

GARLIC

Post-harvest Operations

 INPhO - Post-harvest Compendium



Food and Agriculture Organization
of the United Nations

Garlic: Post-harvest Operations

Organization: Instituto Tecnológico de Veracruz (<http://www.itver.edu.mx>)

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1. Introduction

The famous French chef, X. Marcel Boulestin (1878-1943), is reputed to have said, "It is not really an exaggeration to say that peace and happiness begin, geographically, where garlic is used in cooking." ([Agricultural Outlook, 2000](#)).

Garlic is a crop widely grown for fresh market by many producers on a small scale for local markets and, particularly in the U.S., by a few large-scale producers for processing and fresh sales. About one million hectares (2.5 million acres) of garlic produce about 10 million metric tons of garlic globally each year, according to the United Nations Food and Agriculture Organization ([FAO](#)). Garlic is one of the most popular spices in the world. It is reported that in ancient Egypt, the workers who had to build the great pyramids were fed garlic daily, and the Bible mentions that the Hebrews enjoyed their food with garlic. In the first world war, garlic was widely used as an antiseptic to prevent gangrene and today people use garlic to help prevent atherosclerosis and improve high blood pressure ([Hedrick, 1972](#)). Although widely cultivated, it is only since routine seed production became possible in the 1980's that garlic can be called a domesticated crop, since a strict definition of domestication is the process of selective breeding of a plant or animal to better meet human needs. Clones held by growers today have been maintained as separate entities, but a system to confirm or refute the identity of a given clone has not been established. Only with several seasons of careful field observation can garlic clones be identified, and even then ambiguities often remain. For example, virus infection can dramatically reduce plant size and vigor, and alter leaf color and shape ([USDA, 2006](#)).

There are about 300 varieties of garlic cultivated worldwide, particularly in hot, dry places. Today, garlic is one of the twenty most important vegetables in the world, with an annual production of about three million metric tons. Major growing areas are USA, China, Egypt, Korea, Russia and India ([Innvista, 2005](#)) ([Fig. 1](#)). Garlic has been used as both food and medicine in many cultures for thousands of years, dating as far back as the time that the Egyptian pyramids were built. Later, gravediggers in early eighteenth-century France drank a concoction of crushed garlic in wine which they believed would protect them from getting the plague that killed many people in Europe. More recently, during both World Wars I and II, soldiers were given garlic to prevent gangrene, and today people use garlic to help prevent atherosclerosis (plaque build up in the arteries causing blockage and possibly leading to heart attack or stroke), improve high blood pressure, and reduce colds, coughs, and bronchitis ([UMM, 2004](#)).



Fig.1 Garlic producing areas. India, USA, Russia, Korea, China, Egypt

The percentage composition of typical garlic is: the portion of the plant most often consumed is an underground storage structure called a head. A head of garlic is composed of a dozen or more discrete cloves, each of which is a botanical bulb, an underground structure comprised of thickened leaf bases. Each garlic clove is made up of just one leaf base, unlike onions, which are composed of numerous leaf layers. The above-ground portions of the garlic plant are also sometimes consumed, particularly while immature and tender ([Wikipedia](#), 2006) ([Fig 2](#), Typical garlic)



Fig 2 Typical garlic (DGTA. CBTA 88, 2004)

a) Origin

Garlic is among the oldest known horticultural crops. In the Old World , Egyptian and Indian cultures referred to garlic 5000 years ago and there is clear historical evidence for its use by the Babylonians 4500 years ago and by the Chinese 2000 years ago. Some writings suggest that garlic was grown in China as far back as 4000 years ago. Garlic grows wild only in Central Asia (centered in Kyrgyzstan , Tajikistan , Turkmenistan , and Uzbekistan) today. Earlier in history garlic grew wild over a much larger region and, in fact, wild garlic may have occurred in an area from China to India to Egypt to the Ukraine . This region where garlic has grown in the wild is referred to as its "center of origin" since this is the geographic region where the crop originated and the only place where it flourished in the wild. In fact, although we sometimes hear about "wild garlic" elsewhere in the world, this is the only region where true garlic routinely grows in the wild without the assistance of human propagation. There are other plants locally referred to as "wild garlic", but these are invariably other species of the garlic genus (*Allium*), not garlic itself (*Allium sativum*). For example, *Allium vineale* is a wild relative of garlic that occurs in North America and is commonly called "wild garlic" ([USDA](#), 2006).

The "center of origin" for a plant or animal species is also referred to as its "center of diversity" since it is here that the broadest range of genetic variation can be expected. That is why those who have sought to find new genetic variation in garlic have collected wild garlic in Central Asia .

Once cultivated by the first garlic farmers outside of its "center of origin", what types of garlic did early afficianados grow? In fact, we know almost nothing about the early types of garlic produced. No designation of garlic varieties was made in the early writings discovered to date, be it hardneck or softneck, red or white, early or late, local or exotic. Throughout its

earlier history some have speculated that softneck garlic was the predominant type cultivated although evidence of what would be interpreted as a hardneck type was found interred in Egyptian tombs. It was not until garlic was cultivated in southern Europe within the last 1000 years that the distinction between hardneck and softneck was routinely noted. Until more ancient writings which describe garlic are found, or old, well-preserved samples are unearthed, we can only speculate about the early types of garlic grown.

Garlic producers and consumers have come through 5000 years of history growing and eating their crop with little need to specify type or variety. In fact it is a rather modern habit of only the last few hundred years whereby more detailed descriptions of varieties have come to be developed for any crop plant ([USDA](#), 2006).

b) Taxonomy

Garlic belongs to the family *Liliaceae*. Common garlic is classified as *Allium sativum*, British wild garlic as *Allium oleraceum*, and American wild garlic as *Allium canadense*. The field garlic of Europe and the Americas is classified as *Allium vineale*. False garlic is classified as *Nothoscordum bivalve* ([MEOE](#), 2001).

The origin of garlic as recalled in an Indian legend (from a Sanskrit manuscript dated to AD 350-375): The King of the Asuras, Rahu, stole the elixir of life from Vishnu and drank it. Vishnu's act of revenge was to cut Rahu's head off. Garlic sprang from the blood that was spilled.

Kingdom Plantae
Subkingdom Tracheobionta
Division Magnoliophyta
Class Liliopsida
Subclass Liliidae
Order Liliales
Family Liliaceae
Genus Allium
Species Allium sativum L.

([The plants database](#), 2000).

c) Botanical description

Garlic is a perennial that can grow two feet high or more. The most important part of this plant for medicinal purposes is the compound bulb. Each bulb is made up of 4 to 20 cloves, and each clove weighs about 1 gram. The parts of the plant used medicinally include fresh bulbs, dried bulbs, and oil extracted from the garlic. ([UMM](#), 2004). The Bulb, 12 inches to 18 inches tall (30-45 cm), 9 inches to 12 inches in spread (22.5-30 cm) ([Figure 3](#)).



Fig. 3. Garlic plant

Root

The roots are trimmed and the stems snipped or braided. Depending on where they are grown, the size, shape, colour, and flavour will differ. Colours can range from white to red to purple or pink ([Innvista](#), 2005).

Leaf

Garlic's straplike leaves are 1-2 feet long, surrounding a central flower stalk or scape, which develops a globular cluster of tiny white blossoms ([The Rodales Herb book](#), 1987).

The leaves are flat, linear, gray-green, and longitudinally folded, with a keel on the lower surface. Six to twelve of them grow, widely spaced, along the central stalk of the plant. The bases of non-topsetting types form a semi-stiff pseudostem, which remains upright until bulb maturity, when it bends over near ground level ([Garlic and friends](#), 1996).

A head of garlic is composed of a dozen or more discrete cloves, each of which is a botanical bulb, an underground structure comprised of thickened leaf bases. A garlic bulb is generally four to eight centimeters in diameter, white to pinkish or purple, and is composed of numerous (8-25) discrete cloves. The foliage comprises a central stem 25-100 cm tall, with flat or keeled (but not tubular) [leaves](#) 30-60 cm long and 2-3 cm broad. The [flowers](#) are produced in a small cluster at the top of the stem, often together with several bulblets, and surrounded by a papery basal [spathe](#); each flower is white, pink or purple, with six [petals](#) 3-5 millimetres long. The flowers are commonly abortive and rarely produce any [seeds](#) ([Wikipedia](#), 2006).

A garlic bulb develops from the bud primordia (2 or 3) of the cloves that are planted. Each bud primordia forms between two and six growing points, each of which develops a lateral bud which later develop into a clove. Temperatures during growth determine the rate of leaf growth ([Fig 4](#)), clove, and flower stalk development. Clove formation in non-bolting types differs slightly in that lateral-bud primordia (which form the cloves), form in the axil of the youngest 6-8 foliage leaves, beginning with the oldest one. At maturity, these develop into cloves. The growing point may then either form a clove and go dormant, or form an incomplete leaf that degenerates ([OSU](#), 2005).



Fig. 4 Garlic leaf

Flowers

The scape or flower stem usually emerges coiled, then later straightens to vertical as it grows and develops. A papery spathe covers the umbel at the top of this scape (also called a capsule). This spathe splits along one side to reveal the umbel, which consists of many bulbils that vary greatly in size between cultivars. The small, greenish-white, purple, or pink

flowers vary in number, or may be absent. In many cultivars, these flowers wither as buds, without opening. Even those that open and occasionally produce black withered seeds are sterile, however ([Garlic and friends](#), 1996) ([Fig. 5](#)).



Fig. 5 Garlic flowers (Wikipedia, 2006)

The scape of topsetting types remains rigid and fully upright, even after full senescence. The "true stem" is below ground and almost flat as a pancake, a small disc upon which the cloves rest within the bulb ([Growing Great Garlic](#), 1991).

Unlike onion, garlic produces a compound bulb, made up of 4-15 cloves. They are called cloves from the word cleave, which means both "to cling together" and "to divide along natural lines". Individual cloves are made up of two modified leaves, one which forms the protective papery outer skin, and the other which thickens to form a storage structure ([Garlic and friends](#), 1996). Each clove is inside a protective sheath, and the whole compound group is covered with a thin, papery skin, which is tan colored to pinkish. Flowers are very small, white to pinkish, with six segments and six stamens. These are sterile, borne in a terminal globe-shaped umbel ([Rodale's Illustrated Encyclopedia of Herbs](#), 1987).

Pollen and pollination

Garlic presents no pollination problem and when flowers do appear on garlic they are sterile so seeds are unknown. Both are propagated by bulblets or cloves ([Mann](#), 1952).

d) Cultivars

M.R. Pooler and P.W. Simon, of the University of Wisconsin, Madison, have made an effort to classify a confusing array of garlic varieties into a botanically organized and logical order. Filaree Farm in Okanogan, Washington offers organic planting stock of an exhaustive collection of garlic varieties, using the taxonomic system of Pooler and Simon to organize a catalog of amazing diversity. More than just a sales brochure, this publication can be a valuable reference tool for the would-be garlic grower. All garlics are divided into two common subspecies, based on whether or not they form a hard flower stalk (scape) or not. *Allium sativum* ophioscorodon, or the hardneck garlic, is considered the more primitive type, producing a tall stalk with a cluster of bulbils and undeveloped flowers at the top. These bulbil stalks emerge curled and looped in a variety of ways. How the stalk is produced and emerges is one of the classification descriptors of the different varieties within the general "hardneck" type. All hardneck varieties are sometimes lumped under the designation "rocambole," though this system uses that name for a specific sub-group of the ophioscorodon subspecies. These "ophio" varieties are generally considered the "gourmet" types, with better, more complex flavor than their softneck kin. In general, though, they do not store as well as softneck types. Over millennia of selection, softneck garlics, *A. sativum sativum*, were developed. These produce no hard central stalk or aboveground clusters of bulbils. All energy storage is in clove form within the bulbs produced underground. These

bulbs typically have many more cloves than the hardneck types, some of them small central ones, thought to be converted remnants from what once would have been a bulbil stalk. The leaves form a pseudostem above the ground, which softens and falls over as the garlic matures, very much like the tops of an onion. These are the garlics of the mainstream marketplace, because they yield more, store better, and require less maintenance in the field than the hardnecks (Fig 6). The soft, pliable stems also make them the garlics of choice for braiding. Softneck cultivars may be less hardy than hardnecks in cold winter areas (Fig. 7). Botanical purists, such as Rexford Talbert, insist on a third subspecies, *A. sativum* pekinense, although popular literature seldom if ever mentions this type, or describes how it is set apart from the hardneck, *Allium sativum* ophioscorodon, variety (Heirloom Vegetables, 1998) (Table 1 and Table 2).



Fig 6. Hardneck garlic



Fig. 7 Softneck garlic

Table 1. Examples of Garlic Cultivar Classifications

Cultivar	Species/Subspecies	Variety/Group Name
Spanish Roja	<i>A. sativum</i> ophioscorodon	Rocambole
Persian Star	<i>A. sativum</i> ophioscorodon	Purple Stripe
Red Rezan	<i>A. sativum</i> ophioscorodon	Purple Stripe/Glazed
Metechi	<i>A. sativum</i> ophioscorodon	Purple Stripe/Marbled
Music	<i>A. sativum</i> ophioscorodon	Porcelain
Inchelium Red	<i>A. sativum</i> sativum	Artichoke
Asian Tempest	<i>A. sativum</i> sativum	Artichoke/Asiatic
Chinese Purple	<i>A. sativum</i> sativum	Artichoke/Turban
Nootka Rose	<i>A. sativum</i> sativum	Silverskin
Ajo Rojo	<i>A. sativum</i> sativum	Silverskin/Creole

(Voigt, 2004)

Table 2. Cultivated species of *Allium* (Hanelt 1990)

Botanical names of the designation of taxa	Synonyms	English names
<i>A. ampeloprasum</i> L.		
Leek group	<i>A. porrum</i> L. <i>A. ampeloprasum</i> L. var. <i>porrum</i> (L.) Gay	Leek
Kurrat group	<i>A. kurrat</i> Schweinf. ex Krause <i>A. porrum</i> L. var. <i>aegyptiacum</i> Schweinf.	Kurrat
Great-headed-garlic group	<i>A. ampeloprasum</i> L. var. <i>holmense</i> (Mill.), Aschers. et Graebn. <i>A. ampeloprasum</i> L. var. <i>ampeloprasum</i> auct. <i>A. ampeloprasum</i> var. <i>pater-familias</i> (Boiss.) Rgl. <i>A. ampeloprasum</i> var. <i>bulbilliferum</i> Lloyd	Great-headed garlic
Pearl onion group	<i>A. ampeloprasum</i> var. <i>sectivum</i> Lued. <i>A. cepa</i> L.	
Common onion group	<i>A. cepa</i> var. <i>cepa</i> L. <i>A. cepa</i> var. <i>typicum</i> Rgl.	Onion
Aggregatum group	<i>A. ascalonicum</i> auct. non Strand <i>A. cepa</i> var. <i>ascalonicum</i> Backer <i>A. cepa</i> var. <i>aggregatum</i> G. Don <i>A. cepa</i> var. <i>solanina</i> Alef. <i>A. cepa</i> var. <i>perutile</i> Stearn	Shallot Potato onion Ever-ready onion
<i>A. chinense</i> G. Don		
	<i>A. fistulosum</i> L.	Rakkyo; Ch'iao T'ou
<i>A. fistulosum</i> L.		
	<i>A. bouddhae</i> Deb	Japanese bunching onion; Welsh onion
<i>A. x proliferum</i> (Moench) Schrad.		
	<i>A. cepa</i> var. <i>viviparum</i> (Metzg.) Alef. <i>A. cepa</i> var. <i>bulbiferum</i> Rgl. <i>A. cepa</i> var. <i>prolifera</i> (Moench) Alef. <i>A. canadense</i> auct. non L. <i>A. cepa</i> Proliferum group <i>A. wakegi</i> Araki <i>A. aobanum</i> Araki <i>A. fistulosum</i> var. <i>caespitosum</i> <i>A. sativum</i> L.	Top onion Tree onion Egyptian onion Catawissa onion Wakegi onion
Common garlic group	<i>A. sativum</i> L. var. <i>sativum</i> <i>A. sativum</i> L. var. <i>typicum</i> Rgl. <i>A. pekinense</i> Prokh.	Garlic
Ophioscorodon group	<i>A. sativum</i> L. var. <i>ophioscorodon</i> (Link)	

Botanical names of the designation of taxa	Synonyms	English names
	Doell <i>A. opkioscorodon</i> Link <i>A. sativum</i> L. var. <i>controversum</i> (Schrad.) Moore jr.	
<i>A. schoenoprasum</i> L.		
	<i>A. sibiricum</i> L. <i>A. alpinum</i> (DC.) Hegetschw. <i>A. riparium</i> Opiz <i>A. montanum</i> Schrank non Schmidt	Chives
<i>A. tuberosum</i> Rottl. ex Spr.		
	<i>A. uliginosum</i> G. Don <i>A. chinense</i> Maxim. et auct. non G. Don <i>A. odorum</i> auct. non L.	Chinese chives; Nira

e) *Growth habit*

Planting garlic beside rose bushes helps control the greenfly. It is also a good companion to lettuce, beetroot, summer savoy, chard, and strawberries; but should not be planted near peas and beans. Single garlic cloves are planted annually late in the fall and are referred to as seeds. In the spring, the plant produces long pointed leaves known as garlic shoots which can be used in salads and stir fries. Garlic does not develop its full flavour until the bulbs have dried and the outer layer appears papery. The garlic bulb is formed at the base of the perennial plant and is surrounded by several dry, white, red, or purple layers of skin. It is usually composed of up to twelve bulblets called cloves, which in turn are surrounded by papery layers of skin. When garlic sprouts, diallyl disulfide, the sulfur compound that gives it its distinctive taste and odour, goes into the new growth, causing the garlic itself to become milder. Garlic requires plenty of sunshine and does particularly well in Mediterranean countries where the big, juicy cloves have an excellent flavour. However, these do not keep well ([Innvista](#), 2005).

Garlic likes full sun and well drained soil. Garlic is quite tolerant when it comes to soil types and textures, but it definitely appreciates sandy-clay-loam that is friable (easily crumbled in the hand) and has a high organic content. It does best when the pH is in the 6.2 to 6.8 range. You can get your soil tested at the local university extension office or use one of the soil test kits on the market. Make sure you take samples from several spots in your garden and mix them together to obtain a representative reading. The garden or field should drain easily - standing water just won't cut it as the bulbs could rot in the ground. To increase the tilth of the soil, add organic matter such as well-composted manure. You can also green mulch, that is plant cover crops such as clover or buckwheat and then till them into the ground ([Figure 8](#)) ([The garlic store](#), 2003).



Fig.8 Soil type garlic ([DGTA, CBTA 88, 2004](#))

f) Cultural practices

Like all Alliums, garlic is a fairly heavy feeder that appreciates fairly high levels of fertility. Planting beds should be well amended with compost or other well-rotted organic matter, fertilized, and thoroughly worked before planting ([Fig 9](#)). A high phosphorus and potassium fertilizer should be incorporated before or at planting. Nitrogen will probably not be stable in the soil over the winter, so application should be delayed until the soil warms in the spring. Abundant organic matter in the soil enhances garlic's performance. Raised beds might be advisable to prevent waterlogged soil over the winter. After the ground crusts over with frost in early winter, a mulch of some sort will help prevent winter damage from frost heaving, and growth starting and stopping. During early season growth, plants should be watered whenever necessary to prevent the soil from drying out. In much of temperate North America, garlic grows in the part of the year with the most dependable rainfall ([Voigt, 2004](#)).

As garlic reaches maturity, the leaves will brown then die away. This is the cue that it is time to harvest your garlic crop. If you harvest too early the cloves will be very small, too late and the bulb will have split. Once picked, it is essential that garlic is dried properly, otherwise it will rot. The bulbs are often hung up in a cool, dry place. After a week or so, take them down and brush the dirt off gently - don't wash the bulbs at this stage ([Garlic-Central, 2004](#)).

Garlic should be dug while there are still at least 4 live, green leaves on the plants, since these leaves are attached to the papery wrappers on the bulbs, which quickly deteriorate in moist soil once the leaves die. Under humid summer conditions, bulbs left too long in the soil rapidly lose quality and storability. Wrapperless bulbs do not keep well. Bulbs with 4 or 5 layers of intact wrappings can be rubbed clean of dirt when they have cured and dried, leaving the cloves well covered and protected by the remaining wrappers. Garlic must be undercut or dug since it will not readily pull up out of the ground, even at full maturity ([Voigt,2004](#))



Fig 9 Cultural practices of garlic ([DGTA, CBTA 88, 2004](#))

Curing and Storing: Whole plants should be moved from the field into a dark, dry, well-ventilated area for drying and curing of the bulbs. Bulbs should be moved out of the sunshine as quickly as possible after digging. Do not dry by laying the plants in the sunshine. Tops and roots are allowed to remain on the drying bulbs. After several weeks, drying and curing should be complete, and the unique flavors fully developed within the bulbs (Most garlics will taste fairly similar, fresh from the ground). Tops and roots can be removed once drying and curing are complete. Depending on variety, the bulbs should store for 4-12 months, once they are properly cured. Best flavor also develops during curing. If garlic is planted fairly early in the fall, a cover crop of oats can be sown at planting time to try to provide some winter cover for the young garlic plants. In cold-season, low snow cover areas, a layer of organic mulch, applied after the ground freezes, is usually recommended for fall-planted garlic. Materials such as shredded leaves or straw can be used as mulching materials. This should stabilize the young plants, preventing frost heaving, cold injury, or premature growth in the late winter ([Voigt, 2004](#)).

Planting

g) Planting and Preliminary Actions

Although the bulbils produced at the top of the hardneck stalk can be used to produce bulbs, the process usually takes two years. In general, the size and weight of the clove planted will affect the ultimate size of the bulb formed. In a given planting of a single cultivar, bigger cloves almost always make bigger bulbs. Bulbils can be used in cooking, though they are difficult and tedious to peel. Unless these tiny bulblets are desired for faster reproduction of a garlic strain, it is usually recommended that the topsets be removed as the stalk is fully emerged and begins to uncoil. The development of the bulbils saps strength that will be transferred to the developing underground bulb if the topset is removed. Tender topsets and stems can be used in cooking, if desired. Wholesale removal of topsets is a tedious and smelly job, but will result in the production of much larger bulbs. Green garlic can be produced in much the same way that scallions are produced from onion sets. This can be a way to turn bulblets and undersized cloves left over from planting stock into a deliciously different crop. To grow garlic this way, small cloves or bulbils are planted thickly in rows, in mid to late fall, whenever garlic for mature bulbs is sown. These germinate and root well in late fall, go into dormancy through the coldest part of the winter, and start growing and are usable very early in the spring. Plants are dug, washed, and bunched much like scallions. The whole plant, leaves and all, is then chopped for use in recipes calling for garlic. The flavor is

usually more subtle and less pungent than from mature bulbs, which can be a definite plus in some dishes. When these plants start to bulb, the tops begin to toughen, so harvest should be completed before the daylength reaches the critical level, which cues the bulbing response. Garlic strains can be as unique and different as fine wines. Cooks using garlic in recipes need to become familiar with some of the more obvious differences in texture, taste, and aftertaste among all the various varieties. Just as Riesling is not an acceptable substitute for Merlot, neither is California White always a workable alternative to Spanish Roja for the garlic purist. As with chili peppers, some recipes work best when specific varieties are used. Some are hotter, some are nuttier, some are crunchier, and some hit the diner on different parts of the palate. Part of the wonder of the Filaree catalog is the detailed flavor information included in the variety descriptions. Where possible, try to match specific garlic strains to specific tastes. Like other fine edibles, certain garlics may be "in season" for only part of each year. Throughout much of North America, garlic is best planted in fall, like many other hardy bulbs, such as tulips and daffodils. If planted about 6-8 weeks before the ground can be expected to freeze (where the ground freezes), the cloves have a chance to root and grow a shoot to the soil surface in the fall. Then, in the spring, growth commences immediately, when the frost goes out of the soil, allowing lush growth before conditions would allow spring planting of garlic. In frost-free areas, plant garlic when hardy bulbs normally go into the ground (except in the extreme south where flowering bulbs are planted after a winter in the refrigerator for chilling). Garlic needs no chilling to begin growing. Except in rare early springs, garlic from spring plantings never comes close to making up the difference with fall plantings, and has to mature in the hotter, dryer conditions of mid-summer, as well. Just prior to planting, bulbs are broken apart into individual, unpeeled cloves which should be planted 3-4 inches deep, in 36 inch rows, about 4 inches apart in the row. Care may be taken to align the cloves within the row to keep foliage uniformly arranged in the rows to facilitate cultivation. If cloves are planted with the flattened sides perpendicular to the axis of the row, the leaves will all develop in the plane of the row. This makes mechanical cultivation much easier. In situations where hand cultivation is to be used in dense plantings, the angled sides of the clove should be planted parallel to the plane of the row so that the leaves will emerge perpendicular (crosswise) in the row, allowing plants to be spaced closer without leaf interference ([Voigt, 2004](#)).

Propagation

Garlic is propagated vegetatively from the cloves in each 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. Discard anything that is diseased, small, soft, damaged, or discolored. This is time-consuming, but important. Crack the bulb into individual cloves. Plant cloves basal plate-side down; where winters are mild, plant cloves 1 inch deep; where winters are severe, put them 2-4 inches deep. Mulch will help improve winter survival, suppress weeds, conserve soil moisture, and prevent soil erosion. It will also increase yields by keeping the soil cooler. Garlic quits growing when the soil temperature increases above 90°F. Garlic can also be mulched with clean straw or other organic material immediately after planting. The garlic will have no trouble pushing through an inch or more of mulch. However, mulch 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 ([Figure 6](#)). In-bed spacing of 6 inches by 12 inches is best, except for the variety 'Music,' which requires a spacing of 12 by 12 inches to produce the largest bulbs. Hardneck varieties put up a tall, woody 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 will be 1/3 smaller than if the scape is cut ([ATTRIA, 2001](#)) ([Fig 10](#)).



Fig. 10 Propagation of garlic

Irrigation

irrigation is not always required. As maturity nears, water should be withheld in areas where this is possible. In spring, two side-dress applications of nitrogen fertilizer should be made, the first about the time the soil warms enough to begin planting field corn (about 50-55° F at a 4 in depth), and the second about three to four weeks later. This will help the garlic plants to grow large and robust before they receive the daylength cue to begin bulbing in late spring. The bigger the plants when this signal is received, the bigger the resulting bulbs will be (Figure 9). About 40-50 pounds of actual N per acre, applied alongside the rows, is recommended for each of these side-dress applications. In smaller plantings, this works out to about 1 pound of N per 1,000 square feet of garlic. If conditions become dry in the spring while the garlic is actively growing, irrigation is recommended. The plants need to make as much growth at this stage as possible. All this energy will later be transferred into the bulbs. As the plants begin to bulb and mature, added water should be avoided, to allow better rot control. Varieties that produce topsets should have these scapes removed after they emerge. This forces all the energy of the plant into the bulbs, making them significantly larger. Bulbs will usually begin to be ready to harvest from late June through much of July, depending on garlic variety and where you are, geographically ([Voigt, 2004](#)).

Most of the time garlic really likes moist (not soggy) soil. Watering regularly in the fall during germination is essential. In dry climates, watering in winter is also important. Do not let the upper several inches of soil turn to dust. When do you need to water? Try the old farmer's test of clumping a bit of soil in your fist. If the clump stays together upon releasing your fingers, it is wet enough. If not, water. Keep on watering into the spring when the maximum green shoots are forming. Then about mid- to late June, or when the scapes (on hardnecks) are standing high, STOP. During the last four weeks, when the bulbs are finishing off, and the wrappers are drying out, too much water is not good. You can create a mold or fungus problem. Wet soil also makes for dirty and unappealing wrappers. In drier climates some people like to heavily irrigate at the pre-planting phase to help build a winter deep soil moisture reserve ([The garlic store, 2003](#)).

Fertilization

Five cultural practice considerations or recommendations are as follows: Weeds are frequently the worst problem; garlic is a poor competitor; the crop is in the ground a long time. Avoid, prevent and control them. Garlic is a moderate user of nitrogen; it may or may not require phosphorus, depending on the soil and previous management. It rarely responds to potassium fertilizer and rarely requires micronutrients. A good compost and/or organic matter

management program will satisfy most garlic nutrition needs. Up to half of the nitrogen needs should be available at planting or early in the season; another major need will occur in late winter, after rain caused leaching, and when the garlic begins its strong re-growth. No nitrogen should be applied during the last 60 days before harvest; the garlic should run out of nitrogen late in the season. Garlic can grow in a wide range of soil textures and soil pH. Fertilization, irrigation, and harvest practices may be different for each combination of situations ([SFC, 2006](#)).

1.1 Economic and social impact of the garlic crop

One niche market that has grown tremendously is garlic. From the eleven acres of garlic reported by the national Agriculture Statistics in 1992, New York's Garlic crop has grown to 240 garlic farms and 265 acres in 2002. Hard-neck garlic harvested in New York as a prized specialty crop must be harvested by hand. As new crops like garlic gain popularity among residents, farmers quickly adapt to meet this attraction (Noble, 2005).

U.S. garlic use has soared, hitting a record-high 3.1 pounds per person in 1999, three times the level in 1989. Despite impressive growth for vegetables such as broccoli, bell peppers, and carrots, no other vegetable has experienced stronger growth in demand over the past 10 years. The strong surge in use during the 1990's likely reflects: rising popularity of ethnic foods and restaurants, persistent publicity about the health benefits of garlic, and demand from the health supplements industry. Vigorous demand has resulted in a doubling of U.S. garlic production over each of the last two decades. Output was record high in 1999, and wholesale garlic prices this spring are a third lower than a year earlier. Farm value of the U.S. garlic crop is about \$200 million.

The trend in garlic use is unique among vegetables in that demand has not only increased steadily over many decades but has grown at an increasing rate. Also, despite impressive growth for vegetables such as broccoli, bell peppers, and carrots, no vegetable has experienced stronger growth in demand over the past 10 years. The strong surge in use during the 1990's likely reflects several factors:

- rising popularity of ethnic foods and restaurants;
- persistent health messages circulating in the press about garlic;
- demand from the health supplements industry; and
- the never-ending quest by consumers for new taste experiences.

These demand factors reflect a broadening view of garlic as a "functional food"--one that imparts both the usual taste and nutritional attributes of food, plus certain perceived health-enhancing benefits (broccoli is another example of such a food). Used primarily in cooking to flavor a wide variety of foods, garlic provides vitamin C, potassium, phosphorous, selenium, several amino acids, and a variety of sulfur compounds, including allicin--a naturally occurring compound whose promising health effects are now being studied at several major universities. Garlic has proven itself as a popular food and nutrition item, and is gaining scientific credibility as a significant contributor to good health. Garlic and its benefits are solidly launched, and U.S. production and consumption are likely to continue to grow in the next few years (Agricultural outlook,2000).

Table 3- World country garlic Production (Source: FAOSTAT, 2005)

Country	Production (Mt)	Country	Production (Mt)	Country	Production (Mt)
Algeria	40,000	India	500,000	Palestine, Occupied Tr.	1,400
Argentina	142,735	Indonesia	35,254	Paraguay	770
Armenia	6,000	Iran, Islamic Rep of	70,000	Peru	52,000
Azerbaijan, Republic of	20,919	Israel	6,900	Philippines	14,000
Bangladesh	73,000	Italy	30,472	Portugal	1,400
Bolivia	8,170	Jordan	3,621	Romania	76,172
Bosnia and Herzegovina	7,900	Kenya	2,000	Russian Federation	230,000
Brazil	88,471	Korea, Dem People's Rep	95,000	Réunion	600
Bulgaria	4,300	Korea, Republic of	350,000	Serbia and Montenegro	25,000
Cape Verde	50	Kuwait	400	Slovakia	4,200
Chile	19,500	Kyrgyzstan	25,000	Slovenia	260
China	11,093,500	Latvia	500	Spain	145,300
Croatia	8,200	Lebanon	6,000	Sudan	17,500
Cuba	60,000	Libyan Arab Jamahiriya	3,800	Syrian Arab Republic	37,000
Cyprus	220	Lithuania	400	Tajikistan	100
Czech Republic	1,500	Macedonia, The Fmr Yug Rp	3,500	Tanzania, United Rep of	2,000
Dominican Republic	3,000	Madagascar	820	Thailand	110,000
Ecuador	1,030	Malta	491	Timor-Leste	250
Egypt	162,077	Mauritius	65	Tunisia	6,100
Estonia	200	Mexico	44,431	Turkey	99,500
Ethiopia	71,000	Moldova, Republic of	5,000	Turkmenistan	2,800
France	28,800	Morocco	21,610	Ukraine	100,000
Gaza Strip (Palestine)	0	Myanmar	121,000	United States of America	236,960
Greece	15,200	Nepal	28,614	Uruguay	1,155
Guatemala	5,500	Netherlands	12,000	Uzbekistan	25,000
Haiti	550	New Zealand	1,500	Venezuela, Bolivar Rep of	9,800
Honduras	110	Niger	8,000	West Bank	0
Hungary	6,500	Pakistan	55,900	Yemen	12,000

1.2 World trade

Garlic is cultivated in most countries both in the tropic and temperate zones. In Asia, it is commercially grown in China, Indonesia, Pakistan, Republic of Korea, Thailand, and India. World trade in garlic is dominated by the developing countries and their share of trade has been growing at the expense of that of the developed countries during the past ten years (FAO, 2004).

Garlic production is concentrated both internationally and domestically. With 13 billion pounds annually, China is the leading producer, accounting for 66 percent of world output.

The majority comes from the Shandong Province—a prime agricultural area located southeast of Beijing. South Korea and India are second and third with 5 percent each, and the U.S. ranks fourth with 3 percent of the world production. Garlic falls into three broad product segments—fresh-market, dehydrating, and seed stock—with each differentiated by the way the crop is grown, handled, and used. About a fourth of all U.S. garlic is sold as fresh-market produce. The remainder is sold as various dehydrated products or for certified seed. Under average market conditions, there is little overlap among these three markets, although some lower grade fresh-market garlic is occasionally sold to dehydrators. Changes in relative market prices and stock levels can prompt some shifting of sales between the segments, particularly between fresh and processing markets. While seed and dehydrating garlic are mechanically harvested, fresh-market garlic is hand-harvested. Fresh product is carefully handled to preserve appearance (including sizing, grading, and storing) and is shipped and sold in the same manner as fresh produce. Fresh garlic can be marketed for up to 3 months from the time of harvest with standard warehouse storage, up to 6 months if kept in cold storage, and up to a year under controlled-atmosphere storage. Fresh garlic is used to manufacture crushed, chopped, peeled, and pureed garlic products (Agricultural Outlook, 2000).

U.S. fresh garlic exports to Canada are expected to be more competitive following Canada's imposition of year-round duties on Asian garlic. On January 2, 2001, the Canada Customs and Revenue Agency made a preliminary determination of dumping and applied provisional duties on Chinese and Vietnamese garlic. The Canadian International Trade Tribunal has initiated an inquiry to determine whether the dumping of garlic from the China and Vietnam has caused or is threatening to cause injury to Canadian garlic producers. Canada has applied anti-dumping duties on Chinese garlic since 1997, but only on garlic imported between July and December each year. Canadian growers lobbied the government for year-round duties after import levels of Asian garlic increased sharply during the non-duty period. While the United States captures slightly more than 20 percent of the Canadian import market for fresh garlic, China captures more than half. Canadian imports of fresh garlic from the United States during 1999 were 2,417 tons, valued at \$ 3.4 million.

1.3 Primary product

Garlic is most often used as a seasoning or a condiment ([Figure 11](#)). When crushed or finely chopped it yields allicin, a powerful antibiotic and anti-fungal compound. It also contains [alliin](#), [ajoene](#), [enzymes](#), [vitamin B](#), [minerals](#), and [flavonoids](#). Garlic is widely used in many forms of cooking for its strong flavor, which is considered to enhance many other flavors. Depending on the form of cooking and the desired result, the flavor is either mellow or intense. It is often paired with [onion](#) and [tomato](#). In culinary preparation, it is necessary to remove the parchment-like skin from individual cloves before chopping. Lightly crushing the cloves with the ball of the hand or flat of a knife makes this job much easier. When eaten in quantity, garlic may be strongly evident in the diner's sweat and breath the following day. This is because garlic's strong smelling sulfur compounds are metabolized forming allyl methyl sulfide. *Allyl methyl sulfide* (AMS) cannot be digested and is passed into the blood. It is carried to the lungs and the skin where it is excreted. Since digestion takes several hours, and release of AMS several hours more, the effect of eating garlic may be present for a long time. The well-known phenomenon of "garlic breath" is alleged to be alleviated by eating fresh [parsley](#). This is therefore included in many garlic recipes. However since garlic breath results mainly from digestive processes placing compounds such as AMS in the blood, and AMS is then released through the lungs over the course of many hours, eating parsley is at

best a temporary fix. Because of its strong odor, garlic is sometimes called the "stinking rose" (Wikipedia, 2006).



Fig 11 Garlic typical product (USDA, 2003)

Elements on quality assurance and export marketing

a) Export grading

I. Definition of produce

This standard applies to garlic of varieties (cultivars) grown from *Allium sativum* L. to be supplied fresh¹, semi-dry² or dry³ to the consumer, garlic for processing being excluded.

II. Provisions concerning quality

The purpose of the standard is to define the quality requirements for garlic at the export control stage, after preparation and packaging.

A. Minimum requirements

In all classes, subject to the special provisions for each class and the tolerances allowed, the bulbs must be:

- sound; produce affected by rotting or deterioration such as to make it unfit for consumption is excluded
- clean and practically free of any visible foreign matter
- practically free from pests
- practically free from damage caused by pests
- firm
- free of damage caused by frost or sun
- free of externally visible sprouts
- free of abnormal external moisture
- free of any foreign smell and/or taste⁴

The development and condition of the garlic must be such as to enable them:

- to withstand transport and handling, and
- to arrive in satisfactory condition at the place of destination

Classification

Garlic is classified in three classes defined below:

(i) "Extra" Class

Garlic in this class must be of superior quality and characteristic of the variety and/or commercial type⁵.

The bulbs must be:

- intact
- of regular shape
- properly cleaned

They must be free from defects with the exception of very slight superficial blemishes, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package.

The cloves must be compact.

The roots must be cut close to the base of the bulb in the case of dry garlic.

(ii) Class I

Garlic in this class must be of good quality. They must be characteristic of the variety and/or commercial type.

The bulbs must be:

- intact
- of fairly regular shape

The following slight defects, however may be allowed provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package:

- slight tears in the outer skin of the bulb.
- The cloves must be reasonably compact.

(iii) Class II

This class includes garlic which do not qualify for inclusion in the higher classes but satisfy the minimum requirements specified above.

The following defects may be allowed provided the garlic retains its essential characteristics as regards the quality, the keeping quality and presentation:

- tears in the outer skin or missing parts of the outer skin of the bulb
- healed injuries
- slight bruises
- irregular shape
- up to three cloves missing.

III. Provisions concerning sizing

Size is determined by the maximum diameter of the equatorial section:

(i) The minimum diameter is fixed at 45 mm for garlic in the "Extra" Class and at 30 mm for garlic in Classes I and II.

(ii) In the case of garlic presented loose - with cut stems - or in bunches, the difference in diameter between the smallest and largest bulb in the same package may not exceed:

- 15 mm when the smallest bulb has a diameter of less than 40 mm.
- 20 mm when the smallest bulb has a diameter equal to or more than 40 mm.

IV. Provisions concerning tolerances

Tolerances in respect of quality and size shall be allowed in each package, or in each lot for produce presented in bulk, for produce not satisfying the requirements of the class indicated.

A. Quality tolerances

(i) "Extra" Class

5 per cent by weight of bulbs not satisfying the requirements of the class, but meeting those of Class I or, exceptionally, coming within the tolerances of that class.

(ii) Class I

10 percent by weight of bulbs not satisfying the requirements of the class, but meeting those of Class II or, exceptionally, coming within the tolerances of that class.

Within this tolerance not more than 1 per cent by weight of bulbs may have cloves with externally visible sprouts.

(iii) Class II

10 percent by weight of bulbs satisfying neither the requirements of the class nor the minimum requirements, with the exception of produce affected by rotting or damaged by frost or sun, or any other deterioration rendering it unfit for consumption.

In addition to this tolerance, not more than 5 per cent by weight of bulbs may have cloves with externally visible sprouts.

Size tolerances

For all classes: 10 per cent by weight of bulbs not satisfying the requirements as regards sizing and the size indicated, but conforming to the size immediately above and/or below that specified.

Within this tolerance, not more than 3 per cent of bulbs may have a diameter smaller than the specified minimum but not less greater than 25 mm.

V. Provisions concerning presentation

A. Uniformity

The contents of each package, or lot for produce presented in bulk, must be uniform and contain only garlic of the same origin, variety or commercial type, quality and size (if sized). The visible part of the contents of the package, or lot for produce presented in bulk, must be representative of the entire contents.

B. Packaging

With the exception of dry garlic presented in strings, which may be transported in bulk (loaded directly into a transport vehicle), garlic must be packed in such a way so as to protect the produce properly.

The materials used inside the package must be new, clean and of a quality such as to avoid causing any external or internal damage to the produce. The use of materials, particularly paper or stamps, bearing trade specifications is allowed provided the printing or labeling has been done with non-toxic ink or glue.

Packages, or lots for produce presented in bulk, must be free of all foreign matter.

C. Presentation

Garlic must be presented as follows:

(i) loose in the package, with cut stems, the length of the stem not to exceed:

- 10 cm in the case of fresh and semi-dry garlic,

- 3 cm in the case of dry garlic

(ii) in bunches by:

- number of bulbs,

- net weight

The stems must be evened off.

(iii) in the case of dry and semi-dry garlic only, in strings by:

- number of bulbs, there being at least six bulbs per string

- net weight.

In the case of presentation in bunches or strings, each package must have uniform characteristics (number of bulbs or net weight).

Irrespective of the type of presentation, the stems must be cut cleanly, as must the roots in the case of dry garlic classified in the "Extra" class.

VI. Provisions concerning marking

Each package⁶ must bear the following particulars, in letters grouped on the same side, legibly and indelibly marked, and visible from the outside.

For garlic in strings transported in bulk (loaded directly into a vehicle), these particulars must appear on a document accompanying the goods, and attached in a visible position inside the transport vehicle.

A. Identification

Packer) Name and address or and/or) officially issued or
Dispatcher) accepted code mark ⁷.

B. Nature of produce

- "Fresh garlic", "semi-dry garlic" or "dry garlic", when the contents are not visible from the outside
- Name of the variety or commercial type ("white garlic", "pink garlic", etc.)
- "Smoked", where appropriate.

C. Origin of produce

- Country of origin and, optionally, district where grown, or national, regional or local place name.

D. Commercial specifications

- Class
- Size (if sized) expressed as minimum and maximum diameters of the bulbs (UN/ECE, 1998)

High quality garlic bulbs are clean, white (or other colors typical of the variety), and well cured (dried neck and outer skins). The cloves should be firm to the touch. Cloves from mature bulbs should have a high dry weight and soluble solids content (>35% in both cases). Grades include U.S. No. 1 and unclassified, and are based primarily on external appearance and freedom from defects. Minimum diameter for fresh market is about 4 cm (1.5 inches) (Cantwell, 2006).

B) Market requirements

Packaging

For bulk marketing the tops of garlic are cut off 1 cm above the bulb and only the loose outer skin rubbed off. Garlic may be made up into strings. These are of 2 kg for garlic. This is, however, a labour-intensive operation suited to small-scale production using family labour. It is not cost-effective on a commercial scale.

1 *" means produce with a "green" stem and with the outer skin of the bulb still fresh.*

2 *"Semi-dry garlic" means produce with the stem and outer skin of the bulb not completely dry.*

3 *"Dry garlic" means produce in which the stem, outer skin of the bulb and the skin surround each clove are completely dry.*

4 *This provision does not preclude a specific smell and/or specific taste caused by smoking.*

5 *This provision does not preclude different colouring resulting from smoking.*

6 *Package units of produce prepacked for direct sale to the consumer shall not be subject to these marking provisions but shall conform to the national requirements. However, the markings referred to shall in any event be shown on the transport packaging containing such package units.*

7 *The national legislation of a number of countries requires the explicit declaration of the name and address. However, in the case where a code mark is used, the reference "packer and/or dispatcher (or equivalent abbreviations)" has to be indicated in close connection with the code*

Consumer preferences

Varieties and commercial cultivars

Quality

Duration of storage

On acceptance of a consignment, care must be taken to ensure that the product is dry. Garlic must not be wet or covered with condensation; instead, it must be dry and parchment-like.

The stems, the outer bulb skin around the individual garlic cloves must be completely dry.

Dry garlic may be kept for 6-7 months at temperature of 0-1° C and 65-70 % R.H.

Intended use

Garlic serves as a spice in particular for seasoning meat, sausage products and soups and is also used for pharmaceutical purposes due to its health-promoting and disinfecting action when applied externally. Garlic is also further processed industrially into dry products, such as slices, granules or powder, or by distillation to produce garlic oil.

With the onset of rain or snowfall, cargo handling of conventionally shipped goods must be stopped immediately.

Evaporation losses entail losses of essential oils, sugar and vitamins.

Ventilation

Garlic requires particular ventilation conditions:

Recommended ventilation conditions: air exchange rate: 25 changes/hour (airing) with continuous supply of fresh air.

Garlic consume large quantities of oxygen due to their metabolic activity and have a tendency to self-heating, it is important to dissipate the CO₂ gas arising during respiration by appropriate ventilation measures and to ensure cooling by supplying fresh air if the cargo becomes heated.

With chilled goods, the fresh air supply must be controlled in such a way that the CO₂ content of the circulating hold/container air does not exceed 0.4 vol.%.

Biotic activity

Garlic display 2nd order biotic activity.

Garlic is a living organ in which respiration processes predominate, because its supply of new nutrients has been cut off by separation from the parent plant.

Care of the cargo during the voyage must be aimed at controlling respiration processes (release of CO₂, water vapor, ethylene and heat) in such a way that the cargo is at the desired stage of ripeness on reaching its destination.

In addition, garlic bulbs must be protected from light during the voyage, as there is otherwise an increased risk of sprouting => in the case of conventional loading, put up awnings if the hatches are opened when at sea.

Gases

Due to the increased intensity of respiration and associated oxygen consumption, garlic has a tendency to self-heating and to elevated CO₂ concentrations in the hold. To counter these phenomena, particularly extensive ventilation measures are required.

With chilled goods, the fresh air supply must be controlled in such a way that the CO₂ content of the circulating hold/container air does not exceed 0.4 vol.%. The sensitivity of garlic to ethylene is low. The rate of ethylene production is very low, being below 0.1 µl/kg-h

Self-heating / Spontaneous combustion

Oil content: 0.12 - 0.20% essential oils [1], in particular allicin. Allicin breaks down into diallyl disulfide, which produces the pungent garlic odor/flavor. As a consequence of the respiration process in garlic bulbs, a tendency to self-heating, CO₂ concentration and high O₂ consumption may be observed. Self-heating is associated with losses of essential oils together with sugar and vitamins.

The risk of self-heating is further increased by exposure to excessively high storage temperatures and excessive moisture levels.

Odor

Active behavior -Garlic bulbs exude an unpleasant or pungent odor. An increase in odor intensity may indicate incipient self-heating.

Passive behavior- Garlic bulbs are highly odor-sensitive and should not be stowed together with hides or furs, bones or other animal products.

Contamination

Active behavior- Garlic bulbs may produce dust during loading.

Passive behavior- Garlic bulbs are sensitive to contamination by dirt, fats and oils.

Mechanical influences

Garlic bulbs are sensitive to impact, as they break up easily. According to [13], it is necessary for garlic to be properly treated in the fields, before it is transported. If, in conjunction with high temperatures and high moisture levels, garlic is squashed during storage, rot may set in within a very short period.

Toxicity/Hazards to health

Respiration may cause life-threatening CO₂ concentrations or O₂ shortages. Therefore, before anybody enters the hold/container, it must be ventilated and a gas measurement carried out. The TLV for CO₂ concentration is 0.49 vol.%. Like onions, garlic bulbs consume large amounts of oxygen.

Shrinkage/shortage

Evaporation losses and the associated weight loss entail additional losses of essential oils, sugar and vitamins.

Insect infestation/diseases

Garlic bulbs may be infested by rats or mice. This may be the case even prior to loading, a fact which needs to be taken into account on acceptance of a consignment (TIS, 2006).

1.4 Medicinal uses

Garlic is taken orally to reduce high blood pressure, prevent heart disease and arteriosclerosis, treat earaches, stimulate both the immune and circulatory systems and prevent cancer. Other applications include treating diabetes, arthritis, colds and flu, fighting stress and fatigue and maintaining healthy liver function .

Various official monographs list garlic as being both antibacterial and antimycotic (suppresses the growth of certain fungi. Consequently garlic is administered to treat *Helicobacter pylori* infections, and to inhibit the growth of *Candida albicans*, particularly in cases of recurrent yeast infections .

Parasitic worms are also apparently susceptible to garlic. The World Health Organisation “Monographs on Selected Medicinal Plants” reports garlic has having been used to treat roundworm (*Ascaris strongyloides*) and hookworm (*Ancylostoma caninum* and *Necator americanus*) infestations, listing allicin as the active anthelmintic constituent.

The United States Department of Agriculture lists garlic as being a viricide on its Medicinal Plant Database .

The garlic bulb contains an amino acid derivative called alliin which is in fact odourless and contains no antibacterial properties. However when the garlic bulb is crushed or ground, alliin comes into contact with an enzyme (alliinase) that converts the alliin into allicin.

Allicin is the reason for garlic’s distinctive odour, and is a potent antibacterial agent .

The use of garlic in history goes back thousands of years, with Hippocrates, Galen, Pliny the Elder, and Dioscorides all reporting its use for various conditions, including parasites, low energy, and respiratory and digestive disorders. Garlic’s reputation in Western medicine was established in 1858 when Louis Pasteur confirmed its antibacterial properties.

Traditional Chinese medicine has used garlic since at least A.D. 510, and is still using it for amoebic and bacterial dysentery, tuberculosis, scalp ringworm and vaginal trichomoniasis.

Other folk medicine cultures have traditionally used garlic for treating colds and flu, fever, coughs, headache, hemorrhoids asthma, arteriosclerosis, low blood pressure, both hypoglycemia and hyperglycemia, cancer and as an aphrodisiac (amongst other things) .

Garlic has also been used to treat pinworms.

The antiparasitic nature of garlic is demonstrated in the uses to which it has been applied in folk medicines around the world. For example, it has been traditionally used to treat parasitic worms in such diverse cultures as East Asia , India , Italy , North America , Peru , Saudi

Arabia , Tunisia and the West Indies . Traditional practitioners in Greece have long used garlic extracts to protect against amoebic infections .

Laboratory tests (both in test tubes and in animals) have demonstrated that fresh garlic has antimicrobial activities (including antibacterial, antiviral, antifungal, antiprotozoal, and antiparasitic).

Particular activity against *B. subtilis*, *E. coli*, *P. mirabilis*, *Salmonella typhi*, methicillin-resistant *Staphylococcus aureus*, *Staphylococcus faecalis*, *Salmonella enteritidis*, and *Vibrio cholerae* have been noted.

Bacteria shown to be susceptible to garlic in the test tube include species from *Staphylococcus*, *Escherichia*, *Proteus*, *Salmonella*, *Providencia*, *Citrobacter*, *Klebsiella*, *Hafnia*, *Aeromonas*, *Vibrio* and *Bacillus* genera . Human trials as well as in vitro studies have shown that garlic consumption is active against *Mycobacterium tuberculosis*.

An epidemiological study in China among 214 people from the Shandong province suggested that garlic consumption may have a protective effect against *H. pylori* infection and the development and progression of precancerous gastric lesions .

Fungi demonstrated to be susceptible to garlic in lab tests include the genera *Microsporum*, *Epidermophyton*, *Trichophyton*, *Rhodotorula*, *Torulopsis*, *Trichosporon*, *Cryptococcus neoformans*, and *Candida*, including *Candida albicans*. It is reported that garlic is more effective against pathogenic yeasts than nystatin, especially *Candida albicans*.

Essential garlic oils were active on *Entamoeba histolytica* in clinical trials, confirming its potential for antiamoebic activity.

Antiprotozoan activity has also been demonstrated in lab tests against *Paramecium caudatum*. Garlic has also shown itself in lab tests to have several immune-enhancing effects. Fresh garlic, garlic extracts, oil and oleoresin have been generally recognized as safe when consumed in amounts commonly found in food. Garlic has been used for medicinal purposes in clinical studies lasting up to 4 years without reports of significant toxicity. It is possibly unsafe when consumed in large amounts, with the American Herbal Products Association Botanical Safety Handbook claiming that high doses could be dangerous or even fatal for children. There are, however, no reported cases of significant adverse reactions or mortality in children associated with the ingestion of garlic.

There are no published reports of garlic adversely affecting pregnancy, although it would be wise to avoid consuming large amounts during these times (Theoretically large amounts of garlic might act as an abortifacient causing uterine contractions). There is a lack of reliable information dealing with the use of garlic while breastfeeding, but it has been generally accepted that consuming it in amounts commonly found in food would be safe.

By- products

The sulfur compounds that give garlic its trademark odor are probably also responsible for its benefits. Crush a garlic clove and you start a chemical reaction that produces allicin, an antibacterial compound that has killed nasty stomach bugs in laboratory tests. Allicin and its byproducts might help protect the heart by lowering cholesterol levels and thinning the blood (Healthyme, 2006).

2 Post-production Operations

Traditional and improved picking operations

2.1 Harvesting

Keeping garlic in the ground beyond a certain point does not result in bigger bulbs, but rather dried out, split and nearly useless ones. When to harvest? When the lower third to half of the

leaves have turned brown, but there are still mostly green leaves higher on the plant, it's time to harvest (Figures 12 and 13). Others suggest harvesting when the hardneck scapes are standing straight up but before the pods containing the bulbils open up. You can always test dig one or two plants. You should be able to see the shape of the cloves beginning to bulge through the wrapper. On the High Plains, depending on the weather, harvest can begin as early as the first week of July. There is also a two to three week difference in the harvest dates of the several varieties. So watch you plants carefully. To get the bulb out of the ground, don't just try to pull them. The stalk will break. You must dig, using a pitchfork or the like in order to loosen the soil. Then you can lift the entire plant out of the ground. Don't let the bulb stay in the sun very long as it will sun scald, which reduces its quality ([The garlic store](#), 2003).



Fig. 12 Harvest of garlic by hand ([DGTA. CBTA 88, 2004](#))

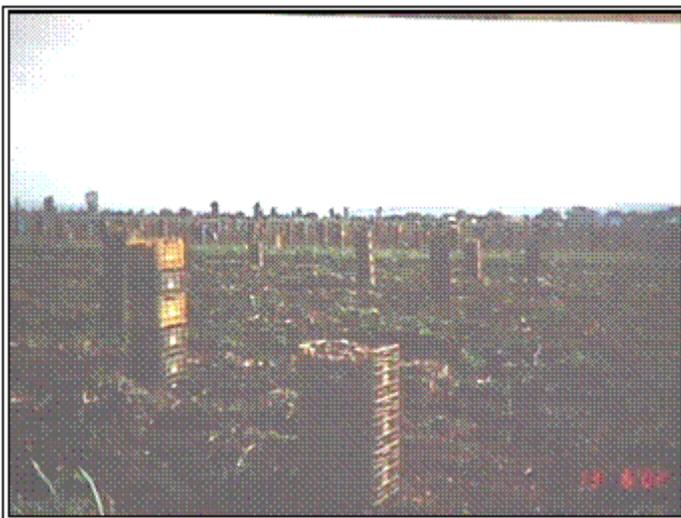


Fig. 13 Harvest tool with garlics ([DGTA. CBTA 88, 2004](#))

a) Yield

Depending on the type of garlic being produced, yields can range from 5,000 to 17,000 lb/acre. Yields are dependent on planting date, plant population and planting stock size and quality (Fig 14). Yield of elephant garlic, which is normally planted at low plant populations,

can range from 1,000 to 6,000 lb/acre. Garlic is ready for harvest when the tops become partly dry and bend to the ground (OSU, 2005).



Fig. 14 Garlic picking and yield ([DGTA. CBTA 88, 2004](#))

2.2 Transportation

Means of transport

Ship, truck, railroad

Not suitable for closed standard containers, as garlic bulbs, like onions, consume large quantities of oxygen and special ventilation measures have therefore to be implemented. Open-sided containers are more suitable, provided that the tarpaulins are rolled up, and wooden dunnage or pallets on the floor of the container improve ventilation. Particular care must be taken on board and at the port of destination to provide adequate weather protection and, where applicable, to roll down the tarpaulins if it starts to rain.

Cargo handling

In damp weather (rain, snow), the cargo must be protected from moisture, since this may lead to self-heating, premature sprouting and root growth

Stowage factor

4.00 m³/t (jointed wooden boxes, 17 kg)

2.65 m³/t (bags)

2.55 - 2.75 m³/t (bags)

Stowage space requirements

Cool, dry, good ventilation

Segregation

Market pen, oil crayon, fiber rope, thin fiber nets

Cargo securing

In order to ensure safe transport, the packages must be stowed and secured in the means of transport in such a manner that they cannot slip, tip or shift during the transport. If loss of volume and degradation of quality are to be avoided, the packages must not be damaged by other articles or items of cargo (TIS, 2006).

2.3 Packing

Fresh market garlic is commonly packaged in cartons, holding 12 display cartons of 1 dozen each; 10-lb cartons holding 12 tube or vexar mesh bags; packages (2-3 bulbs per package); or, 30-lb telescope bulk cartons. Elephant garlic may be packaged as above, or in 5-lb or 10-lb cartons or various count bags of sized cloves as follows:

Clove size	Bag count 5-lb carton	Bag count 10-lb carton
8 cm	16-18	32-36
9 cm	13-14	26-28
10 cm	9-11	18-22
11 cm	7- 8	14-16
12 cm	5- 6	10-12

Note: Garlic imported from Chile is packaged in 22-lb (10-kg) cartons (OSU, 2005)

Garlic is packaged, among other things, in wooden jointed boxes (17 Kg) and in 25 Kg jute bags, baskets or chip baskets ([Fig. 15](#))

Risk factors and loss prevention



Fig. 15 Packing garlic forms

Table 4.- Specifications for export varieties

Varieties	Julie	Graham	Grenada	Peach
Size				
Minimum weight:	250 g	350 g	200 g	170 g
Minimum length:	9.0 cm	10.0 cm	8.0 cm	7.0 cm
Minimum width:	7.5 cm	9.0 cm	7.0 cm	6.0 cm
Minimum breadth:	6.5 cm	9.0 cm	7.0 cm	6.0 cm
Appearance	*	*	*	*
Colour	#	#	#	#
Condition	&	&	&	&

Source: Medlicott, 2000

2.4 Storage

Garlic for seed purposes should not be stored under refrigeration. Optimum storage temperature for garlic for seed is 50 °F with a humidity of 65-70%. Garlic cloves sprout most rapidly between 40 to 50 °F, hence prolonged storage at this temperature range should be avoided. Storage of planting stock at temperatures below 40 °F results in rough bulbs, side-shoot sprouting (witches-brooming) and early maturity, while storage above 65 °F results in

delayed sprouting and late maturity. Store other garlic at 32 °F and 65 to 70 % relative humidity. If in good condition, and well cured when stored, garlic should keep for 6 to 7 months at 32 °F. Relative humidity should be lower than for most vegetables because high humidity causes root and mold growth. In California, where considerable garlic is grown, it is frequently put in common storage, where it can be held for 3 to 4 months or sometimes longer if the building can be kept cool, dry, and well ventilated (OSU, 2005).

The variety of garlic affects potential storage life, and the recommended conditions for commercial storage depend on the expected storage period. Garlic can be kept in good condition for 1-2 months at ambient temperatures (20°-30 °C [68-86 °F]) under low relative humidity (<75%). However, under these conditions, bulbs will eventually become soft, spongy and shriveled due to water loss. For long-term storage, garlic is best maintained at temperatures of -1°C to 0°C (30-32°F) with low relative humidity (60-70%). Good airflow is also necessary to prevent any moisture accumulation. Under these conditions garlic can be stored for more than 9 months. Garlic will eventually lose dormancy, signaled by internal development of the sprout. This occurs most rapidly at intermediate storage temperatures of 5-18°C (41-65°F). Garlic odor is easily transferred to other products and should be stored separately. High humidity in the storages will favor mold growth and rooting. Mold growth can also be problematic if the garlic has not been well cured before storing (PTRIC, 2005).

Responses to Controlled Atmospheres (CA)

Atmospheres with high CO₂ (5-15 %) are beneficial in retarding sprout development and decay during storage at 0-5°C. Low O₂ alone (0.5%) did not retard sprout development of 'California Late' garlic stored up to 6 months at 0°C. Atmospheres with 15% CO₂ may result in some yellow translucent discoloration occurring on some cloves after about 6 months (PTRIC, 2005).

About the only thing that most people agree on is that it is bad to store garlic in plastic bags or sealed containers as these things promote rotting. They also agree that garlic should not be stored in direct sunlight. Four factors affect the storage of garlic; namely, how well it was grown and cured, its varietal type, temperature and humidity. Garlic that was poorly grown and improperly cured will not get any better in storage. Some varieties naturally store longer than others. Silverskins are the longest storing, with Porcelains coming in second and Rocamboles being the shortest storing varieties, with Purple Stripes and Artichokes falling somewhere in the middle. Specific cultivars of each kind can vary from the pattern, but in general, this is the way it is. The USDA recommends storing garlic at 32 °F, so most large chains of stores do that and require their suppliers to do likewise. Garlic stores well at that low temperature for a few months, (if the humidity is not too high, which it sometimes is) but when you remove it from cold storage and place it on the shelf for sale, time catches up with it in a hurry. It either deteriorates rapidly or sprouts fairly soon and tries to grow. This makes for a garlic that is good for immediate use only. Garlic stores best long term when it is kept between 55 °F and 65 °F and between 40% and 60% humidity. If the humidity stays below 40% for a couple of weeks or more, garlic has a tendency to dry out faster than it otherwise would. If humidity goes higher than 60% for any extended period of time, fungus and molds can set in. If the temperature goes below about 55 °F for an extended period of time, garlic tends to want to sprout and grow, even if it is not the right time of year (that's why the refrigerator is not a good place to store garlic). If temperatures stay much over 70 °F for any extended length of time, garlic tends to dry out and deteriorate. These are approximate ranges and need not be taken literally, but are very good guidelines. In our experience, garlic, except Rocamboles will store quite well for four to six months at between 65 °F and 75 °F as long as the humidity is moderate. One of the advantages to keeping garlic around 55 °F is that fungi and other pathogens and pests are much less active than they are with the temperature in the 75-80 °F. range. Keeping them cool, but not cool enough to sprout them is the key to storing

garlic well (Fig 15). It is very hard for the average person to achieve the proper temperature range for ideal storage of garlic. It is important that airflow around the bulbs not be restricted too much as this hastens deterioration. We have found that garlic stored in double paper bags in the shade in a normally air conditioned house seems to do very well. Of course, this is not practical if you have several thousand bulbs, but works quite nicely for a few dozen. Basically, any dark, cool place is appropriate as long as the humidity is not excessive (Gourmet garlic gardens, 1999) .

Cooling system

Storing garlic

Commercially, garlic is stored near 32 °F. However, most home refrigerators are too warm for ideal long-term storage of garlic. Instead, store in a cool, dry, well-ventilated place in well-ventilated containers such as mesh bags. Storage life is 3 to 5 months under cool (60 degree F) dry, dark conditions.

Storing garlic in wine or vinegar. Peeled cloves may be submerged in wine or vinegar and stored in the refrigerator. A dry white or red wine is suggested; white or wine vinegars also work well. The garlic/liquid should be kept for about 4 months in the refrigerator. Discard both the cloves and the liquid if there are signs of mold or yeast growth on the surface of the wine or vinegar. The garlic-flavored liquid and the garlic cloves may be used to flavor dishes. Do not store the garlic/liquid mixture at room temperature because it will rapidly develop mold growth.

Storing garlic in oil. Extreme care must be taken when preparing flavored oils with garlic or when storing garlic in oil. Peeled garlic cloves may be submerged in oil and stored in the freezer for several months. Do not store garlic in oil at room temperature. Garlic-in-oil mixtures stored at room temperature provide perfect conditions for producing botulism toxin (low acidity, no free oxygen in the oil, and warm temperatures). The same hazard exists for roasted garlic stored in oil. At least three outbreaks of botulism associated with garlic-in-oil mixtures have been reported in North America. By law, commercially prepared garlic in oil has been prepared using strict guidelines and must contain citric or phosphoric acid to increase the acidity. Unfortunately, there is no easy or reliable method to acidify garlic in the home. Acidifying garlic in vinegar is a lengthy and highly variable process; a whole clove of garlic covered with vinegar can take from 3 days to more than 1 week to sufficiently acidify. As an alternative, properly dried garlic cloves may be safely added to flavor oils (UCCE, 2006)



Fig. 16 Cooling room for garlic

2.5 Packinghouse operations

a) Inspection

Fresh Market: Garlic intended for braiding or fresh market may be harvested at an earlier stage (some green color still remains in leaves) to allow for some peeling and braiding. To loosen the bulb, run a cutter bar beneath the bulbs. Rows may be windrowed in the same operation using modified potato equipment. If garlic is to be hand harvested, pull the bulbs and gather several rows into one windrow. If tops have not already been removed, arrange the tops to protect the bulbs from sunscald if the un-topped windrow is to be cured in the field. If left in the field to dry, remove tops and roots after they are dry and prior to storage. Leave about 0.5 inch of root and 1 inch of top. Bulbs must then be graded for market (OSU, 2005).

b) Irradiation

Ionizing radiation can be used to process food. Its effect on the food is dependent on the dose level (amount) of irradiation to which the food has been subjected. High-dose levels of irradiation (20 to more than 70 kGy) can be used to sterilize foods by eliminating all vegetative microorganisms and spores in the food. Very low doses of irradiation (less than 0.1 kGy) can be used to inhibit sprouting in potatoes, onions and garlic. The FDA, in 1963 and 1964, approved the use of low-dose ionizing radiation for bacon, for killing insects in wheat and wheat flour, and for the inhibition of sprouting in potatoes. In 1983, the FDA approved sterilization of spices with ionizing radiation. Low-dose irradiation can also be used to inhibit sprouting of onions, garlic, and ginger. The radiation dose for garlic is 0.05 to 0.15 Kgy and this inhibits sprouting (Snyder and Poland, 1995).

The levels of irradiation significantly diminish the viability of living cells whether they are pathogenic bacteria or living garlic cells. Irradiation, as we use it today on foods does not sterilize the food. The more rapidly cells are growing, the more the DNA is dividing, the more susceptible the cells are to irradiation. With bacteria this means that actively growing organisms are more susceptible than spores. In garlic it means that the part of the garlic that is

growing the fastest will be the most effected. That part is the newly sprouting cells (French, 2001).

Garlic bulbs maintain their quality for 120 days, apart from a slight loss of weight. After that, the sprouting phase starts, characterized by a rapid deterioration of the edible organ, exhibited as loss of texture, weight and flavor. The application of gamma rays in commercial doses (60 Gy) to dormant garlic bulbs extends the storage and commercialization periods by 60 days to almost 180 days after harvest (Pellegrini et al., 2001)

c) Pre-treatments

Peeling garlic cloves

Peeling whole cloves requires that the papery skin be removed without cutting into the clove. If the garlic is going to be chopped or sliced, the skin can be removed by pressing the clove with the flat side of a knife until the clove and skin crack. The skin can then be easily removed.

Roasting garlic

Roasted garlic, which has become popular in recent years, is sweet to the taste and is delicious on bread or crackers as an appetizer or served as a vegetable side dish. To prepare roasted garlic, leave the head whole and cut off the tip of the head, exposing the cloves. Allow one-half to one head per person. Put the head (or heads) in a baking dish or wrap them in aluminum foil, sprinkle with olive oil or pat with butter, and season with a little salt and pepper and some fresh or dried thyme if desired. Bake at 350 °F until very soft and tender (about 45 minutes to 1 hour). The roasted garlic cloves can be easily squeezed from their skins and spread with a knife.

Freezing garlic

Garlic can be frozen in a number of ways.

Chop the garlic, wrap it tightly in a plastic freezer bag or in plastic wrap, and freeze. To use, grate or break off the amount needed.

Freeze the garlic unpeeled and remove cloves as needed.

Peel the cloves and puree them with oil in a blender or food processor using 2 parts oil to 1 part garlic. The puree will stay soft enough in the freezer to scrape out parts to use in sautéing. Freeze this mixture immediately - do not store it at room temperature. The combination of the low-acid garlic, the exclusion of air (by mixing with oil), and room-temperature storage can support the growth of *Clostridium botulinum* (UCCE, 2006).

2.6 Processing

Conventional air drying is one of the most frequently used operation for garlic dehydration.

The drying parameters that are usually examined for garlic quality are the following:

air temperature (50 – 90 °C for food materials)

air relative humidity (10 – 40 % for food materials)

air velocity (1-4 m/sec)

Porosity characterizes the overall open structure of a dehydrated material. It is the fraction of the empty volume (void fraction) and it is usually estimated from the apparent density and the true density of the material. Garlic presents the following conditions for drying and porosity:

Air drying, 50-60 °C, velocity 0.09-1.2 m/s; Moisture content (kg/kg db) 0.1; Porosity 0.7-0.8 (Madamba et al., 1993)

Air drying, 70 °C, RH: 14.5%; Moisture content (kg/kg db) 0.05; Porosity 0.13; (Madamba et al., 1994)

Dry only fresh, firm garlic cloves with no bruises. To prepare, separate and peel the cloves. Cut in half lengthwise. No additional predrying treatment is necessary. Dry at 140 °F for 2 hours, then reduce heat to 130 °F until completely dry or crisp. If desired, garlic salt may be made from dried garlic. Powder dried garlic by processing in a blender or food processor until fine. Add 4 parts salt to 1 part garlic powder and blend 1 to 2 seconds. If blended longer, the salt will become too fine and cake together in clumps (UCCE, 2006).

After the tops have dried they may be partially removed by propane flaming. Care should be exercised so that garlic bulbs are not exposed and subjected to flaming damage. Flailing is used to complete top removal. Garlic may be dug with a simple potato digger and windrowed on the soil surface for a brief (1-2 day) curing period, then hand placed into sacks or bins for final curing (10-14 days, or as needed) in the field. Garlic must be protected from sun scald especially during periods of high temperature (over 90 °F) and bright sunlight. Excessive exposure to sunlight may also result in greening (OSU, 2005).

Non-fluid seasonings are dried spices, e.g., thyme and basil, dried flavorings from botanical sources, e.g., garlic powder and lemon powder, salt and sugar. Ingredients such as MSG, autolyzed yeast extract, hydrolyzed (source) proteins, and garlic have not been considered to be non-fluid seasonings. For example, whole garlic is a vegetable, not a spice, while garlic powder is a spice/seasoning (USDA, 2001)

Industrial Processing Possibilities Several options have become available for large scale processing of garlic products.

Garli Garni All Purpose Seasoning

This is not an option for ordering. If you only get one thing... This is it. Use it for everything from eggs for breakfast to steaks at night.

Spicy Herb Pickled Garlic

This is our best selling pickled garlic. We eat 'em out of the jar, or use them for egg salad, tuna salad, sliced thin on sandwiches, etc.

Garli Ghatti

A blend of garlic, romano cheese, and herbs. Kind of like a pesto seasoning. Great on pasta, salads, veggies, etc. Our favorite is sliced tomatoes.

Jalapeno Pickled Garlic

We just use a couple of jalapeno slices in here to give the taste, not the heat of the jalapeno. Drop these in a Bloody Mary... You'll be a hit.

Lemon Garli Garni

This blend of Garli Garni Seasoning and real lemon will spank up any dish you need lemon in. Great on fish, chicken, veggies, and makes the best Bloody Mary you have ever had...

Sweet & Spicy Garlic Mustard

What can we say... We had to make it in a larger size just for our mustard lovers. Mmmm, mustard crusted fish... Just a thought...

California Mop Sauce

This grilling and baking sauce is apple cider vinegar based (for marinating) and no tomato or sugar (won't burn on the grill). Use on all meats or veggies.

Garlic Cooking Wine

This fine white wine has been cured in garlic and then bottled with a couple of cloves of garlic right in the bottle. Use for sauces and sautés, etc.[28]

Raw garlic products



Fig. 17 Whole peeled garlic



1/8 sliced



1/8 diced



3/8 diced

Fig. 18 Sliced and diced garlic



Fig. 19 Crushed and puree garlic

3 Pest Species and Pest Control

a) Indirect Pests of Garlic

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. ([Fig 20](#)).



Fig 20 Removal of scapes

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 TM 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 one-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 ([Fig. 23](#))

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.



Fig 21. Foliar symptoms of Fusarium

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. (Fig 21). This disease is controlled by proper crop rotation with non-susceptible crops for four years, removal of infected plants, and planting disease-free seed.

Fusarium basal rot (Fig 22), is a disease which attacks the basal plate region and the roots. The soil-borne pathogen invades the roots, resulting in empty, tan-colored, non-functional roots. The basal plate region may develop a pinkish growth of mycelium. First visual symptoms are often the yellowing of the tip and dieback of the shoot during the spring. Warm soil temperatures and high soil moisture promote disease development. Since the *Fusarium inoculum* remains as dormant spores in the soil or on plant residue, crop rotation with crops not belonging to the *Allium* genus (e.g., garlic, onions, shallots, leeks, chives) is recommended (Bodnar et al., 1998).



Fig. 22 Basal rot of garlic caused by Fusarium

Pink root

Symptoms of this disease occur primarily in warm weather (>75 °F). 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.

Penicillin mould is a main cause of decay of garlic in storage. The disease appears as masses of blue-green spores usually first seen at the base of the bulb. The primary source of inoculum is diseased bulbs used for planting material. When diseased bulbs are cracked the air-borne spores readily come in contact with healthy cloves. Wounded cloves are particularly susceptible to the disease. Often cloves infected with *Penicillin* become infected with secondary organisms such as bacteria and other fungi, masking the original pathogen. Clove rot and reduced plant stands are often the result of planting infected cloves. Surviving plants which emerge appear weak and yellow. Warm temperatures of 22-25 °C are optimum for spore germination and disease development. Planting garlic too early in late summer when soil temperatures are high may increase the severity of clove rot. Irrigation may be beneficial, as high soil moisture appears to suppress clove decay (Bodnar et al., 1998).

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 ([Fig. 24](#))

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. 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 and 55 °F. 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.

Virtually all sources of garlic contain viruses. Fortunately, most of these viruses in garlic are latent. Latent garlic viruses may not become visible or reduce yields until the garlic plant is stressed or growth interrupted. The most common symptoms of virus infection are colour changes of the leaves. These include mosaics, flecking, streaking and mottling. Leaf shape distortion may also occur. Aphids are one vector capable of transmitting some viruses from infected to healthy plants. Control of virus diseases is achieved through a combination of planting healthy cloves, reducing aphid populations, proper fertility and water management during the growing season (Bodnar et al., 1998).

Pests : All pests that attack onions will affect garlic crops. The most significant pest is likely to be nematodes (eelworms) which attack the roots and bulbs. Bulbs should be inspected before planting to ensure cloves are nematode-free and if possible dusted with nematicidal powder immediately prior to planting. Thrips and onion maggot are two other potentially serious pests



Fig. 23 White rot



Fig. 24 Rust

Pest Control

"Bulb crops" are a crop grouping that includes all of the *Allium* species except chives. Bulb crops include onions (dry and green), leeks, garlic and shallots. Fields that are infested with nutsedge, hard seeded legumes or other difficult to control weeds should be avoided. Many weed problems can be reduced by preparing the land well ahead of planting and using Roundup in a "cropping systems" approach and/or using Paraquat in a stale seed bed approach. Preemergence and early postemergence herbicides may control many weeds for 4 to 6 weeks. Herbicide performance depends on weather, irrigation, soil type and proper selection for the weed species to be controlled. Obtain consistent results by reading the herbicide label and other information about proper application and timing of each herbicide. To avoid confusion between formulations, suggested rates listed in [Table 1](#) are stated in pounds of active ingredient per acre (lb ai/acre) (UF, 2005)

Table 1. Chemical weed controls: garlic

Herbicide	Labeled crops	Time of Application to crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Bensulide (Prefar 4E)	garlic	Preplant Preemergence	5-6	----
Remarks: Preplant incorporate to a depth of 1-2 inches in well worked soil. Apply preemergence and irrigate to incorporate. With overhead irrigation, wet soil at least 2-4 inches deep. For furrow irrigation, thoroughly wet the entire bed top. Controls many grass species.				
Herbicide	Labeled crops	Time of Application to crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Bromoxynil (Buctril)	garlic	Preemergence Postemergence	0.25 0.375	----
(Aim)	garlic	Directed-hooded row-middles	0.008-0.025	0.008-0.025
Remarks: Aim may be applied as a post-directed hooded burn-down application to emerged broadleaf weeds in row middles. Aim is not labeled for grassy weeds. May be tank mixed with other herbicides registered for this treatment pattern. May be applied at 0.33 oz (0.008 lb ai) to 1 oz (0.025 lb ai). Use a quality spray adjuvant such as crop oil concentrate (coc) or non-ionic surfactant (nis) at recommended rates.				
Herbicide	Labeled crops	Time of Application to crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Clethodim (Select) (Arrow)	garlic	Postemergence	0.94-.125	094-.128
Remarks: Material is a selective postemergence herbicide for control of annual and perennial grasses. Always use a crop oil concentrate at 1% v/v in the finished spray. Volume should range from 5 to 40 gallons per acre. Rates range from 6 to 8 oz. of product per acre for annual grasses to up to 16 oz. of product for perennial grasses. Do not apply within 45 days of harvest.				
Herbicide	Labeled crops	Time of Application to crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
DCPA (Dacthal W-75)	garlic	Preemergence Posttransplanting or at layby	6.0-10.5	C
Remarks: Controls germinating annuals. Incorporate 0.5 to 1.0 inch with overhead irrigation or shallow cultivation. Apply layby treatment to weed-free field up to 14 weeks after planting at rates not exceeding 10.5 lb ai./acre per season.				

Herbicide	Labeled crops	Time of Application to crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Fluazifop-p (Fusilade)	garlic	Postemergence	0.188	0.188

Remarks: Controls actively growing grass weeds. A total of 48 oz. of product may be applied to the crop per season. Rates for the control of actively growing grass species at specific growth stages are specified on the label. Depending on the species, the growth stage for best control ranges from the 3- to 8-leaf stage. Use oil concentrates or non-ionic surfactants in the spray mixture. A pre-harvest interval of 45 days must be maintained.

Herbicide	Labeled crops	Time of Application to crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Paraquat (Gramoxone Extra) (Gramoxone Max)	garlic	Preplant Preemergence	0.63 - 0.94	0.63 - 0.94

Remarks: Apply as a broadcast treatment prior to, during or after seeding, but before emergence of the crop for control of emerged weeds. Weeds and grasses emerging after treatment will not be controlled. Crop plants emerged at the time of application will be damaged. Use a non-ionic surfactant with application. Do not apply within 60 days of harvest.

Herbicide	Labeled crops	Time of Application to crop	Rate (lbs. AI./Acre)	
			Mineral	Muck
Sethoxydim (Poast)	garlic	Postemergence	.187	.187

Remarks: For control of actively growing grass weeds. Always add a crop oil concentrate at a rate of 2 pts./acre. Do not apply within 30 days of harvest. A general use rate of 1 pt. material may be used. Do not apply more than 4.5 pts. per acre in one season.

Footnotes

1. This document is HS-193, one of a series of the Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Last revision date: June 2005. Please visit the EDIS Website at <http://edis.ifas.ufl.edu>.

2. William M. Stall, professor, Horticultural Sciences Department, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

The use of trade names in this publication is solely for the purpose of providing specific information. It is not a guarantee or warranty of the product named, and does not signify that they are approved to the exclusion of others of suitable composition.(UF,2005).

4. Gender aspects: Role of the men and women in postharvest operations

Experiences of garlic cultivation in Bolivia

Gathered information proves the presence of 51% of women in the general population of the Ajera South Andean population. Labor of women and children in garlic production is quite important.

Rural and urban population

The only urban centers are located at the capitals of the counties of Tupiza, Cotagaita, Culpina, Incahuasi and El Puente, in the area of Iscayachi. Rural communities where garlic is produced hold nearly 2730 families, which represent 18,193 inhabitants.

In populated centers, both urban as well as rural, other participants of the production chain of garlic have been identified: service and supplies providers, and local transportation, as well as traders, technical support and even credit providers, may be linked to the garlic production process. Based on basic calculations, the mean income of family units involved in garlic production varies depending on the investment; considering 0.25 ha/family the cost ranges from 300 to 500 \$US depending on the seed quality. The income may vary from 650 to 950 \$US per family. Producers say that garlic allows them to have a product to sell during the critical time year comprised from Halloween, through Christmas and until Carnival (ash Friday).

The amount of labor involved in garlic cultivation is important. It has been estimated that one hectare requires at least 310 labor journals, while postharvest handling requires another 310 labor journals. This amount of labor is not usually covered by the family and extra hands must be hired for demanding tasks such as seeding, harvest and post-harvest handling. It has been estimated that one hectare of garlic requires hiring additional 330 labor journals. Based on the production unit of 0.25 hectares per family, producers usually have limited resources to pay for the extra labor and the much-needed extra labor can not be afforded. Additionally, further analysis of the production process indicates an elevated concentration of garlic production and a concomitant shortage of labor mainly during seeding and harvest (AgroBolivia, 2006).

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