:
http://www.entm.purdue.edu/Entomology/ext/targets/ID/id56PDF/dryBulb.pdf

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 1 millimeter long soon after hatching, growing to about 5 mm 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. In general, a four to five year rotation is recommended to minimize spread of soil borne diseases. 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 know 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.

Slide 11. Foliar symptoms of Fusarium.

Slide 12. 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 n 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 in the northern half of the state and late June through mid July in the southern half. Different varieties will mature at different times. In general, garlic varieties mature in the following order from early to late: Tuban, Asiatic, Artichoke, Rocambole, Creole, Glazed Purple Stripe, Purple Stripe, Marbled Purple Stripe, Porcelain, and Silverskin. A span of three to four weeks can take place from the earliest to latest harvest. 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 late June to mid 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. If the soil is not wet at harvest or if the garlic is grown on sandy soils, it is generally not necessary to wash the bulbs. However for finer textured soils that are wet, some growers have found it is easiest to wash the bulbs the day of harvest and then allow them to cure for a few weeks. There is some concern that washing the bulbs may lead to more storage diseases, but this has not been observed in Minnesota. For bulbs that are not washed after harvest, the procedure 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 if there is a lot of soil adhering to the bulbs.

Whether bulbs are washed or unwashed, the plants 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° to 40°F and a relative humidity of 60% to 70%. Table stock garlic also can be stored at room temperature and 60% to 70% relative humidity, but will dehydrate faster than if stored at 32° to 40°F. 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°F, hardneck garlic can be stored for up to seven months without significant dehydration. Temperatures between 42° and 52° Fahrenheit will cause sprouting, and humidity greater than 70% tends to promote rooting.

Planting stock garlic should be stored at room temperature and 60% to 70% relative humidity.

Sources for Garlic Seed

Dakota Garlic/Gene Raak
1220 31st. St.
Edgerton, MN 56128
Telephone: 507-442-3587
Email: eugeneraak@yahoo.com

Girardin Gourmet Gardens
29321 Enger Court
Cannon Falls, MN 55009
507-263-5897

Hood River Garlic, LLC
P.O. Box 1701
Hood River, OR 97031
Telephone: 541-386-1220
Website: www.hoodrivergarlic.com

Living Song
7616 25th St. SW
Howard Lake, MN 55349
Telephone number: 320-543-3394
Web page: www.marienne.com/jerryford.php
Email: jerry@marienne.com

Peck's Patch
2250 Cty Hwy P
Chippewa Falls, WI 54729
Telephone: 715-723-8379
Email: pecks-patch@hotmail.com

SunFresh Foods
Paul & Karen Schmidt
19499 Killdeer Rd
Preston, MN 55965
pschmidty@earthlink.net

Tom and Maria Coffman
56115 120th Ave
West Concord, MN 55985
507-527-2090

TheGarlicStore.com
46050 Weld County Road 13
Fort Collins, CO 80524
Telephone: 1-800-854-7219 (M-F; 10 AM - 6 PM Mountain Time)
Website: www.TheGarlicStore.com
Email: TheChiefClove@TheGarlicStore.com

Filaree Farm
182 Conconully Hwy
Okanogan, WA 98840
Telephone: 509-422-6940
Website: www.filareefarm.com
Email: info@filareefarm.com

Grace & Glory Garlic
Address 3022 Elm Ave
Northboro, IA 51647
Telephone: 712-534-2545
Website: www.grace&glorygarlic.com
Email: kmboush@iamotelephone.com or grace&glorygarlic@iamotelephone.com

Johnny's Selected Seeds
955 Benton Avenue
Winslow, Maine 04901
Telephone: 877-564-6697
Website: www.johnnyseeds.com/default.aspx

Maplewood Gardens,
PO Box 73
Elderon, Wisconsin 54429
Telephone: 715-454-6609
Email: drgarlic@pcpros.net

Seed Savers Exchange
RR 3, Box 239
Decorah, Iowa 52101
319-382-5872
Web page:
http://www.seedsavers.org/

Territorial Seed Company
P.O. Box 157
Cottage Grove, OR 97424
541-942-9547
Web page:
http://www.territorial-seed.com/stores/1/index.cfm

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

Z NATURES CROPS – certified organically grown garlic
12967 Hialeah Path
Apple Valley, MN 55124
Telephone: 952-688-0783; 612-396-5960
Email: jmzimmer@Hotmail.com

Further Reading & Information

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Kamenetsky, R. (2007) Garlic: botany and horticulture. Hort. Reviews 33:123-172.

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Volk, G. M., A.D. Henk, C. M. Richards (2004) Genetic Diversity among U.S. Garlic Clones as Detected Using AFLP Methods. J. Amer. Soc. Hort. Sci. 129:559-569. http://www.garlicseedfoundation.info/JASHSgarlic.pdf

Useful Websites:

http://www.garlicseedfoundation.info/classifieds.htm
More information about garlic

http://www.bignewsforgarlic.com/
Learn about a SARE study on garlic diversity

http://www.extension.umn.edu/distribution/cropsystems/DC7317.html