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REVIEW ARTICLE

ORIGIN, DISTRIBUTION, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETIC DIVERSITY AND BREEDING OF GARLIC (*Allium sativum* L.)

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ABSTRACT

Garlic belongs to the family Amaryllidaceae, Subfamily Allioideae, Genus *Allium*, Subgenus *A.* subg. *Allium* and Species *Allium sativum* L. Common Names in India are Assamese: Naharu, English: Garlic, Hindi: Lahsan, Lahsun, Lassan, Kannada: Belluli, Malayalam: Vellulli, Manipuri: Chanam, Mizo: Purunvar, Purun-var, Tamil: Acanam, Tangkhul: Hanam, Telugu: Velluli and Urdu: Lehsan. Garlic (*Allium sativum L.*) belongs to the genus Allium. In this genus more than 750 species are identified and divided in 60 taxonomic groups. It is a bulbous plant whose domestication is very old. Its primary center is in Central Asia while the Mediterranean and Caucasian regions are recognized as the secondary center of garlic. Three ways to propagate garlic: From cloves, from bulbils and from seed. The first and most common is to remove cloves from an existing bulb and plant them individually. The second, and less common way to propagate, is by using bulbils. "Bulbil" is the darling and utterly fitting name for the tiny mini-cloves that develop in amongst the flowers of hardneck garlic**.** So if you grow hardneck garlic in the garden and allow just one of your plants to grow scapes, flower, and go to seed, you can harvest the bulbils in the late summer and plant them that fall. Propagating garlic from seed is technically possible, although it's very difficult to do so – and it's almost impossible to get hold of seeds unless you collect your own. Garlic is used worldwide in cooking and industry, including pharmacology/medicine and cosmetics, for its interesting properties. Garlic has a long history of cultivation by asexual propagation. Due to its asexual nature, improvement of garlic has been limited as compared to onion. With the impending climate change, it is predicted that like all other crops, garlic cultivation will also suffer the consequences. Ninety percent of garlic is grown in Asia and increase in temperature will expose garlic to various biotic and abiotic stresses. The constant increase in garlic production and the demand for garlic products with specific characteristics require breeding and selection of this crop and its adaptation to different climatic conditions. Commercial garlic varieties are completely sterile and are propagated vegetatively. While often known for its addition to Italian foods, garlic seems to be used in virtually all cuisines as a strong flavoring agent. The bulbs are also sometimes used for medicinal purposes, to ease health conditions while preventing chronic health problems. Historically, garlic was used primarily for its medicinal components. In ancient civilizations, people used it in hopes of increasing their strength. 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. 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. Yield, propagation, pests and diseases, cultivation, harvesting, peeling garlic cloves, roasting garlic, raw garlic products, primary product, curing and storing are also briefly covered. In this review article on Origin, Domestication, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of Garlic are discussed.

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INTRODUCTION

Garlic belongs to the family Amaryllidaceae, Subfamily Allioideae, Genus *Allium*, Subgenus *A.* subg. *Allium* and Species *Allium sativum* L. (Wikipedia, 2023). Common Names in India (IBP, 2023) are Assamese: Naharu, English: Garlic, Hindi: Lahsan, Lahsun, Lassan, Kannada: Belluli, Malayalam: Vellulli, Manipuri: Chanam, Mizo: Purunvar, Purun-var, Tamil: Acanam, Tangkhul: Hanam, Telugu: Velluli and Urdu: Lehsan. Vernacular names in Africa (Agbo So et al., 2021) are Benin: Gungbé – Ayo, Fonbgé – Tchiayo; Burkina Faso: Mooré – Gando, Layi, Dioula – Laii, Fulfuldé – Toumé Ghana: Twi – Gyene Kankan, Ga Adangbe – Aya, Hausa – Tafarmuwa; Mali : Bambara – Tumé, Tamachek – Teskart; Nigéria : Hausa – Tafárnúúwáá, Igbo – Oy Ayón, Ayún, Yoruba – Àlubósa, Ayúu Sénégal: Wolof – Laji, Manding Bambara – Layi; Togo: Ewe – Ayo, Kabyè – Ayo, Moba-Gabdjak; Niger: Hausa- Tafárnúúwáá, Zarma-Tafárnúúwáá, Fulfuldé; Toumé, Tamachek – Teskart. Garlic (*Allium sativum L.*) belongs to the genus Allium. In this genus more than 750 species are identified and divided in 60 taxonomic groups.It is a bulbous plant whose domestication is very old. Its primary center is in Central Asia while the Mediterranean and Caucasian regions are recognized as the secondary center of garlic (Agbo So *et al*., 2021). Garlic (*Allium sativum*) is a species of bulbous flowering plant in the genus *Allium*. Its close relatives include the onion, shallot, leek, chive, Welsh onion, and Chinese onion. It was known to ancient Egyptians and has been used as both a food flavoring and a traditional medicine. China produced 73% of the world's supply of garlic in 2021 (Wikipedia, 2023). Three ways to propagate garlic: From cloves, from bulbils and from seed. The first and most common is to remove cloves from an existing bulb and plant them individually. The second, and less common way to propagate, is by using bulbils. "Bulbil" is the darling and utterly fitting name for the tiny mini-cloves that develop in amongst the flowers of hardneck garlic**.** So if you grow hardneck garlic in the garden and allow just one of your plants to grow scapes, flower, and go to seed, you can harvest the bulbils in the late summer and plant them that fall. Propagating garlic from seed is technically possible, although it's very difficult to do so – and it's almost impossible to get hold of seeds unless you collect your own.

We use the term "clone" to indicate garlic cultivars, strains, or genotypes that are asexually propagated. The major distinction among garlic clones is the tendency to produce a flower stalk, or not. Those producing a flower stalk are referred to as "bolting," "stalking," or "hard neck" types, whereas those without a flower stalk are "non-bolting," "non-stalking," or "soft neck." Sometimes a third category, "incomplete or partial bolting," is used for clones in which the inflorescence begins to develop but stem elongation is incomplete and mature flowers do not develop. There is a presumption that this character is stable across environments but this is unproven. Likewise, it is assumed that, like onion, garlic bulb formation is a response to photoperiod and some reference is made to "shortday" cultivars (which produce bulbs as photoperiods lengthen slightly in the spring in regions near the Equator), and "long-day" cultivars (which produce bulbs as photoperiods lengthen dramatically in the spring in regions farther from the Equator) (Simon and Jenderek, 2003). The word garlic is a derivative of the old English word 'Garleac'. It means 'spear-shaped leek', which belongs to the leek family. Garlic, also scientifically known as *Allium sativum,* belongs to the same genus as onion, shallots, and leek. They are all bulbous flowering plants. Garlic in Sanskrit is *'Mahosuddha', meaning 'one that cures all'.* There are various uses of garlic and it stands true to these claims. This vegetable is an integral ingredient in today's global cuisine culture, medicinal practices, traditions and folklore. Being such a versatile component, it is widely used and loved by all. In 1922, a team led by Howard Carter discovered Tutankhamun's tomb. Their findings included tonnes of gold, silver and garlic. The youngest Pharaoh from Egypt was mummified with garlic by his side. The Egyptians are not the only community of people who revere garlic. Garlic is famous worldwide (Dube, 2021). Garlic is 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 of garlic produce about 10 million metric tons of garlic globally each year, according to the United Nations Food and Agriculture Organization. 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 (Simon, 2024).

Garlic (*Allium sativum* L.), an asexually propagated crop, is an important vegetable and medicinal plant (Wang *et al.,* 2016). Garlic, *Allium sativum L.*, is one of the few vegetable cultures propagated only vegetatively—by division of the ground or aerial bulbs; this explains the impossibility of applying the well-established breeding techniques for sexually propagated crops. Garlic is mostly used as a spice in the form of bulbs fresh from the field or after storage. However, there has been a recent increase in the consumption of dehydrated garlic. In many regions, people use fresh leaves as salad; in late winter or early spring, this is an important source of vitamins and minerals. A number of reports illustrate the successful use of garlic as medicine over many years. Modern medicine provides a scientific explanation with the discovery of substances with specific bactericidal effects called phytoncids (Batchvarov, 1993). 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. 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 peopleuse garlic to help prevent atherosclerosis and improve high blood pressure (Medina and García, 2007). 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 (Medina and García, 2007).

The genus *Allium* is economically important because it includes several important vegetable crops – onion, garlic etc., as well as many ornamental species. The garlic is the second most important *Allium*species. It is grown worldwide as an important spice and medicinal plant. The bulb, composed of few to many cloves, is the main economic organ. The fresh leaves, pseudostems and bulbils (to psets) are also consumed. Like onion, garlic has been used by humans for a very long time (STAVělíková, 2008). Modern cultivars of garlic (*Allium sativum* L.), one of the most economically important plants, are completely sterile and thus propagated only vegetatively. The lack of sexual propagation prohibits genetic studies and conventional breeding, and fertility restoration should significantly broaden variability and make the improvement of economically important traits possible (Rotem Neta *et al*., 2011). Recent introductions of fertile *A. sativum* accessions from Central Asia, restoration of flowering ability and fertility by environmental manipulations and increased variation by seed propagation open the way for in-depth physiological and genetic studies, as well as conventional and molecular breeding in this plant. However, the regulation of floral development and fertility in geophytes remains obscure, and fundamental physiological and genetic knowledge is required for both basic and applied purposes (Rotem Neta *et al*., 2011).

Garlic is used worldwide in cooking and industry, including pharmacology/medicine and cosmetics, for its interesting properties. Identifying redundancies in germplasm blanks to generate core collections is a major concern, mostly in large stocks, in order to reduce space and maintenance costs. Yet, similar appearance and phenotypic plasticity of garlic varieties hinder their morphological classification (Egea *et al*., 2017). Molecular studies are challenging, due to the large and expected complex genome of this species, with asexual reproduction. Classical molecular markers, like isozymes, RAPD, SSR, or AFLP, are not convenient to generate germplasm core-collections for this species. The recent emergence of high-throughput genotypingby-sequencing (GBS) approaches, like DArTseq, allow to overcome such limitations to characterize and protect genetic diversity (Egea *et al.,* 2017). Garlic is a world's favorite, versatile horticultural commodity consumed for culinary, medicinal and antimicrobial purposes and is being cultivated for 5000 years. The aroma in garlic is due to volatile organosulfur compound 'Allicin' that makes it popular indaily cooking in Indian household and rest of the world, especially, Asia and the Mediterranean region. Its medicinal value has been appreciated especially, in the Unani and Ayurvedic systems of medicine for digestive system disorders, blood cholesterol, sterility, cough. The antibacterial action by virtue of allicin has been found to have potential even in organic farming for treatment of plant diseases (Malik *et al.,* 2017). There are unique researchable aspects of garlic improvement in general and long day garlic in particular that pertain to Indian as well as world garlic research community. In order toprovide for its ever increasing population, meet export and processing demands by the year 2050, India will have to produce 30 lakh tone of garlic. The increase from present 12.5 lakh tone production will entail the need for genetic improvement via creation of variability, better plant protection measures, improved production technology, molecular understanding and explorations and introductions (Malik *et al*., 2017).

Garlic has a long history of cultivation by asexual propagation. Due to its asexual nature, improvement of garlic has been limited as compared to onion. With the impending climate change, it is predicted that like all other crops, garlic cultivation will also suffer the consequences. Ninety percent of garlic is grown in Asia and increase in temperature will expose garlic to various biotic and abiotic stresses. To evolve against these stresses, quality improvement of garlic to withstand these stresses is of principal concern (Khar *et al*., 2020). Research work on creation of genetic diversity, collection of genetic resources, interspecific hybridization, and manipulation of flowering is needed through conventional techniques. Biotechnological approaches for garlic improvement through genetic transformation, marker-assisted selection, genomics-aided breeding, and other novel technologies may help in achieving higher yields under climate change scenarios. In this chapter, we have discussed various approaches and what has been done in these areas in different parts of the world to address the loss in crop yield which is likely to be caused by the biotic and abiotic stresses in the future (Khar *et al.,* 2020). Garlic, an economically important vegetable, spice, and medicinal crop, produces highly enlarged bulbs and unique organosulfur compounds (Sun *et al.,* 2020).

Garlic is an important vegetable, aromatic and nutraceutical crop. The constant increase in garlic production and the demand for garlic products with specific characteristics require breeding and selection of this crop and its adaptation to different climatic conditions. Commercial garlic varieties are completely sterile and are propagated vegetatively. For ages new varieties have been selected only from existing living collections, natural or induced mutations. In the last 20 years, garlic fertility has been restored and research and breeding have undergone rapid progress. Currently, breeding in garlic is developing in three main directions: conventional vegetative selection from variable germplasm collections, breeding and selection from sexually- reproduced populations and employment of biotechnological tools. However, novel methods of genome editing and marker-assisted breeding are not yet available due to the extremely large and repetitive garlic genome. Fertility restoration, hybridization and seed production are the most important goals in future breeding. The variability of seed-producing garlic lines is already available, but breeding and propagation from seed is still far from the commercial stage. Large investments are involved in the developing of seed-propagated garlic and breeding via hybridization, but the advantages of this approach for the future improvement of modern garlic are evident. The status of garlic research and breeding and possible ways for future research and practices are discussed (Shemesh-Mayer and Kamenetsky-Goldstein, 2021). Garlic is an important vegetable, aromatic and nutraceutical crop. The constant increase in garlic production and the demand for garlic products with specific characteristics require breeding and selection of this crop and its adaptation to different climatic conditions. Commercial garlic varieties are completely sterile and are propagated vegetatively. For ages new varieties have been selected only from existing living collections, natural or induced mutations. In the last 20 years, garlic fertility has been restored and research and breeding have undergone rapid progress. Currently, breeding in garlic is developing in three main directions: conventional vegetative selection from variable germplasm collections, breeding and selection from sexually- reproduced populations and employment of biotechnological tools (Shemesh-Mayer and Kamenetsky-Goldstein, 2021).

While often known for its addition to Italian foods, garlic seems to be used in virtually all cuisines as a strong flavoring agent. The bulbs are also sometimes used for medicinal purposes, to ease health conditions while preventing chronic health problems. Historically, garlic was used primarily for its medicinal components. In ancient civilizations, people used it in hopes of increasing their strength. Indeed, some historical documents note that ancient Greeks used garlic as a performance-enhancing boost for the Olympics. What's particularly interesting about garlic is that it was concurrently used by different civilizations and cultures for similar benefits, all without contact between these cultures. Still, the garlic grown in the United States isn't like the "wild garlic" found in Asia and the Middle East. It most closely resembles the varieties first harvested in Europe nearly 1,000 years ago. But garlic was also found to grow in the wild by indigenous civilizations in North America, where it was used in teas for medicinal purposes (Cherney, 2022). 'Garlic' (*Allium sativum* L.) is the second most important cultivated *Allium* known throughout the world. It is known for its versatile use as a spice, condiment, vegetable and an intended medicinal panacea. Its clove contains sulphur-based compound 'Alliin' (S-allyl-L-cysteine sulfoxide) predominantly as an active ingredient, which on physical injury to the clove becomes 'Allicin'. Alliin and allicin both are devoid of lachrymatory factor so, it does not make one tears-up while chopping garlic cloves (Chaudhari *et al*., 2022).

Garlic is a vegetable that can be eaten raw or cooked. It is also sold as a dietary supplement. Garlic contains several sulfur-containing phytochemicals that are metabolized when eaten and can affect cardiovascular health and inflammation. These chemicals include allicin, *diallyl disulfide* (DADS), *diallyl trisulfide* (DATS), and *S-allylmercaptocysteine* (SAMC) (Examine, 2023). Garlic (*Allium sativum* L.) is a bulbous perennial crop cultivated in different temperate and subtropical climates all over the world. It belongs to the genus Allium, which includes almost 1008 species distributed in 15 subgenera and more than 70 sections. Within the Alliaceae family, garlic is the most widely consumed bulb after onion (Papaioannou *et al.,* 2023). Cultivation of leek, onion and garlic is as old as the history of the human race, and as extensive as civilization itself. References to these plants in the Bible and the Koran reflect their importance toancient civilizations both as flavorful foods and as healing herbs. ''It has been truly said of this species (garlic) that, if we could only divest it of its evil smell, it would rank among the most attractive of our British plants. The rank pungent taste and smell that pervade the stems and leaves of all the species of the large genus Allium results from a volatile essential oil, which is rich in sulphur.' Those favoring garlic include growers who earn their living from their garlic crop; both professional and amateur chefs who skilfully use garlic to enhance their dishes; foodies who seek out restaurants where virtually all dishes on the menu feature garlic; and the tens of thousands of attendees at garlic festivals all over the world (Block, 2023).

The center of origin of garlic and its closest wild relative, *Allium longicuspis,* is considered Central Asia. Religious writings, historical records and ancient medical texts, especially from the Mediterranean and Asia, have repeatedly referenced and/or prescribed the use of garlic in health and disease. More recent studies have demonstrated that allicin and other garlic organosulfur compounds exhibit broad-spectrum antibacterial and antimycotic effects. Garlic has been classified based on growth traits, morphology, presence/absence of flowering stalk, isozymes profiles, molecular markers and ecophysiological characteristics. Garlic is considered sterile and is mostly propagated asexually, but fertile wild garlic has been discovered and collected in its center of origin, in Kazakhstan and Kyrgyzstan (Dhall *et al*., 2023). With a history of human use of over 7,000 years, garlic is native to central Asia, and has long been a staple in the Mediterranean region, as well as a frequent seasoning in Asia, Africa, and Europe (TS, 2023). Garlic, perennial plant of the amaryllis family (Amaryllidaceae), grown for its flavourful bulbs. The plant is native to central Asia but grows wild in Italy and southern France and is a classic ingredient in many national cuisines. The bulbs have a powerful onionlike aroma and pungent taste and are not usually eaten raw (EEB, 2024).

Area and Production: 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 (Medina and García, 2007). 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 (Medina and García, 2007).

Estimates of horticultural statistics by NHB, the three major garlic growing states of India were Madhya Pradesh (60,000 ha), Rajasthan (45,000 ha) and Uttar Pradesh (37,200 ha) and the highest production was seen in Madhya Pradesh (270,000 t), followed by Gujarat (250,000 t) and Rajasthan (218,400 t). The highest productivity was shown by Punjab (12.16 t/ha), followed by West Bengal (11.94) and Maharashtra (11.43). The long day garlic is, however, cultivated by states of Himachal Pradesh, Uttarakhand and Jammuand Kashmir only but on very small area (Malik *et al*., 2017). The principle producers of garlic are China, Egypt, India, Turkey, South Korea and Spain. In India, garlic is commercially cultivated throughout the country. But the long day garlic is cultivated only in temperate region especially in Jammu and Kashmir, Himachal Pradesh, and Uttarakhand. This type requires long photoperiod (13+ hours) with warm temperature (20-25 °C) for bulbing. In temperate India, the planting time for long day garlic falls around September-October. The increase in day length from around February following the decline in snowfall and rise in temperature till the month of May is congenial for bulbing and bulb development (Malik *et al.,* 2017). The species are cultivated in many countries of the world mainly for its bulb. In 2018, the world production of garlic was 26,639,081 tons/year. The world's biggest producers of garlic are Chinawith 21,263,237 tons, India with 1,400,000 tons, and Bangladesh with 381,851 tons. In Africa, the main garlic producing countries are Egypt with 280. 216 tons, Ethiopia with 138. 664 tons and Algeria with 103. 627 tons. Niger's production is estimated at 3,761 tons for an area of 317 hectares with a yield of 11.86 kg/ha (Agbo So *et al.,* 2021). Today, an estimated 10 million tons of garlic are produced worldwide. While used as a food-flavoring agent, garlic is still considered as a "natural antibiotic" by many cultures. In the 21st century, garlic continues to be a common seasoning in

foods and packaged goods, but its potential medicinal properties are also gaining more appreciation in Western cultures (Cherney, 2022).

In 2021, world production of garlic was 28 million tonnes, with China alone accounting for 73% of the total (Wikipedia, 2023). In 2010, worldwide production of garlic reached 17.6 million tons with china as an absolute leader of production and export with 13.6 million tons (GH, 2023). The total world production for garlic reached 28,204,854.32 metric tons in 2021, with China being the largest producer, accounting for nearly 73% of total world production at 20,513,385.83 tons. In Greece, garlic is cultivated in approximately 780 ha with a total production of 8230 tons (Papaioannou *et al.,* 2023).

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 becomepartly dry and bend to the ground (Medina and García, 2007).

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 forease of digging, good soil drainage, and reduction of soil compaction. 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 (Medina and García, 2007).

No sexual reproduction, that is, production of true garlic seed, was underway in cultivated garlic before the 1980's. Therefore, relatively small numbers of garlic clones, perhaps numbering only a few thousand, have been in the hands of growers around the world through most of history. We conjecture that these clones represent the cumulative array of garlic diversity resulting from sexual reproduction in the wild which has been disseminated from its center of origin throughout history and then been able to successfully produce a crop in the hands of garlic growers around the world today. Superimposed upon the variation resulting from sexual reproduction of garlic in the wild, we can also expect to find variation due to mutations that accumulated throughout the history of cultivation of the crop (Simon, 2024).

Pests and Diseases: Garlic plants are usually hardy and not affected by many pests or diseases. Garlic plants are said to repel rabbits and moles. The California Department of Food and Agriculture (CDFA) conducts a certification program to assure freedom from nematode and white rot disease caused by *Stromatinia cepivora*, two pathogens that can both destroy a crop and remain in the soil indefinitely once introduced. Garlic may also suffer from pink root, a typically non-fatal disease that stunts the roots and turns them pink or red; or leek rust, which usually appears as bright orange spots. The larvae of the leek moth attack garlic by mining into the leaves or bulbs. Botrytis neck and bulb rot is a disease of onion, garlic, leek and shallot. *Botrytis allii* and *Botrytis aclada* cause this disease in onion and *Botrytis porri* causes it in garlic. "Initial symptoms usually begin at the neck, where affected tissue softens, becomes water-soaked, and turns brown. In a humid atmosphere, a gray and feltlike growth (where spores are produced) appears on rotting scales, and mycelia may develop between scales. Dark-brown-to-black sclerotia (the resting bodies of the pathogen) may eventually develop in the neck or between scales" (Wikipedia, 2023).

Cultivation: It is cultivated in many countries throughout the world for the bulb and used as a spice and functional food. The plant vegetatively propagates. It is native to Central Asia (Agbo So *et al*., 2021). Garlic is easy to grow and can be grown year-round in mild climates. While sexual propagation of garlic is possible, nearly all of the garlic in cultivation is propagated asexually by planting individual cloves in the ground. In colder climates, cloves are best planted about six weeks before the soil freezes. The goal is to have the bulbs produce only roots and no shoots above the ground. Harvest is in late spring or early summer. Garlic plants can be grown closely together, leaving enough space for the bulbs to mature, and are easily grown in containers of sufficient depth. Garlic does well in loose, dry, well-drained soils in sunny locations, and is hardy throughout USDA climate zones 4–9. When selecting garlic for planting, it is important to pick large bulbs from which to separate cloves. Large cloves, along with proper spacing in the planting bed, will also increase bulb size. Garlic plants prefer to grow in a soil with a high organic material content, but are capable of growing in a wide range of soil conditions and pH levels. There are different varieties of garlic, most notably split into the subspecies of hardneck garlic and softneck garlic. The latitude where the garlic is grown affects the choice of type, as garlic can be day-length sensitive. Hardneck garlic is generally grown in cooler climates and produces relatively large cloves, whereas softneck garlic is generally grown closer to the equator and produces small, tightly packed cloves. Garlic scapes are removed to focus all the garlic's energy into bulb growth. The scapes can be eaten raw or cooked (Wikipedia, 2023).

Harvesting: Elephant garlic, also known as giant garlic or great-headed garlic (Fig. 1), is a type of garlic that is prized for its large size and mild flavor. Unlike traditional garlic, which has multiple small cloves, elephant garlic has only a few large cloves that are

easier to peel and chop. It is a popular ingredient in Mediterranean, Middle Eastern, and African cooking, as well as in many other cuisines around the world. To harvest garlic, simply wait until the tops of the plants have died back, which usually occurs in late summer or early fall. Dig up the bulbs carefully and allow them to dry in a well-ventilated area for several weeks. Once the garlic has cured, it can be stored for several months, allowing you to enjoy its flavor and health benefits throughout the year (GC, 2023).

Elephant Garlic	Garlic

Fig. 1. Elephant Garlic and Garlic

Today, garlic is the second most widely consumed Allium worldwide, at an annual level of 14 million metric tons. The garlic bulb is made up of numerous smaller bulbs, called cloves, although occasionally bulbs contain only a single clove, usually called a ‘‘round.’’ Garlic bulbs are cleanly broken apart into cloves (called ‘‘cracking’’) within 24 hours of planting, when the temperature starts to turn cool (*e.g.,* in the fall in the Northern Hemisphere) to prevent premature sprouting. The cloves are planted with the pointed end of the clove up/basal plate down, at least two inches (5 cm) below the surface and seven inches (18 cm) between plants and rows. In warmer climates hardneck garlic should be stored at 7 to 10 1C (45 to 50 1F) for about three weeks before planting. If desired, garlic can be grown to maximum bulbil formation and the bulbils planted. Advantages of using the bulbils are that there are many more bulbils than cloves, and that the bulbils are not in contact with the soil, which prevents transmission of soil-borne diseases and pests. A disadvantage of using the bulbils for propagation is that it takes several years to produce decent sized bulbs from them (Block, 2023). Garlic is the strongest-flavored edible Allium. The fresher the garlic, the milder the taste. Fresh-from-the-ground garlic, sometimes called ‘‘green garlic,’’ which has not been cured has a higher moisture content, is milder and is a popular item at farmers markets. Good garlic should be firm and the cloves not dried up or discolored. Garlic is relatively fragile; bruising will trigger the chemical reactions that release allicin. Garlic should not be stored in a refrigerator since the combination of low temperature, oxygen and moisture will trigger mildewing and premature sprouting. ‘‘Frost-free’’ refrigerators will dry out the bulb. Garlic should be stored at room temperature in a cool, ventilated location. The preferred means of storing garlic (typically for 2 to 6 weeks) is in a clay jar with holes for air circulation. Longer term storage is possible, although some cooks recommend purchasing only the amount of garlic needed for short-term use to ensure freshness. While the large bulb of the elephant garlic (*A. ampeloprasum*) closely resembles garlic, with its fewer cloves (about four to eight) it is easier to peel. Due to its lower sulfur content, elephant garlic’s flavor is milder than that of garlic. Botanically elephant garlic is the ancestor of today’s leeks (Block, 2023).

Keeping garlic in the ground beyond a certain point does not result in bigger bulbs, but ratherdried 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 timeto harvest (Fig. 2). 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 (Medina and García, 2007).

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 (Medina and García, 2007).

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.

Harvest of garlic by hand

Harvest tool with garlics

Garlic picking and yield

Fig. 2. Harvesting of garlic

To prepareroasted 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 themin 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 (Medina and García, 2007).

Primary product: Garlic is most often used as a seasoning or a condiment. When crushed or finelychopped 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. Itis 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" (Fig. 3) (Medina and García, 2007).

Whole peeled garlic

Whole peeled garlic

1/8 Sliced

3/8 diced

3/8 diced

Crushed garlic

Puree garlic

Fig. 3. Raw garlic products

Fig. 4. String of garlic

Storage: Domestically, garlic is stored warm [above 18 °C (64 °F)] and dry to keep it dormant (to inhibit sprouting). It is traditionally hung; softneck varieties are often braided in strands called plaits or grappes. Peeled cloves may be stored in wine or vinegar in the refrigerator. Commercially, garlic is stored at 0 °C (32 °F), in a dry, low-humidity environment. Garlic will keep longer if the tops remain attached. Garlic is often kept in oil to produce flavored oil; however, the practice requires measures to be taken to prevent the garlic from spoiling which may include rancidity and growth of *Clostridium botulinum*. Acidification with a mild solution of vinegar minimizes bacterial growth. Refrigeration does not assure the safety of garlic kept in oil, requiring use within one month to avoid bacterial spoilage. Garlic is also dried at low temperatures, to preserve the enzymatic activity and sold and kept as garlic granules, and can be rehydrated to reactivate it. Stored garlic can be affected by *Penicillium* decay known as "blue mold" (or "green mold" in some locales), especially in high humidity. Infection may first appear as soft or water-soaked spots, followed by white patches (of mycelium) which turn blue or green with sporulation. As sporulation and germination are delayed at low temperature, and at −4 °C are inhibited entirely, in refrigerated cloves one may only see the white mycelium during early stages. *Penicillium hirsutum* and *Penicillium allii* are two of the predominant species identified in blue mold (Fig. 4) (Wikipedia, 2023).

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 0-1º C and 65-70 % R.H. (Medina and García, 2007).

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 sunshineas quickly as possible after digging. Do not dry by laying the plants in the sunshine. Tops androots 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 (Medina and García, 2007).

ORIGIN AND DISTRIBUTION

Garlic is one of the oldest horticultural crops. There are Egyptian and Indian references to garlic 5000 years ago, clear evidence of Babylonian usage 4500 years ago, and usage in China 2000 years ago, although some writings suggest that it was grown there as long as 4000 years ago. In spite of its long history, little is known about early garlic production or plant types used for cultivation (Simon and Jenderek, 2003).

Garlic is among the oldest known horticultural crops. In the Old World , Egyptian and Indiancultures 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 geographicregion 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". 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. 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 1000years that the distinction between hardneck and softneck was routinely noted (Medina and García, 2007).

The first mentions about the garlic are 6,000 years old; Sumerians, Egyptians or Jews used it. The parts of garlic plants were found also in Southern Moravia. They come from 2000 B.C. (STAVělíková, 2008). Scientists believe that wild relatives of garlic were widely dispersed in Central Asia about 10,000 years ago. Semi-nomadic tribes cultivated this plant as food condiment and medicinal plants. From Central Asia garlic was introduced to the Mediterranean basin, India and China. There is evidence that garlic has been in use in China and India for more than 5,000 years and in Egypt since before 2,000 BCE. European traders facilitated its further distribution, and, from the Mediterranean region, garlic was introduced to sub-Saharan Africa and to the Americas by explorers and colonists. Today garlic is known only as a cultivated plant, and its wild relatives are not found (FRG, 2008). Garlic is undoubtedly one of the true joys of culinary life on our planet. Although there is some debate about it, the most recent theory based on molecular and biochemical research is that garlic was first developed from wild *Allium longicuspis* in Central Asia, about 5,000–6,000 years ago. Wild *A. longicuspis* is found in the Tien Shan (Celestial or Heavenly) mountains, on the border between China and Kyrgyzstan, and those mountains were home to the great horseback traders of the Bronze Age, the Steppe Societies, ca 3500–1200 BCE (Hirst, 2019). Scholars are not completely in agreement that the closest wild garlic to the current domesticated variety is *A. longicuspis*, in part because since *A. longiscuspis* is sterile, it can't be the wild ancestor, but rather a cultivated plant abandoned by nomads. Indian botanist Deepu Mathew and colleagues suggest *A. tuncelianum* in southeast Turkey and *A. macrochaetum* in southwest Asia are more likely progenitors. Although there are a few collections in the region of where it was domesticated in Central Asia and the Caucasus which are seed-fertile, today's garlic cultivars are almost entirely all sterile and have to be propagated by hand. That must be a result of domestication. Other characteristics that appear in domesticated varieties are increased bulb weight, thinner coat layer, reduced leaf length, shorter growing seasons, and resistance to environmental stress. Remains of garlic come from the Cave of the Treasure, near Ein Gedi, Israel, ca 4000 BCE (Middle Chalcolithic). By the Bronze Age, garlic was being consumed by people throughout the Mediterranean, including the Egyptians under the 3rd dynasty Old Kingdom pharaoh Cheops (~2589–2566 BCE). Excavations at Minos' palace at Knossos on the Mediterranean island of Crete recovered garlic dated between 1700–1400 BCE; the New Kingdom Pharaoh Tutankhamun's tomb (~1325 BCE) contained excellently preserved garlic bulbs. The remains of a braid of 300 cloves of garlic were found in a room at the Tsoungiza Hill site, on Crete (300 BCE); and athletes from Greek Olympians to the Roman gladiators under Nero are reported to have eaten garlic to increase their athletic prowess. It wasn't just Mediterranean people with a jones for garlic; China started using garlic at least as early as 2000 BCE; in India, garlic seeds have been found at Indus Valley sites such as Farmana dated to the mature Harappan period between 2600–2200 BCE. The earliest references in historical documents come from the Avesta, a collection of Zoroastrian holy writings compiled during the 6th century BCE (Hirst, 2019).

Garlic is supposed to be the native of Central Asia, North-eastern Iran. One finds mention of garlic in ancient texts in Egypt and India. The Babylonians used garlic for its medicinal properties 4500 years ago. Garlic reached India roughly the same time as China via the trading routes. When Indian merchants returned home from Babylon, they brought this pungent, flavourful herb that made a permanent place for itself in every household. Spain and Italy have garlic as a 'must have' ingredient, but China tops them all. With 21 million tonnes of net production, China tops the global production and consumption list (Dube, 2021). Garlic has its primary center of origin in Central Asia (Kazakhstan), and the Mediterranean and Caucasian zones are considered as thesecondary centers. *Allium longicuspis* is designated as its ancestor because of its many similarities with the species. Evidence for its use as a medicinal plant dates to more than 1550 B. C and its distribution to other parts of the world was made possible by nomadictraders and great conquests. Today, it is cultivated in many countries of the world in Asia, Europe, America and Africa where it is consumed as a spice or therapeutic food (Agbo So *et al*., 2021). Garlic, scientifically known as *Allium sativum*, is a close relative of the onion and is native to Central Asia. The garlic bulb contains several cloves and each clove is covered with a soft translucent peel. Garlic has been used as a seasoning in food as well as a traditional remedy for over 3,000 years. Sir Louis Pasteur, the scientist who discovered pasteurization, used the anti-bacterial qualities of this herb as early as 1858. A report in the Journal of Pharmaceutical Research suggested that one clove per day may bring a vast improvement in your overall health, while two to three cloves daily could help keep the common cold at bay (Nagdeve, 2021). Garlic is an age-old spice that's made from a bulbous plant. But before it became the cooking staple it's known as today, garlic had a rich history of cultivation, medicinal benefits, and consumption. It's thought that garlic originated in India and Egypt around 5,000 years ago, and some historical documents suggest it was used in China about 4,000 years ago. The species of garlic found in this region are often referred to as "wild garlic" because of their indigenous nature. Garlic was also mentioned in Biblical texts, as well as ancient Greek materials (Cherney, 2022).

A. sativum was domesticated long ago; with references to its use as a vegetable, condiment, and medicinal plant dating back to ancient Egypt and India 5000 years ago, garlic is one of the oldest known crops. Central Asia is considered as garlic's primary center of origin, from where it spread to southeastern Asia, Egypt, and the Mediterranean region. Regarding garlic's ancestry, the most recent theory is that *A. longicuspis* Regel is either the closest wild relative or the wild progenitor of cultivated garlic, although there is some debate over it (Papaioannou *et al.,* 2023). While the origin of Allium species remains speculative, evidence suggests that garlic and onion were first domesticated in the central Asian mountainous regions of Tajikstan, Turkmenia, Uzbekistan and northern Iran, Afghanistan and Pakistan and most likely brought to the Middle East by Marco Polo and other Silk Road/spice route travelers. Recent research pinpoints the northwestern side of the Tien Shan Mountains (*e.g*., Kyrgyzstan, Kazakhstan) as the most likely center of origin of garlic. It has been suggested that *A. longicuspis*, genetically identical to *A. sativum*, might have been cultivated by semi-nomadic hunter-gatherers more than 10 000 years ago and transported along trading routes between China and the Mediterranean. From the Mediterranean region garlic was brought to sub-Saharan Africa and the Americas by explorers and colonists. It is also thought that garlic was introduced to China by traders from Central Asia, and into Japan from Korea, where it was very popular (Block, 2023).

Generally, all parts of all *Allium* species may be consumed by humans. Many taste good, yet some are less edible or even unpalatable. Domestication probably started by both protection and the rational use of wild plants, followed by transplanting into gardens. Human selection and natural events resulted in the development of variation now common in several cultivated species. The cultivation of domesticated *Allium* species (onion, garlic and others) during ancient times is well covered. Here I will discuss another aspect: the location of the crops in the genus' phylogenetic system, and whether its progenitor exists in nature. Were the crop plants' domestication a single or multiple event?. Like cultivated garlic, wild populations of *Allium longicuspis* Regel are sterile. The two plants are practically indistinguishable and are thus considered synonyms. Supposedly, the transition to vegetative reproduction resulted from selections for earliness and large bulbs, and fertility was restored by physiological manipulations, experimentally and in open fields. It was suggested that *A. longicuspis* is the direct wild-growing ancestor of *A. sativum* and also that it is feral cultivated garlic since it grows along roads and in places of abandoned settlements in Central Asia. The Turkish wild species *A. tuncelianum*, assumed the wild progenitor of garlic, is only distantly related and cannot be the progenitor (Friesen, 2023). It is native to South Asia, Central Asia and northeastern Iran and has long been used as a seasoning worldwide, with a history of several thousand years of human consumption and use (Wikipedia, 2023). Identification of the wild progenitor of common garlic is difficult due to the sterility of its many cultivars, which limits the ability to cross test with wild relatives. Genetically and morphologically, garlic is most similar to the wild species *Allium longicuspis*, which grows in central and southwestern Asia. However, because *Allium longicuspis* is also mostly sterile, it is doubtful that it is the ancestor of *Allium sativum*. Other candidates that have been suggested include *Allium tuncelianum*, *Allium macrochaetum*, and *Allium truncatum*, all of which are native to the Middle East. *Allium sativum* grows in the wild in areas where it has become naturalized. The "wild garlic", "crow garlic", and "field garlic" of Britain are members of the species *Allium ursinum*, *Allium vineale*, and *Allium oleraceum*, respectively. In North America, *Allium vineale* (known as "wild garlic" or "crow garlic") and *Allium canadense* (known as "meadow garlic", "wild garlic", or "wild onion") are common weeds in fields. Single clove garlic (also called pearl or solo garlic) originated in the Yunnan province of China (Wikipedia, 2023).

Garlic is one of the oldest known food flavoring and seasoning plant that managed to infuse itself into culinary tradition of many civilizations across the world. It started its journey in central Asia, domesticated during Neolithic times, spread to the Middle East and northern Africa in 3000 BC, which quickly enabled it to reach Europe. By offering its unique nutritional value and wide array of medicinal benefits, this plant was quickly identified as one of the most precious gifts of our nature, which was expanded with selective breeding into wide array of popular garlic types that are currently used all over the world. The incredible journey of garlic through our history touched every major civilization of the ancient world, but its true origins lie in West and Central Asia. There, wild plant called *Allium longicuspis* evolved for millennia, eventually shaping itself into the form of the modern *Allium sativum*, or garlic. This plant was identified by the ancient Indians who managed to domesticate it around 6 thousand years ago, incorporating its taste and medicinal properties (especially belief in its aphrodisiac powers) in their famous culture. Around 3000 BC, trading parties from India reached Middle East, where they introduced garlic to the mighty Babylonian and Assyrian empires, who embraced this plant and spread it across neighboring civilizations (GH, 2023).

Global Distribution: Iran, Kazakhstan, Kirgizstan, Tadzhikistan, Turkmenistan, Uzbekistan Introduced: Albania, Algeria, Amur, Austria, Baleares, Baltic States, Bangladesh, Belarus, Cambodia, Canary Is., Central European Rus, China North-Central, China South-Central, China Southeast, Corse, Cuba, Czechoslovakia, Dominican Republic, East European Russia, Egypt, Ethiopia, France, Galápagos, Germany, Greece, Haiti, Hungary, Illinois, India, Iraq, Italy, Jamaica, Korea, Leeward Is., Libya, Mexico Central, Mexico Northwest, Mexico Southeast, Mexico Southwest, Morocco, North European Russi, Northwest European R, Pakistan, Poland, Primorye, Puerto Rico, Romania, Sardegna, Seychelles, Sicilia, South European Russi, Spain, Switzerland, Tennessee, Thailand, Trinidad-Tobago, Tunisia, Turkey, Ukraine, Yugoslavia (IBP, 2023).

Indian Distribution

All over India (IBP, 2023). 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. 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 of us who have sought to find new genetic variation in garlic have collected wild garlic in Central Asia. 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 (Simon, 2024).

Throughout history, humans migrating and travelling through Central Asia and surrounding areas have collected wild garlic (and still do) and carried it with them for later consumption and cultivation. In 1989 I was fortunate enough to participate in a germplasm collection expedition seeking garlic and other alliums in nature reserves of Central Asia. We observed primarily hardneck garlic in the wild, but some softneck plants also occurred. It is easy to imagine early garlic connoiseurs migrating beyond the natural range of wild garlic and carrying wild garlic far from its center of origin. Only with cultivation could a supply for subsequent years be assured. And so garlic came to be cultivated. The wild hardneck garlic we collected is among the more prolific for production of true garlic seeds. We presume that the vast diversity that has been observed in cultivated garlic goes back to variation generated from sexual reproduction in the wild crop. In contrast to wild garlic, as far as we know, garlic in cultivation throughout history has only been propagated asexually by way of vegetative cloves, bulbs, and bulbils (or topsets), not from seed. These asexually propagated, genetically distinct selections of garlic we cultivate are more generally called "clones". Unlike sexually reproduced crops propagated from seed, vegetative reproduction assures a very uniform crop. Yet this asexual lifestyle of cultivated garlic forgoes the possibility of combining traits profferred by interpollinating diverse parental stocks. Let's say you have two garlic clones, clone A and clone B. Clone A has excellent yield but poor storage ability while clone B stores well but yields poorly. Without an opportunity for interpollination and sexual reproduction, the only way to obtain a garlic clone with high yield and long storage is to wait for the desired mutations(s) to occur in clone A or clone B. If these two clones can, however, be interpollinated and set true seed, a very realistic opportunity exists to develop a new line with both desired traits in several generations of progeny selection beyond this cross. Sexual reproduction and selection are at the heart of plant breeding in agriculture and, for that matter, evolution in wild plants (Simon, 2024).

TAXONOMY

Garlic belongs to the Family Amaryllidaceae, Subfamily Allioideae, Genus *Allium*, Subgenus *A.* subg. *Allium* and Species *Allium sativum* L. (Medina and García, 2007; STAVělíková, 2008; Wikipedia, 2023; IBP, 2023). 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 candense*. The field garlic of Europe and the Americas is classified as *Allium vineale*. False garlic is classified as *Nothoscordum bivalve.*The origin of garlic as recalled in an Indian legend (from a Sanskrit manuscript dated to AD350-375): 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 **(**Medina and García, 2007). Garlic (*Allium sativum L.*) belongs to the genus Allium. In this genus more than 750 species are identified and divided in 60 taxonomic groups. It is a bulbous plant whose domestication is very old. Its primary center is in Central Asia while theMediterranean and Caucasian regions are recognized as the secondary center of garlic (Agbo So *et al.,* 2021). Garlic belongs to the family *Liliaceae*. Common garlic is classified as *Allium sativum*, Britishwild garlic as *Allium oleraceum*, and American wild garlic as *Allium candense*. The field garlic of Europe and the Americas is classified as *Allium vineale*. False garlic is classified as *Nothoscordum bivalve.*The origin of garlic as recalled in an Indian legend (from a Sanskrit manuscript dated to AD350-375): 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 (Simon and Jenderek, 2003).

Plant systematists have struggled with the taxonomy of garlic. It is a diploid species (2n = 2x = 16) in the subgenus Allium of the Alliaceae (formerly in the Liliaeceae, and then the Amaryllidaceae). The other cultivated plants in this subgenus are leek, usually tetraploid, or elephant garlic, usually hexaploid (both *A. ampeloprasum* L.). Leek and garlic have flat, folded leaves. Elephant garlic and garlic form a bulb, but leek does not. Elephant garlic bulbs consist of 2 to 6 large cloves and several small cloves, while garlic bulbs usually have more cloves of a relatively consistent size, especially for bolting types. Bolting garlic, leek, and elephant garlic all have a solid scape, unlike the hollow scape of the most economically important Allium, onion (A.cepa L.). Garlic flower color ranges from white to pink to purple and inflorescences almost always include not only flowers but also bulbils (small, undivided bulbs occurring in the inflorescence; also referred to as “topsets” or “air bulbs”), whereas *A. ampeloprasum* inflorescences form bulbils only sporadically. Early classifications considered A. sativum to be a species known only in cultivation, with *A. longicuspis* Rgl. as a closely related wild relative originating in Central Asia. The diversity of Central Asian garlic supports the idea that this region is the primary center of origin of garlic, although this region was likely much larger in past history. The distinctiveness of *A. longicuspis* as a separate species, primarily differing from garlic in having exserted anthers, has been brought into question. Several botanical varieties of garlic are described in the literature, including *A. sativum* var. *sativum* L., which rarely or never flowers; *A. sativum* var. *ophioscorodon* (Link) Doll (the varietal name meaning “serpent garlic”), which regularly flowers; and *A.sativum* var. *pekinense* (Prokh.) Makino, which rarely flowers, like *A.sativum* var. *sativum*, but has wider leaves (Simon and Jenderek, 2003).

Subspecies and varieties: At present, three main classifications of garlic are accepted. With the first, the *Allium sativum* L. species is divided into three subspecies: (1) *A. sativum* var. *sativum*—nonbolting, (2) *A. sativum* var. *ophioscorodon*—bolting, with snake-like twisting flower stems, and (3) *A. sativum* var. *scordoprasum*—bolting, with nontwisting stems (includes rocambole and the other noncultivable garlics) (Batchvarov, 1993).

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 (Medina and García, 2007).

Hardneck garlic

Softneck garlic

Fig. 5. Hardneck garlic and Softneck garlic

Dube (2021) has classified only five types as follows

Artichoke Garlic: The garlic you have in your kitchen right now is the artichoke garlic. It's the most commonly grown garlic and has a subtle and delicious flavour.

Rocambole Garlic: This garlic variant is brownish and grows in Russia and Spain. It is known for its sweet taste.

Porcelain Garlic: This garlic is found mainly in the northern belts. It has several layers of flesh with purple stripes on the inside.

Asiatic Garlic: Used all over Asia but cultivated and popularised by the Asia Temple in Korea. This garlic has a strong taste and smell.

Himalayan Single Clove Garlic: Among the most expensive garlic produce, with only one clove per bulb. It has a lotus-like appearance. Because it grows in Kashmir, 'snow garlic' and 'Kashmiri garlic' are other names. It is seven times more potent than any other variety of garlic. However, scientifically this claim is not proved entirely. This type is popular among the sick and elderly.

There are two subspecies of *A. sativum*, ten major groups of varieties, and hundreds of varieties, or cultivars. *A. sativum* var. *ophioscorodon* (Link) Döll, called *Ophioscorodon* or hardneck garlic, includes porcelain garlics, rocambole garlic, and purple stripe garlics. It is sometimes considered to be a separate species, *Allium ophioscorodon* G. Don. *A. sativum* var. *sativum*, or softneck garlic, includes artichoke garlic, silverskin garlic, and creole garlic. There are at least 120 cultivars originating from Central Asia, making it the main center of garlic biodiversity (Wikipedia, 2023). There are two sub-varieties of *allium sativum*: *Allium sativum* var. *sativum* (soft-necked garlic) and *Allium sativum* var. *ophioscorodon* (hard-necked garlic). Soft-necked garlic is the most commonly found. Bulb garlic is available in many forms, including fresh, frozen, dried, fermented (black garlic) and shelf stable products (in tubes or jars) (TS, 2023).

U.S. Department of Agriculture geneticist Gayle Volk used DNA analysis to classify many different cultivars of garlic into ten major types (Block, 2023):

Rocambole (limited storage, 6 to 11 large cloves with loose, easily peeled skin), Purple Stripe (8 to 12 cloves, bright purple streaks on bulb wrappers and clove skins), arble Purple Stripe, Glazed Purple Stripe, Porcelain (satiny white bulb wrappers with 4 to 6 large cloves), Artichoke, Silverskin, Asiatic, and Turban and Creole. The sexual sterility of garlic limits development of genetic varieties, *e.g.,* those showing superior pest resistance, size, yield, quality and tolerance of temperature extremes during growth (Fig.6).

Fig. 6. Examples of the diversity of garlic cultivars

Synonyms (Medina and García, 2007; IBP, 2023)

Allium arenarium Sadler ex Rchb., nom. inval.
Allium controversum Schrad. ex Willd.
Allium longicuspis Regel
Allium ophioscorodon Link
Allium pekinense Prokh.
Allium sativum f. *sagittatum* Kazakova
Allium sativum subsp. *asiae-mediae* Kazakova
Allium sativum subsp. *controversum* (Schrad. ex Willd.) K.Richt.
Allium sativum subsp. *subrotundum* (Gren. & Godr.) K.Richt.
Allium sativum var. *ophioscorodon* (Link) Döll
Allium sativum var. *pekinense* (Prokh.) F.Maek.
Allium sativum var. *vulgare* Döll, nom. inval.
Allium scorodoprasum subsp. *viviparum* (Regel) K.Richt.
Porrum ophioscorodon (Link) Rchb.
Porrum sativum (L.) Rchb., nom. illeg.

BOTANICAL DESCROIPTION

Different types of garlics to grow

Hardneck garlic: This garlic produces a long flowering stalk, called a “scape,” in early summer. Beneath the soil, a single row of cloves develops around this central stalk. Hardneck garlic produces fewer cloves per bulb than softneck varieties, but each individual clove is larger, and many believe it to be more flavorful. Hardneck types are also usually more winter hardy than softneck garlic and are therefore the garlic of choice for short-season gardeners. Once harvested and cured, hardneck garlic stores for up to six months (Fig. 7).

Softneck garlic: Softneck garlic is not usually as winter hardy as hardneck garlic and is often grown in milder regions. The bulbs are packed with cloves — sometimes more than 20 in a bulb! — that range in size from small to large. They do not produce a central scape, but instead have soft, flexible stems and leaves. This is why you’ll sometimes see softneck garlic braided for

storage. And speaking of storage, softneck garlic stores very well, with the cloves remaining firm and flavorful for up to a year (Fig. 7).

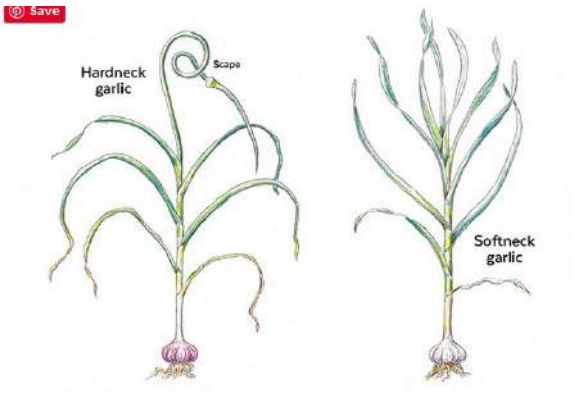


Fig. 7. Hardneck and Softneck garlic

The Life Cycle of a Garlic Plant: Bulb and Flower Development: Garlic bulbs contain a variable number of cloves, usually ranging from 8 to 14, and are covered by outer tunics (*i.e.,* the dry sheaths of older foliage leaves). The cloves are lateral shoots that develop from the axillary meristems located on the adaxial side of foliage leaves. Each clove is itself a small bulb and is covered by dry, protective leaves, which vary in color (white, purple or reddish) and cover a modified storage leaf that constitutes the fleshy part of the clove. The apical meristem of the clove is located at the apex of a very short stem called the basal plate, and is flanked by the developing leaf primordial (Parreño *et al*., 2023). The life cycle of a garlic plant (Fig. 8) starts when a clove exits dormancy and sprouts after being exposed to temperatures between 5 °C and 10 °C for several weeks. One of the earliest events in the development of a new plant is the emergence of adventitious roots at the periphery of the basal plate, preceding the development of flat foliage leaves. Foliage leaves are initiated from the apical meristem and eventually form a pseudostem. The root system and the leaves usually develop before bulb formation (Parreño *et al*., 2023).

Cloves for planting should be from large (but not giant) bulbs and be in good condition.

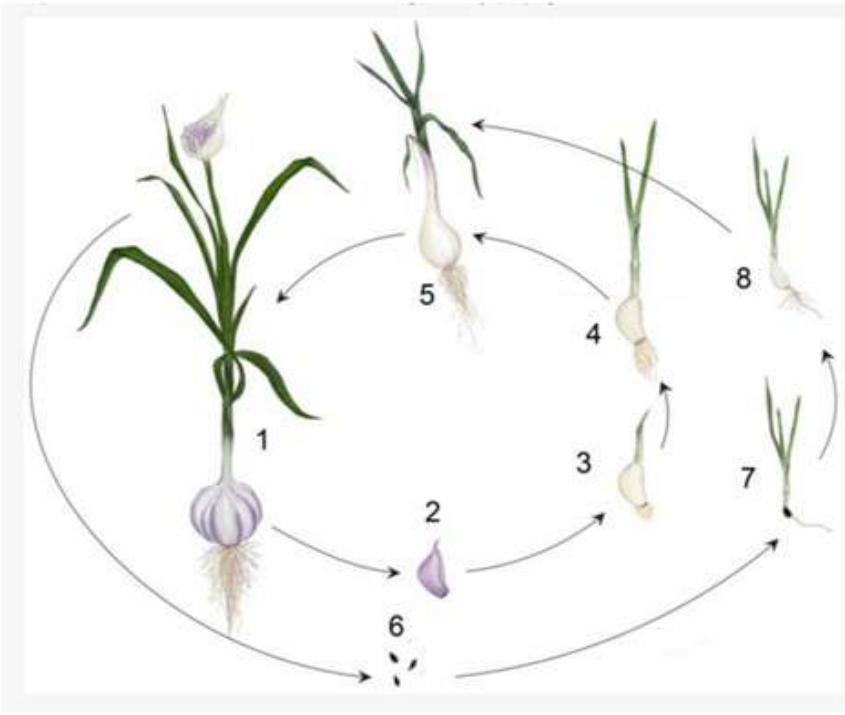


Fig. 8. Life cycle of a garlic plant showing the different stages from the germination of a seed or clove to a mature plant. (1) Adult garlic plant of a bolting cultivar bearing a floral scape. (2) Dormant clove, recently detached from the mother plant, which has not yet produced adventitious roots. (3) Sprouted clove in which new adventitious roots and the first leaves have emerged. (4) Young garlic plant in which the formation of new cloves has not yet been initiated. (5) Garlic plant in which the bulb is actively thickening as a result of the growth of new cloves. (6) True seeds are produced only in some fertile garlic varieties. (7) When a seed germinates, a new seedling emerges, with a primary root emerging from the embryo's apical meristem and new leaves developing from the shoot apical meristem. (8) Under inductive conditions, seed-derived plants can also produce new bulbs, which can then be vegetatively propagated if desired.

		
Cloves	Scape/Flower stalk	Bulbils (softneck types don't tend to bolt)
		
Bulbils (softneck types don't tend to bolt)	Bulbils (softneck types don't tend to bolt)	Bulbils **(Hardneck types** to grow scapes, flower, and go to seed)
		
First remove the bulbils and allow the actual flower to develop	Seeds	True Seeds

Fig. 9. 3 Methods of Propagation

Asexual Propagation: The garlic bulb of commerce typically weighs 60 to 120 g, and consists of cloves surrounded by the dried basal sheaths of the foliage leaves. Bolting garlic bulbs usually consist of 4–12 cloves that tend to be relatively similar in size, while nonbolting garlic usually have more cloves that can vary greatly in size. Cloves are sessile lateral bulbs, that originate from axillary buds of inner (younger) foliage leaves. An outer, thin protective leaf and an inner, thickened, bladeless storage leaf are the most predominant parts of a garlic clove, with the storage leaf accounting for most of the volume and weight of the clove. The storage leaf subtends a central vegetative bud over a flattened basal plate, which is a modified very short stem. The central vegetative bud includes a predominant sprout leaf and several foliage leaf primordia that surround the apical meristem (Simon and Jenderek, 2003).

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. The Bulb, 12 inches to 18inches tall (30-45 cm), 9 inches to 12 inches in spread (22.5-30 cm). The roots are trimmed and the stems snipped or braided. Depending on where they are grown, the size, shape, colour, and flavour will differ. Colors can range from white to red topurple or pink. Garlic's straplike leaves are 1-2 feet long, surrounding a central flower stalk or scape, whichdevelops a globular cluster of tiny white blossoms. 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 bulbmaturity, when it bends over near ground level. 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 3-5millimetres long. The flowers are commonly abortive and rarely produce any seeds. 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. The scape or flower stem usually emerges coiled, then later straightens to vertical as it growsand 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. 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. 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. Each clove is inside a protective sheath, and the whole compound group iscovered 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 (Fig. 9). (Medina and García, 2007).

The percentage composition of typical garlic is: the portion of the plant most often consumedis 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 (Medina and García, 2007).

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 canbe 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 (Medina and García, 2007).

Garlic is sterile (does not produce fertile botanical seeds by sexual reproduction), asexually propagating by its cloves, despite some progress in recent years to restore garlic fertility. Besides, cloves must be reproduced every year, since they cannot be stored for longer periods and then germinated, as happens with standard botanical seeds. Such peculiarity adds extra cost and inconvenience to its maintenance, mainly for large germplasm collections. The peculiar garlic reproduction could lead to low genome diversity, since meiosis is not involved in its clonal reproduction by vegetative propagation (Egea *et al.,* 2017).

Allium sativum L. is an annual herbaceous bulbous plant. It's a plant that can be erect or prostrate at heights ranging from 20 to 70 cm. The stem or pseudo-stem is very short forming a tray at the base from which adventitious roots start. It consists of a succession of leaves that fit together through their leaf sheaths. The root system of garlic is of the adventitious type, rather thick and little branched, with an epidermis, a multicellular cortex, and an endoderm that surrounds the central stele. The root development of the plant is sensitive to soil moisture and temperature. The leaves are linear and alternate with a tubularsheath and their number varies from 9 to 12 in the species. They can measure up to 40 cm long and 2 cm wide. The limbs are broad and streamlined and the bases of all the leaves are located at the bulb. The bulb (or head) is characterized by a great diversity of shape and color. It can be white, brown, light brown, violet, light violet or dark violet while the observedrounded, elliptical or circular, transverse wide elliptical and transverse narrow elliptical. Each bulb is formed of several cloves or pods which represents the reproductive organ of the garlic. Each clove consists of a protective tunic, often colored, a single fleshy leaf sheath, and a small bud. The number of cloves per bulb varies considerably depending on the variety. Some varieties have 4 to 6 cloves per bulb, whilein others the number can reach 10 or even 14 cloves per bulb. The inflorescences are umbels composed of perfect flowers with 6 petals, 6 anthers and 3 locules composed of 2 ovules each. Theycan be large or small containing a more or less important number of sterile flowers and bulbils. However, the ability to produce inflorescences is not observed in all varieties. This ability is most common in central Asian and Spanish varieties (Agbo So *et al.,* 2021). Leaves flat, scape slender, spathes long-beaked, heads bearing bulbils and flowers, sepals lanceolate acuminate, inner filaments 2-toothed. Flora of China, efloras.org: Bulb solitary, globose to applanate-globose, usually consisting of several bulbels covered with a common tunic; tunic white to purple, membranous, entire. Leaves broadly linear to linear-lanceolate, shorter than scape, to 2.5 cm wide, apex acuminate. Scape 25--50 cm, terete, covered with leaf sheaths for ca. 1/2 its length. Spathe deciduous; beak 7--20 cm. Umbel with many bulblets and few flowers. Pedicels slender, longer than perianth; bracteoles ovate, rather large, membranous, apex acute. Perianth usually pale red; outer segments ovate-lanceolate, ca. 4 × 1.4 mm; inner ones ovate, ca. 3 × 1.4 mm. Filaments shorter than perianth segments, connate at base and adnate to perianth segments; outer ones subulate; inner ones broadened at base, 1-toothed on each side, teeth with apex filiform and longer than perianth segments Ovary globose. Style not exserted (Fig. 10.)(IBP, 2023).

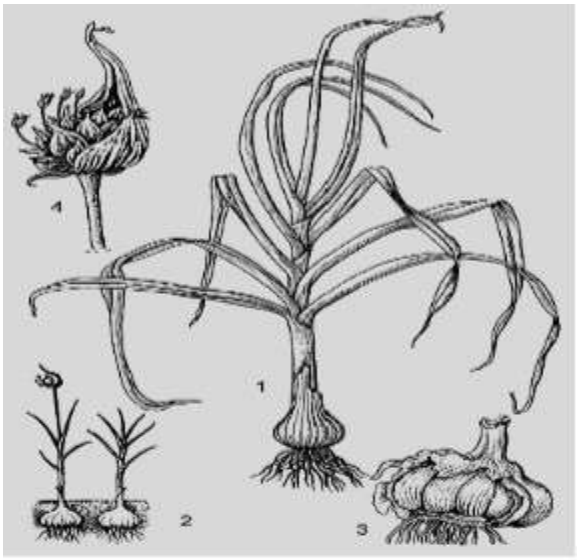


Fig. 10. Ail (*Allium sativum*): 1,2, Plnt habit; 3, Bulb; 4, Inflorecence

Botanists describe alliums as ‘‘low growing perennials in which the rhizomes, roots, and bulbs can be important storage organs. The leaves [tubular in onions, flat in garlic] arise from the underground stem and often have long sheathing bases, which can give the appearance of a stem, as typified by leeks. No leaves occur on the flower stalk (the ‘scape’) except the single spathe that encloses the young inflorescence’’. The bulbs, which often clump, consist of the swollen base of the stem and several fleshy leaves or scales held together by a disk or hardened stem tissue called a basal plate. There are two main sub-species of garlic, namely hardneck (stiffneck) and softneck. Hardneck garlic (*Allium sativum* ssp. *ophioscorodon*), also called ophio or top-set garlic, produces scapes or flower stalks and prefers northerly climates with cold winters. When sliced through the bulb midsection, the hardneck type typically reveals a single circle of 6 to 11 cloves around a central woody stalk. Before flowering, the scape (‘‘top set’’) curls upward as it grows, looping the loop with 1 to 3 coils, like pig’s tails (Figure 1.3), before straightening and then grows little seed-like bulbils. Garlic is completely sterile and is therefore propagated asexually only from cloves (Block, 2023).

Allium sativum is a perennial flowering plant that grows from a bulb. It has a tall, erect flowering stem that grows up to 1 m. The leaf blade is flat, linear, solid, and approximately 1.25–2.5 cm wide, with an acute apex. The plant may produce pink to purple flowers from July to September in the Northern Hemisphere. The bulb has a strong odor and is typically made up of 10 to 20 cloves. The cloves close to the center are symmetrical, and those surrounding the center can be asymmetrical. Each clove is enclosed in an inner sheathing leaf surrounded by layers of outer sheathing leaves. If garlic is planted at the proper time and depth, it can be grown as far north as Alaska. It produces hermaphroditic flowers. It is pollinated by bees, butterflies, moths, and other insects (Wikipedia, 2023).

Garlic plants grow about 60 cm (2 feet) tall. Depending on the variety, the long leaves typically arise from a short hard stem above the bulb or emerge from a softer pseudostem made up of overlapping leaf sheaths. The bulb is covered with membranous skin and encloses up to 20 edible bulblets called cloves. The spherical flower cluster is initially enclosed in a pair of papery tapered bracts; the bracts split open when the green-white or pinkish flowers bloom. Flower stalks sometimes arise bearing tiny bulbils (tiny secondary bulbs that form in place of flowers) and sterile blossoms. Garlic is usually grown as an annual crop and is propagated by planting cloves or top bulbils, though seeds can be also be used (Fig. 11, 12) (EEB, 2024).

Garlic

Garlic

Garlic

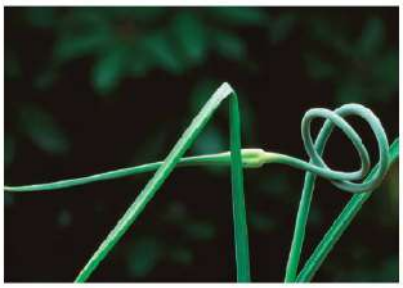
Sowing of cloves	**Sowing of clove**	Germination
		
Young seedlings	**Green garlic**	**Scapes or Flower Stalks Stage**
		
Scape	**Flowering stage**	Bulbs (top-setting, grown in lieu of flowers)
		
Young Bulb Stage	**Harvesting Stage**	Harvested garlic left to dry
		
Guarding Onion Field	**Onion bags**	

Fig. 11.Botanical Description

a H type

b A type

Fig. 12. Flowering stalk develops regularly, produces purple umbels and Flowers, pollen is present in theb flower but never reaches First pollen mitosis	Flower stalk develops and produces an umbel With only bulbils and no /few flowers

Fig. 12. H type and A type umbel

Sexual Propogation: In 1998, a special project for restoring the fertility of garlic was initiated in Israel. In the framework of this project, our collection missions to Central Asia have gathered over 300 garlic genotypes from locally cultivated or natural populations in Uzbekistan, Tadjikistan, Kirgizistan, and Kazakhstan. This region is recognized as the primary centre of origin of garlic and the main and richest source for genetic diversity, worldwide. The collected clones were evaluated in Israel for their potential fertility and other useful traits. It was found that following stalk elongation, flower differentiation, pollination, and fertilization, true garlic seeds might be obtained in more than 30 clones. In seven of the most fertile accessions, about 400-500 seeds were produced per umbel, without the removal of topsets. Germination rates reached about 90%, and the seedlings developed into young plants with two to five leaves. At the end of the season, single-clove bulbs with white, purple, gray and brown skins, differing in bulbing ability and ripening, were obtained. These plants vary widely in their physiological and horticultural characteristics, and probably contain most of the worldwide variability of the garlic genepool. Seed propagation of garlic on a massive scale may become a feasible option in the future. Sexual reproduction can be exploited in plant breeding, for improvements to yield, tolerance to biotic and abiotic stresses and quality. In addition, in established varieties, seeds (which normally do not transmit viruses) may be used for the production of virus-free propagation material (Fig. 13) (FRG, 2008).

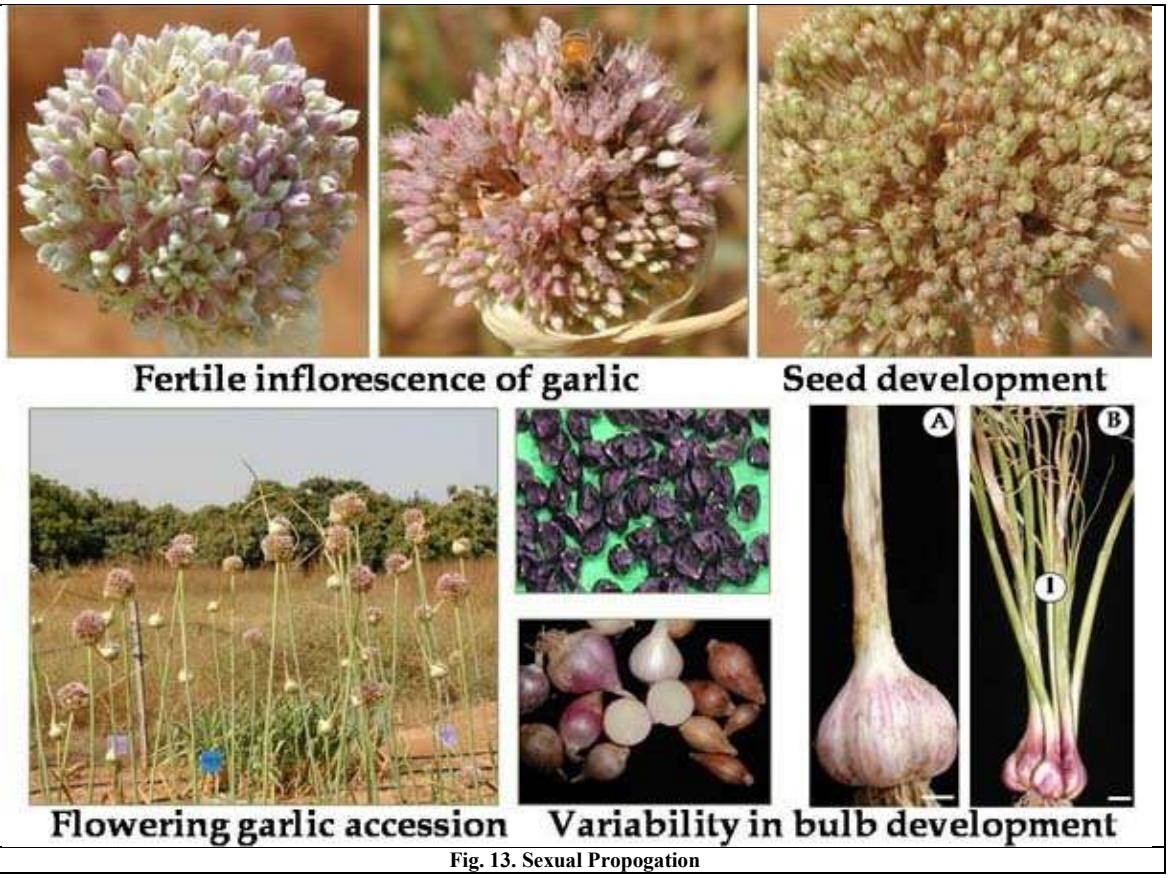


Fig. 13. Sexual Propogation

Floral Biology and Pollination: Garlic presents no pollination problem and when flowers do appear on garlic they are sterileso seeds are unknown. Both are propagated by bulblets or cloves (Medina and García, 2007). The lack of sexual processes prohibits genetic studies and conventional breeding in commercial cultivars of garlic. Recent restoration of garlic flowering ability by environmental manipulations has opened new avenues for physiological and genetic studies. The *LEAFY* homologue *gaLFY* has been shown to be involved in the floral development, while two alternatively spliced *gaLFY* transcripts are expressed in flowering genotypes. In the present work, quantitative real-time PCR and two techniques of RNA in situ hybridization were employed to analyze spatiotemporal expression patterns of the *gaLFY* during consequent stages of the garlic reproductive process. Temporal accumulation of *gaLFY* is strongly associated with reproductive organs, significantly increased during florogenesis and gametogenesis, and is down-regulated in the vegetative meristems and topsets in the inflorescence. The two alternative transcripts of the gene show different expression patterns: a high level of the long *gaLFY* transcript coincided only with floral transition, while further up-regulation of this gene in the reproductive organs is associated mainly with the short *gaLFY* transcript. It is concluded that *gaLFY* is involved at different stages of the sexual reproduction of garlic. These new insights broaden our basic understanding of flower biology of garlic and help to establish conventional and molecular breeding systems for this important crop (Rotem Neta *et al*., 2011).

GENETICS AND CYTOGENETICS

It is a diploid species (2n = 2x = 16) in the subgenus Allium of the Alliaceae (formerly in the Liliaeceae, and then the Amaryllidaceae). The other cultivated plants in this subgenus are leek, usually tetraploid, or elephant garlic, usually hexaploid (both *A. ampeloprasum* L.). Leek and garlic have flat, folded leaves. Elephant garlic and garlic form a bulb, but leek does not. Elephant garlic bulbs consist of 2 to 6 large cloves and several small cloves, while garlic bulbs usually have more cloves of a relatively consistent size, especially for bolting types. Bolting garlic, leek, and elephant garlic all have a solid scape, unlike the hollow scape of the most economically important Allium, onion (*A.cepa* L.) (Simon and Jenderek, 2003). Garlic has a large diploid genome ($2n = 2x = 16$), of an estimated haploid (1C) size of 15.9 gigabase pairs (Gbp); that is, 32 times larger than rice (*Oryza sativa*) (Egea *et al.,* 2017). Garlic is a diploid (2n = 2x = 16) sterile species, which is primarily propagated asexually via its bulblets (*e.g.,* cloves) due to obligate apomixes. Despite the existence of a few fertile wild genotypes, most of the germplasm collections worldwide comprise nonflowering plants and thus clonal selection is the method of choice in garlic breeding (Papaioannou *et al*., 2023). Here, we report a chromosome-level genome assembly for garlic, with a total size of approximately 16.24 Gb, as well as the annotation of 57 561 predicted protein-coding genes, making garlic the first *Allium* species with a sequenced genome. Analysis of this garlic genome assembly reveals a recent burst of transposable elements, explaining the substantial expansion of the garlic genome (Sun *et al.,* 2020).

GENETIC DIVERSITY

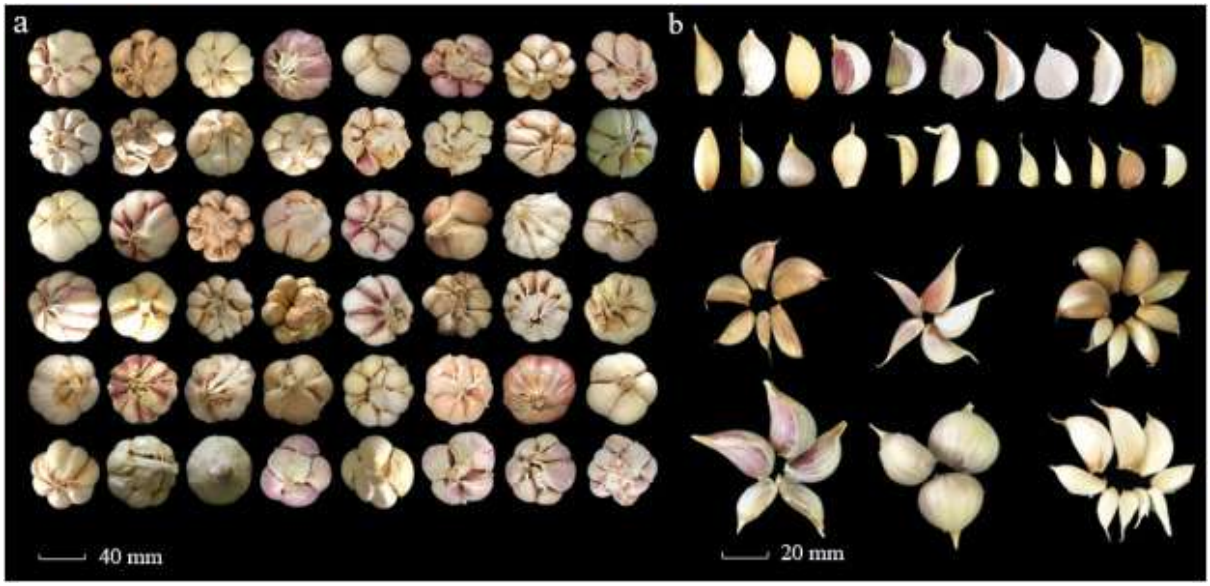


Fig. 14. Typical garlic bulbs (a) and cloves (b) with diverse phenotypes

A wide range of morphological diversity has been observed in garlic, including flowering ability (and scape length of flowering clones), leaf traits (color and attitude), bulb traits (shape, outer leaf scale color, clove color, number, size, and organization of cloves), plant maturity, bulbing response to temperature and photoperiod, cold-hardiness, bulbil traits (number, size, color, and ease of removal), and flower traits (timing, number, size, color, petal closure, and stigma position) (Simon and Jenderek, 2003). Although garlic is propagated vegetatively, considerable variation has been found in morphological traits. Majorcharacters found to contribute to genetic diversity are bulbweight, diameter, yield, number of cloves per bulb, maturity,plant height, number of green leaves and bulbing period. Diversity assessment on the basis of morphological, physical-chemical, productive and molecular characteristics, allicin content, pungency, productive and qualitative characteristics and chemotaxonomic classification have been studied. In diversity assessment did not detect any significant relationship between genetic diversity and geographical origin.

Therefore, probably, genetic factors have more influence than ecology. Allicin is a major chemical constituent of garlic andis use in pharmaceuticals. Multiple factors, *viz.*, genotype, environment, S fertilization and light spectrum, relative water content, soil type and harvesting date have been found to influence allicincontent in garlic bulbs (Fig. 14, 15) (Lawande *et al*., 2009).

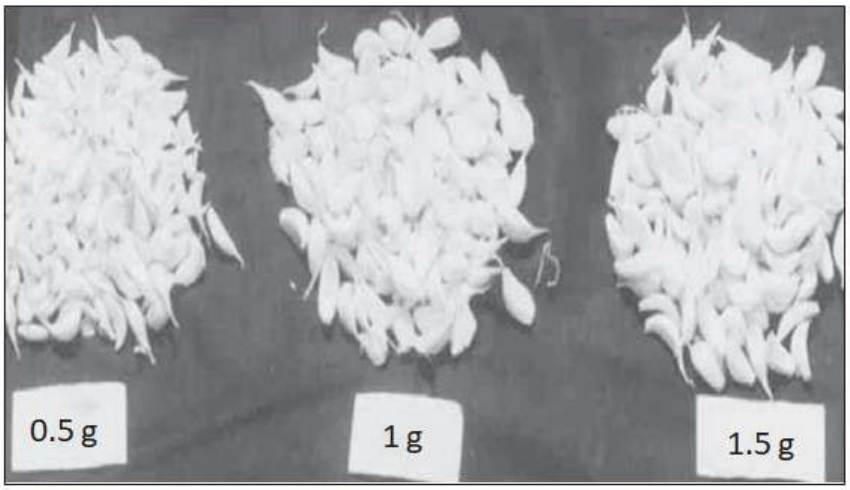


Fig.15. Bigger cloves > 1.5 g enhances yield

A wide range of morphological diversity has been observed in garlic, including flowering ability (and scape length of flowering clones), leaf traits (color and attitude), bulb traits (shape, outer leaf scale color, clove color, number, size, and organization of cloves), plant maturity, bulbing response to temperature and photoperiod, cold-hardiness, bulbil traits (number, size, color, and ease of removal), and flower traits (timing, number, size, color, petal closure, and stigma position). Detailed classification of garlic germplasm collections based solely on morphological diversity has been considered difficult due to the subjective nature of categorization for several of these traits (Simon and Jenderek, 2003).

China is the biggest garlic producer in the world; however, the genetic background of garlic from China is not well understood. In this study, population structure and clustering analysis of garlic germplasm was performed using amplified fragment length polymorphism (AFLP), simple sequence repeat (SSR) and insertion–deletion (InDel) markers. Among 212 accessions of garlic, genetic diversity analysis identified 546 alleles amplified by AFLP, SSR and InDel primers, and 492 of these were polymorphic. All accessions were divided into five groups by structure analysis and neighbor-joining clustering. Most traits, including allicin content, were only slightly affected by population structure, which indicated that this germplasm can be used as populations for association mapping. The results provide a molecular basis for understanding the genetic diversity of the garlic germplasm preserved in China (Wang *et al*., 2016).

Garlic is used worldwide in cooking and industry, including pharmacology/medicine and cosmetics, for its interesting properties. Identifying redundancies in germplasm blanks to generate core collections is a major concern, mostly in large stocks, in order to reduce space and maintenance costs. Yet, similar appearance and phenotypic plasticity of garlic varieties hinder their morphological classification. Molecular studies are challenging, due to the large and expected complex genome of this species, with asexual reproduction. Classical molecular markers, like isozymes, RAPD, SSR, or AFLP, are not convenient to generate germplasm core-collections for this species. The recent emergence of high-throughput genotyping-by-sequencing (GBS) approaches, like DArTseq, allow to overcome such limitations to characterize and protect genetic diversity. Therefore, such technology was used in this work to: (i) assess genetic diversity and structure of a large garlic-germplasm bank (417 accessions); (ii) create a core collection; (iii) relate genotype to agronomical features; and (iv) describe a cost-effective method to manage genetic diversity in garlic-germplasm banks. Hierarchical-cluster analysis, principal-coordinates analysis and STRUCTURE showed general consistency, generating three main garlic-groups, mostly determined by variety and geographical origin. In addition, high-resolution genotyping identified 286 unique and 131 redundant accessions, used to select a reduced size germplasm-bank core collection. This demonstrates that DArTseq is a cost-effective method to analyze species with large and expected complex genomes, like garlic. To the best of our knowledge, this is the first report of high-throughput genotyping of a large garlic germplasm. This is particularly interesting for garlic adaptation and improvement, to fight biotic and abiotic stresses, in the current context of climate change and global warming (Egea *et al.,* 2017).

Genetic diversity was assessed among 53 Indian garlic accessions using SSR markers. Initially, 24 SSR primer pairs were used for screening three selected garlic accessions. Out of 24 SSR primer pairs, 10 primer pairs which consistently showed good amplification and polymorphism were selected for DNA profiling. SSR primer pairs showed PIC values ranging from 0.30 to 0.99. Based on AMOVA we found that the greater part of the genetic diversity was expected due to intra population with 84% variation and only 16% of variation was due to among populations suggesting presence of genetic structure. The results of cluster analysis and principal component analysis largely correspond to each other. Population structure analysis revealed genetic differentiation of accessions. The results of present study revealed existence of significant variability in Indian garlic germplasm (Kumar *et al.,* 2019). Studies on the analysis of genetic diversity through morphological markers revealed a wide variation in the color, shape and number of cloves and the ability to flower. Biochemical markers such as Esterase (EST), Phosphoglucomutase (PGI),

Malate Deshydrogenase (MDH), and Diaphorase (DIA as well as molecular markers such as *Random Amplified Polymorphic DNA* (RAPD), *restriction fragment length polymorphism* (RFLP), *Amplified Fragment Length Polymorphism* (AFLP), and *Simple Sequence Repeats* (SSRS) *Inter-Simple Sequence Repeat* (ISSR) were successfully used. RFLPs or RAPD are the most used for assessing genetic variability within asexually reproducing garlic species. Work using SSRs markers is limited in garlic relative to other crops. Studies have revealed a great diversity of shapesand color of the bulb, size, date of maturity. The most used markers for genetic analysis are morphological markers and molecular markerssuch as RFLP or RAPD (Agbo So *et al*., 2021). Cultivated garlic varieties show widemorphological and agronomic variations in characteristics such as bulb color and size, plant height, time of flowering, the number and size of cloves, dormancy of the cloves, and adaptationto agro-climatic conditions (Agbo So *et al*., 2021).

Molecular markers were used to characterize the genetic diversity of 27 garlic accessions/landraces from Greece. SSR and ISSR markers revealed significant levels of diversity (the greatest amount of it was distributed within the accessions rather than among them) indicating the possible presence of genetic structures. Our results also confirm previous studies regarding the existence of redundancy in garlic germplasm collections. Nearly identical clustering results were obtained using UPGMA, STRUCTURE, and PCoA clustering analyses based on SSR data. However, the results obtained using the SSR markers were incongruent with those obtained by the ISSR analysis. Finally, significant associations were detected between specific chemical compounds, the morphological traits of the bulb and genetic loci. Studies assessing genetic diversity are important to improve management and conservation of agrobiodiversity and to facilitate and accelerate breeding programs. The results of our study will aid the exploitation of this valuable genetic resource for future crop improvement through identifying potential markers related to bulb traits and important chemical compounds of the secondary metabolism. These breeding objectives, together with fertility restoration and pathogen protection, are important breeding targets for elite cultivar development strategies and for the preservation and utilization of the Greek garlic germplasm collection (Papaioannou *et al*., 2023).

Garlic exhibits wide biodiversity, environmental adaptation capacity, and phenotypic plasticity, resulting in the establishment of diverse ecotypes in various areas of cultivation. This variation in domesticated garlic is primarily due to spontaneous mutations arising throughout the history of large-scale cultivation, but also due to variability inherited from its wild ancestor. Clonal propagation is thought to have caused a genetic bottleneck, accounting for the narrow genetic base observed in this crop. On the other hand, clonal lineages within this species exhibit high levels of diversity in several phenotypic characteristics and valuable agronomic traits, such as stress and drought tolerance. A wealth of variability, primarily related to the crop's morphological and genetic characteristics, chemical composition, and nutritional value, exists in germplasm accessions, particularly local landraces that are still cultivated by farmers either for trade or for their own consumption. So far, variation assessment of garlic germplasm collections has revealed a significant amount of diversity in morphological, agronomic, and chemical traits. Recently, garlic genotypes from different areas of Greece were evaluated for their chemical composition, quality, and bulb morphology. In a more comprehensive survey, examined the phenotypic diversity of thirty-four Greek garlic accessions, using morphological descriptors and agronomic traits. It was also determined their levels of organosulfur compounds, pyruvate, total sugars, total phenolics, and antioxidant properties. All these studies revealed remarkable diversity, demonstrating the need for the valorization of Greek garlic genotypes and their importance for conservation and breeding (Papaioannou *et al.,* 2023).

BREEDING

Germplasm

Maintenance of garlic (*Allium sativum L*.) genetic resources has had a long tradition in the Czech Republic. The collection was founded in 1951 and its current holder is the Crop Research Institute, Department of Vegetables and Special Crops in Olomouc. The collection consists of 613 genotypes. The oldest genotype was acquired in 1954. The collection has been evaluated according to the Descriptor list for *Allium* spp. (IPGRI 2001). 17 characters of the Descriptor list were supplemented with 5 additional characters. The photos of all garlic genotypes were taken. The genotypes were divided into the three main morphological groups according to the ability to produce the scape: the first group with the scape (bolting) – 300 genotypes, the second part without the scape (non-bolting garlic) 205 genotypes and the third part presents semi-bolting garlic – 108 genotypes. The last morphological type has bulbils in the different parts of the pseudostem (Stavělíková, 2008).

Due to apomictic nature of garlic, exploration and clonalselection have been the most widely implemented breeding strategies in India. The ICAR's Directorate of Onion andGarlic Research (DOGR), Rajgurunagar; ICAR institutes likeVivekananda Parvatiya Krishi Anusandhan (VPKAS), Almora, Central Institute of Temperate Horticulture (CITH), Srinagar; state university Mahatama Phule Krishi Vidyapeeth (MPKV), Rahuri and National Horticulture Research and Development Foundation (NHRDF), New Delhi have been instrumental in developing and identify clones suitable for different day length conditions of the country after rigorous evaluation through All India Network Research Project on Onion and Garlic (AINRPOG) and AICRP (Vegetable crops) (Malik *et al*., 2017).

We have significantly reduced the analyzed garlic germplasm-bank size, identifying redundant accessions and thus generating a unique (non-redundant) core collection, with the consequent reduction in space and maintenance expenses. To our knowledge, this is the first work of high-throughput garlic genotyping. The obtained results show that DArTseq is a cost-effective method to perform genotyping-by-sequencing and genetic diversity analyses of such species with huge, expected complex and mostly unknown (without reference) genome, with clear applications for biodiversity conservation. DArTseq has generated consistent results, in accordance with variety and geographical origin. They remark the relevance of genetic versus agro-morphological data,

especially in the context of peculiar garlic-plasticity for environmental adaptation. Additionally, the high number of samples analyzed in this work and the amount of data generated should be useful for plant breeders in general, as well as for garlic adaptation and improvement in particular. This, along with other molecular markers and agro-morphological information represent useful tools to improve management strategies in germplasm-banks. In fact, having a core collection of characterized genotypes and phenotypes could help breeders to select plants with better adaptability. This is important for productivity and to face biotic and abiotic stresses, to fight the current climate change and global warming (Egea *et al*., 2017).

Garlic Breeding Goals

Most of the variation described has been for some of the typical bulb and flower traits, including outer and inner bulb scale color, clove number and color, time of bulb maturity, time of flowering, stalk length, and flower petal color, pedicel color, number, and ovary wall color. Given the range of flowering habits observed among diverse garlic clones, a better understanding of flowering genetics will be of particular interest. Of most interest to garlic growers are yield and bulb storage parameters, but no reports to date have included data detailing these attributes. A search for genetic resistance to viruses and other diseases ranks high among garlic breeding goals (Simon and Jenderek, 2003). Another very critical trait, likely associated closely with yield, is seedling vigor. This was a crucial variable contributing to the initial successes in obtaining garlic seed, and it will also be critical for success in developing seed-propagated garlic. Since clonally propagated garlic typically develops from a clove several grams in size, and a seedling has a weight equivalent to only a small fraction of a clove, early seedling vigor will be essential for crop propagation from seed. Perhaps other technologies such as transplanting of seedlings, rather than direct seeding, will also be used to make seed-propagated garlic a viable economic possibility, although this would add back another production cost and hence reduce the economic benefits of a seed-propagated crop. Field trails to evaluate the possibilities for direct seeding are underway and they will apply intense selection pressure to test the feasibility of seed-propagated garlic (Simon and Jenderek, 2003).

Garlic Breeding Methods

Initial efforts to produce garlic seed included only a very few fertile clones that were interpollinated and then progeny were either interpollinated again or self-pollinated. As garlic breeding proceeds, there are two distinct directions that can be taken: development of new clones for asexual propagation, or development of seed-propagated garlic cultivars (Simon and Jenderek, 2003). The development of seed-propagated garlic cultivars is only in its very initial stages and no clear indication of its likelihood of success is possible for several years. The possibility that seed-propagated garlic will have low or no virus contamination is a strong incentive for true seed propagation. The combination of tissue culture to remove viruses, plus “seed” garlic field production costs exceed $2500/ha. Garlic breeding methods to be used include the usual recurrent phenotypic selection from (at least initially) a broad genetic base of materials. As self-pollination has been demonstrated to be possible and to result in reasonably vigorous and more uniform families, it seems likely that cultivar development strategies for seed-propagated garlic will include an emphasis on inbred development for hybrid cultivars, like onions. Since male sterile/female fertile clones have been well documented, these clones are an obvious choice for seed parents. As for other outcrossing crop species, hybrid cultivars not only can take advantage of hybrid vigor (which has been widely observed in garlic but not reported), but they also encourage growers to return to seed producers for seed in subsequent production years. With the large investment involved in developing seed-propagated garlic, there is little incentive for large-scale seed producers to develop open-pollinated cultivars that could be seed propagated by the grower, although public sector programs may develop open-pollinated seed-propagated garlic cultivars (Simon and Jenderek, 2003).

Breeding: The restoration of flowering ability, sexual hybridization, and seed production in garlic (*Allium sativum* L.) has resulted in an increase in genetic variability available to agriculture and has opened new avenues for the breeding of this important crop. In this review, the current status of flower development, fertility, hybridization, sexual propagation, and seed production in garlic is discussed. We summarize the main stages in the life cycle of garlic from true seeds to flowering and bulb formation, and recent advances in our understanding of floro- and gametogenesis. Flowering and fertility of garlic are tightly regulated by environmental conditions, and therefore the seed production cycles in various climatic zones are complex and challenging. Recent establishment of modern molecular tools and the creation of large transcriptome catalogs provide a better understanding of the molecular and genetic mechanisms of flowering and fertility processes, and accelerate the breeding process by using molecular markers for desirable traits (Shemesh-Mayer, E. and Goldstein, R.K. 2018).

Before the development of techniques to produce garlic seed in relatively large quantities, garlic breeding was not a realistic possibility. In fact, there is no evidence indicating that sexual reproduction and selection were ever utilized by garlic growers throughout history so that, while garlic has been one of the longest cultivated horticultural crops, breeding the crop has just begun. Clonal selection has been successful in altering some traits in garlic such as clove number and earliness and routine treatments to reduce or eliminate viruses clearly improve production, but without sexual reproduction, desired traits found in different clones cannot be combined. With the possibility of seed production, garlic breeding can commence. Information on the current status of true seed derived plants is scarce, as most of the large-scale seed production has been performed by private industry. In breeding of garlic, Selection for Improved Floral Characteristics and Fertility and Selection for Improved Seed Size and Vigor (Simon and Jenderek, 2003). Being an asexually propagated crop, methods of improvement through cross- pollination are not viable in garlic. Most of the varieties developed are through introductions and clonal selection. Based on temperature and day-length response, garlic has been classified as havinglong-day and short day varieties. It has also been classified as having hard neck and soft neck varieties. Hard-neck varieties bolt and flower but these flowers are usually sterile,while soft-neck varieties do not flower at all. Hard neck varieties cannot be braided for storage whereas softneck varieties can be braided and stored. Hard neck (long- day varieties) is characterized by big bulbs, less number of cloves(10-15), ease of peeling and, generally, have low storage life. Typical examples are

Agrifound Parvati and Chinese garlic. Because of big size, their productivity is higher and these fetch a good price in local and international markets. Soft-neck (short-day) varieties are characterized by small bulbs, more number of cloves (20-45), more aroma and are, generally, good storers, *e.g.,* Indian garlic varieties G41, G1, G50, G282. Breeding methods for development of garlic are limited to clonal selection and mutagenesis among conventional methods, and somaclonal variation among biotechnological approaches (Lawande et al., 2009).

Traditional garlic-breeding research has been limited to evaluation for yield and other morphological characters to identify the best genotypes. Genetic studies have revealed positive interaction between plant-height, bulb-weight, bulb-diameter and mean clove-weight. Significant positive correlation between clove and bulb mean-weight, negative correlation between clove mean-weight and clove-number has also been reported. Variation in yield is explained by leaf number and bulb mean-weight. Therefore, these important characteristics could help in garlic selection programme and yield improvement (Lawande *et al*., 2009). Garlic is grown throughout the world but the crop invariably suffers from productivity lower than its potential, owing to several inherent and extrinsic factors, especially in developing countries like India. The objectives of garlic improvement, thus, should be induction of sterility, creation of variability and molecular elucidation of genome for breeding superior cultivars adapted to different agro-climatic environments; and establishment of effective biotic and abiotic stress management and post harvest practices adoptable by resource poor farmers and suitable for sustained ecological well being. In Indian context, the improvement and cultivation of long day type garlic needs to be encouraged to commensurate with world leaders in production. Therefore, this review has been attempted to bring together the achievements made in garlic research in India and elsewhere, and their possible applications in attaining desired productivity and quality in both short and long day types (Malik *et a*l., 2017).

Varieties

In India, most varieties have been developed through clonal selection and one or two through introduction. National Horticultural Research and Development Foundation (NHRDF) has been at the forefront of garlic research (with maximum number of varieties developed under their research programmes) (Table 1), followed by agricultural universities, *viz.,* Gujarat Agricultural University (GAU), Punjab Agricultural University (PAU), MPKV, Rahuri, etc. Most of the varieties developed in these institutes are short-day type and can be grown under tropical and sub tropical climates. Some temperate varieties have also been released at the national level and prominent among them is Agrifound Parvati. Other temperate varieties of significance are VLG- 1 (VPKAS, Almora), SKUAG 1 (SKUAST, Srinagar), DARL 52 and Solan Local (YSPUHF, Solan) (Lawande et al., 2009).

Table 1. Varieties of garlic and their important horticultural traits

Variety	Institution	Year of release	Photoperiod	Colour	Yield potential (t/ha)
G-41 (Agrifound White)	NHRDF	1989	Short Day	White	13
G1 (Yamuna Safed)	NHRDF	1991	Short Day	White	15-17
G-50	NHRDF	1996	Short Day	White	15-20
G282	NHRDF	1990	Short Day	White	17-20
G323	NHRDF	1990	Short Day	White	17-20
Godavari	MPKV	1987	Short Day	White	10-11
Shweta	MPKV		Short Day	White	10-11
T-56-4	PAU		Short Day	White	8-10
Bhima Omkar	DOGR	2009	Short Day	White	8-10
GG4	JAU	2009	Short Day	White	
Ooty1	TNAU		Intermediate	White	15-17
G313(Agrifound Parvati)	NHRDF	1992	Long Day	Purple	17-22
VLG1	VPKAS		Intermediate	White	14-15
DARL52	DARL	2003	Intermediate	White	12-15

Besides these, varieties selected by farmers over the years are also available in the market, *e.g.,* Jamnagar Local, Ooty Local, Jeur Local etc. At present, there are 25 varieties in garlic (Table 2). The garlic varieties developed and/or released specifically for short, intermediate (Table 3) and long day conditions of India(Table 3) are enlisted below (Malik et al., 2017):

Table 2. The yield potential of some popular short and intermediate day garlic cultivars of India

Cultivar	Yield (t/ha)	Source
Bhima Purple (SD)	6-7	DOGR, Pune
Bhima Omkar (SD)	8-14	DOGR, Pune
Agrifound White (SD)	12-14	NHRDF, New Delhi
Yamuna Safed (SD)	15-17	NHRDF, New Delhi
Phule Baswant (SD)	10-11	MPKV, Rahuri
Ooty-1 (ID)	15-17	TNAU, Coimbatore

SD: Short Day, ID: Intermediate Day

Table 3. The yield potential of long day garlic cultivars of India

Cultivar	Yield (t/ha)	Source
VL Garlic-1	14-15	VPKAS, Almora
VL Lahsun-2	24-26	VPKAS, Almora
CITH-G-1	25-35	ICAR-CITH, Srinagar
CITH-G-3	25-28	ICAR-CITH, Srinagar
Mukteshwar-Sel-2	16-21	RS ICAR-CITH, Mukteshwar

Agrifound Parvati	17-18	NHRDF
Agrifound Parvati-2	17-22	NHRDF

(Recommended for states of Jammu and Kashmir, HimachalPradesh, Uttarakhand and North Eastern States)

Table 4. Examples of Garlic Cultivar Classifications (Medina and García, 2007)

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

Table 5. Some garlics have protected status in the UK and the EU (Wikipedia, 2023)

Name	Source
Aglio Rosso di Nubia (Red Garlic of Nubia)	Nubia-Paceco, Provincia di Trapani, Sicily, Italy
Aglio Bianco Polesano	Rovigo, Veneto, Italy (PDO)
Aglio di Voghiera	Ferrara, Emilia-Romagna, Italy (PDO)
Ail blanc de Lomagne	Lomagne in the Gascony, France (PGI)
Ail de la Drôme	Drôme, France (PGI)
Ail rose de Lautrec, a rose/pink garlic	Lautrec, France (PGI)
Ail violet de Cadours	Cadours, France (PDO)
Ajo Morado de Las Pedroñeras, a rose/pink garlic	Las Pedroñeras, Spain (PGI)
Jinxiang Da Suan	China (PGI)
Taşköprü Sarımsağı	Turkey (PDO)

Fingerprint Garlic Clones

Fingerprinting was developed to prove, or disprove, the identity of humans. Today the term "fingerprinting" is used more widely to include evaluation of DNA patterns of any organism. High-profile criminal/legal proceedings have made the concept of fingerprinting (in its broader sense) familiar to the general public in that context. The very same DNA methodologies useful for humans are applicable for any organism. What can be learned from garlic fingerprinting? Three situations arise where it would be useful to have an unequivocal means to verify the identity of a garlic clone: identification of existing garlic clones in production, tracking of new garlic clones derived from true seed as they enter and move into production, and development of a garlic lineage. For garlic, there is a good likelihood in any large collection that several garlic clones held under different names that, in fact, are identical. Another scenario we often confront is that several clones occur as a mixture under the same name. This brings us to the first motivation for fingerprinting garlic. The possibility that perhaps only a few thousand garlic clones were collected in Central Asia and found their way into cultivation outside of that region with a vegetative method of propagation, makes the prospects for an opportunity to fingerprint most of the garlic cultivated today a realistic proposal. Furthermore, with true garlic seed being produced on a large scale today, many new clones will certainly enter the production stream for the first time in history. With this, the need for varietal identification becomes more urgent. A DNA fingerprinting effort of garlic today will serve as a useful foundation for tracking new clones coming to growers in the future. A third rationale for DNA fingerprinting of garlic is more subtle. This methodology not only tells us that clone A is different from clone B and clone C, but it also can tell us how closely related clones A, B, and C are relative to each other. In this way DNA fingerprints provide modern insights into historical events for which no other historical record is available. Comparative analysis of DNA fingerprints have provided important insights about the origins and movement of human populations, cultivation and domestication histories of crops and farm animals, and sources of disease organisms (Simon, 2024).

Molecular markers

The role of molecular markers as a tool for genetic analyses and crop improvement has gained importance through the years. Their use has become common in model species and important crops. Indeed, genetic diversity and polymorphism assessments are major priorities in plant and crop-breeding studies. Large-scale identification of molecular markers like single-nucleotide polymorphism (SNP) on genome and transcriptome represent interesting approaches. Classical molecular-markers to assess genetic diversity and polymorphism in garlic have been described. Among others, they include isozymes, random-amplified polymorphic DNA (RAPD), simple-sequence repeats (SSR), amplified-fragment length polymorphism (AFLP) and insertions-deletions (Egea *et al.,* 2017).

USES

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, grave diggers 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 (Medina and García, 2007).

The herb may be consumed raw, but the taste is so potent that most people usually prefer cooking it or adding it to various dishes before eating.

- You can chop, crush, slice, mince, or even juice garlic. Cutting it activates the alliinase enzyme that is highly beneficial to health.
- Minced garlic gives a delicious, fragrant aroma when warmed in olive oil. This can form a base for soups, stews, and curries. It is one of the main ingredients in a good pasta sauce.
- The herb is also an essential ingredient in various kinds of toothpaste and mouthwashes as it helps prevent tooth cavities and oral bacteria.

Word of Caution: Excessive intake may irritate the digestive system. Also, garlic can cause bad breath (Nagdeve, 2021). Worldwide, more than 11 varieties of garlic are grown. There are various uses of garlic. Apart from the bulb or cloves that we most frequently eat, the leaves and flowers of the garlic plant are also edible (Dube, 2021).

Garlic is widely used around the world for its pungent flavor as a seasoning or condiment. The garlic plant's bulb is the most commonly used part of the plant. With the exception of the single clove types, garlic bulbs are normally divided into numerous fleshy sections called cloves. Garlic cloves are used for consumption (raw or cooked) or for medicinal purposes. They have a characteristic pungent, spicy flavor that mellows and sweetens considerably with cooking. The distinctive aroma is mainly due to organosulfur compounds including allicin present in fresh garlic cloves and ajoene which forms when they are crushed or chopped. A further metabolite allyl methyl sulfide is responsible for garlic breath. Other parts of the garlic plant are also edible. The leaves and flowers (bulbils) on the head (spathe) are sometimes eaten. They are milder in flavor than the bulbs, and are most often consumed while immature and still tender. Immature garlic is sometimes pulled, rather like a scallion, and sold as "green garlic". When green garlic is allowed to grow past the "scallion" stage, but not permitted to fully mature, it may produce a garlic "round", a bulb like a boiling onion, but not separated into cloves like a mature bulb. Green garlic imparts a garlic flavor and aroma in food, minus the spiciness. Green garlic is often chopped and stir-fried or cooked in soup or hot pot in Southeast Asian (i.e. Vietnamese, Thai, Myanmar, Lao, Cambodian, Singaporean), and Chinese cookery, and is very abundant and low-priced. Additionally, the immature flower stalks (scapes) of the hardneck are sometimes marketed for uses similar to asparagus in stir-fries. Inedible or rarely eaten parts of the garlic plant include the "skin" covering each clove and root cluster. The papery, protective layers of "skin" over various parts of the plant are generally discarded during preparation for most culinary uses, though in Korea immature whole heads are sometimes prepared with the tender skins intact. The root cluster attached to the basal plate of the bulb is the only part not typically considered palatable in any form. An alternative is to cut the top off the bulb, coat the cloves by dribbling olive oil (or other oil-based seasoning) over them, and roast them in an oven. Garlic softens and can be extracted from the cloves by squeezing the (root) end of the bulb, or individually by squeezing one end of the clove. In Korea, heads of garlic are heated over the course of several weeks; the resulting product, called black garlic, is sweet and syrupy, and is exported to the United States, United Kingdom, and Australia. Garlic may be applied to different kinds of bread, usually in a medium of butter or oil, to create a variety of classic dishes, such as garlic bread, garlic toast, bruschetta, crostini, and canapé. The flavor varies in intensity and aroma with the different cooking methods. It is often paired with onion, tomato, or ginger. Immature scapes are tender and edible. They are also known as "garlic spears", "stems", or "tops". Scapes generally have a milder taste than the cloves. They are often used in stir frying or braised like asparagus. Garlic leaves are a popular vegetable in many parts of Asia. The leaves are cut, cleaned, and then stir-fried with eggs, meat, or vegetables. Garlic powder is made from dehydrated garlic and can be used as a substitute for fresh garlic, though the taste is not quite the same. Garlic salt combines garlic powder with table salt (Wikipedia, 2023).

The most notable records from those ancient times come from Egypt, where garlic was used regularly by both nobles, common people and slaves as food seasoning, medicinal ingredient, religious ingredient (they believed it can prolong life), antiseptic for curing wounds and preventing gangrene, and even as a direct source of strength. Judging by the records found by archeologist and historians, Egyptian royals fed garlic to slaves who build famous pyramids in an attempt to give them more strength. Inside of the tomb of the famous pharaoh Tutankhamen, garlic was not only placed in various clay pots, but also, several of them were modeled in the shape of garlic bulbs. Arrival of garlic into ancient Greece and Rome gave another big boost to its popularity. By that time garlic was used for almost everything - from food medicine to religious and superstition rituals. They claimed garlic can repel scorpions, treat dog bites, cure asthma, protect against leprosy, and if hanged above entrance door of the house it could stop the spread of smallpox! In Asia garlic was viewed more as medical ingredient than a food seasoning plant. One of the cultures who viewed it that way were Buddhists, who between 1st and 10th century AD avoided consummation of garlic. Today, garlic represents one of the most popular flavorings in South Asia, together with ginger and onion. One of the most influential moments in the history garlic happened during the expansion of the Muslim rule across Middle East and Eastern Europe. This enabled spreading of garlic into central and Western Europe where it was greeted as excellent medical remedy. Medical books from 1660s described it as an excellent cure for plague and small pox. On the more serious note, famous chemist and microbiologist proved in 1858 that garlic could kill germs, greatly reducing the possibility of wound infections. Because of these findings, garlic was used extensively as an antiseptic and dysentery cure during both World Wars (GH, 2023).

Uses in Different Regions

Fig. 16. Garlic crushed using a garlic press

Garlic is a fundamental component in many or most dishes of various regions, including eastern Asia, South Asia, Southeast Asia, the Middle East, northern Africa, southern Europe, Eastern Europe and parts of Latin America. Latin American seasonings, particularly, use garlic in sofritos and mofongos. Oils can be flavored with garlic cloves. These infused oils are used to season all categories of vegetables, meats, breads, and pasta. Garlic, along with fish sauce, chopped fresh chilis, lime juice, sugar, and water, is a basic essential item in dipping fish sauce, a highly used dipping sauce condiment used in Indochina. In East and Southeast Asia, chili oil with garlic is a popular dipping sauce, especially for meat and seafood. Tuong ot toi Viet Nam (Vietnam chili garlic sauce) is a highly popular condiment and dip across North America and Asia. In some cuisines, the young bulbs are pickled for three to six weeks in a mixture of sugar, salt, and spices. In eastern Europe, the shoots are pickled and eaten as an appetizer. Laba garlic, prepared by soaking garlic in vinegar, is a type of pickled garlic served with dumplings in northern China to celebrate the Chinese New Year. Garlic is essential in Middle Eastern and Arabic cooking, with its presence in many food items. In the Levant, garlic is traditionally crushed together with olive oil, and occasionally salt, to create a Middle Eastern garlic sauce called Toum ("garlic" in Arabic). While not exclusively served with meats, toum is commonly paired with chicken or other meat dishes such as shawarma. Garlic is also a key component in some hummus varieties, an Arabic dip composed of chickpeas, tahini, garlic, lemon juice, and salt. Lightly smoked garlic is used in British and other European cuisine. It is particularly prized for stuffing poultry and game, and in soups and stews. Emulsifying garlic with olive oil produces *aioli*. Garlic, oil, and a chunky base produce *skordalia*. Crushed garlic, oil, and water produce a strong flavored sauce, mujdei. Blending garlic, almond, oil, and soaked bread produces *ajoblanco*. *Tzatziki*, yogurt mixed with garlic and salt, is a common sauce in Eastern Mediterranean cuisines (Wikipedia, 2023).

Spiritual and religious uses: Garlic is present in the folklore of many cultures. In Europe, many cultures have used garlic for protection or white magic, perhaps owing to its reputation in folk medicine. Central European folk beliefs considered garlic a powerful ward against demons, werewolves, and vampires. To ward off vampires, garlic could be worn, hung in windows, or rubbed on chimneys and keyholes. In the foundation myth of the ancient Korean kingdom of Gojoseon, eating nothing but 20 cloves of garlic and a bundle of Korean mugwort for 100 days let a bear be transformed into a woman. In celebration of Nowruz (Persian calendar New Year), garlic is one of the essential items in a Haft-sin ("seven things beginning with 'S'") table, a traditional New Year's display: the name for garlic in Persian is *seer*, which begins with *sin*, (pronounced "seen") the Perso-Arabic letter corresponding to "S". In Islam, it is recommended not to eat raw garlic prior to going to the mosque. This is based on several hadith (Wikipedia, 2023).

Medicinal uses: Garlic is taken orally to reduce high blood pressure, prevent heart disease and artherosclerosis, 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 incases 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 MedicinalPlant 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 (Medina and García, 2007).

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 theElder, 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, arterioscelrosis, 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) (Medina and García, 2007). 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 (Medina and García, 2007). 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 (Medina and García, 2007).

NUTRITION VALUE

Indeed, garlic contains bioactive compounds, including, among others: (i) lectins, which have wide applications in biomedicine and biotechnology; (ii) peptides with angiotensin I-converting enzyme (ACE) inhibitory activity, being related to its antihypertensive activity; and (iii) *N*-feruloyltyramine, which protects against CVD by suppressing platelet activation. Besides, this species is rich in enzymes with industrial interest; for instance: (i) nucleases (DNase and RNase), with application in molecular biology; (ii) cellulases for biotechnological applications, like conversion of biomass into biofuel; (iii) superoxide dismutases (SOD), which represent a main defense against oxidative stress, being widely used in pharmacology/medicine, cosmetics, food, agriculture, and chemical industries; (iv) proteases/hemagglutinases, with application in medical tests; and (v) alliinases (also known as alliinases), that catalyze conversion of alliin to allicin, which is the main therapeutic agent of garlic (Egea *et al*., 2017). Garlic is very low in calories, saturated fats, and sodium. It has several useful minerals such as phosphorus, potassium, magnesium, zinc, calcium, and iron, and trace minerals like iodine, sulfur, and chlorine. According to the *USDA National Nutrient Database*, garlic is a rich source of B-vitamins (folate, thiamine, niacin, and B-6), and vitamins C, A, and K. Garlic is one of the rare dietary sources of organic compounds, allicin, allisatin 1, and allisatin 2 (Table 6) (Nagdeve, 2021):

Table 6. Nutriet content of garlic

. **Nutrient**	**Value**
Water [g]	58.58
Energy	149
Energy [kJ]	623
Protein [g]	6.36
Total lipid (fat) [g]	0.5
Ash [g]	1.5
Carbohydrate, by difference [g]	33.06
Fiber, total dietary [g]	2.1
Sugars, total including NLEA [g]	1
Calcium, Ca [mg]	181
Iron, Fe [mg]	1.7
Magnesium, Mg [mg]	25
Phosphorus, P [mg]	153
Potassium, K [mg]	401
Sodium, Na [mg]	17
Zinc, Zn [mg]	1.16
Copper, Cu [mg]	0.3
Manganese, Mn [mg]	1.67
Selenium, Se [µg]	14.2
Vitamin C, total ascorbic acid [mg]	31.2
Thiamin [mg]	0.2
Riboflavin [mg]	0.11
Niacin [mg]	0.7
Pantothenic acid [mg]	0.6
Vitamin B-6 [mg]	1.24
Folate, total [µg]	3
Folate, food [µg]	3
Folate, DFE [µg]	3

Choline, total [mg]	23.2
Carotene, beta [µg]	5
Vitamin A, IU [IU]	9
Lutein + zeaxanthin [µg]	16
Vitamin E (alpha-tocopherol) [mg]	0.08
Vitamin K (phylloquinone) [µg]	1.7
Fatty acids, total saturated [g]	0.09
10:0 [g]	0
16:0 [g]	0.09
Fatty acids, total monounsaturated [g]	0.01
18:1 [g]	0.01
Fatty acids, total polyunsaturated [g]	0.25
18:2 [g]	0.23
18:3 [g]	0.02
Tryptophan [g]	0.07
Threonine [g]	0.16
Isoleucine [g]	0.22
Leucine [g]	0.31
Lysine [g]	0.27
Methionine [g]	0.08
Cystine [g]	0.07
Phenylalanine [g]	0.18
Tyrosine [g]	0.08
Valine [g]	0.29
Arginine [g]	0.63
Histidine [g]	0.11
Alanine [g]	0.13
Aspartic acid [g]	0.49
Glutamic acid [g]	0.81
Glycine [g]	0.2
Proline [g]	0.1
Serine [g]	0.19

Studies have shown that garlic is a rich source of beneficial sulphur compounds, bioactive substances and antioxidants. It is also among the richest sources of phenolic compounds. Collectively, these chemicals have shown promising properties. They are anti-inflammatory, anti-fungal, antibacterial, etc. In addition, they lead to better cardiovascular functioning, renal functioning, gut health, and obesity control. Garlic also fights cancer. No wonder Doctors too prescribe garlic to their patients. Garlic contains a plethora of nutrients and minerals (Dube, 2021).

The nutritional content of garlic is as follows (Dube, 2021):

Portion size – 100 gm of Garlic

- Calories- 149
- Fat – 0.5 gram
- Sodium – 17 mg
- Carbohydrate – 33.1 grams
- Fibres – 2.1 grams
- Sugar – 1 gram
- Proteins – 6.4 grams
- Potassium – 401 mg

While garlic is a low-calorie food, it's not particularly rich in the daily nutrients you need. But as per the U.S. Department of Agriculture's (USDA) MyPlate guidelines, it is on the list of healthy ingredients you can include in your diet. Nutritionally speaking, garlic is most useful as a spice or as a way to bring out the flavors of other healthy foods, like vegetables. The following nutrition facts for garlic from the USDA are based on a serving estimate of 1 teaspoon (tsp) (Cherney, 2022).

- Calories: 4
- Protein: 0.18 grams (g)
- Fat: 0.01 g
- Carbohydrates: 0.93 g
- Fiber: 0.06 g
- Natural sugars: 0.03 g
- Calcium: 5 milligrams (mg)
- Iron: 0.05 mg (0.03 percent daily value, or DV)
- Magnesium: 0.7 mg
- Potassium: 11 mg

- Vitamin C: 0.9 mg (1 percent DV)

Garlic is also thought to be a source of amino acids (the building blocks of proteins) and enzymes, which can help your body build muscles and protect your gut health, respectively (Cherney, 2022). Nutritional value per 100 g of garlic is given in Table 7.

Nutritional value per 100 g of garlic is given in Table 7.

Nutritional value per 100 g (3.5 oz)	
Energy	623 kJ (149 kcal)
Carbohydrates	33.06 g
Sugars	1 g
Dietary fiber	2.1 g
Fat	0.5 g
Protein	6.36 g
Vitamins	**Quantity %DV**†
Thiamine (B1)	17%; 0.2 mg
Riboflavin (B2)	8%; 0.11 mg
Niacin (B3)	4% 0.7 mg
Pantothenic acid (B5)	12%; 0.596 mg
Vitamin B6	73%; 1.2350 mg
Folate (B9)	1%; 3 µg
Choline	4%; 23.2 mg
Vitamin C	35%; 31.2 mg
Minerals	**Quantity; %DV**†
Calcium	14%; 181 mg
Iron	9%; 1.7 mg
Magnesium	6%; 25 mg
Manganese	73%; 1.672 mg
Phosphorus	12%; 153 mg
Potassium	13%; 401 mg
Sodium	1%; 17 mg
Zinc	11%; 1.16 mg
Other constituents	**Quantity**
Water	59 g
Selenium	14.2 µg

In the typical serving size of 1–3 cloves (3–9 grams), garlic provides no significant nutritional value, with the content of all essential nutrients below 10% of the Daily Value (DV). When expressed per 100 grams, garlic contains several nutrients in rich amounts (20% or more of the DV), including vitamins B6 and C, and the dietary minerals manganese and phosphorus. Per 100 gram serving, garlic is also a moderate source (10–19% DV) of certain B vitamins, including thiamin and pantothenic acid, as well as the dietary minerals calcium, iron, and zinc.

The composition of raw garlic is around 59% water, 33% carbohydrates, 6% protein, 2% dietary fiber, and less than 1% fat (Wikipedia, 2023). Fresh or crushed garlic yields the sulfur-containing compounds allicin, ajoene, diallyl polysulfides, vinyldithiins, and *S*-allylcysteine, as well as enzymes, saponins, flavonoids, and Maillard reaction products when cooked, which are not sulfur-containing compounds. The phytochemicals responsible for the sharp flavor of garlic are produced when the plant's cells are damaged. When a cell is broken by chopping, chewing, or crushing, enzymes stored in cell vacuoles trigger the breakdown of several sulfur-containing compounds stored in the cell fluids (cytosol). The resultant compounds are responsible for the sharp or hot taste and strong smell of garlic. Some of the compounds are unstable and continue to react over time. Although many humans enjoy the taste of garlic, these compounds are believed to have evolved as a defensive mechanism, deterring animals such as birds, insects, and worms from eating the plant. A large number of sulfur compounds contribute to the smell and taste of garlic. Allicin has been found to be the compound most responsible for the "hot" sensation of raw garlic. This chemical opens thermo-transient receptor potential channels that are responsible for the burning sense of heat in foods. The process of cooking garlic removes allicin, thus mellowing its spiciness. Allicin, along with its decomposition products diallyl disulfide and diallyl trisulfide, are major contributors to the characteristic odor of garlic, with other allicin-derived compounds, such as vinyldithiins and ajoene. Because of its strong odor, garlic is sometimes called the "stinking rose". When eaten in quantity, garlic may be strongly evident in the diner's sweat and garlic 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 allegedly alleviated by eating fresh parsley. The herb is, therefore, included in many garlic recipes, such as *pistou*, *persillade*, and the garlic butter spread used in garlic bread. Abundant sulfur compounds in garlic are also responsible for turning garlic green or blue during pickling and cooking. Under these conditions (*i.e.*, acidity, heat) the sulfur-containing compound alliin reacts with common amino acids to make pyrroles, clusters of carbon-nitrogen rings. These rings can be linked together into polypyrrole molecules. Ring structures absorb particular wavelengths of light and thus appear colored. The two-pyrrole molecule looks red, the three-pyrrole molecule looks blue, and the four-pyrrole molecule looks green (like chlorophyll, a tetrapyrrole). Like chlorophyll, the pyrrole pigments are safe to eat. Upon cutting, similar to a color change in onion caused by reactions of amino acids with sulfur compounds, garlic can turn green (Wikipedia, 2023).

Adverse effects and toxicology: Garlic is known to cause bad breath (halitosis) and body odor, described as a pungent garlicky smell to sweat. This is caused by allyl methyl sulfide (AMS). AMS is a volatile liquid which is absorbed into the blood during the metabolism of garlic-derived sulfur compounds; from the blood it travels to the lungs (and from there to the mouth, causing bad

breath; see garlic breath) and skin, where it is exuded through skin pores. Washing the skin with soap is only a partial and imperfect solution to the smell. Studies have shown sipping milk at the same time as consuming garlic can significantly neutralize bad breath. Mixing garlic with milk in the mouth before swallowing reduced the odor better than drinking milk afterward. Plain water, mushrooms, and basil may also reduce the odor; the mix of fat and water found in milk, however, was the most effective. The green, dry "folds" in the center of the garlic clove are especially pungent. The sulfur compound allicin, produced by crushing or chewing fresh garlic, produces other sulfur compounds: ajoene, allyl polysulfides, and vinyldithiins. Aged garlic lacks allicin, but may have some activity due to the presence of S-allylcysteine. Some people suffer from allergies to garlic and other species of *Allium*. Symptoms can include irritable bowel, diarrhea, mouth and throat ulcerations, nausea, breathing difficulties, and, in rare cases, anaphylaxis. Garlic-sensitive people show positive tests to diallyl disulfide, allylpropyldisulfide, allylmercaptan, and allicin, all of which are present in garlic. Several reports of serious burns resulting from garlic being applied topically for various purposes, including naturopathic uses and acne treatment, indicate care must be taken for these uses, usually testing a small area of skin using a low concentration of garlic. On the basis of numerous reports of such burns, including burns to children, topical use of raw garlic, as well as insertion of raw garlic into body cavities, is discouraged. In particular, topical application of raw garlic to young children is not advisable. The side effects of long-term garlic supplementation are largely unknown. Possible side effects include gastrointestinal discomfort, sweating, dizziness, allergic reactions, bleeding, and menstrual irregularities. Some breastfeeding mothers have found, after consuming garlic, that their babies can be slow to feed, and have noted a garlic odor coming from them. If higher-than-recommended doses of garlic are taken with anticoagulant medications, this can lead to a higher risk of bleeding. Garlic may interact with warfarin, saquinavir, antihypertensives, calcium channel blockers, the quinolone family of antibiotics such as ciprofloxacin, and hypoglycemic drugs, as well as other medications.[78] The American Veterinary Medical Association does not recommend feeding garlic to your pets (Wikipedia, 2023).

HEALTH BENEFITS

The sulfur compounds that give garlic its trademark odor are probably also responsible for itsbenefits. 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 . (Medina and García, 2007). Since ancient times, garlic, onion and related species have been widely used in many parts of the word as vegetables, as well as in traditional folk medicine. Garlic and onion have been the most intensively investigated. Garlic showed lipid-lowering effects, antiplatelet activity and antiatherosclerotic activities. The cardiovascular effects of garlic are among the best investigated of all medicinal plants species. Louis Pasteur was the first to describe the antibacterial effect of onion and garlic juices. Garlic exhibits a broad antibiotic spectrum against both gram-positive and gram- negative bacteria. *Helicobacter pylori* (*H. pylori*) is a bacterium implicated in the etiology of stomach cancer and ulcers. The incidence of stomach cancer is lower in populations with high intake of *Allium* vegetables (STAVělíková, 2008).

Garlic (*Allium sativum* L. fam. Alliaceae) is one of the most researched and best-selling herbal products on the market. For centuries it was used as a traditional remedy for most health-related disorders. Also, it is widely used as a food ingredient--spice and aphrodisiac. Garlic's properties result from a combination of variety biologically active substances which all together are responsible for its curative effect. The compounds contained in garlic synergistically influence each other so that they can have different effects. The active ingredients of garlic include enzymes (e.g. alliinase), sulfur-containing compounds such as alliin and compounds produced enzymatically from alliin (e.g. allicin). There is a lot of variation among garlic products sold for medicinal purposes. The concentration of Allicin (main active ingredient) and the source of garlic's distinctive odor depend on processing method. Allicin is unstable, and changes into a different chemicals rather quickly. It is documented that products obtained even without allicin such as aged garlic extract (AGE), have a clear and significant biological effect in immune system improvement, treatment of cardiovascular diseases, cancer, liver and other areas. Some products have a coating (enteric coating) to protect them against attack by stomach acids. Clinically, garlic has been evaluated for a number of purposes, including treatment of hypertension, hypercholesterolemia, diabetes, rheumatoid arthritis, cold or the prevention of atherosclerosis and the development of tumors. Many available publications indicates possible antibacterial, anti-hypertensive and anti-thrombotic properties of garlic. Due to the chemical complexity of garlic and the use of different processing methods we obtain formulations with varying degrees of efficacy and safety (Majewski, 2014).

Besides being appreciated in cooking as common seasoning for thousands of years, garlic is also used in pharmacology and cosmetics. Indeed, it is known to have medical properties, protecting against different diseases, like, for instance, hypercholesterolemia, hypertension, atherosclerosis, and thrombosis, reducing the risk of developing cardiovascular disease (CVD). Other recognized bioactivities are antimicrobial (albeit being probiotic), antiasthmatic, antioxidant, anticarcinogenic (Egea et al., 2017). There are several historical references about what "class of person" used the strong smelling and tasting flavors of garlic and why, and in most of the ancient societies where garlic was used, it was primarily a medicinal cure-all and a spice eaten only by the working classes at least as long ago as Bronze Age Egypt. Ancient Chinese and Indian medical treatises recommend eating garlic to aid respiration and digestion and to treat leprosy and parasitic infestation. The 14th-century Muslim physician Avicenna recommended garlic as useful for toothache, chronic cough, constipation, parasites, snake and insect bites, and gynecological diseases. The first documented use of garlic as a magic talisman comes from medieval period Europe where the spice had a magical significance and was used to protect humans and animals against witchcraft, vampires, devils, and disease. Sailors took them as talismans to keep them safe on long sea voyages (Hirst, 2019).

Unknown Benefits are as follows (Dube, 2021)

The Most Potent Superfood: Garlic has always been known for having medicinal properties: As per studies, people who consume garlic during the flu season have a 63% lower risk of catching the virus. This miraculous property of garlic is due to 'allin', a well-known immunity booster. So the next time you have a cold, you know what to do.

Weight Loss And Garlic: Time and again, we have heard that garlic aids weight loss. Garlic is a very nutritionally dense, low-calorie food. About 3 grams of garlic contains 4.5 calories. In addition, it has loads of nutrients like zinc, selenium, vitamin E, and vitamin C. Garlic works as an energy booster. It keeps one fit and increases metabolism.

Garlic as a Blood Pressure Lowering Agent: We all know someone whose morning ritual includes chewing raw pods of garlic on an empty stomach. Consuming 600 to 1500 mg of garlic daily on an empty stomach has the same effect as taking prescribed medication atenolol. Garlic is also known for lowering cholesterol levels in patients and promoting heart and cardiovascular health. So if done daily and religiously, this habit can have very beneficial results in the long run.

As a Cure to Alzheimer's and Dementia: The phenolic compounds present in garlic benefit the nervous system. It helps in the efficient production of neurotransmitters. All the facts make garlic a good cure for 'memory related' issues such as Alzheimer's and Dementia. So please don't forget to make garlic a part of your meals.

Increases Athletic Performance: During the first Olympics, athletes carried garlic with them. Garlic is a pick me up as it provides an instant surge of energy and vigour. This practice holds to date as garlic boosts the functioning of almost every organ system and thus enhances a person's athletic capabilities.

Bone Density: Garlic is among the very few vegetable sources of selenium and sulphur. While selenium directly influences bone health, Sulphur acts as a metabolite in the calcium cycle. Combining these two will give anyone solid and healthy bones. So if you are tired of talking just milk for better bones, you have a competent alternative now!

Healthier And Longer Life: The saying is that if consumed regularly, garlic can increase a person's life span significantly. Since garlic improves immunity, promotes heart and gut health, and contains rich antioxidants, longevity is the most apparent by-product. It also is good for one's skin and hair. Garlic is truly nature's most potent superfood!

Garlic is a strong-smelling, flavoring herb noted for its many health benefits. It contains a powerful compound called allicin that can help to lower cholesterol. The health benefits of garlic may include easing the symptoms of the common cold, lowering blood pressure, and reducing the risk of heart ailments as well as neurodegenerative disorders. The purpose of a garlic clove is aplenty. Right from cooking purposes to medicinal uses, it is truly an all-rounder when it comes to choosing to eat healthily. Moreover, it adds a delightful flavor to all your recipes. Also, you can consume garlic in a variety of forms – such as garlic bread, garlic aioli, garlic mashed potatoes, and so on. With so many different uses, let us explore the health benefits of garlic in detail (Nagdeve, 2021).

Health Benefits of Raw Garlic are as follows (Nagdeve, 2021):

May Ease Cold and Cough: A 2014 paper published in the *Cochrane Database of Systematic Reviews* cited a study that assessed 146 participants over three months to find out the impact it had on patients suffering from cold and cough. As part of the study, researchers divided the total number of participants into two equal groups. One group took a placebo tablet while the other group took a garlic tablet. At the end of the study, researchers found that people who took garlic every day for three months instead of a placebo had fewer bouts of cold as compared with the placebo group.

Might Reduce Hypertension: According to a 2014 report in the *Integrated Blood Pressure Control* journal, aged garlic extract has the ability to lower blood pressure in hypertensive individuals. However, further studies are required to verify if they can be considered an alternative therapy for hypertension.

Might Help To Lower Cholesterol Levels: Raw garlic, rich in the allicin compound, can prevent LDL (bad) cholesterol from oxidizing. Research shows a reduction in cholesterol and triglycerides in rats consuming raw garlic. However, there is not enough research to verify this health benefit definitively.

May Boost Heart Health: Garlic has significant cardioprotective properties, which can help to prevent major heart diseases like atherosclerosis, hyperlipidemia, thrombosis, hypertension, and more. While most reviewed research supports the correlation between garlic intake and cardioprotection, per the *Nutrition Journal* study, further research is needed to decide proper form and dosage. One should keep a close tab on the proper use of this herb i.e. use of different preparations available, dose, duration, and its interaction with generic drugs.

May Help To Prevent Neurodegenerative Diseases: The antioxidant and anti-inflammatory properties of raw garlic may help prevent future neurodegenerative diseases. As per a study in the *Libyan Journal of Medicine*, garlic and its preparations can help in preventing the risk of cardiovascular ailments and stroke. However, further studies are required to identify particular garlic compounds responsible for its effects.

Can reduce the Risk of Dementia: Oxidative damage can play a huge role in cardiovascular diseases and dementia, as the risk of these diseases increases with age. Aged garlic extract (AGE) has antioxidant properties that may help reduce the risk of common brain diseases like dementia and Alzheimer's disease. High doses of AGE have shown to increase antioxidant enzymes, as well as reduce oxidative stress to those with blood pressure problems.

May Help Prevent Heavy Metal Poisoning: High doses of garlic may prevent organ damage caused by heavy metals. The sulfur compounds in this herb can possibly reduce lead levels in the blood. They may also prevent the signs of toxicity, such as headaches and blood pressure, and also can aid in better absorption of iron and zinc in the blood. A 2012 report published in *Basic and Clinical Pharmacology and Toxicology* reveals that garlic can be effective in reducing blood and tissue lead concentrations among human beings and animals alike.

Can Heal Wounds: It can act as an effective herbal remedy for the infected wound. Place 2 crushed cloves on the infected area to get instant relief.

May Improves Bone Health: Herbs like garlic and onion may impact estrogen levels in menopausal women, reducing the risk of osteoarthritis. They may also minimize bone loss and improve overall bone health in both men and women. Also according to a study in the *Electronic Physician* journal, garlic consumption can reduce oxidative stress in the pathophysiology of many diseases such as osteoporosis.

Might Boost Digestion: Daily inclusion of raw garlic cloves in your diet can aid digestive problems. Even inflammation or irritation of the gastric canal may be reduced using this herb. Garlic might help to clear up most intestinal problems like dysentery, diarrhea, and colitis. Its role in dispelling worms is phenomenal. It does not affect the good bacteria in the intestine but destroys the harmful ones. It not only enhances digestion but can also help to relieve stomach gas.

Can Regulate Blood Sugar: Eating raw garlic cloves may reduce blood sugar levels, according to a study published in the *Journal of Nutrition.*

May Boost Immunity: Garlic has phytonutrients that can help to reduce oxidative stress, strengthening your immunity. The herb may also reduce fatigue and boost energy. A 2012 report in the *African Journal of Traditional, Complementary, and Alternative Medicines* revealed a study conducted on rats to ascertain if garlic played a contributory role in enhancing immune function. Researchers discovered that the extracts significantly increased white blood cell counts and showed more immune-stimulating effects.

May Aid in Eye Care: It is rich in nutrients like selenium, quercetin, and vitamin C, all of which can contribute to eye health and may also help with eye infections and inflammation.

May Help Prevent Acne: Garlic, along with other ingredients like honey, cream, and turmeric, can be used as a home remedy for acne scars and blocking the onset of acne. This herb may be effective in skin cleanser and an antibiotic substance that can help to resolve several skin conditions, including skin rashes, psoriasis, cold sores, and blisters. Additionally, it can also help in cell synthesis, protecting against UV rays, and delaying aging.

Garlic is consumed by many populations to treat a variety of disorders including fever, cough, ulcers, bronchitis and other respiratory problems, rheumatism, tuberculosis, typhoid, arteriosclerosis, diabetes, hyperlipidemia, and the prevention of atherosclerosis. Studies on pharmacological properties have revealed that garlic hassignificant antibacterial, antifungal, antiviral, and heart disease activity. Garlic is known to be hepatoprotective, antihelmintic, anti-inflammatory, and antioxidant (Agbo So et al., 2021).

According to Cherney (2022) Health Benefits ofgarlic are:

Historically, garlic was used for the following medicinal purposes: Appetite stimulant, Blood pressure regulator, Colic, Constipation, Cough, Depression, Diarrhea, Fever, Infections, Intestinal parasites, Menstrual symptom relief, Muscle pain relief, Rheumatism, Seasickness, Skin diseases, Strength-building , and Wounds. Today, research supports some of these medicinal benefits, but most studies remain inconclusive overall. Research primarily supports garlic's potential antibacterial benefits, as well as its ability to help control cholesterol-causing lipids in the blood. Garlic also has antioxidants, which may help prevent free radicals that contribute to chronic illnesses, such as heart disease and cancer. Some of the most promising research on garlic's health benefits pertains to cholesterol and high blood pressure. But the research on these effects is limited. The National Center for Complementary and Integrative Health describes conflicting studies on the effects of garlic supplements on cholesterol. In some small studies, garlic supplements were shown to lower blood cholesterol within three months. In other studies, though, garlic had no effects on cholesterol whatsoever.While garlic may provide antioxidants that are shown to potentially help ward off certain types of cancer over time, such benefits are tied to eating garlic — garlic supplements don't have the same effects. Some of the most widely studied cancer effects from garlic include cancers of the colon, stomach, breast, esophagus, and pancreas. Another potential benefit of chewing on garlic is boosting heart health. This is compared with swallowing garlic or extracts that have not been chewed (Cherney, 2022).

According to Migala (2023) health benefits of garlic are as follows:

Garlic May Help Lower Blood Pressure: A couple of cloves a day may help keep a visit to the cardiologist away. "Garlic stimulates the synthesis of nitric oxide, which dilates blood vessels, and inhibits ACE (angiotensin-converting enzyme) activity," says Raj. (ACE inhibitors help relax blood vessels.) This could potentially support healthy blood flow and pressure.

Garlic May Help Quell Inflammation: Scientists believe that chronic inflammation is a driver behind chronic diseases, including heart disease, diabetes, cancer, and arthritis, according to Harvard Health Publishing. Garlic helps inhibit the activity of certain inflammatory proteins, says Raj. In a randomized, controlled, double-blind study of 70 women with the inflammatory autoimmune disease rheumatoid arthritis, the group who took 1,000 milligrams of garlic supplements per day for eight weeks had lower inflammatory markers, less pain and fatigue, and fewer tender joints compared with a placebo group.

Garlic May Help Lower Cholesterol: Another potential benefit of garlic for the heart: improving cholesterol levels. How? "Garlic may help decrease the production of cholesterol by the liver," says Dr. Bazilian. While more research is needed to determine the relationship between garlic intake and cholesterol levels, a meta-analysis and review of studies concluded that taking garlic supplements was effective in lowering both total cholesterol and high LDL cholesterol levels, which are two risk factors for heart disease.

Garlic May Support Immune Function: Can adding a little more garlic to your dinner tonight boost your immune system? While there's not enough evidence to suggest that garlic will prevent or treat the common cold, for instance, it can play a role in your body's defense mechanisms in a few ways. The allicin (one of the plant chemicals Raj highlights) in garlic provides antibacterial properties, says Bazilian. Scientists also believe that garlic has antiviral properties that may work in two ways, Bazilian says: by blocking the entry of viruses into cells, and by strengthening the immune response so that it can effectively fight off potential invaders. It's these things that can help support a healthy immune system overall.

Garlic May Reduce Blood Clotting: One more perk of garlic for your heart health: "Compounds in garlic and onions have been shown to decrease the 'stickiness' of our platelets and have anticlotting properties," says Bazilian. These things may help guard against atherosclerosis, a process in which plaque buildup leads to a hardening and narrowing of the arteries. Per the National Heart, Lung, and Blood Institute (NHLBI), atherosclerosis increases your risk for blood clots that can cause heart attacks and stroke. Of course, eating garlic shouldn't be the only preventive measure you take to protect your arteries. The NHLBI recommends following a heart-healthy eating plan, getting plenty of exercise, managing your weight, and avoiding or quitting smoking.

Garlic Provides a Host of Antioxidants: Garlic's nutrients and plant compounds give it "strong antioxidant properties," per a research review. Not only do antioxidants benefit blood vessels and reduce inflammation, but they may soak up the damaging free radicals that can lead to diseases like cancer (though this anticancer potential needs to be borne out in human research, says the American Institute for Cancer Research).

Garlic Makes Other Healthy Foods Taste Great: Bazilian includes garlic in the same category of food as onions, herbs, and spices, adding that "garlic brings great flavor to foods, so it helps us eat more of the foods that we're supposed to be eating more of, like vegetables, whole grains, lean proteins, and beans." Adding flavor through garlic can also potentially help you reduce the need for excess salt on your foods — and for just 4 calories per clove, according to the U.S. Department of Agriculture.

Garlic has been used for traditional medicine in diverse cultures such as in Egypt, Japan, China, Rome, and Greece. In his *Natural History*, Pliny gave a list of conditions in which garlic was considered beneficial (*N.H.* xx. 23). Galen, writing in the second century, eulogized garlic as the "rustic's theriac" (cure-all). Alexander Neckam, a writer of the 12th century, discussed it as a palliative for the heat of the sun in field labor. In the 17th century, Thomas Sydenham valued it as an application in confluent smallpox, and William Cullen's *Materia Medica* of 1789 found some dropsies cured by it alone (Wikipedia, 2023). Garlic consumption confers many health benefits, as it is a good source of vitamins, metals, saponins, flavonoids, organic acids, and various organosulfur compounds originating from alliin that is metabolized to allicin by the enzyme alliinase. Allicin and other sulfoxides may encounter many transformations resulting in various organosulfur volatiles, responsible for garlic's medicinal properties, as well as its flavor and aroma. Garlic has been proven beneficial for the prevention and treatment of cardiovascular and other metabolic diseases, and it stimulates the immune system, while it also possesses antifungal, antibacterial, antigenotoxic, antiviral, and antispasmodic properties (Papaioannou *et al*., 2023). Supplementation with garlic lowers circulating markers of oxidative stress (e.g., malondialdehyde) and inflammation (*e.g*., C-reactive protein and TNF-α). Supplementation with garlic can also reduce total cholesterol levels, particularly in people with cardiovascular disease, and improve other measures of cardiovascular health (coronary artery calcium, carotid intima-media thickness, etc.). However, its direct effects on cardiovascular morbidity and mortality are currently unclear. Observational studies also show that garlic consumption, through food or as a supplement, is associated with a lower risk of gastric and colorectal cancers (Examine, 2023). In ancient and medieval times, garlic was prized for its medicinal properties and was carried as a charm against vampires and other evils. The plant is used in traditional and folk medicine in many places, and there is some evidence that it may help prevent heart disease (EEB, 2024).

Garlic's main drawbacks: Garlic consumption can cause "garlic breath" and body odor, which are typically most pronounced after eating raw garlic. These side effects are also frequent-reported "adverse events" in clinical trials. Some supplement

formulations (*e.g.*, aged garlic extract) are designed to minimize such odors. In rare cases, garlic may cause an allergic reaction (Examine, 2023).

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