



ISSN: 2230-9926

Available online at <http://www.journalijdr.com>

IJDR

International Journal of Development Research

Vol. 13, Issue, 03, pp. 61956-61977, March, 2023

<https://doi.org/10.37118/ijdr.26395.03.2023>



REVIEW ARTICLE

OPEN ACCESS

ORIGIN, DISTRIBUTION, TAXONOMY, BOTANICAL DESCRIPTION, GENETIC DIVERSITY AND BREEDING OF CAPSICUM (*Capsicum annuum* L.)

*Swamy, K.R.M.

Retd. Principal Scientist & Head, Division of Vegetable Crops, ICAR-Indian Institute of Horticultural Research, Bengaluru- 560089

ARTICLE INFO

Article History:

Received 16th January, 2023

Received in revised form

02nd February, 2023

Accepted 27th February, 2023

Published online 28th March, 2023

KeyWords:

Pré operatório; Coluna lombar;
Tratamento cirúrgico; Fisioterapia.

*Corresponding author: Swamy, K.R.M.,

ABSTRACT

Capsicum and Chilli peppers (*Capsicum annuum* L.) belongs to the *Capsicum* genus and family Solanaceae. The common names in English are Cayenne Pepper, Chili Pepper, Christmas Pepper, Ornamental Pepper, Red Pepper and Sweet Pepper. The names in different Indian languages are Hindi: Mirch, Manipuri: Morok, Tamil: Mulaga, Malayalam: Pacha Mulagu, Mizo: Hmarcha-te, Vai-hmarcha, and Angami: Kedi-chusi. The genus *Capsicum* was originated in South America and it is believed that both Mexico and Central America could also be considered as a diversity spot for the taxa and it is classified as an important genetic resource for agriculture and food. The archaeological evidence at sites located in southwestern Ecuador showed that chili pepper was domesticated more than 6,000 years ago, and it is one of the first cultivated crops in the Central and South Americas. Chili crops are grown in Pakistan, India, China, Ethiopia, Myanmar, Mexico, Vietnam, Turkey, Peru, Ghana, Bangladesh, Japan, Africa, and America. The genus *Capsicum* comprises varying number (20- 200) species of which only six species (namely *Capsicum annuum*, *C. baccatum*, *C. frutescens*, *C. chinense*, *C. pubescens* and *C. assamicum*) are cultivated. The last one was recently identified as a distinct domesticated species from the North Eastern part of India. *Capsicum assamicum*, popularly known as Naga chilli or Bhut Jolokia, is a chilli species endemic to Northeast region of India and is widely cultivated in the states of Assam, Nagaland, and Manipur. It is one of the top ten hottest chillies in the world and is popular for its pungency and aroma, peculiar to this chilli species. It is consumed either raw or as a spice in culinary preparations and also used traditionally for home remedies against several ailments for ages. Its high capsaicin content of 3–5 percent makes it the most promising chilli species for extraction of oleoresin on a commercial scale, having wide applications in pharmaceutical and defense sectors, besides its use as a value-added product. Of the six domesticated species of the genus *Capsicum*, *C. annuum* is the most widely cultivated in India for its pungent (chilli syn. hot pepper) and non-pungent (sweet pepper syn. capsicum, bell pepper) fruits. The cultivation of Pepper (chilli and sweet) market types prevalent in India can broadly be grouped into the following 4 categories: (i) fresh market (green, red, multi-color whole fruits), (ii) fresh processing (sauce, paste, canning, pickling), (iii) dried spice (whole fruits and powder), and (iv) industrial extracts (paprika oleoresin, capsaicinoids and carotenoids). Besides conventional nutritional food uses, a number of versatile food (paprika oleoresin) and non-food (defense, spiritual, ethnobotanical) uses of chillies are known. Capsicums are used in salads, baked and stuffed dishes, stews, stir-fries, salsa, pizzas and cheeses, pickles and for stuffing olives. They may also be used for producing paprika which is used for colouring foods, flavouring and in sauces. Chillies are the most important spice crop in the world. They may be used fresh, in pickles, sauces, salsa, pizzas, flavouring and pastes. There is an increasing demand in Australia for new ways of using chillies for culinary use. Peppers may also be used as ornamental plants or as a source of extracts for use in various pharmaceutical or cosmetic products. Some studies state that pungency of red fruits is due to the synthesis and accumulation of capsaicinoids characteristics from the genus *Capsicum*. These are secondary metabolites originated in the seed testa, and capsaicin is the most important element including dihydrocapsaicin, nordihydrocapsaicin, homocapsaicin and homodihydrocapsaicin. It has been confirmed that capsaicin and dihydrocapsaicin build up approximately 90% of the total content of capsaicinoids in chili. The main objectives of peppers genetic breeding are characteristics such as productivity, disease and pests resistance, fruit characteristics (bioactive compounds, fruit color, pungency, flavor), and abiotic stresses (drought, salinity). In this review article Origin, Distribution, Taxonomy, Botanical Description, Genetics and cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of Capsicum (*Capsicum annuum* L.) are discussed.

Copyright©2023, Swamy, K.R.M. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Citation: Swamy, K.R.M. 2023. "Origin, distribution, taxonomy, botanical description, genetic diversity and breeding of capsicum (*Capsicum annuum* L.)", *International Journal of Development Research*, 13, (03), 61956-61977.

INTRODUCTION

Capsicum is a herbaceous plant belonging to the family Solanaceae. The genus *Capsicum* comprises variable number of species (25- 200) among which five common cultivated species include *Capsicum annuum* L., *Capsicum frutescens* L., *Capsicum chinense* Jacq., *Capsicum baccatum* L., and *Capsicum pubescens* L. (Roy, 2016). *Capsicum* L. (tribe Capsiceae, Solanaceae) is an American genus distributed ranging from the southern United States of America to central Argentina and Brazil. The genus includes chili peppers, bell peppers, ajies, habaneros, jalapeños, ulupicas and pimientos, well known for their economic importance around the globe. The genus comprises a diverse group of sweet and hot chili peppers, which have been used as spices since 6000–6500 BCE. Today, they are of great commercial interest and are consumed by one fourth of the global population (Barboza *et al.*, 2022). *Capsicum* is a popular vegetable and spice crop belonging to the nightshade family Solanaceae, which is amply cultivated for its succulent berries and seeds in tropical and subtropical climate regions all around the globe. The word “*Capsicum*” comes from the Greek word kapsimo, meaning “to bite” or “to swallow.” Astonishingly, *Capsicum* pods have been well known since the beginning of civilization in the Western hemisphere and have been part of the human diet since 7500 BC. Habitually, people eat this botanical spice in raw, dried, and cooked form, and it is also used in making paste, pickle, and sauce. Although, from place to place, the name and type of *Capsicum* berries vary, the most common variety is called “pepper or chili pepper,” which itself can vary greatly in color, shape, size, appearance, flavor, and pungency. Basically, the color diversity of *Capsicum* fruit is linked to the presence of pigments like chlorophyll (green), anthocyanins (violet/purple), α -carotene, β -carotene, zeaxanthin, lutein, and β -cryptoxanthin (yellow/orange) (Gomez-Garcia and Ochoa-Alejo, 2013).

Its fruit forms are varied, from large to small, sweet to sour, and very hot/pungent to bland. Despite being a single species, *C. annuum* has many forms, with a variety of names, even in the same language. Official names aside, in American English, any variety lacking heat is colloquially known as a sweet pepper, and those sweet peppers that have a blocky shape are referred to as bell peppers. A variety that produces capsaicin is colloquially known as a hot pepper or chili pepper. In British English, the sweet varieties are called “peppers” and the hot varieties “chillies”, whereas in Australian English and Indian English, the name “capsicum” is commonly used for bell peppers exclusively and “chilli” is often used to encompass the hotter varieties. The genus *Capsicum* consists of all the ‘chilli pepper plants’, and the confusing terminology ‘chilli’ is often used frequently and interchangeably with other names including ‘chile’, ‘aji’, and ‘paprika’ to refer to multiple species. The genus name *Capsicum* derives from a Greek-based derivative of the latin word ‘kapto’, meaning ‘to bite’, in reference to the heat or pungency of the species’ fruit. Although it has also been speculated to derive from the Latin word ‘capsa’, a box, referring to the shape of the fruit in forms of the typical species. The common name ‘chile’ is a variation of ‘chil’, derived from the Nahutal (Aztec) dialect (La jiao, 2020). In Indian English, the word “capsicum” is used exclusively for *Capsicum annuum*. All other varieties of hot capsicum are called chilli. In northern India and Pakistan, *C. annuum* is also commonly called *shimla mirch* in the local language (Wikipedia, 2023). *Capsicum annuum*, flowering plant of the nightshade family (Solanaceae), widely cultivated for the hot or mild peppers of its thousands of varieties and cultivars. *Capsicum annuum* is the most economically important of the species in the *Capsicum* genus. Its common forms include bell, poblano, cayenne, pimiento (including those used to make paprika), jalapeño, serrano, and various other chili peppers. The fruits of this species are integral ingredients in the cuisines of many countries worldwide. The plant is also grown as an ornamental or as a source of medicine (Sottosanti, 2023). A capsicum is another name for “chili pepper” in many countries, though in the scientific world, the name refers to the genus of flowering plants in the nightshade family Solanaceae. Capsicums in general are cultivated for their

fleshy berries and seeds, and they are grown in many places around the world. While these harvest berries vary in name from place to place and their type, the most common variety are called “chili peppers”, which themselves vary wildly in shape, size, appearance, flavor and piquancy, or heat (Hultquist, 2019). The name “capsicum” has several possible sources. It may derived from the Green “kapto”, which is “to gulp”, referring to the spicy heat of chili peppers when you eat them. Or, it may derived from the Latin “capsa”, which translates to “box”, potentially referring to the hollow nature of most chili peppers (Hultquist, 2019).

The fruit of *Capsicum* plants have a variety of names depending on place and type. The piquant (spicy) varieties are commonly called chili peppers, or simply “chillies”. The large, mild form is called red pepper, green pepper, or bell pepper in North America and United Kingdom and typically “capsicum” in New Zealand, Australia, Singapore and India. The fruit is called paprika in some other countries (although paprika can also refer to the powdered spice made from various capsicum fruit). The generic name may come from Latin capsa ‘box’, presumably alluding to the pods or the Greek word κάπτω kapto ‘to gulp’. The name “pepper” comes from the similarity of the flavour to black pepper, *Piper nigrum*, although there is no botanical relationship with it or with Sichuan pepper. The original term, chilli (now chile in Mexico) came from the Nahuatl word chilli, denoting a larger *Capsicum* variety cultivated at least since 3000 BC, as evidenced by remains found in pottery from Puebla and Oaxaca (Long An, 2015). The genus *Capsicum* consists of all the ‘chilli pepper plants’, and the confusing terminology ‘chilli’ is often used frequently and interchangeably with other names including ‘chile’, ‘aji’, and ‘paprika’ to refer to multiple species. The genus name *Capsicum* derives from a Greek-based derivative of the latin word ‘kapto’, meaning ‘to bite’, in reference to the heat or pungency of the species’ fruit. Although it has also been speculated to derive from the Latin word ‘capsa’, a box, referring to the shape of the fruit in forms of the typical species. The common name ‘chile’ is a variation of ‘chil’, derived from the Nahutal (Aztec) dialect. Common Names of *Cucumis annuum* are Capsicum, Long Peppers, Bell Peppers, Paprika Peppers, Wrinkled Peppers, Cherry Peppers, Tabasco Peppers, Cluster Peppers And Bird Peppers Cayenne Pepper, Green Pepper, Chili Pepper, Christmas Pepper, Ornamental Pepper, Red Pepper, Sweet Pepper, Paprica, and Paprika (NCSE, 2023; Ratnala, 2023). *Capsicum* spp. has several Vernacular names in different languages viz., English- Chillies, long chillies, red chillies; Hindi- Lalmirch; Gujarati- Marcha; Marathi- Mirchi; Kannada- Mensana Kayi; Sanskrit- Raktamaricah, Katuvirah; Malayalam- Kappalmulaku, Mulaku, Paccamulaku, Pacha Mulagu, Cuvannamulaku; Bengali & Oriya- Lanka morich; Tamil- Mulaga, Milagai; Telugu- Mirapakaya; Manipuri- Morok; Mizo - Hmarcha-te, Vai-hmarcha ; Angami- Kedi-chusi and Ayurveda- Kantkari kul (Bhalabhai *et al.*, 2021; Garg, 2023). The fruits are peppers that may be green, yellow, orange or red when ripe. While the species can tolerate most frost-free climates, *C. annuum* is especially productive in warm and dry climates (INaturalist, 2023). *Capsicum* is a popular vegetable and spice crop belonging to the nightshade family Solanaceae, which is amply cultivated for its succulent berries and seeds in tropical and subtropical climate regions all around the globe. The word “*Capsicum*” comes from the Greek word kapsimo, meaning “to bite” or “to swallow.” Astonishingly, *Capsicum* pods have been well known since the beginning of civilization in the Western hemisphere and have been part of the human diet since 7500 BC. Habitually, people eat this botanical spice in raw, dried, and cooked form, and it is also used in making paste, pickle, and sauce (Dhamodharan *et al.*, 2022). Although, from place to place, the name and type of *Capsicum* berries vary, the most common variety is called “pepper or chili pepper,” which itself can vary greatly in color, shape, size, appearance, flavor, and pungency. Basically, the color diversity of *Capsicum* fruit is linked to the presence of pigments like chlorophyll (green), anthocyanins (violet/purple), α -carotene, β -carotene, zeaxanthin, lutein, and β -cryptoxanthin (yellow/orange) (Dhamodharan *et al.*, 2022).

Peppers can be eaten raw, cooked, pickled, roasted, or dehydrated. Pungent chilies can be used as condiments or spices for seasoning. Some peppers are also used as colouring in some foods. Pepper extracts are used in pharmaceutical products for such conditions as arthritis and athlete's foot. The fruits contain many phytochemicals, including vitamin C, vitamin A, flavonoids, anthocyanins, and carotenoids, as well as capsaicinoids, which are spicy components of hot peppers (Sottosanti, 2023). Mainly, this botanical contains a good source of vitamin C, vitamin A, vitamin E, vitamin B5, potassium, magnesium, iron, calcium, phosphorus, and carotenoids. Interestingly, capsaicin phenolic compounds are helpful in preventing and treating many ailments. So, it intends as a beneficial milestone in the pharmaceutical industry and a boon to humanity. This chapter highlights the tremendous pharmacological uses and health benefits of capsicum species and its active compounds in multifarious aspects (Dhamodharan *et al.*, 2022). Since the start of history, natural medicine has been of great interest and attention to humankind. A heap of empirical research indicates that spices have undoubtedly made our lives more interesting and may also make them longer. Capsicum is a highly regarded indispensable spice all over the globe for its umpteen culinary and medicinal facets. It has been used for more than 7000 years in Mexico and is believed to have originated in tropical Central America (Dhamodharan *et al.*, 2022). Chili contains important levels of pigments (*i.e.*, chlorophyll, anthocyanin, and lutein) with potential health benefits; it also contains additional outstanding health-promoting chemical compounds, such as vitamins, minerals, flavonoids, carotenoids, and capsaicinoids, in general. And capsaicin, the major active compound responsible for the pungent taste of these species has been proven to have a positive role in health (Hernández-Pérez *et al.*, 2020). Capsicum is a stimulant, digestive, rubefacient, stomachic, sialagogue, alterative, antispasmodic, febrifuge, depurative, analgesic, anti-ulcer, diuretic, antibacterial, antifungal, antidiabetic, anthelmintic, cardioprotective, diuretic, mosquito repellent (La jiao, 2020) In this review article Origin, Distribution, Taxonomy, Botanical Description, Genetics and cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of Capsicum (*Capsicum annuum* L.) are discussed.

ORIGIN AND DISTRIBUTION

Capsicum is consumed for the first time by Red Indians in 7000 before Christian ear. Domestication forms occur in Mexico *i.e.* *C. baccatum* var *pendulum*, *C. frutescens*. In 1542, this plant is introduced to India, to reach South East Asia including Indonesia (Djarwaningsih, 2005). The red fruits of wild *C. annuum* var. *glabriusculum* attract birds, which eat them and disperse viable seeds, but their pungency discourages consumption by wild mammals. Rats experimentally fed hot chili peppers for 2-11 months became desensitized to aversion, but indifferent rather than developing a preference for this spicy food. Nonetheless, the widespread and common little yellow-shouldered bat (*Sturnira lilium*), which sometimes favours solanaceous fruits, has been reported to consume pungent *Capsicum* in northwestern Argentina and disperse the seeds — which is favoured by local people who recognise this increases the number of wild plants, as they gather the fruits for home seasoning and village marketing (MacBryde, 2006). Chili was first discovered by Christopher Columbus in tropical America, and its use spread rapidly throughout the world because of its pungent flavour. Various classified as herb, fruit or vegetable, it is now an inseparable part of Asian cuisine. The name “chilli” is derived from the Mexican word, *chilli* (Ratnala, 2023). The study of crop origins has traditionally involved identifying geographic areas of high morphological diversity, sampling populations of wild progenitor species, and the archaeological retrieval of macroremains. Recent investigations have added identification of plant microremains (phytoliths, pollen, and starch grains), biochemical and molecular genetic approaches, and dating through C accelerator mass spectrometry. We investigate the origin of domesticated chili pepper, *Capsicum annuum*, by combining two approaches, species distribution modeling and paleobiolinguistics, with microsatellite

genetic data and archaeobotanical data. The combination of these four lines of evidence yields consensus models indicating that domestication of *C. annuum* could have occurred in one or both of two areas of Mexico: northeastern Mexico and central-east Mexico. Genetic evidence shows more support for the more northern location, but jointly all four lines of evidence support central-east Mexico, where preceramic macroremains of chili pepper have been recovered in the Valley of Tehuacán. Located just to the east of this valley is the center of phylogenetic diversity of Proto-Otomanguean, a language spoken in mid-Holocene times and the oldest protolanguage for which a word for chili pepper reconstructs based on historical linguistics. For many crops, especially those that do not have a strong archaeobotanical record or phylogeographic pattern, it is difficult to precisely identify the time and place of their origin. Our results for chili pepper show that expressing all data in similar distance terms allows for combining contrasting lines of evidence and locating the region(s) where cultivation and domestication of a crop began (Kraft *et al.*, 2014).

Domestication process occurred independently from wild species of *Capsicum* in different regions of Mexico, Central and South America. Suppose that these wild species were part of the human diet since long before domestication (at least 7200 years ago), not only as a spice, but also as a food source. The ancient civilizations believed that peppers had mystical and spiritual powers. It had great importance in Aztec, Mayan and Inca civilizations and fruits were consumed fasting in order to curry favor and please the gods. The peppers were grown and selected for different purposes, and it undoubtedly shows that Native Americans were the first “pepper breeders” in the world. Many kinds of current cultivated peppers have been developed by them. Currently, there are many selection methods in plant breeding (including chili peppers) and choosing method depends mainly on the intended objective and plants used as parents (Padilha and Barbieri, 2016). Most abundantly, chili crops are grown in Pakistan, India, China, Ethiopia, Myanmar, Mexico, Vietnam, Turkey, Peru, Ghana, Bangladesh, Japan, Africa, and America (Saxena *et al.*, 2016). Capsicums (*Capsicum annuum*) and chillies (*Capsicum frutescens*) originate from South and Central America (GWA, 2016). It is generally accepted that the *Capsicum* genus originated in Bolivia, and consists of 25–30 species. These species were domesticated around 7000 years ago independently in the latter regions. The wild progenitor of *C. annuum* is thought to be the bird pepper and was probably domesticated in southern Mexico and introduced to Europe in the fifteenth century. Secondary regions of diversity are found in Europe (Balkan area) and in Asia, where large phenotypic variation in morphology, phytonutrient content, and response to biotic and abiotic stresses are observed. Key traits selected for pepper domestication were nondeciduous fruit, which remain on the plant until harvest, change in position from erect to pendant fruit, fruit appearance, and reduced pungency (Morris and Taylor, 2017). *Capsicum*, also known as peppers, is a genus of flowering plants native to tropical America and belongs to the nightshade family Solanaceae. The original geographic distribution of *Capsicum* is very difficult to determine as the humans have been affecting spreading since primitive time (Kulkarni *et al.*, 2017). Although the center of origin of *Capsicum* is generally recognized from South America, studies on isoenzymes indicate that the east of Mexico is the first domestication center of *C. annuum*, including the state of Tamaulipas. In general, most researchers agree that the progenitor for the cultivated *C. annuum* var. *annuum*, originated from the wild *C. annuum* var. *glabriusculum*. Even if the genetic variation of wild populations of *C. annuum* has been shown to be high, there is evidence of genetic fluxes occurring between them (Martínez-Ávalos *et al.*, 2018). *Capsicum annuum* var. *glabriusculum* is widely distributed in Mexico, south of the United States of America, Central America, Colombia and down up to many regions in Perú. At Northeastern Mexico is commonly found from the sea level up to about 1200m, is particularly found in disturbed zones in low deciduous forest and thorn scrubs. Apparently the main limitant for its growth is altitude and is rarely found at 1000 masl (meters above sea level) (Martínez-Ávalos *et al.*, 2018).

Generally *Capsicum* spp. are grown as a spice in the equatorial regions of the countries like India, Mexico, United States of America, Japan, Turkey and African States (Bhalabhai *et al.*, 2021). Since the initial stages of farming, chilli has been considered as a part of a human nutrition. It is believed that chili pepper is originated from northern Amazon basin and due to this reason, it has spread over the regions of Central America, South America, the West Indies and the states of U.S.A. The oldest variety of chilli in the globe is the Tepin or Chiltepin pepper (*Capsicum annuum* var. *glabriusculum*) which is usually known as the “Mother chilli”. The origin of chili pepper is around 7500BC from cave dig out in Mexico and prehistoric cemeterial grounds in Peru. With the help of prehistorical records at places situated in southwestern Ecuador, it can be predicted that chili peppers were domesticated over 6000 years ago. Christopher Columbus for the first time termed them “peppers” because of their similar appearance with white and black pepper of genus *Piper* of Europe and also carried pungent hot taste. As he mistook America for India, he also mistook chilli as a “Black pepper” that is why chilli known as “chili pepper”. After Columbus, chillies were spread throughout the world. In 1494, Diego Alvarez Chanca for the first time carried chillies to Spain and also marked their therapeutic properties. After Spain chilli was further introduced in the South Asian countries like India and China, from China it spread further to Japan than quickly it turned out to be an important spice in many local cuisines. In the beginning chilli was used as an ornamental plant but in a short time it became a common spice. During 16th century, Portuguese imported the chillies from South America to India via their trading community of Goa (Bhalabhai *et al.*, 2021). Before Vasco-Di-Gama came to India we were already using long pepper known as a Pippali which is endemic to Bengal and also its wild variety was cultivated in Malabar Coast in 16th century. In India, *Capsicum* spp. is grown in the states like Andhra Pradesh, Tamilnadu, Karnataka, Gujarat, Maharashtra and Orissa. Out of India’s total chilli export, 75% chilli is produced in the state of Andhra Pradesh (Bhalabhai *et al.*, 2021).

Most abundantly, chili crops are grown in Pakistan, India, China, Ethiopia, Myanmar, Mexico, Vietnam, Turkey, Peru, Ghana, Bangladesh, Japan, Africa, and America (Dhamodharan *et al.*, 2022). Five *Capsicum* species viz., *C. annuum*, *C. chinense*, *C. frutescens*, *C. baccatum* and *C. pubescens*, were independently domesticated for their fruits in different areas of Central and South America. Archaeological records from ca. 8000 BCE indicate the presence of *Capsicum* species remains associated with human settlements in northern Peru. At least three *Capsicum* species (*C. frutescens*, *C. chinense* and *C. baccatum*) would have been cultivated/consumed along the Andes from around 4000–4500 BCE. On the whole, archaeological remains show that *Capsicum* species, together with beans (*Phaseolus* spp.) and several pumpkins (*Cucurbita* spp.), were amongst the first cultivated plants in the Americas that were domesticated by humans. Domesticated chili peppers spread outside the Americas after Columbus’ expeditions in the 15th century, first introduced into Europe and subsequently into Africa and Asia. Since that time, thousands of landraces have been developed in different regions around the world, some of which are currently recognised as secondary diversification centres (Barboza *et al.*, 2022). *Capsicum* species are widely distributed across the Americas, from central Argentina and southern Brazil to the southern extreme of the United States of America, although most of the clades recognised here correspond to a particular geographic region. Approximately half of the species are country-level endemics in South America. The remaining species have wider distributions, the most widely distributed are *C. annuum* var. *glabriusculum*, *C. baccatum* var. *baccatum*, *C. chacoense* and *C. rhomboideum*. Species richness is highest in the Andean Region (22 species), concentrated in Bolivia and Peru, each with 14 species (Barboza *et al.*, 2022). Capsicum was introduced to Mediterranean region, Central Asia, Western Asia, Himalayas, India, Bangladesh, Indochina (except Thailand), Malesia (except Sumatra, Malaya, southeastern islands), Korea, most of Africa (except southern), Madagascar, USA (southeastern), Caribbean, South America (northern half), New Guinea, Australia (Northern, Queensland, New South Wales) (EPPO, 2023). Chilli was

introduced into Europe in 1493 by Christopher Columbus, who discovered it in tropical America. Believed to be a native of Mexico and Peru, it was widely used by the people of Central and South America prior to Columbus’s discovery. It spread so quickly that by 1542, three types of chilli were already introduced into India. As most European languages referred to chilli as a kind of pepper, attempts were made to differentiate it from pepper by coining new words for chilli. Jacob de Bondt, a Batavian physician, used the term *Piper chilensis* in 1630. Pepper traders in Java also sought to give it a name distinct from pepper but this did not come to pass. Some varieties of chillies are still known as peppers (Ratnala, 2023). The numerous races of chillies are broadly divided into the two species: *Capsicum annuum* L and *Capsicum frutescens* L. Berries of *Capsicum frutescens*, also called hot peppers, are more pungent than those of *Capsicum annuum*, known as sweet peppers. Chillies are commercially grown in virtually every tropical region being an easily cultivable crop. In Singapore, the most commonly used chillies are the small and thin *chilli padi* and the long and thick green chilli (Ratnala, 2023).

The origin of chillies is believed to be as old as 7000 B.C. used in Mexico. Chillies were grown and cultivated from 3500 BC. Mexicans used it to spice up their food. Chilli was brought to the rest of the world by Christopher Columbus who discovered America in 1493. Christopher had set from Spain to reach India to bring spices such as pepper back to his country. Christopher not only mistook America for India, but also mistook chili as the black pepper. That is how the chili got the name ‘chile pepper.’ He took chile pepper back to Spain where it became a very famous spice. Chilli spread to rest of the European countries. Chilli became the indispensable spice in European cuisines. Chilli became popular in Portuguese. In 1498, the Portuguese explorer Vasco-da-Gama reached Indian shores bringing with him the pungent spice. Chili seeds were brought to North America for cultivation. In 1888, experiments began for cross breeding of chili plants. New breeds of chili plants were evolved. In 1906, a new variety of chili, Anaheim, was grown. Soon, more chili varieties were evolved such as strong breed of Mexican chile. In 1912, Wilbur L. Scoville, a pharmacist found a new method to measure the pungency of the chili. This new method came to be known as Scoville Organoleptic Test. Unlike, earlier methods, the Scoville test was subjective and accurate. There are more than 400 different varieties of chillies found all over the world. The world’s hottest chili “Naga Jolokia” is cultivated in hilly terrain of Assam in a small town Tezpur, India. Chilli became extremely popular in India after it was first brought to India by Vasco-da-Gama. Chilli found its way in ayurveda, the traditional Indian medical system. According to ayurveda, chili has many medicinal properties such as stimulating good digestion and endorphins, a natural pain killer to relieve pains. Today, it is unimaginable to think of India cuisine without the hot spice, chili. India has become world’s largest producer and exporter of chili, exporting to USA, Canada, UK, Saudi Arabia, Singapore, Malaysia, Germany and many countries across the world. It contributes 25% of world’s total production of chili. Some of the hottest chillies are grown in India. Indian chillies have been dominating international chili market. Majority of chili grown in India is cultivated in states such as Andhra Pradesh, Maharashtra, Karnataka, Gujarat, Tamil Nadu and Orissa (Ramdev, 2023). After being introduced by the Portuguese, chile peppers saw widespread adoption throughout South, Southeast, and East Asia, especially in India, Thailand, Vietnam, China, and Korea (Wikipedia, 2023). Capsicum originated in the New World tropics and sub-tropics. Mexico is the centre of diversity for *C. annuum*. Peppers were introduced into Spain by Columbus in 1493. Cultivation spread from the Mediterranean region to England by 1548 and to Central Europe by the close of the 16th century. It was brought to India by the Portuguese from Brazil prior to 1885. In China it came under cultivation during the late 1700s. (Vidhi, 2023)

TAXONOMY

Capsicum pepper and chilli pepper (*Capsicum annuum*) belongs to the Family Solanaceae and the genus Capsicum (Long An, 2015; Garg, 2023; Wikipedia, 2023; CABI, 2023). Within the Solanaceae,

the genus *Capsicum* can be recognised by its shrubby habit, actinomorphic flowers, distinctive truncate calyx with or without appendages, anthers opening by longitudinal slits, nectaries at the base of the ovary and the variously coloured and usually pungent fruits. The highest diversity of this genus is located along the northern and central Andes (Barboza *et al.*, 2022). *Capsicum* (also known as peppers) is a genus of flowering plants in the tribe Capsiceae in the subfamily Solanoideae of the nightshade family Solanaceae. The chili pepper (also chile pepper or chilli pepper), from Nahuatl *chilli* is the fruit of plants from the genus *Capsicum*, members of the nightshade family, Solanaceae. In Britain, Australia, Ireland, New Zealand, South Africa, Pakistan, India, and other Asian countries, it is usually known simply as the chilli. Its species are native to the Americas, where they have been cultivated for thousands of years. In modern times, it is cultivated worldwide, and has become a key element in many cuisines. In addition to use as spices and food vegetables, *Capsicum* species have also found use in medicines (Long An, 2015).

Capsicum Species

The number of global species within the *Capsicum* genus has long been subject to debate, with various authors ascribing 20 to 50 species to the genus. However TPL (2010) has reported 40 species as accepted species.

Table 1. Accepted species of genus *Capsicum*

<i>Capsicum annuum</i> L.
<i>Capsicum baccatum</i> L.
<i>Capsicum buforum</i> Hunz.
<i>Capsicum caballeroi</i> M.Nee
<i>Capsicum campylopodium</i> Sendtn.
<i>Capsicum cardenasii</i> Heiser & P.G.Sm.
<i>Capsicum ceratocalyx</i> M.Nee
<i>Capsicum chacoense</i> Hunz.
<i>Capsicum chinense</i> Jacq.
<i>Capsicum coccineum</i> (Rusby) Hunz.
<i>Capsicum cornutum</i> (Hiern) Hunz.
<i>Capsicum dimorphum</i> (Miers) Kuntze
<i>Capsicum dusenii</i> Bitter
<i>Capsicum eximium</i> Hunz.
<i>Capsicum flexuosum</i> Sendtn.
<i>Capsicum friburgense</i> Bianch. & Barboza
<i>Capsicum galapagoense</i> Hunz.
<i>Capsicum geminifolium</i> (Dammer) Hunz.
<i>Capsicum havanense</i> Kunth
<i>Capsicum hookerianum</i> (Miers) Kuntze
<i>Capsicum hunzikerianum</i> Barboza & Bianch.
<i>Capsicum lanceolatum</i> (Greenm.) C.V.Morton & Standl.
<i>Capsicum leptopodium</i> (Dunal) Kuntze
<i>Capsicum lycianthoides</i> Bitter
<i>Capsicum minutiflorum</i> (Rusby) Hunz.
<i>Capsicum mirabile</i> Sendtn.
<i>Capsicum mositicum</i> Toledo ex Handro
<i>Capsicum parvifolium</i> Sendtn.
<i>Capsicum pereirae</i> Barboza & Bianch.
<i>Capsicum pubescens</i> Ruiz & Pav.
<i>Capsicum ramosissimum</i> Witasek
<i>Capsicum recurvatum</i> Witasek
<i>Capsicum rhomboideum</i> (Dunal) Kuntze
<i>Capsicum schottianum</i> Sendtn.
<i>Capsicum scolnikianum</i> Hunz.
<i>Capsicum sinense</i> Jacq.
<i>Capsicum spina-alba</i> (Dunal) Kuntze
<i>Capsicum stramonifolium</i> (Kunth) Standl.
<i>Capsicum tovarii</i> Eshbaugh, P.G.Sm. & Nickrent
<i>Capsicum villosum</i> Sendtn.

There are presently considered to be five domesticated species of *Capsicum* from approximately 25 recognised species in the genus, the primary distinguishing characteristics being flower and seed colour, shape of the calyx, number of flowers per node and their orientation; these five species are *C. annuum*, *C. frutescens*, *C. chinense*, *C. baccatum* and *C. pubescens*. Cultivated *C. annuum* is

thought to have been domesticated from wild populations of *C. annuum* var. *glabriusculum* in Mexico, possibly multiple times from geographically separate wild populations (Long An, 2015). Surprisingly, approximately 35 species of *Capsicum* exist in nature; only five have been domesticated for human consumption, namely *Capsicum annuum* (ancho/poblano, bell, cayenne, thai, jalapeno, paprika, pimiento, piquin, and serrano), *Capsicum baccatum* (aji amarillo, aji limon, criolla sella, malawi piquante, and bishop's crown), *Capsicum chinense* (scotch bonnets, trinidad scorpions, bhut jolokia, and carolina reaper), *Capsicum frutescens* (tabasco, bird-eye, kambuzi, malagueta, and siling labuyo), and *Capsicum pubescens* (rocoto pepper) (Fig. 1) (Carrizo *et al.*, 2016). Of these species, the *Capsicum annuum* is the most economically important crop due to its pungent odor and taste.

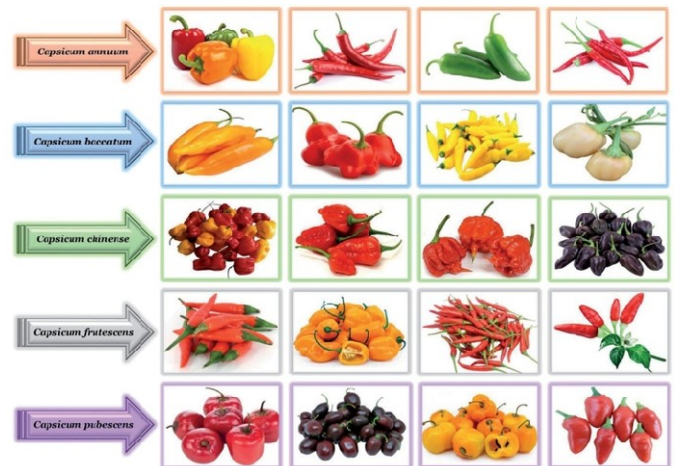


Fig. 1. Five major domesticated species of *Capsicum*

The *Capsicum* genus consists of about 30 wild species and five domesticated species: *Capsicum annuum*, *C. baccatum*, *C. chinense*, *C. frutescens* e *C. pubescens*. (Padilha and Barbieri, 2016). At present, this genus is believed to consist of 27 species, 5 of which are domesticated and used as fresh vegetables and spices: *Capsicum annuum*, *Capsicum baccatum*, *Capsicum chinense*, *Capsicum frutescens*, and *Capsicum pubescens* (Kulkarni *et al.*, 2017). The genus *Capsicum* L. (family Solanaceae, subfamily Solanoideae) includes approximately 32 species originated in America. Five of these varieties have been domesticated as food the next five: *C. annuum* L., *C. frutescens* L., *C. baccatum* L., *C. pubescens* Ruiz. & Pav., and *C. chinense* Jacq. However, it is considered that *C. annuum* is the species with higher economic importance and is the only one native from Mexico. *C. annuum* includes a high variety of shapes, colors and fruits both wild and cultivated (Martínez-Ávalos *et al.*, 2018). *Capsicum* L. (Capsiceae, Solanaceae) comprises ca. 35 species native to tropical and temperate Central and South America, Mexico and the West Indies. The genus includes the sweet and hot chili peppers, which have been popular from ancient times and at present are of great commercial interest, not only for the taste and colour of their fruits, but also because of their essential oils and the presence of capsaicin (Barboza *et al.*, 2019). The five major cultivated and economically most important species of *Capsicum* are *C. annuum* L., *C. chinense* Jacq., *C. frutescens* L., *C. baccatum* L. and *C. pubescens* (Barboza *et al.*, 2019).

There are 20-27 different species of capsicums in the world, but only 5 of them have been domesticated, all of them chili peppers (Hultquist, 2019). The genus *Capsicum* is now widely accepted as consisting of 26 wild species and just 5 domesticated species. With knowledge of the differences between each of these five domesticated species of the *Capsicum* genus, you can easily learn to differentiate by learning what exactly makes each one of these unique and different from the others (Bray, 2019). Origin of *Capsicum* spp. is tropical South America. The plants are small and evergreen including more than 20 species. Out of these 20 species five species are known to be domesticated like *Capsicum annuum*, *Capsicum frutescens*,

Capsicum chinense, *Capsicum baccatum* and *Capsicum pubescens* (Bhalabhai *et al.*, 2021). *Capsicum* L., with 43 species, is placed in the tribe Capsiceae (subfam. Solanoideae, Solanaceae) together with *Lycianthes* (Dunal) Hassl. Five main domesticated species: *C. annuum* L., *C. chinense* Jacq. and *C. frutescens* L., *C. baccatum* L. and *C. pubescens* Ruiz & Pav. (Barboza *et al.*, 2022).

Domesticated *Capsicum* Specie

There are five domesticated Species of *Capsicum* viz., *C. annuum*, *C. baccatum*, *C. chinense*, *C. frutescens* and *C. pubescens*. Morphological characters that generally differentiate the domesticated species of *Capsicum* is given in Table 2 (MacBryde, 2006) and the

Table 2. Morphological characters that generally differentiate the domesticated species of *Capsicum*

Species	Flowers per node	Calyx	Corolla colour	Corolla-lobebasal spots	Anthercolour	Seed colour
<i>C. annuum</i> var. <i>annuum</i>	1 (-5)	no ring; often teeth	white to dingy white (rarely purple)	none	blue-purple	straw(tan)
<i>C. frutescens</i>	usually 2-4 (1-6)	no ring; usually no teeth	greenish white or greenish	none	blue-purple	straw(tan)
<i>C. chinense</i>	(1-) 2 (-5)	annular ring; no teeth	greenish white or white	none	blue	straw(tan)
<i>C. baccatum</i> var. <i>pendulum</i>	1 (-2)	no ring; teeth	white (cream) or greenish-white	yellow-green	white to yellowish	straw(tan)
<i>C. pubescens</i>	1	no ring; teeth	purple or purple-white	none	purple (purple-white)	black (brown/black)

Table 3. Taxonomic characters of the five cultivated species of *Capsicum*

Species	Corolla colour	Corolla throat spots	Corolla shape	Anther colour	Calyx teeth	Seed colour	Flowers/ node
<i>C. annuum</i>	White	None	Rotate	Blue purple	Present	Tan	1
<i>C. frutescens</i>	Greenish white	None	Rotate	Blue	None	Tan	1-3
<i>C. chinense</i>	White to greenish white	None	Rotate	Blue	Present	Tan	1-5
<i>C. baccatum</i>	White	Green yellow	Rotate	Yellow	Present	Tan	1-2
<i>C. pubescens</i>	Purple	None	Rotate	Purple	Present	Black	1

Surprisingly, approximately 35 species of capsicum exist in nature; only five have been domesticated for human consumption, namely *Capsicum annuum* (ancho/poblano, bell, cayenne, thai, jalapeno, paprika, pimiento, piquin, and serrano), *Capsicum baccatum* (aji amarillo, aji limon, criolla sella, malawi piquante, and bishop's crown), *Capsicum chinense* (scotch bonnets, trinidad scorpions, bhut jolokia, and carolina reaper), *Capsicum frutescens* (tabasco, bird-eye, kambuzi, malagueta, and siling labuyo), and *Capsicum pubescens* (rocoto pepper). Of these species, the *Capsicum annuum* is the most economically important crop due to its pungent odor and taste (Dhamodharan *et al.*, 2022). *Capsicum* consists of 20–27 species, five of which are widely cultivated: *C. annuum*, *C. baccatum*, *C. chinense*, *C. frutescens*, and *C. pubescens*. Phylogenetic relationships between species have been investigated using biogeographical, morphological, chemosystematic, hybridization, and genetic data (Wikipedia, 2023). *Capsicum* is a small genus of approximately 25 species that, in pre-Columbian times, was restricted to the Americas.

Five *Capsicum* species were domesticated in the Americas, although the regions of their domestication remain informed speculation: *Capsicum annuum* (bell pepper and jalapeño) in Mexico or northern South America; *Capsicum frutescens* (tabasco) in the Caribbean; *Capsicum chinense* (habanero and Scotch bonnet) in Amazonia; *Capsicum baccatum* (aji) in Bolivia; and *Capsicum pubescens* (rocoto) in the southern Andes. Domestication focused on the fruits; small, erect, deciduous red fruits of the wild forms were unconsciously selected to produce large, hanging, persistent, multi-coloured fruits. Along with these features came changes in capsaicin content and other compounds that give chillies their characteristic flavours. Although all five species contribute to the global spice trade, *Capsicum annuum* is the most important (Harris, 2023). There are at least 35 other species known to exist in the wild. Most of these species produce small berry-like fruits and are more challenging to grow (Calvin, 2022). As astounding as that is, the overwhelming majority of these peppers belong to only five different species in the *Capsicum* genus. While each existing pepper variety can be categorized into one of these five species, there are 25 known species in the *Capsicum* genus, most of them being non-domesticated (Zeana, 2023).

taxonomic characters of the five cultivated species are given in Table 3 (Vidhi, 2023).

Details of the five domesticated *Capsicum* spp.

Species *Capsicum annuum*: *Capsicum annuum* ("annual") is the most widely distributed pepper species in the world. The fruits of the different varieties show considerable diversity; their size ranges from 1–25 cm, and their hotness extends from the very mild, slightly sweet bell pepper to the small but very hot jalapeño. Also, the form and color of the fruit is many-faceted (Roth, 2014). *Capsicum annuum* is a species of the plant genus *Capsicum* native to southern North America and northern South America. This species is the most common and extensively cultivated of the five domesticated capsicums. The species encompasses a wide variety of shapes and sizes of peppers, both mild and hot, ranging from bell peppers to chili peppers. Cultivars are descended from the wild American bird pepper still found in warmer regions of the Americas. In the past some woody forms of this species have been called *Capsicum frutescens*, but the features that were used to distinguish those forms appear in many populations of *Capsicum annuum* and there is no consistently recognizable *Capsicum frutescens* species. Although the species name *annuum* means "annual" (from the Latin *annus* "year"), the plant is not an annual and in the absence of winter frosts can survive several seasons and grow into a large perennial shrub. The single flowers are an off-white (sometimes purplish) color while the stem is densely branched and up to 60 centimetres (24 in) tall. The fruit are berries that may be green, yellow or red when ripe. While the species can tolerate most climates, *Capsicum annuum* is especially productive in warm and dry climates (Long An, 2015). Of the five domesticated species of *Capsicum*, this particular species is the most common as well as the most extensively cultivated. Peppers of this species include a wide range of flavors and intensities from sweet to mild to hot. Many favorites are members of this species, including: Bell pepper, Cayenne, Jalapeño, New Mexican (Bray, 2019). Certainly the most well-known pepper species, *Capsicum annuum* is home to some of the most beloved varieties. These include the jalapeño, cayenne, bell, poblano, and so many more.

The heat levels of annuum peppers varies widely. Some have none at all, like bell peppers, and some are very spicy, like the assam and cayenne peppers. Size also ranges from enormous and thick walled to tiny, berry-like pods. *C. annuum* is also home to many of the most gorgeous pepper plants and pods. The fish pepper plant has beautiful white and green variegated leaves and striped peppers. The pimenta da neyde pepper is one of the most commonly cross-bred varieties thanks to its nearly black foliage and dark purple peppers. Jalapeños are one of the most popular spicy peppers in the world, typically found in their unripe green color at grocery stores. Standard jalapeños will turn red when fully ripe, though some are unique colors, such as purple. NMSU even crossbred yellow, orange and brown varieties! (Calvin, 2022). Most of the peppers you have encountered most likely are strains of *Capsicum annuum*, considering it contains more pepper varieties than any other species and can be found in cultivation all over the world. Popular *Capsicum annuum* include jalapenos, cayennes, serranos, plobanos, chili peppers, bell peppers, and most other sweet peppers (Zeana, 2023). Morphological characters of the species are given in Fig.2. *Capsicum annuum*, native from southern North America through Central America to South America, has been cultivated by Indigenous peoples of the Americas for thousands of years, and globally for over 400 years (Hultquist, 2019).

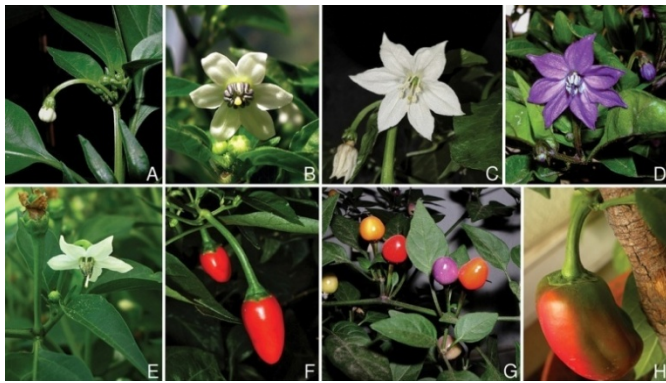


Fig. 2. *Capsicum annuum* var. *annuum*. A. flower bud on pendent pedicel; B. flower with connivent anthers; C. flower with hexamerous corolla (note nectar droplets on the limb) and style near the same length as the anthers; D. flower with heptamerous purple corolla; E. flower with pentamerous corolla and style exceeding the anthers; F. mature fruits on pendent pedicels; G. mature fruits on upright pedicels; H. mature fruits on pendent pedicels

Species *Capsicum chinense*: *Capsicum chinense*, despite the name, originated in the Caribbean, and includes the hottest species known, including Habeneros and Scotch Bonnet. A typical feature, apart from intense spiciness, is the characteristic aroma. Varieties of *C. chinense* prefer a damp, tropical climate, as for instance with the varieties fatalli in tropical Africa, datil in Florida, adjuma in Surinam, and naga morich in Bangladesh. All have in common (in addition to extreme "hotness") a delicate, fruity aroma absent from all other species, and characteristic exclusively of the raw fruit (Roth, 2014). *Capsicum chinense*, commonly known as "yellow lantern chili", is a species of chili pepper native to the Americas. *Capsicum chinense* varieties are well known for their exceptional heat. Some taxonomists consider them to be part of the species *Capsicum annuum*. However, the annuum and chinense peppers can easily be identified by the number of flowers or fruit per node - one for annuums and two for chinense. Despite its name, *Capsicum chinense* or "Chinese capsicum" is misleading. All *Capsicum* species originated in the New World. Nikolaus Joseph von Jacquin (1777-1817), a Dutch botanist, erroneously named the species in 1776, because he believed they originated in China. *Capsicum chinense* is native to Central America, the Yucatan region, and the Caribbean islands. In warm climates such as these, it is a perennial and can last for several years, but in cooler climates, *Capsicum chinense* does not usually survive the winter. However, it will readily germinate from the previous year's seed in the following growing season. Varieties and Cultivars include Adjuma (Suriname), Aji dulce, Aji Panca (Peru), Arriba Saia (Brazil), 5- Bhut jolokia (Assam) (Long An, 2015).

The Chinese species boasts many of the hottest cultivars in the world. As this species originated in the Amazon Basin, quickly becoming common throughout Central and South America, the Caribbean and the tropic, the intensity of this species certainly lends its heat to countless traditional cuisines in these parts of the world. Too hot for many to handle, this species includes fiery cultivars such as: Habanero, Scotch bonnet, Red Savina habanero. While the Chinese peppers offer the heat hardcore pepper-lovers crave, these tropical natives are a finicky variety, requiring specific conditions and long growing seasons that may not be ideal for growing in your own backyard (Bray, 2019). Home to all of the hottest pepper varieties, *Capsicum chinense* is highly regarded in the pepper enthusiast world. Chinese peppers are typically pungent with powerful floral flavors. Many also have notes of citrus. The immense variety of peppers in the Chinese species continues to grow as it remains one of the most popular for cross breeding. The Chinese species is known for having some of the 'ugliest' peppers, with wrinkled skin and long, stinger-like bottoms. However, this is actually a good thing to many growers. The more strange a variety, the better. With high heat levels, wide variation in shape and size, and addictive flavor, it is no wonder that Chinese remains the king of the capsicum species for many pepper geeks (Calvin, 2022). The wild variant of *Capsicum chinense* is native to the Caribbean and Yucatan peninsula of Mexico. This pepper species has a reputation for being quite hot. Despite their heat, they can be quite tasty with flavors ranging from citrus like to smoky (Zeana, 2023). Morphological characters of the species are given in Fig. 3.

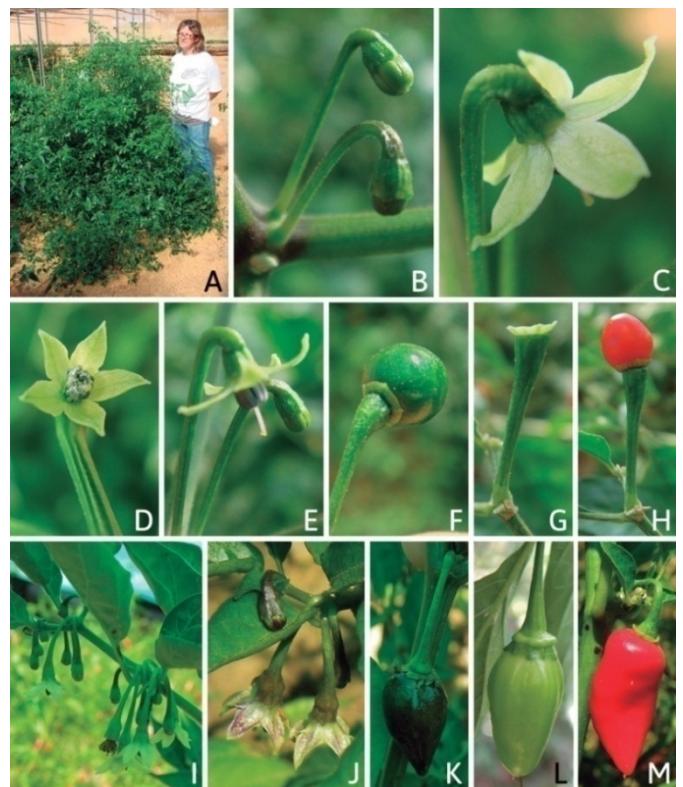


Fig. 3. *Capsicum chinense* (A–H from wild plants I–M from domesticated plants) A. plant B. flower buds C. flower on geniculate pedicel D. flower, in front view E. flower, in full anthesis F. immature fruit G. fruiting pedicel H. mature fruit I. flowering branch J. flowers on pendent pedicels K, L. immature fruits M. mature fruit

Species *Capsicum frutescens*: *Capsicum frutescens* usually has small — only 1–3 cm long — "hot" fruit, and distinguishes itself through a characteristic aroma. This species is used above all as a condiment. Well-known varieties include piri-piri (African devil) and Thai chili (bird's eye). The variety "Tabasco" serves as the basis for the well-known sauce of the same name (Roth, 2014). *Capsicum frutescens* is a species of chili pepper that is sometimes considered to be part of the species *Capsicum annuum*. The *Capsicum frutescens* species likely originated in South or Central America. It spread quickly throughout the tropical and subtropical regions in this area and still grows wild

today. *Capsicum frutescens* is currently native to the majority of Central America as well as Northern and Western South America. It is believed that *Capsicum frutescens* is the ancestor to the *Capsicum chinense* species. Pepper cultivars of *Capsicum frutescens* can be annual or short-lived perennial plants. *Capsicum frutescens* has a smaller variety of shapes compared to other *Capsicum* species, likely because of the lack of human selection. More recently, however, *C. frutescens* has been bred to produce ornamental strains, because of its large quantities of erect peppers growing in colorful ripening patterns. Varieties and Cultivars include Kambuzi pepper, Malawian pepper, Malagueta pepper, Piri piri, also called African Bird's Eye or African devil (Long An, 2015). The *Frutescens* species has the distinction of being much less widely cultivated than the others outlined here. The tabasco pepper – used to create the wildly popular world famous sauce for more than 160 years – is a member of the *Frutescens* species. Believed to have its origin in Brazil, this species also includes the famous malagueta chili pepper variety. The compact habit and high pod yield of the individual plants in this species make it a particularly good choice for container gardening (Bray, 2019). *Capsicum frutescens* is a wild chili pepper having genetic proximity to the cultivated pepper *Capsicum chinense* native to Central and South America. Pepper cultivars of *C. frutescens* can be annual or short-lived perennial plants. Flowers are white with a greenish white or greenish yellow corolla, and are either insect- or self-pollinated. The plants' berries typically grow erect; ellipsoid-conical to lanceoloid shaped. They are usually very small and pungent, growing 10–20 millimetres (0.39–0.79 in) long and 3–7 millimetres (0.12–0.28 in) in diameter. Fruit typically grows a pale yellow and matures to a bright red, but can also be other colors. *C. frutescens* has a smaller variety of shapes compared to other *Capsicum* species. *C. frutescens* has been bred to produce ornamental strains because of its large quantities of erect peppers growing in colorful ripening patterns (Bray, 2019).

The famous Tabasco Brand hot sauce uses a single pepper variety, and it comes from the *frutescens* species. These peppers are typically medium-spicy with thin walls and small pods. This makes tabasco peppers not the ideal choice for hot sauce, but it has become tradition. Most *frutescens* pepper varieties have a bullet shape and ripen to red or orange. There are some types that will go through a variety of colors before reaching a final ripe coloration. Flavor is generally uninspiring, though they make great peppers for cooking with heat. The pods will add plenty of spice to a dish without meddling with the intended flavors. Great for chili, stir fry and of course, hot sauce! (Calvin, 2022).

Capsicum frutescens is a wild chili pepper having genetic proximity to the cultivated pepper *Capsicum chinense* native to Central and South America. Pepper cultivars of *C. frutescens* can be annual or short-lived perennial plants. Flowers are white with a greenish white or greenish yellow corolla, and are either insect- or self-pollinated. The plants' berries typically grow erect; ellipsoid-conical to lanceoloid shaped. They are usually very small and pungent, growing 10–20 millimetres long and 3–7 millimetres in diameter. Fruit typically grows a pale yellow and matures to a bright red, but can also be other colors. *C. frutescens* has a smaller variety of shapes compared to other *Capsicum* species. *C. frutescens* has been bred to produce ornamental strains because of its large quantities of erect peppers growing in colorful ripening patterns (Zeana, 2023). Closely related to both *Capsicum annum* and *Capsicum chinense*, this species has produced far fewer varieties and its peppers usually don't get as big. This species is believed to have originated in South or Central America. Other noteworthy peppers include Thai peppers, African bird's eye and the malagueta pepper (Zeana, 2023). Morphological characters of the species are given in Fig. 4.

Species *Capsicum baccatum*: *Capsicum baccatum* (“berry-like”) came originally from Bolivia or perhaps Peru, and the large, elongated, hot fruit is distinguished by its very unique, fruity bouquet. The variety *C. baccatum* var. *pendulum* is called “Aji” in South America, and was even known among the Incas. *C. baccatum* varieties are a solid component of today's Peruvian cuisine, making a delicacy, for example, out of Cuy chactado (Roth, 2014). *Capsicum baccatum* is a species of the plant genus *Capsicum* (chili pepper) native to southern North America and northern South America. The *Capsicum baccatum* species, particularly the Aji amarillo chili, has its origins in ancient Peru. It is typically associated with Peruvian cuisine, and is considered part of its condiment trinity together with red onion and cilantro. Aji amarillo literally means yellow chili; however, the yellow color appears when cooked, as the mature pods are bright orange. Cultivated *baccatum* (*Capsicum baccatum* var. *pendulum*) is the domesticated pepper of choice of Bolivia, Ecuador, Peru and Chile. Pepper varieties in the *Capsicum baccatum* species have white or cream colored flowers, and typically have a green or gold corolla. The flowers are either insect or self-pollinated. The fruit pods of the *baccatum* species have been cultivated into a wide variety of shapes and sizes, unlike other capsicum species, which tend to have a characteristic shape. The pods typically hang down, unlike a *Capsicum frutescens* plant, and can have a citrus or fruity flavor. Cultivars of species *Capsicum baccatum* are Aji, Bishop's crown, Lemon drop and Peppadew (Long An, 2015). With nearly as many cultivars as *Annuum* and a wide range of pods from fiery hot to non-pungent, *Baccatum* are one of the easiest to identify visually. This species has distinctive coloring on the flowers, and typically grows tall, often reaching heights of about 5 feet. The *Baccatum* species includes the popular South American cultivars commonly known as Aji's, like aji amarillo and aji panca (Bray, 2019). *Capsicum baccatum* peppers come in a wide variety of shapes and heat levels. Some aji varieties are long and slender, while others take on more curled and bizarre shapes. Some notable examples: Brazilian starfish, bishop's crown. Flavor ranges from super sweet and fruity to bitter and earthy. Some believe that the *baccatum* species is home to some of the tastiest peppers out there! *C. baccatum* plants are often very tall and highly prolific. Recent cultivars are much larger than this species' ancestors, resulting in pendulum-like hanging pods. Peppers often have long stems as well

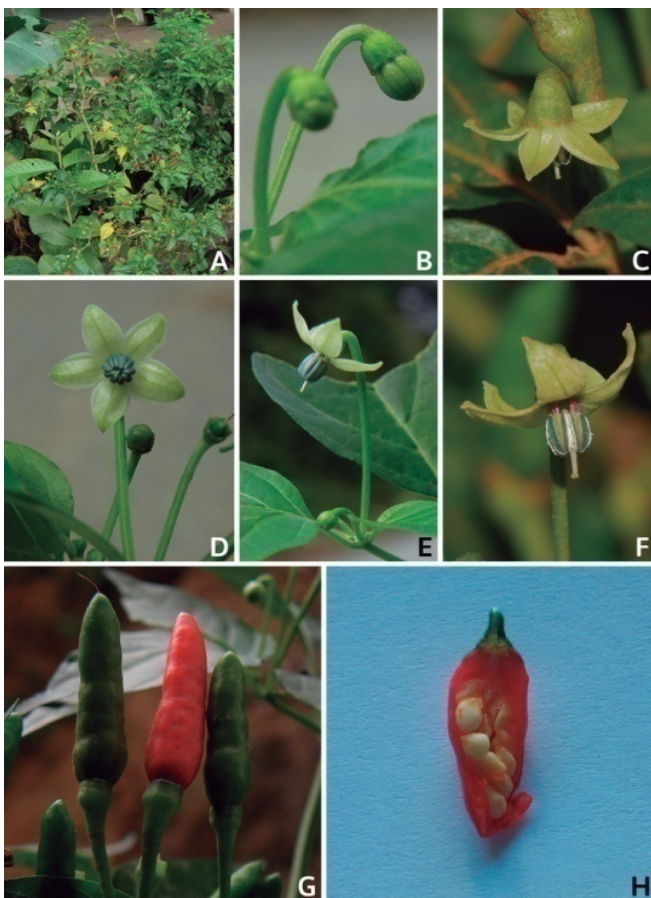


Fig. 4. *Capsicum frutescens* A. plant B. flower buds C. flower showing the calyx D. flower, in lateral view E. flower, in front view (note the connivent anthers) F. flower after anthers dehiscence G. immature (green) and mature (red) fruits H. fruit, in longitudinal section showing the seeds.

(Calvin, 2022). While the other domesticated pepper species can be commonly found in cultivation throughout the Americas, *baccatum* peppers are mainly only popular in South American countries such as Peru and Brazil. These peppers are unique from varieties of other species as they have a notably citrus or fruity flavor and a pleasant fragrant smell. Most peppers of *baccatum* origin will have the prefix “aji” at the start of the name, such as the aji amarillo and aji omnicolor, and every *baccatum* pepper plant will have cream or yellow dimples on their flower pedicels (Zeana, 2023). Morphological characters of the species are given in Fig.5.

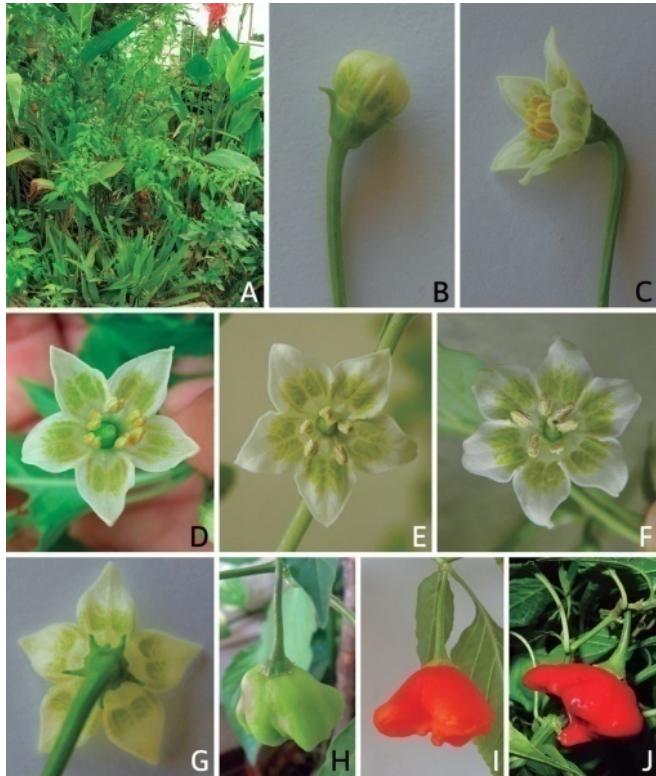


Fig. 5. *Capsicum baccatum* var. *umbilicatum* A. plant B. flower bud C. flower, lateral view D. flower short-styled E. flower long-styled F. flower hexamerous G. flower, seen from behind H. immature fruit I, J. mature fruits

***Capsicum pubescens*:** *Capsicum pubescens* (“hairy”) grows especially in higher regions of the Andes, from Columbia to Bolivia, but also in southern Mexico. In contrast to the other *Capsicum* species, its seeds are black. Representative varieties include Rocoto (Bolivia, Peru) and Manzano (Mexico). *C. pubescens* is the only *Capsicum* species tolerant to light frost (Roth, 2014). *Capsicum pubescens* is a species of the genus *Capsicum* (pepper), known as rukutu, ruqutu (Quechua, hispanicized rocoto) and luqutu (Aymara, hispanicized locoto) and in Mexico known as the “Manzano” pepper which means “apple” for its apple-shaped fruit. This species is found primarily in Central and South America, and is known only in cultivation. The species name, *pubescens*, means hairy, which refers to the hairy leaves of this pepper. The hairiness of the leaves, along with the black seeds, distinguish this species from others. As they reach a relatively advanced age and the roots lignify quickly, sometimes they are called tree chili. Of all the domesticated species of peppers, this is the least widespread and systematically furthest away from all others. It is reproductively isolated from other species of the genus *Capsicum*. A very notable feature of this species is its ability to withstand cooler temperatures than other cultivated pepper plants, although it cannot withstand frost. *Capsicum pubescens* is found in cultivation primarily in north-western South America, as well as southern Central America. It is believed to have evolved from other, more primitive *Capsicum* species also occurring in the same area. *Capsicum pubescens* grows at higher elevations than other species, and cannot survive the tropical heat in the lowlands. Cultivars include Canario (yellow), Rojo (red), Peron (pear-shaped),

Orange (most common color in Mexico) and Rocoto Longo (Long An, 2015). *Capsicum pubescens* is probably the least common. It does not have a wild form. With distinguishing features that include a height of up to eight feet, vibrant purple flowers and unique pods that are typically apple or pear shaped, *Capsicum pubescens* is quite easy to tell apart from other species. It is also more likely than not the most difficult to grow. The *Pubescens* species includes the Mexican manzano pepper as well as the Peruvian rocoto (Bray, 2019). Known for their ‘hairy’ foliage, *Capsicum pubescens* varieties are certainly the strangest domesticated pepper plants. Commonly known as the ‘tree pepper,’ ripe pods are thick walled and juicy. The *pubescens* species is home to some of the only known cold-resistant pepper varieties. Some plants maintain a low and wide structure with small leaves while others can grow to be quite tall. Heat varies, but some types can be quite spicy. The pepper shape is usually rotund, ranging from apple-like to more oblong. This makes them perfect for stuffing! *Capsicum pubescens* seeds are jet black, and the plant’s flowers are purple (Calvin, 2022). Perhaps the most easily identifiable pepper species, *pubescens* pepper plants have deep purple flowers, large black seeds, and the stems and leaves are covered in small hairs. This is likely the first pepper to be domesticated, with its origins traced back to Peru before the Inca Empire. The pepper has been domesticated for so long that we don’t even know what wild ancestor this plant came from. The fruits tend to be large and have thick flesh, such as the manzano and locoto peppers. Despite originating so close to the equator, it is actually the most cold-tolerant pepper plant because it has been grown in high elevations in the Andes Mountains for thousands of years. If left to grow for many years, the plants can become huge, leading some to call it the tree pepper (Zeana, 2023). Morphological characters of the species are given in Fig. 6.

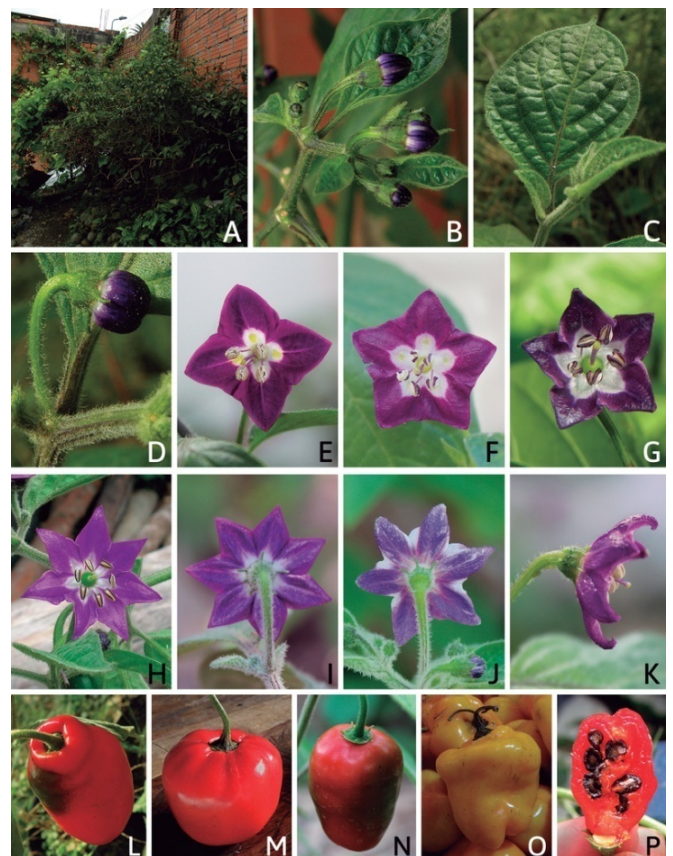


Fig. 6. *Capsicum pubescens* A. plant B. reproductive nodes C. young leaves, adaxial surface D. flower bud on geniculate pedicel E–H. flowers, in front view, showing 4-7-merous corollas I, J. flowers, seen from behind K. flower, in lateral view L–O. mature fruits from different provenance (L, N from Bolivia, M from Peru, O from Mexico) P. fruit, in longitudinal section, showing the black seeds

Interspecific Hybridization: *Capsicum* species do not hybridise with species in other genera of the Solanaceae. Pepper breeding continues to be highly rewarding for the improvement of *Capsicum*.

Interspecific crossing between many *Capsicum* species has been tried experimentally (often repeatedly) for agronomic and taxonomic purposes. Fertile hybridisations can occur between taxa within the *Capsicum annuum* complex to varying degrees and also these species with *C. baccatum* but not with *C. pubescens* (MacBryde, 2006) (Table 4).

Table 4. Crossability (including hybrid viability) of *Capsicum annuum* with other *Capsicum* in the three complexes of domesticated species

<i>Capsicum annuum</i> (C _A) reciprocal crosses with other <i>Capsicum</i> species		<i>Capsicum</i> sp. as female / male complex
Interspecific parent and species		
<i>C. frutescens</i>	(C _A)	(+) / +
<i>C. chinense</i>	(C _A)	(+) / (+)
<i>C. galapagoense</i>	(C _A)	† / +
<i>C. chacoense</i>	(C _B or C _A)	0 / +
<i>C. baccatum</i>	(C _B)	+ / +
<i>C. praetermissum</i>	(C _B)	† / †
<i>C. tovarii</i>	(C _B)	0 / 0
<i>C. pubescens</i>	(C _P)	0 / 0
<i>C. cardenasii</i>	(C _P)	0 / †
<i>C. eximium</i>	(C _P)	0 / †

F₁ hybrids produce: viable seeds +, or some viable seeds (+); non-viable seeds †; or no fruits and/or seeds 0.

Synonyms and characteristics of five domesticated *Capsicum* spp. are given in Table 5 (Hundal and Dhall, 2005)

Table 5. Synonyms and characteristics of five domesticated *Capsicum* spp.

Species	Synonyms	Place of origin	Characteristics
<i>C. annuum</i>	<i>C. purpureum</i> <i>C. grossum</i> <i>C. cerasiformae</i>	Mexico/Central America	Milky white large corolla, single flower at each node, presence of calyx teeth, yellow and smooth seeds, annual, medium to large size fruits, medium pungent
<i>C. chinense</i>	<i>C. luteum</i> <i>C. umbilicatum</i> <i>C. sinense</i>	Amazonia	Dull white corolla, two or more flowers at each node, devoid of calyx teeth, constriction between the base of calyx and pedicel, yellow and smooth seeds.
<i>C. frutescens</i>	<i>C. minimum</i>	Amazonia	Greenish white corolla, two or more flowers at each node, devoid of calyx teeth, no constriction between base of calyx and pedicel, yellow and smooth seeds, perennial, small size fruits, highly pungent.
<i>C. baccatum</i>	<i>C. pendulum</i> <i>C. microcarpum</i> <i>C. angulosum</i>	Peru and Bolivia	Cream to white colored corolla with yellow to green spots on each corolla lobe, one or more flowers at each node, presence of calyx teeth, yellow and smooth seeds.
<i>C. pubescens</i>	<i>C. eximium</i> <i>C. tovarii</i> <i>C. cardenasii</i>	Peru and Bolivia	Deep purple to faintly violet corolla with white center, one or more flowers in each node, presence of calyx with small teeth, black to brown and rough seeds.

Capsicum annuum var. *glabriusculum*, is a variety of wild chili pepper belonging to the family Solanaceae and is considered as the origin for all cultivated chili species of the world. This species is an important genetic resource for agriculture and food, is widely distributed in northeastern Mexico in altitudes from 0 – 1200 m.a.s.l. This species grows mainly at low altitudes and its upper limit reaches 1000m., it prefers temperatures above 18.3 °C and its production and harvest may occur at two seasons, one during the beginning of the summer and the main one occurring in the middle of the autumn in northeast México (Martínez-Ávalos *et al.*, 2018). Among the 5 cultivated species of the genus *Capsicum*, *C. annuum* is the most widely cultivated in India for its pungent (chilli syn. hot pepper) and non-pungent (sweet pepper syn. capsicum, bell pepper) fruits. The cultivation of Pepper (chilli and sweet) market types prevalent in India can broadly be grouped into the following 4 categories: (i)

fresh market (green, red, multi-color whole fruits), (ii) fresh processing (sauce, paste, canning, pickling), (iii) dried spice (whole fruits and powder), and (iv) industrial extracts (paprika oleoresin, capsaicinoids and carotenoids). Besides conventional nutritional food uses, a number of versatile food (paprika oleoresin) and non-food (defense, spiritual, ethnobotanical) uses of chillies are known (Reddy *et al.*, 2022).

Grouping of *Capsicum annuum*: *Capsicum annuum*, the genus type species, is often grouped with *C. frutescens* (chillies, hot or tabasco pepper) as species *C. annuum* sensu lato. In the literature, the rich variation of *C. annuum* sensu stricto has mainly been classified according to fruit shape, but there is no satisfactory cultivar group classification. Recently it was described fruit morphology of five varieties of *C. annuum*. A common grouping of cultivar groups for *C. annuum* is as follows: (CABI, 2023)

- Abbeviatum; fruits ovate, wrinkled, 2-5 cm long. Also called wrinkled pepper;
- Acuminatum; fruits slender, curved, up to 11 cm long, mild to extremely pungent. Also called chilli;
- Cerasiforme; fruits globose with firm flesh, up to 2.5 cm in diameter, mild to pungent, red, yellow or purple. Also called cherry pepper or bird's eye pepper;
- Conoides; fruits subconical, up to 3 cm long, very pungent. Also called cone pepper;
- Fasciculatum; fruits clustered, erect, up to 7.5 cm long, very pungent. Also called cluster pepper;
- Grossum; fruits large with basal depression, inflated, red, orange, yellow, or purple, flesh thick and mild. Also called sweet pepper or paprika;
- Longum; fruits drooping, up to 30 cm long, mild or pungent, red, yellow or whitish. Also called long pepper (CABI, 2023).

Bhut Jolokia- New Species of Assam: *Capsicum assamicum* is illustrated and described as a new species, with a note on its 'internal transcribed spacer' based molecular phylogeny and differential proteomic analysis. It is closely related to *C. frutescens* and *C. chinense*, but can be distinguished by its profusely branched habit, yellow green corolla, pale blue anther, orange red and sub-conical to conical fruits with rough, uneven, dented skin, and anatomical details of the stem (Purkayastha *et al.*, 2012). Hottest pepper in the World, Bhoot Jolokia, Ghost pepper was earlier considered as hybrid between *C. frutescens* and *C. chinense*, but described as independent species in 2012. The species is differentiated by its profusely branched habit, two flowered clusters, yellow green corolla, orange red conical fruit with dented surface when mature. Bhut Jolokia often considered as hybrid between *C. chinensis* and *C. frutescens*, Flora of Assam treated it under *C. chinensis*, has been recognised as distinct species *Capsicum assamicum* J. Purkay. & Lok. Singh, 2012. Catalogue of life treats it accepted name. It was once considered as hottest pepper with Scovelli Heat Unit (SHG) of 1,041,047 (Eflora, 2016). Verma *et al.* (2013) and Roy (2016) opined that *C. assamicum* is nothing but *C. chinense*. India's hottest chilli 'Bhoot Jolokia', or 'Bih Jolokia' earlier identified as *Capsicum chinense*, now identified as *Capsicum assamicum* Purakayastha *et al.*, as new species from Assam, India. But after the detail investigation as well as literature survey it has been found the new species has no novel characters other than *Capsicum chinense* Jacq. Hence the establishment of the species is in question (Verma *et al.*, 2013).

BOTANICAL DESCRIPTION

The *Capsicum* plant (*C. annuum* L.) is a tender perennial subshrub, with a densely branched stem. The plant reaches 0.5–1.5 m. Single white flowers develop into the fruit, which is typically green when unripe, but may lack chlorophyll causing a white color. Ripening fruits usually change to red, although some varieties may ripen to yellow, orange, peach, brown, or purple. The species are grown in temperate climates as an annual, but they are especially productive in warm and dry climates (Hultquist, 2019). Shrubs, subshrubs, rarely trees, vines or short-lived perennials or annuals, occasionally with a

thick lignified xylopodium, glabrous or glabrescent or sparsely to densely pubescent with simple, branched, eglandular or glandular, uniseriate trichomes. Stems woody at the base, sometimes with fissured bark and lenticels; young stems angled, herbaceous, usually weak and fragile and occasionally somewhat scrambling. Sympodial units difoliate or unifoliate, the leaves usually geminate, blades simple, entire, concolorous or discolorous, glabrous to densely pubescent with eglandular and/or glandular simple or branched uniseriate trichomes; petioles generally well-developed. Inflorescences axillary, usually unbranched (rarely branched), with few to many (up to 20 or more) flowers clustered or, more rarely, on short rachis or spaced along an elongate rachis, sometimes with flowers solitary or paired. Flowers 5-merous (4–8-merous in domesticated species), actinomorphic, all perfect. Pedicels erect, slightly spreading or pendent, geniculate at their distal end or non-geniculate. Calyx truncate, entire, circular or five-angled in outline, often with 3–10 appendages. Corolla stellate, rotate-stellate, campanulate or campanulate-urceolate, entirely white, yellow, violet or fuchsia or with greenish-yellow and/or maroons or purple spots within, rarely entirely greenish-white or mostly purple, the lobes spreading or reflexed at anthesis, usually with interpetalar membrane. Stamens five (up to eight in domesticated species), usually equal (rarely unequal), the filaments glabrous and broadened at the base to form a staminal plaque fused to the corolla base, each plaque with two short lateral auricles, the anthers dorsifixed, ellipsoid or ovoid, yellow, cream or blue to purple, connivent in pre-anthesis, usually free when mature, dehiscent by longitudinal slits. Gynoecium usually bicarpellate, rarely 3–4-carpellate; ovary superior, glabrous, subglobose to ovoid (rarely ellipsoid), with an annular nectary at the base; styles straight or slightly curved, cylindrical or clavate, glabrous, commonly exerted beyond the anthers, sometimes heteromorphic (long, medium and short styles); stigma globose or discoid, sometimes somewhat bilobed, finely papillate. Fruit glabrous berry, globose, subglobose or somewhat elongate, the mesocarp juicy, the pericarp red, orange-red, greenish-golden yellow or, rarely, dark burgundy or purple-blue at maturity (in domesticated species, fruits of various shapes and colours), pungent or not; fruiting pedicels erect or deflexed; fruiting calyx discoid or campanulate, not accrescent or slightly accrescent. Seeds flattened to slightly angled, mostly C- or D-shaped, subglobose or ellipsoid (rarely reniform or teardrop-shaped), pale yellow to yellow, brownish-yellow to brown or brownish-black to black, seed coat smooth, reticulate or reticulate marginally tuberculate. Stone cells absent or present, if present, not more than six. Embryo usually imbricate (less frequently annular or coiled); endosperm firm, whitish and relatively abundant. Chromosome number: $2n = 24, 26$ (Barboza *et al.*, 2022) (Fig. 7).

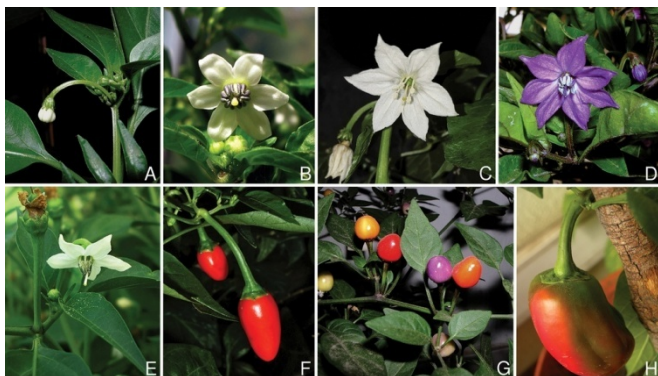


Fig. 7. *Capsicum annuum* var. *annuum*. A. flower bud on pendent pedicel; B. flower with connivent anthers; C. flower with hexamerous corolla (note nectar droplets on the limb) and style near the same length as the anthers; D. flower with heptamerous purple corolla; E. flower with pentamerous corolla and style exceeding the anthers; F. mature fruits on upright pedicels; G. mature fruits on pendent pedicels; H. mature fruits on pendent pedicels

A very variable, normally annual herb or subshrub, 0.5-1.5 m tall, erect, much branched, grown as an annual. Taproot strong, lateral roots numerous. Stem irregularly angular to subterete, up to 1 cm in diameter, much branched, often tomentose near branchings, green to

brown-green, often with purplish spots near nodes. Leaves alternate, simple, very variable; petiole up to 10 cm long; leaf-blade ovate, up to 10(-16) cm x 5(-8) cm, acuminate at apex, margin usually entire, subglabrous, light to dark green. Flowers usually borne singly, terminal; pedicel up to 3 cm long in flower, up to 8 cm long in fruit; calyx cup-shaped, persistent and enlarging in fruit, usually with 5 conspicuous teeth; corolla campanulate to rotate with five to seven lobes, 8-15 mm in diameter, usually white; five to seven stamens with pale blue to purplish anthers; ovary 2(-4)-locular, style filiform, white or purplish, stigma capitate. Fruit a non-pulpy berry, very variable in size, shape, colour and degree of pungency, usually more or less conical, up to 30 cm long, green, yellow, cream or purplish when immature, red, orange, yellow, brown when mature. Seed orbicular, flattened, 3-4.5 mm in diameter, approximately 1 mm thick, pale yellow (CABI, 2023). The plant is an herb or small shrub that grows to a height of 0.3–1.2 metres and a width of 15–30 cm. Its glossy leaves are roughly oval in shape with smooth margins and can reach up to 7.5 cm in length. The leaves of some cultivars turn dark purple or black as the plant grows. The star- or bell-shaped flowers have 4–5 petals and are white, greenish, or purple or lavender in colour. The fruits are true berries and come in many shapes and sizes. For example, bell peppers are large, roundish, and furrowed, whereas cayenne peppers are long and thin. Depending on the cultivar, the fruits may be green, red, yellow, orange, or black, and many change colour as they mature. Given that the myriad of forms cross-pollinate easily, varieties and cultivars are often difficult to quantify and are usually classified by characteristics of the fruits, such as size, shape, colour, flavour, and pungency (Sottosanti, 2023). Cayenne or Capsicum derives its name from the Greek, 'to bite,' in allusion to the hot pungent properties of the fruits and seeds. Green chilli is almost essential to Indian cooking. Most of the varieties of pepper referred to as chili peppers belong to *C. annuum* L. It is a shrub or annual or perennial herb, 20-80 cm tall, with stems becoming hairless. Leaves are solitary or paired; leaf-stalk 4-7 cm; leaf blade oblong-ovate, ovate, or ovate-lance-shaped, 4-13 x 1.5-4 cm, becoming hairless, base narrowed, margin entire, tip short tapering or pointed. Inflorescences solitary, flowers or few-flowered clusters. Flower-stalks are bent at tip, 1-2 cm. Sepal-cup cup-shaped, wavy, 2-3 x 3 mm. Flowers are white, about 1 cm, anthers purplish, 1.8-2 mm. Capsicum fruits are orange, yellow, or purple colored, variously shaped. Chilli fruit is mostly red (Garg, 2023). Chili peppers (*C. annuum* L.) are perennial woody plants grown as herbaceous annuals. It is said to be the first-ever domesticated crop in America. The size of the plant can range from two to four feet tall, depending on the species. Typically, leaves are smooth, simple, entire, glabrous, and flat. The flowers are usually solitary, creamy white, and the seeds are straw-colored. In Capsicum there are four different types of plants (Fig. 8). In addition, chili plants are grown for ornamental purposes, owing to their bright, shining fruits with a diverse range of colors (Saxena *et al.*, 2016).



Fig. 8. Different types of chili plants

Small chili pepper is an erect, branched and half-woody plant, growing to a height of 0.8 to 1.5 meters. Leaves are oblong-ovate to ovate-lanceolate, 3 to 10 centimeters long, and pointed at the tip. Flowers are solitary or several in each axil, stalked, pale green or yellowish-green, and 8 to 9 millimeters in diameter. Fruit is commonly red when ripe, oblong-lanceolate, 1.5 to 2.5 centimeters long. Seeds are numerous and discoid. (La jiao, 2020). Chili peppers are perennial woody plants grown as herbaceous annuals. It is said to be the first-ever domesticated crop in America. The size of the plant can range from two to four feet tall, depending on the species. Typically, leaves are smooth, simple, entire, glabrous, and flat. The flowers are usually solitary, creamy white, and the seeds are straw-colored. In addition, chili plants are grown for ornamental purposes, owing to their bright, shining fruits with a diverse range of colors (Dhamodharan *et al.*, 2022). Chilli shrubs are perennial and short-lived. They can grow up to 1.5 m in height. Their stems are woody at the base, fleshy and either erect or semi-prostrate. The shrub consists of a main tap root with many lateral roots. The leaves can grow up to 12 cm long and 7.5 cm wide and are unequal in shape with a pointed tip. Chilli flowers occur singly or in small groups of two to three flowers. They are small and bisexual, have five to six petals each. Flowers of *Capsicum annuum* are white-green, while those of *Capsicum frutescens* are yellow or white-green. The chilli fruit is hollow with many seeds. They are found in different colours like green, orange, white, yellow and red. Pungency varies in different varieties. Red chillies get their colour from a colouring compound called capsanthin and have a hot, pungent taste due to a chemical called capsaicin. The numerous small chilli seeds also contain capsaicin (Ratnala, 2023).

GENETICS AND CYTOGENETICS

There is a list of known genes can be useful to pepper breeders. The list started with 50 genes in 1965, nowadays there is the total of 292 different genes, such as *dw-1* (dwarf, plants with 15 or 20 cm in height), *Ef* (early flowering), *me-2* (*Meloidogyne* spp. resistance) and others (Padilha and Barbieri, 2016). The pungent flavour of red pepper types is due to the alkaloid capsaicin but the sweet or bell types are only slightly pungent. Pungent flavour is reported to be genetically dominant over non-pungent flavour (Vidhi, 2023). *Capsicum* species are diploids, with most having 24 chromosomes ($n = x = 12$) (MacBryde, 2006). The total length of the chili pepper genome has been estimated to be between 1498 cM and 2268 cM, which is approximately two to three times larger than the tomato genome (MacBryde, 2006). Chili peppers (*Capsicum*) are diploid and predominantly perform self pollination. In comparison level, the size of *C. annuum* genome (3.48GB) is around three to four times larger than tomato size (*Solanum lycopersicum*). The average exon/intron length is 286.5 bp/541.6 bp; Number of genes is around 34,900; Total length of transposable elements 2.34 Gb (76.4%). The hot pepper genome shared highly conserved syntenic blocks with the genome of tomato, its closest relative within the Solanaceae family (Padilha and Barbieri, 2016). *In situ* nuclear DNA contents varied significantly between 23 *C. annuum* genotypes with somatic chromosome number $2n = 24$. *Capsicum* cytogenetic analyses in India were carried out by a few groups, especially at Andhra University, Vishakhapatnam (Reddy *et al.*, 2022). Most *Capsicum* species are $2n=2x=24$. All are diploid. The *Capsicum annuum* and *Capsicum chinense* genomes were completed in 2014. The *Capsicum annuum* genome is approximately 3.48 Gb, making it larger than the human genome. Over 75% of the pepper genome is composed of transposable elements, mostly *Gypsy* elements, distributed widely throughout the genome. The distribution of transposable elements is inversely correlated with gene density. Pepper is predicted to have 34,903 genes (Wikipedia, 2023).

GENETIC DIVERSITY

Cultivated *Capsicum annuum* var. *annuum* is very diverse regionally and worldwide, having a wealth of innumerable strains, landraces and varieties that defy both facile description and clustering into an inclusive and practicable classification. Sometimes typical characteristics (fruit shape, size, and pungency) have been featured

and organised, recognising the Cerasiforme Group (cherry peppers), Conoides Group (conical peppers), Longum Group (*e.g.*, Cayenne peppers) and Grossum Group (blocky sweet or bell peppers), but as more plants are considered the array of variations and combinations of notable traits increases (*e.g.*, fruit sizes and shapes intermediate, whether fruits are erect or pendent), and the groups become less distinct and meaningful (MacBryde, 2006.). Variations in the fruit morphological features of *Capsicum annuum* varieties were studied. Varieties studied include var. *abbreviatum*, var. *annuum*, var. *accuminatum*, var. *grossum*, and var. *glabriusculum*. The fruit morphology revealed attenuated fruit shape with rounded surfaces in var. *glabriusculum*, and cordate fruit shape with flexuous surface in var. *annuum*, *abbreviatum* and *accuminatum*. The fruit is a berry and may be green, yellow, or red when ripe. The fruit epidermal cell-wall patterns are polygonal in shape with straight and curved anticlinal walls in all the five varieties. The fruit of var. *abbreviatum* and var. *grossum* is trilocular, while that of var. *accuminatum* and *annuum* is bilocular, and that of var. *glabriusculum* is tetralocular. *Capsicum annuum* var. *glabriusculum* had the highest mean number of seeds (108.4) and var. *annuum* had the lowest number of seeds (41.3) per fruit. The fruit is conspicuously hollowed in var. *glabriusculum*, *accuminatum*, and *annuum* but inconspicuously hollowed in var. *abbreviatum* and var. *grossum*. These features are shown to be good taxonomic characters for delimiting the five varieties of *Capsicum annuum* (Zhigila *et al.*, 2014). Fruits of *Capsicum* can vary tremendously in color, shape, and size both between and within species, which has led to confusion over the relationships among taxa. Chemosystematic studies helped distinguish the difference between varieties and species (Wikipedia, 2023) (Fig. 9).



Fig. 9. Genetic Diversity in fruits of *Cpsicum annuum*

Capsicum and chilli varieties are many and produce fruit with a wide range of shapes and colours. Chilli varieties range widely in pungency. Chilli varieties also range widely in pungency (GWA, 2016). The term chilli refers to fruit which is usually cone-shaped and smaller and the pungency may be mild to intensely hot. The main compound responsible for pungency is capsaicin. Within a chilli variety, the greatest pungency is with small, red fruit, especially in the cross-walls, close to the seeds and pith area (GWA, 2016). Capsicum exhibits extensive morphological variation, especially in fruit size, shape, and color. Inflorescences range from single to seven flowers at single node. The calyx may vary from long, spine like projections to truncate sepals to green sepals. The corolla is infrequently campanulate with variable coloration between different species. Pubescence of stems and leaves vary from glabrous to pubescent. Seeds are cream colored to black seeds (Kulkarni *et al*, 2017). Bell pepper, also known as sweet pepper or a pepper and capsicum, is a cultivar group of the species *Capsicum annuum*. Cultivars of the plant produce fruits in different colors, including red, yellow, orange, green, chocolate/brown, vanilla/white, and purple. Bell peppers are sometimes grouped with less pungent pepper varieties as sweet peppers. Wider variation was found for fruit shape. As per consumer's preference blocky fruits are more preferable and higher percentage of blocky fruits were observed (38.09%) and others were Campanulate (33.33%), Triangular (14.28%), Elongate (9.52%) and Tomato (4.72%) (Fig. 10). Fruits are categorized into three categories based on fruit shape at blossom end as like; Sunken (61.90%), Pointed (23.80%) and Blunt (14.28%). Fruit shape at pedicel attachment was found obtuse (14.28%), truncate (19.04%) and lobate (66.66%). Blocky fruit shape, lobate pedicel attachment, sunken blossom end, pendent fruit position and dark green fruit colour at maturity are desirable horticultural attributes (Ferdousi *et al*, 2021).

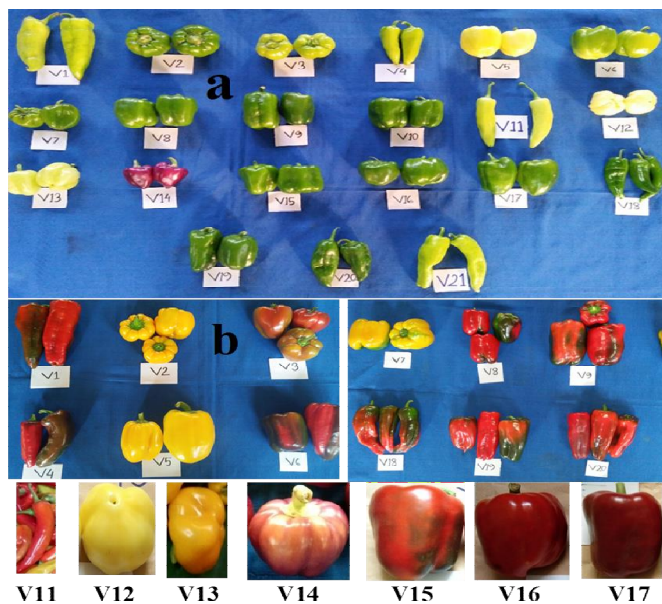


Fig. 10. Variation of fruit color, shape and size at (a) intermediate stage and (b) mature stage. (Here; V1- AVPP 0701; V2- AVPP 0402; V3- AVPP 0504; V4- AVPP 9807; V5- AVPP 0408; V6- AVPP 1112; V7- AVPP 1115; V8- AVPP 0019; V9- BARI M1; V10- BARI M2; V11- LS; V12- WBP 107; V13- YEP 054; V14- PBP 057; V15- RBP 040; V16- PL 730; V17- CA 008; V18- CA 010; V19- CA 009; V20- CA 012 and V21- CA 011)

It can be concluded that a distinct morphological variation was observed among twenty-one sweet pepper genotypes. Among different morphological traits studied, a higher frequency was observed for nodal anthocyanin, dark green leaves, intermediate branching habit and flower position, blocky fruit shape, green and red color of fruit, sunken blossom end shape etc. indicating fitness of genotypes. The study suggested that the genotypes like AVPP 0701, 0504, 0408 and 0019; BARI M1; CA 008 exhibited distinct variation in various aspects while PBP 057 having purple color can be used in future breeding program for the development of superior open pollinated varieties or hybrids in Bangladesh for higher yield and quality improvement of sweet pepper (Ferdousi *et al*, 2021). High

genetic variability was found in fruits and seeds of 23 pepper genotypes based on 12 qualitative and eight quantitative descriptors. The evaluation of collected and evaluated germplasm under a multivariate statistical approach provided a unique opportunity to select superior genotypes (G1 and G15) and to identify quantitative characters associated with *C. chinense* and *C. annuum* species. This genetically heterotic germplasm can be used to develop new cultivars (Sampaio *et al.*, 2023).

BREEDING

Germplasm Sources: (Vidhi, 2023)

Capsicum genetic resources are being maintained in the following Organizations (Vidhi, 2023):

- Southern Plant Introduction Station, Griffin, Georgia, USA- approximately 3000 accessions, evaluation data entered in the Germplasm Resources Information Network (GRIN), a centralized computer database system
- Asian Vegetable Research and Development Centre (AVRDC), Shanhua, Tainan, Taiwan – About 7500 base/active collection
- Centra Agronomic Tropical de Investigaciones y Enseñanza (CATIE), Turrialba, Costa Rica
- Centre for Genetic Resources, Wageningen, the Netherlands
- Central Institute of Genetics and Germplasm, Gatersleben, Germany
- National Bureau of Plant Genetic Resources, New Delhi, India
- Indian Institute of Vegetable Research, Varanasi, India.

Breeding history

The genetic inheritance of important agro-horticultural traits, mutant forms, male sterility, disease, pest resistance, and quality characteristics were all required for the purpose of early capsicum study. It has been said in a number of places that these characteristics are driven by single genes with a dominant or recessive mode of action, and that some of these characteristics are governed by quantitative trait loci. *Capsicum annuum* is by far the most significant member of the *Capsicum* family, owing to the fact that it is the species of the genus *Capsicum* that is most often economically produced. When plant breeding first started, it was based mostly on the ability of individuals to be selected, which was a time-consuming and unstructured process. Bringing the notions of Mendelian genetics and inheritance into the field of vegetable breeding was a pivotal moment in the history of the field. Currently, plant breeders are using a variety of ways to select for desirable characteristics in their crops, with the methodology chosen depending on the objectives of the breeding programme. The primary goals of capsicum breeders are genetic enhancement in productivity, biotic and abiotic resistance and nutraceutical compounds (Selvakumar *et al.*, 2022).

Breeding Objectives

The main objectives of peppers genetic breeding are characteristics such as productivity, disease and pests resistance, fruit characteristics (bioactive compounds, fruit color, pungency, flavor), and abiotic stresses (drought, salinity). The search for the hottest pepper is one of the goals in breeding programs. For profit, and with aid of advertising to attract "peppers lovers", breeding companies use techniques to obtain hybrid increasingly hot. In 1992 "*Habanero*" pepper (*Capsicum chinense*) was the most stinging pepper in the world with around 200,000 SHU (Scoville unit for measuring pungency). Currently, there are several cultivars known as "nuclear peppers", all belonging to the species *C. chinense*, reaching over 1,000,000 SHU. Examples of this type of pepper cultivars: Bhut Jolokia, Trinidad 7-pot Jonah, Trinidad Scorpion, Naga Morich, Trinidad Moranas, Trinidad Moruga Scorpion The last cultivar launched was "Carolina Reaper" (*C. chinense*), developed by the American company. This cultivar exceeds 1,569,300 SHU, being recognized the hottest pepper in the

world by Guinness Book (Padilha and Barbieri, 2016). According to Selvakumar *et al.* (2022) a variety of colors, including medium or dark green at the unripe stage and red, yellow, or orange at the mature stage, are among the key targets of genetic enhancement of sweet peppers. Research in this initiative aims to find and develop new varieties of capsicum that are rich sources of antioxidants as well as vitamins. Flavonoids and carotenoids (red, yellow, and orange carotenoids), which contain vitamin A precursors such as alpha and beta carotene, as well as β -cryptoxanthin are also included in this category. Breeding efforts are also focused at increasing fruit set and yield in varying climatic situations, including open and protected. Low temperatures, drought, and salt stress are all being studied as part of breeding efforts to combat abiotic threats. Breeding for long-term storage stability of carotenoid extract and resistance to *Phytophthora* fruit rot are also on the research agenda. Powdery mildew, anthracnose, *Phytophthora* fruit rot, bacterial wilt and viruses, are some of the most common diseases that affect sweet peppers in open-field as well as in the green house production. Another important objective is to develop sweet pepper genotypes that are more tolerant to tropicalization, since this is a cool-season crop. Produce will be accessible throughout the year for a longer amount of time in places that are not usual. The primary breeding goals in protected culture are to develop sweet pepper lines with an indeterminate growth habit, tolerant to training and pruning systems, blocky fruit, resistance to biotic stress, and resistance to root-knot nematode.

Vidhi (2023) listed the following breeding objectives of Capsicum:

- Earliness
- Desirable fruit shape and size (oblate or round fruit in bell pepper and long fruits in chilli), segment-wise fruit shape, size, wrinkleness, fruit colour, seed content and pungency in Indian context
- Superior fruit quality (pleasing flavour, high sugar/acid ratio, high pigment content and vitamin C in bell pepper and high capsaicin, $C_{18}H_{27}NO_3$ (a fat soluble, flavour-less, odourless and colourless compound))
- High oleoresin in chilli
- Resistance to diseases (fruit rot, cercospora leaf spot, powdery mildew, bacterial leaf spot, *Phytophthora* root rot, root knot, common leaf-curl virus)
- Resistance/tolerance to insects (thrips, mite, aphid, fruit borer)
- Resistance/tolerance to abiotic stresses (heat, water stress, salinity)
- Rejuvenation ability after winter in hot-pepper in north India
- High yield
- Colour retention in dry chillies on drying

Breeding

Chilli (*Capsicum annuum*) is an important commercial and export-oriented crop in India. An overview of chilli breeding research in India has been given. Germplasm sources resistant to *Chilli/pepper leaf curl virus* (ChiLCV) *Chilli veinlet mottle virus* (ChiMoV), *Cucumber mosaic virus* (CMV), anthracnose, bacterial wilt, nematodes and powdery mildew have been identified and used in current breeding programs. The northeast region has emerged as having a novel diversity in the cultivated species of the genus *Capsicum*. Nuclear and cytoplasmic male sterility system have been developed and exploited at commercial scale to develop hybrids and their seeds. The developmental accomplishments including national releases of commercial chilli cultivars (open pollinated varieties and hybrids) (Reddy *et al.*, 2014). The World Vegetable Center in Taiwan holds the world's largest *Capsicum* collection of 8165 accessions, and covers 11% of global diversity. Besides traditionally-important traits like earliness and higher yield, bell pepper breeding is now challenged by the emergence of new pests and diseases. New varieties are needed with desirable fruit color, pungency, shape and nutritional quality, along with resistance to phytophthora, anthracnose, bacteria, viruses, powdery mildews, root-knot nematodes, heat, cold, drought and salinity tolerance; all of these characteristics represent major breeding goals along with higher yields (Sagar *et al.*, 2021). Conventional breeding methods like introduction, pure line selection,

pedigree selection, mutational and heterosis breeding, and backcross breeding are now being assisted by new breeding approaches like rootstock breeding along with modern genomic tools to break down existing barriers, and to speed up traditional breeding programs (Sagar *et al.*, 2021). Development and implementation of hybrid cultivars are key aspects of bell pepper production, for which the genetic male sterility system is being exploited commercially in both the public and private sectors. However, in comparison of chili pepper, utilization of the cytoplasmic male sterility (CMS) system in bell pepper is restricted, owing to high instability of male sterility expression at low temperature, and poor fertility restoration (*Rf*) ability. This chapter describes recent advances in genetic improvement of bell pepper by using various cultivated and wild species as sources of important traits (Sagar *et al.*, 2021). Many types of peppers have been bred for heat, size, and yield. Along with selection of specific fruit traits such as flavor and color, specific pest, disease and abiotic stress resistances are continually being selected. Breeding occurs in several environments dependent on the use of the final variety including but not limited to: conventional, organic, hydroponic, green house and shade house production environments (Wikipedia, 2023). *Capsicum* breeding began with choosing wild species for desired characteristics, with additional development based on precision selection. To improve capsicum yields, traditional methods such as mass selection, pedigree, single-seed descent, backcrossing, and hybridization are being used. Molecular technology has grown into an important tool that, when coupled with classic selection and hybridization procedures, has the potential to result in great success in an established capsicum genetic breeding programme (Selvakumar *et al.*, 2022).

Breeding Methods

Mass selection: The nutritive value of chili pepper is largely determined by ascorbic acid content. The fruits at five ripening stages viz., (M_1 , M_2 , M_3 , M_4 and M_5) from seventeen cultivars of *Capsicum annuum* L and one cultivar of *Capsicum frutescens* L were analyzed for ascorbic acid content. Among eighteen genotypes the *C. annuum* var. IC: 119262(CA₂) showed higher ascorbic acid content (mg/100g FW i.e., 208.0±0.68 (M_1), 231.0±0.66 (M_2), 280.0±0.31 (M_3), 253.0±0.34 (M_4) and 173.7±0.27 (M_5). The present study reports that the ascorbic acid content in eighteen genotypes of *Capsicum* L showed variation from one another, among the genotypes CA₂ represents more ascorbic acid. The study revealed that ascorbic acid content increased from green to red while, decreased in red partially dried and red fully dried fruits. The variability of ascorbic acid content in the genotypes suggests that these selected genotypes may be use full as parents in hybridization programs to produce fruits with good nutritional values (Kumar and Tata, 2009). Mass selection and Pedigree method (or Genealogical method), Single Seed Descent - SSD method, Backcross, Recurrent Selection and Hybridization are those more utilized. The choice of the best method or combination of them depends mainly on the type of inheritance (monogenic, oligogenic, or polygenic) from traits to be improved (Padilha and Barbieri, 2016). Mass selection were successfully utilized by indigenous peoples of tropical America, whereby seeds of the best plants were saved for the next growing season. This method should be used for populations with genetic variability and selected in environments where the traits express themselves and for those of high heritability. The pedigree method involves keeping records of matings and their progeny. This includes making single plant selections and self-pollination (Padilha and Barbieri, 2016).

The SSD (single seed descent method): This method does not need selection during the breeding process, is also utilized in the development of recombinant inbred lines (RILs). Advancement of generations can be performed in greenhouses (Padilha and Barbieri, 2016).

Recurrent selection: This involves selecting individuals from a population followed by intercrossing to form a new population (Padilha and Barbieri, 2016).

Backcross: This is used particularly for traits controlled by one or few genes, which involves selection of individual plants and successive crosses to a recurrent parent. Hybridization is an important factor in evolution of plants as a source of new genetic combinations and as a mechanism of speciation (Padilha and Barbieri, 2016).

Hybridization: Hybridization and pedigree breeding with simple selection methods can be used to improve most traits controlled by both additive and non-additive genes (Padilha and Barbieri, 2016). Pepper flowers are complete, they have calyx, corolla, and male and female sex organs. Thus, the hybrid plants can be produced using manual emasculation technique and subsequent pollination or using the system of male sterility. The manual emasculation technique is relatively easy due the distinction of sex organs. Technique consists in removing male structure (anthers - which contains pollen) and permanence of female structure (stigma). Crossings are run by the breeder, putting extracted pollen of the plant used as a parent on flower stigma of the plant used as mother.

that of *C. annuum*, all the more confusing. Most commercially grown and used capsicums belong to *C. annuum*, while the other three species are restricted in their occurrence and use and are little known outside the Latin American countries.

Important hilli Varieties Grown in India: Important Chilli Varieties grown in India are Bhut Jolokia (Eastern Region), Guntur (Andhra Pradesh), Kashmiri (Kashmir), Jwala (Gujrat), Kanthari/Bird Eye (Kerala), Byadagi (Karnataka), Ramnad Mundu.Gundu (Tamil Nadu), Dhani (Manipur), Madras Puri (Andhra Pradesh), Khola (Goa), Dalle Khursani (Sikkim), Naga Chili (Nagaland), Sankeshwari (Maharashtra) and Mathania (Rajasthan) (Maheshwat, 2021).

Important Capsicum Varieties Grown in India: Important Capsicum Varieties grown in India are Arka Mohni, Arka Basant, Arka Gaurav, Arka Athulya, Pusa Deepti, Pusa Meghdoot, Yolo Wonder, California Wonder, Chinese Giant, World Beater, Bharat,

Table 5. Main classical techniques used in *Capsicum* breeding program

Technique name	Principle
Mass selection	Seeds of the best plants were saved for the next growing season; oldest method
Pedigree method	Keeping records of matings and their progeny. This includes making single plant selections and self-pollination
SSD (Single seed descent)	This method involves the advance of generations without selection, it is also utilized in the development of recombinant inbred lines
Recurrent selection	Selecting individuals from a population followed by intercrossing to form a new population
Backcross	Used particularly for traits controlled by one or few genes, which involves selection of individual plants and successive crosses to a recurrent parent
Hybridization	Genes of one specie or variety move into another through the process of crossing
Biotechnology	The bud induction obtained is a simple and efficient protocol developed for <i>in vitro</i> propagation

Before this transaction, flower that will receive pollen is emasculated to avoid stigma contamination with own pollen. Cross flower is covered (e.g., with aluminum foil) to prevent insects action contaminated with foreign pollen, and its identified with label. However, seeds production of hybrid peppers originated from manual emasculation techniques has high cost. An alternative to solve this problem is the use of male sterility (Padilha and Barbieri, 2016). The male sterility in peppers can be found naturally, as spontaneous mutants or by action of mutagenic agents. There are several genes that determine male sterility and it can be genetic or cytoplasmic type. More than 20 genes have been found for genetic male sterility (GMS) (Padilha and Barbieri, 2016).

Biotechnology: The bud induction obtained is a simple and efficient protocol developed for *in vitro* propagation of five varieties of cultivars. Seeds of *Capsicum annuum* L. of five varieties red, yellow, green, purple and white were decontaminated and placed in a culture bottle containing a Murashige and Skoog medium, supplemented with 6-benzylaminopurine (BAP, 5 mg/l) and naphthalene acetic acid (NAA, 1 mg/l) or indole-3-acetic acid (IAA, 0.5 mg/l) and then were incubated in the dark for 10 - 12 days for germination. Leaf explants excised from 4 weeks -old aseptic seedlings were cultured on a MS medium supplemented with hormones BAP, kinetin (Kin), the combination of BAP + Kin, BAP with NAA (0.1 or 0.01 mg/l) and BAP with IAA (0.5 mg/l). The 2.0 mg/l BAP with 0.1 mg/l NAA media was observed to be more suitable for callus formation. The highest number of regenerated shoot buds was obtained when shoot explants were cultured on a MS medium supplemented with 2.0 mg/l BAP and 0.5 mg/l IAA. The mean number of shoot per explants was obtained in red (6.3), yellow (3.6), purple (3.3), and white (3.0) variety of *C. annuum* whereas 3.0 mg/l BAP and 0.5 mg/l IAA were observed to be more suitable for green (6.6) variety of *C. annuum*. Plantlets were successfully acclimatized in greenhouse (Swamy *et al.*, 2014). The main classical methods utilized in chili pepper breeding are listed in Table 5 (Padilha and Barbieri, 2016).

Varieties

Many hundreds of varieties and hybrids, both natural and artificial, which come in all shapes, colours, sizes and degrees of pungency make the classification of the domestic Capsicums and most notably

Solan Hybrid-2, Early Bounty, Hira, Lario, Bombay (Red), Orobelle (Yellow) and Indra (Green) (Delince, 2014).

Chili varieties recommended for national release in India

Varieties: G-4 or Bhagyalakshmi, G-5 or Andra Jyothi, K-2, J-218, Bhaskar or X-235 Muslawadi, Arka Lohit/Sel-1, LCA206-B, Phule C-5, AKC-86-39, BC-14-2, RHRC-Cluster Erect, PMR57/88-K, LCA-334, ASC-2000-02, KA-2 or Kashi Anmol, LCA-353, BC-25, PC-7, HS- HP-154, IVPBC-535 or Kashi Sinduri-Paprika, PC-56, VR-338, ACS-06-2, HOE-888, ARCH-236, Sungrow-86-235, ARCH-228.

Hybrids: Arka Meghana or MSH-172, Arka Sweta or MSH-149, CCH-2 or Kashi Surkh, KCH-3, CCH-3 or Kashi Early, BSS-453, NCH-587, VNR-332 or Rani, HH-41786, BSS-378, VNR-Vidya,

USES

Capsicum has significant economic value, for example as spices, vitamin, traditionally medicine, and as an ornamental plant (Djarwaningsih, 2005). Capsicums are used in salads, baked and stuffed dishes, stews, stir-fries, salsa, pizzas and cheeses, pickles and for stuffing olives. They may also be used for producing paprika which is used for colouring foods, flavouring and in sauces. Chillies are the most important spice crop in the world. They may be used fresh, in pickles, sauces, salsa, pizzas, flavouring and pastes. There is an increasing demand in Australia for new ways of using chillies for culinary use (GWA, 2016). Capsicum is an annual, perennial flowering shrub widely known for its fruit, commonly used fresh or cooked; as a dry powder for its flavor, aroma, and color or processed into oleoresins. Capsicum oleoresin is prepared commercially by solvent extraction of dried ripe fruit and subsequent solvent evaporation (Kulkarni *et al.*, 2017). Peppers are generally consumed fresh or processed for use as vegetables and spice. They may also be used as ornamental plants or as a source of extracts for use in various pharmaceutical or cosmetic products (Morris and Taylor, 2017). Chili is considered as one the first cultivated plants from Meso America and its continued use is confirmed from 7000 to 5000 years A.C. The wild chili pepper also known as chile piquín (*Capsicum annuum* var. *glabriusculum*) is very important in the Mexican culture and was

used as food since prehispanic times. It is used daily in the Mexican diet, either fresh green or red or dried, in dust, in brine, sauces, salads, moles, stuffed chili, sweet candies and many other presentations. Among the main uses of the chili in México are (Martínez-Ávalos *et al.*, 2018):

Ceremonial: Used by curanderos in different ceremonies, such as "cleaning" referring to avoid the bad vibes and is commonly used as cure for evil eye. It is used in ceremonial foods, rituals, and special parties, as for example with the Huicholes.

Medicinal: it is known that they were used by prehispanic ethnic groups *e.g.*, Aztecs used them to heal tooth ache, ear infections, constipation and labor pains, and these types of use was appreciated by the first Spaniards in America. It is used for the digestive system against dyspepsia, is also used for toothache, diarrhea, ear pain, cough and to lower fever, since the capsaicin activates blood circulation. There are some medicines that have been obtained from oleoresins from *Capsicum* spp., they act at the mucosa's alleviating respiratory ailments. May be the most popular remedy using chili in food for hangover. It was also used as punishment by the Aztecs as depicted at the Mendocino Code, they would make bad boys or children to inhale smoke from burning dried chillies. It is still used to stop children from sucking their fingers or to stop them from using the pacifier. Chili is also used mixed up with soap, onions and garlic as repellent against aphids in cultivated plants.

Ornamental: Chili is considered as an emblematic plant from the Mexican culture and it is used as ornament in dishes, altars, religious parties and amulets among others.

Gastronomic: May be this is the most common and important use in Mexico. There are many recipes using wild chili peppers and is considered as an important part of the gastronomy from different regions from Mexico. Another very important use of chili is in cosmetics, paints and foods and at the industry it is used to obtain oleoresins, and from them Capsaicin is obtained, and used in human and animal food *e.g.*, birds and even in personal defense.

La jiao (2020) listed the following uses: 1) Fruit is a popular condiment. 2) Mixed with or made into pickles, and is a principle ingredient in Indian curries. 3) The leaves are used as vegetable, with a very pleasant and somewhat piquant flavor. 4) In tropical countries, eaten fresh to promote digestion. 5) In Taiwan and the Batanes Islands, leaves used in soup. and 6) An excellent source of calcium and iron, a good source of phosphorus and vitamins A and B. According to Bhalabhai *et al.* (2021) since the ancient time, chili peppers have been used by human civilization. Chili has been specially used in the preparations of different culinary dishes and also in medicinal purposes as well. Barboza *et al.* (2022) reported that *Capsicum annuum* var. *annuum* is the economically most important member of the genus. The fruits are widely used in international cuisine in a broad spectrum of meals and preparations, because of their aroma, flavour, texture and level of pungency. Some cultivars have good acceptance as ornamental plants due to the colour of the leaves and the brightness of the colourful and usually erect fruits (*e.g.*, Christmas peppers, Bolivian rainbow). Chillies are used fresh or dried, whole or powdered in cooking to give food its characteristic hot, spicy and pungent taste. Chillies are pickled in salt, eaten raw in salads, made into sauces or stored in brine. A liquid chili extract is used in colouring food as well as animal feed. Chillies are a good source of Vitamin C. They also contain vitamins B1 and B2, beta carotene, protein, calcium and phosphorous (Ratnala, 2023). *Capsicum* fruits can be eaten raw or cooked. They are suitable for stuffing with fillings such as cheese, meat, or rice. They are also frequently used both chopped and raw in salads, or cooked in stir-fries or other mixed dishes. They can be sliced into strips and fried, roasted whole or in pieces, or chopped and incorporated into salsas or other sauces, of which they are often a main ingredient. They can be preserved in the form of a jam, or by drying, pickling, or freezing. Dried Capsicum may be reconstituted whole, or processed into flakes or powders. Pickled or marinated Capsicum are frequently added to

sandwiches or salads. Frozen Capsicum are used in stews, soups, and salsas. Extracts can be made and incorporated into hot sauces (Wikipedia, 2023). Larger, sweeter variants are called "capsicums" in Australia and New Zealand, "peppers" in the United Kingdom and Canada, and "bell peppers" in the United States. The smaller, hotter varieties are called chilis, chilies, chillies, chile, or chili peppers, or in parts of the US, "peppers". Capsinoid chemicals provide the distinctive tastes in *C. annuum* variants. In particular, capsaicin creates a burning sensation ("hotness"), which in extreme cases can last for several hours after ingestion. A measurement called the Scoville scale has been created to describe the hotness of peppers and other foods (INaturalist, 2023). Some cultivars grown specifically for their aesthetic value include the U.S. National Arboretum's 'Black Pearl' and the 'Bolivian Rainbow'. Ornamental varieties tend to have unusually colored fruit and foliage with colors such as black and purple being notable. All are edible, and most (like 'Royal Black') are hot (INaturalist, 2023).

Nutritional Value

The purpose of the study was to determine the nutritional value and antioxidant activity in an assortment of six pepper genotypes, depending on the variety (bell and sweet) and the color of the fruits (green, yellow and red). In this way, the content of dry matter, soluble substance, carbohydrates, acidity, vitamin C, antioxidant activities, total polyphenols and total flavonoids from fresh fruit have been investigated. In addition, were also studied the correlation coefficients between the quality parameters by Pearson Correlation. The obtained results indicate that the red sweet pepper genotypes recorded significant differences for most of the analyzes, highlighting the Slonovo Uvo cultivar with a content in polyphenols of 202.6 mg GAE/100g fw, in vitamin C of 204 mg/100g fw and antioxidant activity of 1376 μ M TE/100g fw. Significant positive correlations have been identified between soluble substance and carbohydrate content and between vitamin C and total phenol content, also in sweet pepper with redfruit (Soare *et al.*, 2017).

La jiao (2020) reported the following health benefits:

- Fruit contains the active principles: capsaicin, 0.14% and capsinin.
- Capsaicin (trans-8-methyl-N-vanillyl-6-nonenamide) is the principal pungent component in hot peppers, including red chili peppers, jalapeños, and habaneros.
- Cayenne pepper contains fatty oil, 15-20%; some volatile oil; capsaicin, 0.15 - 0.5%; starch, 0.8-1.4%; pentosans, 8.57%; and pectin, 2.33%.
- Study yielded two chemical compounds: Ortho- hydroxy- N-benzyl- 16- Methyl- 11, 14- diene- octadecamide and 9, 12-diene-octadecanoic acid.
- Yields ester, terpenoids, noncarotenoids, lipoxygenase derivatives, carbonyls, alcohols, hydrocarbons, capsaicin, dihydrocapsaicin, capsinoninoid, and capsinoid.
- Qualitative studies have yielded the presence of reducing compounds saponins, alkaloid salts, alkaloids, quaternary bases, anthracenosides, flavanosides, flavonols, coumarin derivatives, steroid glycosides, and anthocyanosides. (28)

Chili peppers are a good source of dietary fiber, riboflavin, thiamin, folate, niacin, iron, protein, phosphorus, and copper. Aside from that, it also contains high amounts of vitamin A, vitamin C, vitamin K, vitamin E, vitamin B6, potassium, and manganese. Chili fruits are also rich in many phytochemicals such as carotenoids (lutein, β -carotene, β -cryptoxanthin, zeaxanthin, violaxanthin, and capsanthin), capsaicinoids (capsaicin, dihydrocapsaicin, nordihydrocapsaicin, homocapsaicin, homodihydrocapsaicin, and nonivamide), and flavonoids (quercetin, luteolin, kaempferol, catechin, epicatechin, rutin, apigenin, myricetin, and cyanidin) (Dhamodharan *et al.*, 2020). Morphological and anatomical characteristics vary in different commercial varieties. *Capsicum* spp. contains significant number of bioactive compounds and dietary antioxidants. The principal

bioactive component in chilli is Capsaicin which is accountable for its pungent taste and several health benefits. It plays crucial role in the treatment of cardiovascular diseases. Red color of ripe *Capsicum* spp. is due to the powerful antioxidant compound Capsanthin. *Capsicum* spp. also contains various vitamins, and among them the amount of vitamin C is highest. From the ancient time *Capsicum* spp. has been used to cure several common problems such as high cholesterol, skin problems, stomachic and other pains (Bhalabhai *et al.*, 2021).

Capsicum spp. contains different vitamins, minerals and amino acid which are very beneficial for our nourishment and better health. It has high amount of vitamin C and other vitamins such as vitamin A, E and B-complex group of vitamins such as a thiamin (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3) and pyridoxine (vitamin B6). Some minerals such as a potassium, iron, manganese, magnesium and many different flavonoids like lutein, zeaxanthin, β -carotene, α -carotene, cryptoxanthin are also present in chili pepper. The amount of nutritional constituents present in 100 g chilli of different form such as raw green, raw red, and cayenne or spices are represented in Table 6 and 7 (Bhalabhai *et al.*, 2021).

Table 6. Major components of *Capsicum* spp.

Constituents	Raw green chilli	Raw red chilli	Spices or Cayenne
Calories	40.0 (167 kJ)	18.0 (75.4kJ)	16.7 (69.9 J)
Carbohydrate	33.4 (140 kJ)	14.3 (59.9 kJ)	7.0 (29.3 kJ)
Fat	1.7 (7.1 kJ)	1.7 (7.1 kJ)	7.6 (31.8 kJ)
Protein	4.9 (20.5kJ)	2.1 (8.8 kJ)	2.1 (8.8 kJ)

Table 7. Other Components of *Capsicum* spp.

Constituents	Raw green chilli	Raw red chilli	Spices or Cayenne
Carbohydrate	04.3 g	4.0 g	3.0 g
Dietary fiber	0.7 g	0.7 g	1.4 g
Sugars	2.3 g	2.4 g	0.5 g
Total fat	0.1 g	0.2 g	0.9 g
Saturated fat	0.0 g	0.0 g	0.2 g
Monounsaturated fat	0.0 g	0.0 g	0.1 g
Polyunsaturated fat	0.0 g	0.1 g	0.4 g
Total omega-3 fatty acids	2.3 g	5.0 mg	34.6 mg
Total omega-6 fatty acids	46.8 mg	103 mg	405 mg
Protein	0.9 g	0.8 g	0.6 g
Tryptophan	11.7 mg	11.7 mg	-
Threonine	33.3 mg	33.3 mg	-
Isoleucine	29.3 mg	29.3 mg	-
Leucine	47.3 mg	47.3 mg	-
Lysine	40.0 mg	40.0 mg	-
Methionine	10.8 mg	10.8 mg	-
Cystine	17.1 mg	17.1 mg	-
Phenylalanine	27.9 mg	27.9 mg	-
Tyrosine	18.9 mg	18.9 mg	-
Arginine	43.2 mg	43.2 mg	-
Histidine	18.4 mg	18.4 mg	-
Alanine	36.9 mg	36.9 mg	-
Aspartic acid	129 mg	129 mg	-
Glutamic acid	119 mg	119 mg	-
Glycine	33.3 mg	33.3 mg	-
Proline	39.1 mg	39.1 mg	-
Serine	36.0 mg	36.0 mg	-
Vitamin A	530 IU	428 IU	2185 IU
Retinol	0.0 mcg	0.0 mcg	0.0
Retinol activity equiv.	26.5 mcg	21.6 mcg	109
α -carotene	10.4 mcg	16.2 mcg	0.0
β -carotene	302 mcg	240 mcg	1146
β -cryptoxanthin	22.5 mcg	18.0 mcg	328
Lycopene	0.0 mcg	0.0 mcg	0.0
Lutein + zeaxanthin	326 mcg	319 mcg	691
Vitamin C	109 mg	64.7 mg	4.0
Vitamin E (α - Tocopherol)	0.3 mg	0.3 mg	1.6

Vitamin K	6.4 mcg	6.3 mg	4.2
Thiamin	0.0 mg	0.0 mg	0.0
Riboflavin	0.0 mg	0.0 mg	0.0
Niacin	0.4 mg	0.6 mg	0.5
Vitamin B6	0.1 mg	0.2 mg	0.1
Folate	10.4 mcg	10.4 mcg	5.6
Food folate	10.4 mcg	10.4 mcg	5.6
Folic acid	0.0 mcg	0.0 mg	0.0
Dietary folate equiv.	10.4 mcg	10.4 mcg	5.6
Vitamin B12	0.0 mg	0.0 mcg	0.0
Pantothenic acid	0.0 mg	0.1 mg	-
Choline	5.0 mg	4.9 mg	2.7
Calcium	8.1 mg	6.3 mg	7.8 mg
Iron	0.5 mg	0.5 mg	0.4 mg
Magnesium	11.2 mg	10.4 mg	8.0 mg
Phosphorus	20.7 mg	19.4 mg	15.4 mg
Potassium	153 mg	145 mg	106 mg
Sodium	3.2 mg	4.0 mg	1.6 mg
zinc	0.1 mg	0.1 mg	0.1 mg
Copper	0.1 mg	0.1 mg	0.0 mg
Manganese	0.1 mg	0.1 mg	0.1 mg
Selenium	0.2 mg	0.2 mg	0.5 mg
Cholesterol	0.0 mg	0.0 mg	0.0 mg
Alcohol	0.0 g	0.0 g	0.0 mg
Water	39.5 g	39.6 g	0.4 g
Ash	0.3 mg	0.4 g	0.3 g
Caffeine	0.0 mg	0.0 mg	0.0 mg
Theobromine	0.0 mg	0.0 mg	0.0 mg

Several bioactive compounds are present in different species of *Capsicum*. For the evaluation of various constituents of chilli, different systematic techniques have been used such as gas chromatography and high-performance liquid chromatography. Through the use of these analytical techniques various compounds such as nordihydrocapsaicin, homocapsaicin and homodihydrocapsaicin can be detected from the *Capsicum* spp. Around 80-90% part of Capsaicinoid present in *Capsicum* spp. is made up of Capsaicin (8-methyl-N-vanillil-6-nonenamide). *Capsicum* spp. is a very important component in pharmaceuticals and has considerable biological efficacy. At the distinct phases of ripening in *Capsicum* spp. (*Capsicum annuum* var *annuum*), some major compounds like 2-isobutyl-3-methoxypyrazine, 2,3-butanedione, trans-2-hexenal, 3-carene, linalool and hexanal have been identified to be present. Oleoresin is an oil dissoluble decoction of *Capsicum* (especially in red fruits of chilli) and is also a significant element of chilli. A principal component of this oleoresin is again Capsaicin which is responsible for its flavor. Furthermore, carotenoids such as Capsorubin and Capsanthin are present in chilli which are important component for the color of red chilli (Bhalabhai *et al.*, 2021). Nutritional value of 100 g green pepper (Gudeshar, 2023): Calories: 40, Total Fat: 0.2 grams, Vitamin C : 404%, Iron : 6%, Vitamin B6 : 15%, Magnesium : 6%, Sodium: 7 mg, Potassium: 340 mg, Total Carbohydrates: 9 grams, Protein: 2 grams, Vitamin A: 2 grams and Calcium : 0.01. According to Dhamodharan *et al.* (2022) chilli peppers are a good source of dietary fiber, riboflavin, thiamin, folate, niacin, iron, protein, phosphorus, and copper. Aside from that, it also contains high amounts of vitamin A, vitamin C, vitamin K, vitamin E, vitamin B6, potassium, and manganese. Chili fruits are also rich in many phytochemicals such as carotenoids (lutein, β -carotene, β -cryptoxanthin, zeaxanthin, violaxanthin, and capsanthin), capsaicinoids (capsaicin, dihydrocapsaicin, nordihydrocapsaicin, homocapsaicin, homodihydrocapsaicin, and nonivamide), and flavonoids (quercetin, luteolin, kaempferol, catechin, epicatechin, rutin, apigenin, myricetin, and cyanidin).

Capsaicin content in *Capsicum*

Considering the importance of capsaicin in health and disease, and its commercial implications in the pharmaceutical and food industry, *Bhut jolokia* (*Capsicum chinense* Jacq) offers great potential for future exploitation due to its high capsaicinoid content (Roy, 2016). The capsaicin content in parts (placenta, seeds and periderm) of some peppers grown in some parts of Nigeria was evaluated. Capsaicin was extracted from the pepper parts was carried-out via the solvent

extraction technique using methanol. A Gas Chromatograph-Mass Spectrometer, (GCMS QP-2010, Shimadzu Analytical Instruments) was used for determination of capsaicin content. Capsaicin content was highest in the placenta, followed by the seeds for all the pepper samples utilized in the study. The outer flesh (periderm) had the lowest content of capsaicin. The capsaicin content of the placenta ranged from 1.1652 ± 0.0002 in the Yellow pepper from Nsukka (*Capsicum chinense*) to 0.3226 ± 0.0002 mg/g in the "Atarugu" pepper (*Capsicum annuum* var) obtained from Zaria. The capsaicin content of the outer flesh ranged from 0.4619 ± 0.0050 in the Yellow pepper from Nsukka (*Capsicum chinense*) to 0.0070 ± 0.0002 mg/g in the "Atarugu" pepper (*Capsicum annuum* var) obtained from Zaria. The parts of the yellow pepper (*Capsicum chinense*) had higher capsaicin content than the respective parts of the remaining peppers analyzed in the study. Also, the pepper parts of *Capsicum chinense* variety had higher capsaicin contents than those of *Capsicum annuum*, with parts of the large-fruited *Capsicum annuum* var having the least capsaicin content. The results from this study which employed the use of Gas Chromatography-Mass Spectrometry show that the placenta has the highest concentration of capsaicin in the pepper fruit. Therefore, it is recommended that the placenta be employed for use as a source of capsaicin rather than the seeds and outer flesh which constitute the bulk of the pepper fruit, but have Capsaicin is the chemical responsible for fruit pungency in chillis. The pungency of chilli is mainly due to the presence of capsaicin. It has been found to be effective, both *in vitro* and *in vivo*, against inflammatory and pain conditions. Capsaicin has been reported to be used orally or locally for the reduction of rheumatoid arthritis pain, inflammatory heat, and noxious chemical hyperalgesia. Due to its tremendous analgesic and anti-inflammatory activity, capsaicin, a lipophilic alkaloid, has been used in clinical practice. Capsaicin is currently used in topical ointments, in concentrations of between 0.025% and 0.075%, as a cream to provide temporary relief from minor aches and pains of muscles and joints associated with arthritis, simple backache, strains, and sprains, often in combination with other rubefacients (Dzoyem and Bakowsky, 2017).

Capsaicin for medicinal use comes from *Capsicum frutescens* and is the active ingredient in the extract of hot peppers. It is most concentrated in the rib or membrane, less in the seeds, least in the flesh. Capsaicin depletes substance P in the afferent type C sensory nerve fibers, affecting only proprioception. Unlike other treatments for neuropathy, such as local anesthetics, opiates, anti-seizure medications or tricyclic antidepressants, capsaicin specifically treats pain without impairing other aspects of the nervous system. In incomplete depletion of substance P from suboptimal use, it may cause paradoxical increase of pain (La jiao, 2020). Capsaicin for medicinal use comes from *Capsicum frutescens* and is the active ingredient in the extract of hot peppers. It is most concentrated in the rib or membrane, less in the seeds, least in the flesh. Capsaicin depletes substance P in the afferent type C sensory nerve fibers, affecting only proprioception. Unlike other treatments for neuropathy, such as local anesthetics, opiates, anti-seizure medications or tricyclic antidepressants, capsaicin specifically treats pain without impairing other aspects of the nervous system. In incomplete depletion of substance P from suboptimal use, it may cause paradoxical increase of pain. The capsaicin content in parts (placenta, seeds and periderm) of some peppers grown in some parts of Nigeria was evaluated. Capsaicin was extracted from the pepper parts was carried-out via the solvent extraction technique using methanol. A Gas Chromatograph-Mass Spectrometer, (GCMS QP-2010, Shimadzu Analytical Instruments) was used for determination of capsaicin content. Capsaicin content was highest in the placenta, followed by the seeds for all the pepper samples utilized in the study. The outer flesh (periderm) had the lowest content of capsaicin. The capsaicin content of the placenta ranged from 1.1652 ± 0.0002 in the Yellow pepper from Nsukka (*Capsicum chinense*) to 0.3226 ± 0.0002 mg/g in the "Atarugu" pepper (*Capsicum annuum* var) obtained from Zaria. The capsaicin content of the outer flesh ranged from 0.4619 ± 0.0050 in the Yellow pepper from Nsukka (*Capsicum chinense*) to 0.0070 ± 0.0002 mg/g in the "Atarugu" pepper (*Capsicum annuum* var) obtained from Zaria. The parts of the yellow pepper (*Capsicum*

chinense) had higher capsaicin content than the respective parts of the remaining peppers analyzed in the study. Also, the pepper parts of *Capsicum chinense* variety had higher capsaicin contents than those of *Capsicum annuum*, with parts of the large-fruited *Capsicum annuum* var having the least capsaicin content. The results from this study which employed the use of Gas Chromatography-Mass Spectrometry show that the placenta has the highest concentration of capsaicin in the pepper fruit. Therefore, it is recommended that the placenta be employed for use as a source of capsaicin rather than the seeds and outer flesh which constitute the bulk of the pepper fruit, but have lower capsaicin content (Nwokem, 2021).

The fruit of most species of *Capsicum* contains capsaicin (methyl-n-vanillyl nonenamide), a lipophilic chemical that can produce a burning sensation (pungency or spiciness) in the mouth of the eater. Most mammals find this unpleasant, whereas birds are unaffected. The secretion of capsaicin protects the fruit from consumption by insects and mammals, while the bright colors attract birds that will disperse the seeds (Wikipedia, 2023). Capsaicin is present in large quantities in the placental tissue (which holds the seeds), the internal membranes, and to a lesser extent, the other fleshy parts of the fruits of plants in this genus. The seeds themselves do not produce any capsaicin, although the highest concentration of capsaicin can be found in the white pith around the seeds. Most of the capsaicin in a pungent (hot) pepper is concentrated in blisters on the epidermis of the interior ribs (septa) that divide the chambers, or locules, of the fruit to which the seeds are attached (Wikipedia, 2023). The amount of capsaicin in the fruit is highly variable and dependent on genetics and environment, giving almost all types of *Capsicum* varied amounts of perceived heat. The most recognized *Capsicum* without capsaicin is the bell pepper, a cultivar of *Capsicum annuum*, which has a zero rating on the Scoville scale. The lack of capsaicin in bell peppers is due to a recessive gene that eliminates capsaicin and, consequently, the hot taste usually associated with the rest of the genus *Capsicum* (Wikipedia, 2023). Chili peppers are of great importance in the medicine of Indigenous peoples, and capsaicin is used in modern medicine mainly in topical medications as a circulatory stimulant and analgesic. In more recent times, an aerosol extract of capsaicin, usually known as capsaicin or pepper spray, has become used by law enforcement as a nonlethal means of incapacitating a person, and in a more widely dispersed form for riot control, or by individuals for personal defense. Pepper in vegetable oils, or as a horticultural product can be used in gardening as a natural insecticide (Wikipedia, 2023). The pungency of chillies is due to a specialized metabolite, capsaicin, concentrated in tissues that surround the seeds inside the fruits. Synthetic capsaicin is used in pepper sprays (Harris, 2023).

HEALTH BENEFITS

It contained remedy for dyspepsia, skin rashes, snake bites, rheumatism and arthritis. Not only in Latin America but the uses of chili pepper had been distributed globally along with its utilization and production. In the authorized text of the Tibetan medical culture, fruits of chilli are noted for their use as a medicine in the treatment of piles, parasitic protozoa, leprosy and acceleration of the digestive warmth of the stomach. In Africa, *Capsicum* spp. are used as spasmolytic, counter-irritant, pulmonary sterilant and antitussive agents. The functional group of alkaloid components, known as Capsaicinoids is the main component of *Capsicum* spp. Generally, *Capsicum annuum* was used to relieve odontalgia. The fruits of chili pepper are useful to stimulate abdominal activities and increase blood circulation. *Capsicum frutescens* was also used traditionally for managing hyperglycemia, blood pressure, to increase blood circulation, to cure mouth wound, infested wounds, to reduce blood clots and to enhance the gastric juice flow and saliva. Chili pepper and its derivatives were also used to treat chronic syndromes, diabetic problems and muscle pain (Bhalabhai *et al.*, 2021).

Importance and applications of different parts of *Capsicum* spp. as given by Bhalabhai *et al.* (2021) are as follows:

Leaves (Capsaicin): In the preparation of food and medicines.

Decreases the risk of cancer, cataracts, cardiovascular problems and macular degeneration. In the preparation of chicken soup Tinola in Philippine, traditional fermented Korean dish and in a storable dish of Japanese food.

Fruits (Vitamin C, Aand vitaminE): Green fruits As vegetable salad in Bangladesh. Decline the health problems caused by free radicals. Helps in synthesis of red blood cells. Inhibits early senescence of skin and used for producing some natural skin oils. Lowering the risk of lung cancer, stomach cancer and prostate cancer.

Red fruits (Capsaicin): Used as spice and medicine. Declines the abdominal acid output and intestinal mucosal inflammation. Has anti-inflammatory, anti-obesity and pain-relieving properties.

Seeds: Used in the production of essential oil. Essential oil is effective as pain reliever in joint and muscle aches. Increases hair growth. Accelerates blood circulation. Helps in wound healing.

In folk medicine, Capsicum has been used as stomachic, carminative, aphrodisiac, digestive, antispasmodic, counterirritant, astringent, depurative, rubefacient, and antiseptic. Capsicum has been used for diarrhoea, toothache, respiratory complaints, cramps, flatulence, to treat neuralgia, fresh burns, and arthritic pain. In India, Capsicum annuum has been used for treatment of lumbago in combination with garlic, storax, and pepper in the form of plasters. It has been used in combination with Cinchona bark to treat rheumatism, snake bite and gout. The Capsicum tincture has been used for flatulence or poor appetite. Capsicum has also been used in brain complaints, delirium, chronic ulcers, muscular pain, loss of consciousness, cholera, dyspepsia, jaundice, and typhoid fever (Kulkarni *et al*, 2017). Capsicum species have a wide array of phytochemicals such as carotenoids, capsaicinoids, and phenolic compounds, particularly the flavonoids quercetin and luteolin (Asnin and Park, 2015). Carotenoids are the pigments responsible for the yellow, orange, and red colors of many types of peppers (Dzoyem and Bakowsky, 2017). A chemical called chilli oleoresin-1, extracted from the dried chillies of *Capsicum annuum*, is used in pain balms, plasters and prickly heat powders. The Chinese use the leaves of the chilli plant to relieve toothaches. Chillies stimulate gastric juices and are therefore used for their carminative and stimulant properties in European medicine to dispel flatulence and increase appetite. Indians believe chillies aid in the circulation of blood. Oil extracted from chillies is used as drying oils. Malays use it to treat vomiting, dyspepsia, diarrhoea and cholera. Javanese use the juice of chilli leaves called *daun sabarang* as a counter irritant on the skin after childbirth. They also use it as a stimulant, and sometimes give it to infants to treat diarrhoea (Ratnala, 2023). Chillies are also used by the Indians in exorcism to dispel the "evil eye" (Ratnala, 2023).

Folkloric uses of chillis are as follows (La jiao, 2020):

- Bruised berries used as powerful rubefacient; used for sore throats. Also used as gargle.
- Externally, a strong rubefacient that acts gently with no danger of vesication.
- Arthritis and rheumatism: Crush fruit, mix with oil and apply on affected part.
- Dyspepsia and flatulence: Eaten as condiment or drunk as infusion as a stimulant and antispasmodic.
- Infusion of the fruit is stimulant, stomachic and antispasmodic; used for dyspepsia and flatulence.
- Infusion preparation: 3-10 grains every 2 hours to a cup of boiling water.
- Toothache: Juice of the pepper pressed into the tooth cavity.
- Rheumatism: Poultice of cayenne applied over affected parts.
- Fomentation of leaves and fruits applied to rheumatic pains.
- Leaves of some varieties used for dressing wounds and sores.
- Strong infusion of fruit of hotter varieties applied as lotion for ringworm of the scalp.

- Used in typhus intermittent fevers and dropsy.
- Externally, used as rubefacient, and internally as stomachic.
- Chile vinegar, made from pouring hot vinegar upon the fruit, used as stomachic.
- Chillies, combined with cinchona, used for lethargic affections, atonic gout, dyspepsia with flatulence, tympanites and paralysis.
- As rubefacient, mixed with with 10 to 20% cotton-seed oil, applied as cataplasm or as liniment.
- Powder or tincture used for relaxed uvula.
- Used in typhus intermittent fevers, gout, dyspepsia, cholera.
- Ancient Mayans used it for treatment of coughs, sore throat and coughs.
- In Jamaica, used by traditional healers to treat diabetes mellitus.
- Aztecs used chile pungency for toothaches

INaturalist (2023) reported that hot peppers are used in traditional medicine as well as food in Africa. English botanist John Lindley described *C. annuum* in his 1838 *Flora Medica* thus: It is employed in medicine, in combination with *Cinchona* in intermittent and lethargic affections, and also in atonic gout, dyspepsia accompanied by flatulence, tympanitis, paralysis etc. Its most valuable application appears however to be in *cynanche maligna* (acute diphtheria) and *scarlatina maligna* (malignant Scarlet fever, used either as a gargle or administered internally). In Ayurveda, *C. annuum* is classified as follows: 1) *Guna* (properties) – *ruksha* (dry), *laghu* (light) and *tikshna* (sharp), 2) *Rasa* (taste) – *katu* (pungent), and 3) *Virya* (potency) – *ushna* (hot)

Chilli is one of the best spices used in the kitchen for cooking various dishes such as pickles, chutney, etc. Red chillies are used as dried and powdered in both vegetarian and non-vegetarian dishes. Chilli is used all around the world, due to its universal use, it is referred to as "the Queen of Spices". The following health benefits are reported by Vedantu (2023):

- **Appetizer:** A mixed paste of chillies, salt and turmeric are used to make pickles. A small amount of it is used as an appetizer.
- **Diarrhoea:** A combination of chillies, camphor, cumin seeds and asafoetida are given as a tablet to cure diarrhoea.
- **Pain and Sprain:** To ease pain and sprain a mixture of red chillies with castor oil can be used.
- **Numbness:** Mustard oil along with red chillies can be applied to cure lack of sensation in the legs.
- **Heart Attack:** The University of Cincinnati found that chilli lowers blood pressure, reduces cholesterol levels and prevents arteriosclerosis. This is due to the presence of capsaicin in it.

There are many nutritious elements inside green chili, which are supposed to increase the following immunity (Gudeshar, 2023):

- Green chillies are also very useful for hair growth. There are certain types of elements found inside green chillies, which increase hair growth. So if you want to grow hair, then green chili can be very beneficial inside it.
- Diabetes occurs when the level of glucose inside the blood increases too much. An element called capsaicin is found inside green chili, which does a lot in correcting diabetes. It works to reduce the increased glucose level in the blood. But the amount of green chillies should be eaten right, eating more green chillies can cause harm instead of benefiting your health.
- Eating green chili is also beneficial because it is full of antioxidants. This means that it reduces the production of free radicals, these free radicals damage the cells of the body. Such chili food can be quite beneficial for you.
- Some people have a lot of digestion problems. If you also have digestion problems, then green chillies can be very beneficial for you. Chilli is very beneficial for gastrointestinal problems. If the problem of pet gas remains for a long time, it can give rise to many problems.

- Capsaicin is found in chilli which helps a lot in improving digestion. If you have digestive problems, then you should not forget to consume green chillies.
- Increasing weight becomes a problem for some people. Even after they eat very little food, their body weight is not able to reduce. Can do. If you want, you can try using it once. There are certain types of properties found inside green chillies, which help in controlling obesity, so there is no harm in using it once within free.
- Some people have a lot of blood pressure problems. An element called capsaicin is found inside green chili, which works to reduce blood pressure. If you have problems with low or high blood pressure, then you can use this.
- Let us tell you that green chillies are very beneficial for the eyes. Chilli contains beta carotene which helps a lot in keeping the eyes healthy. Apart from this, it is also very beneficial in increasing the eyesight. Green chillies can be very beneficial to prevent age-related eye diseases.
- Now-a-days you are seeing that the problem of eyes is happening to every human being. Even the eyes of small children are getting weak. In such a situation, green chilli can be a very beneficial thing.
- Today's lifestyle has become such that a person goes under stress. And many people even commit suicide due to stress. In such a situation, you can understand what has happened. But let us tell you that green chili can be very beneficial for providing relief from stress. There are special types of elements found inside green chilli, which help a lot in fixing your mood. That is why green chillies are very beneficial.
- Green chili can also be very beneficial in removing bacterial infection. According to research, properties like anti-bacterial, antiviral and anti-microbial are found inside green chilli, which can help you fight infections caused by bacterial.
- Green chilli is also very beneficial for the skin. Green chilli contains vitamin C and antioxidant properties which are beneficial for the skin. Vitamin C works to protect the skin from inflammation and sun rays. Apart from this, it also works to maintain the glow of the skin.
- It is very common to have a cold. If you also have a stuffy nose due to a cold, then green chillies inside it can help a lot. By putting capsaicin nose spray in the nose for about 1 month, it gets rid of the problem of blocked nose. If you are also troubled by the problem of blocked nose, then it can be very beneficial for you. By the way, you do not need to make this spray yourself. It is very easily available inside the market.
- Green chilli also proves to be very beneficial for the health of the brain. When a person becomes very old, then his chances of getting Alzheimer's disease increase, the habit of forgetting the person suffering from this disease increases. Green chilli can help a lot inside Alzheimer's disease.
- Green chillies are very beneficial in arthritis. Arthritis is also known as Arthritis in English. And this disease can happen at any age. This disease is seen in women as compared to men. It affects any joints of the body. Due to which there is swelling inside the joints and pain starts. Green chillies have anti-inflammatory and anti-arthritis properties which work to reduce inflammation. Apart from this, the properties of reducing pain are also found inside green chilli.
- Cancer is a deadly disease. If the doctor tells someone that he has cancer, then he starts feeling mentally tired too. He starts to feel that now the end of his life is near. By the way, let us tell you that an element called capsaicin is found inside green chilli, which works to protect against cancer. However, it is not possible to cure cancer with its help. But if you consume original green chilli, then it can be very beneficial for you. Consuming green chilli reduces the risk of lung cancer, men should consume green chilli because they are at risk of prostate cancer.
- Green chilli is also very beneficial for bones and teeth. Vitamin C is found in good quantity inside green chilli. And vitamin C can be very beneficial for teeth and for bones. Friends, if you want to

remove the problem of bones, then green chilli can prove to be very beneficial for you.

The mechanism behind the therapeutic potential of chili pepper has been appraised in several hefty pieces of literature. Chili is effective against a great number of ailments such as cancer, rheumatoid arthritis, bronchitis, macular degeneration, anemia, osteoporosis, coronary heart disease, diabetes, obesity, hypertension, sinus infection, migraine, neurological disorders, menopausal problems, and digestive complications (Dhamodharan *et al.*, 2020). The following health benefits are reported: Stimulant, digestive, rubefacient, stomachic, sialagogue, alterative, antispasmodic, febrifuge, depurative. Studies have suggested analgesic, anti-H. pylori, anti-ulcer, diuretic, antibacterial, antifungal, antidiabetic, anthelmintic, cardioprotective, diuretic, mosquito repellent, insecticidal properties (La jiao, 2020). Capsicum species is a good resource of healthy food, mainly including proteins, trace elements, vitamins, minerals, and other substances. In recent years, with the continuous enhancement of people's pursuit of nutritious, healthy food, and increasing health care awareness, chili pepper has been developed as a medicinal health supplement, functional food, and cosmetic component, especially in the dietary aspect. Moreover, its active phytochemical constituents represent a key role in treatment and disease prevention by modulating various cellular pathways (Dhamodharan *et al.*, 2022). The mechanism behind the therapeutic potential of chili pepper has been appraised in several hefty pieces of literature. Chili is effective against a great number of ailments such as cancer, rheumatoid arthritis, bronchitis, macular degeneration, anemia, osteoporosis, coronary heart disease, diabetes, obesity, hypertension, sinus infection, migraine, neurological disorders, menopausal problems, and digestive complications (Dhamodharan *et al.*, 2022).

REFERENCES

- Barboza, G.E., García, C.C., Bianchetti, L.B., Romero, M.V. and Scaldaferrro, M. 2022. Monograph of wild and cultivated chili peppers (*Capsicum* L., Solanaceae). *PhytoKeys* 200 (2022). <https://phytokeys.pensoft.net/issue/3790/>
- Barboza, G.E., Carrizo García, C., Leiva González, S., Scaldaferrro, M. and Reyes, X. 2019. Four new species of *Capsicum* (Solanaceae) from the tropical Andes and an update on the phylogeny of the genus. *PLoS ONE* 14(1): e0209792. <https://doi.org/10.1371/journal.pone.0209792>
- Bhalabhai, J.G., Rajhans, S., Pandya, H. and Mankad, A. 2021. A Comprehensive Review on *Capsicum* spp. *IJRAR*, 8(4): 581-599
- Bora, A., Nakhuru, K.S., Gogoi, B.J., Chattopadhyay, P. and Dwivedi, S.K. 2020. Ethnic Uses and Commercial Applications of *Capsicum assamicum* (Bhut jolokia). In: (Edr) *Phytomedicine*. 1st Edition. Imprint CRC Press
- Bray, M. 2019. Genus *Capsicum*: The Classification Of Peppers. <https://www.pepperscale.com/genus-capsicum/>
- CABI. 2023. *Capsicum annuum* (bell pepper). *CABI Compendium*. <https://www.cabidigitallibrary.org/doi/10.1079/cabicompendium.15784>
- Calvin. 2022. *Capsicum* Species and Pepper Varieties. <https://peppergeek.com/capsicum-pepper-species/>
- Carrizo, G.C., Barfuss, M.H., Sehr, E.M., Barboza, G.E., Samuel, R. and Moscone, E.A. 2016. Phylogenetic relationships, diversification and expansion of chili peppers (*Capsicum*, Solanaceae). *Annals of Botany*, 118(1):35-51.
- Chiliplant. 2023. Chili history, origin & distribution. *Chiliplant*. <https://chili-plant.com/interesting-facts/chili-history-origin-distribution/>
- Delince, J. 2014. Varieties of *Capsicum*. <https://www.slideshare.net/THANKLORD/varieties-of-capsicum>
- Dhamodharan, K., Vengaimaran, M. and Sankaran, M. 2022. Pharmacological Properties and Health Benefits of *Capsicum* Species: A Comprehensive Review. In: (Eds. Orlex B. Baylen Yllano) *Capsicum - New Perspectives* [Working Title]

- Djarwaningsih, T. 2005. Review: Capsicum spp. (Chilli): origin, distribution, and its economic value. *Biodiversitas*, 6 (4): 253-258.
- Dzoyem, J.P. and Bakowsky, U. 2017. Capsicum species. In: *Medicinal Spices and Vegetables from Africa*, First Edition. 2017. Copyright Elsevier. <https://www.elsevier.com/books/medicinal-spices-and-vegetables-from-africa/kuete/978-0-12-809286-6>
- Eflora. 2016. *Capsicum chinense x Capsicum frutescens*. Efloraofindia. <https://efloraofindia.com/2016/08/01/capsicum-chinense-x-capsicum-frutescens/>
- EPPO. 2023. Capsicum annum(CPSAN) . EPPO Global Database. <https://gd.eppo.int/taxon/CPSAN>
- Ferdousi, J., Zakaria, M., Hoque, M.A., Saha, S.R., Ivy, N.A. and Hossain, M.I. 2021. Morphological Characterization of Twenty One Sweet Pepper (Capsicum annum L.) Genotypes Collected from Native and Alien Sources. <https://www.researchgate.net/publication/354375956>
- Garg, J.M. 2023. Chilli - Capsicum annum - Flowers of India. <http://www.flowersofindia.net/catalog/slides/Chilli.html>
- Gomez-Garcia, M.D. and Ochoa-Alejo, N. 2013. Biochemistry and molecular biology of carotenoid biosynthesis in chili peppers (Capsicum spp.). *International Journal of Molecular Sciences*, 14(9):19025-19053.
- Gudeshar, P. 2023. Green chillies scientific name and fact. <https://www.scientificname.in/green-chillies-scientific-name-and-fact/>
- GWA. 2016. Growing capsicums and chillies. Agriculture and Food. Government of Western Australia. <https://www.agric.wa.gov.au/capsicums-and-chillies/growing-capsicums-and-chillies>
- Harris, S. 2023. Capsicum species (Solanaceae). Chilli peppers. Plant 274. <https://herbaria.plants.ox.ac.uk/bol/plants400/Profiles/cd/Capsicum>
- Hernández-Pérez, T., Gómez-García, M.R., Valverde, M.E. and Paredes-López, O. 2020. Capsicum annum (hot pepper): An ancient Latin-American crop with outstanding bioactive compounds and nutraceutical potential. A review. *Comprehensive Reviews in Food Science and Food Safety*. First published: 27 September 2020, <https://doi.org/10.1111/1541-4337.12634>
- Hultquist, M. 2019. Capsicum. Chili pepper madness. <https://www.chilipeppermadness.com/frequently-asked-questions/capsicum/>
- Hundal, J.S. and Dhall, R.K. 2005. Breeding for Hybrid Hot Pepper. *Journal of New Seeds*, 6(2):31-50
- iNaturalist. 2023. Chili Pepper (Capsicum annum) – iNaturalist. <https://www.inaturalist.org/taxa/48514-Capsicum-annuum>
- Jiménez, M. 2022. The History Of Chilis In India. Greengos Cantina. <https://greengoscantina.com/the-history-of-chilis-in-india/>
- Kraft, K.H., Brown, C.H., Nabhan, G.P., and Gepts, P. 2014. Multiple lines of evidence for the origin of domesticated chili pepper, Capsicum annum, in Mexico. *Proceedings of the National Academy of Sciences of the United States of America* 111(17): 6165-6170
- Kulkarni, Y.A., Suryavanshi, S.V., Auti, S.T. and Gaikwad, A.B. 2017. Capsicum: A Natural Pain Modulator. In: *Nutritional Modulators of Pain in the Aging Population*, 2017. <https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/capsicum-pubesens>
- Kumar, O.A. and Tata, S.S. 2009. Ascorbic Acid Contents in Chili Peppers (Capsicum L.). *Notulae Scientia Biologicae*, 1 (1): 50-52
- La jiao. 2020. Siling-labuyo/ Capsicum annum L./ Chile Pepper / Cayenne. <http://www.stuartxchange.org/SilingLabuyo.html>
- Long An. 2015. Genus Capsicum. *The Worldwide Vegetables*. <http://theworldwidevegetables.weebly.com/genus-capsicum.html>
- MacBryde, B. 2006. Consensus Document on the Biology of the Capsicum annum Complex (Chili peppers, Hot peppers and Sweet peppers). ED. Environment Directorate, Organisation for Economic Co-operation and Development, Paris 2006
- Maheshwat, S. 2021. 12 varieties of Indian chillies you must know about. Onmanorama. <https://www.onmanorama.com/food/features/2021/04/07/indian-chillies-you-must-know-about.html>
- Martínez-Ávalos, J.G., Venegas-Barrera, C.S., Martínez-Gallegos, R., et al. 2018. A Review on the Geographical Distribution, Fruit Production and Concentration of Capsaicinoids in Capsicum annum var. glabriusculum in the Northeastern Region of Mexico. *Preprints.org*; 2018. DOI: 10.20944/preprint201811.0517.v1.
- Morris, W.L. and Taylor, M.A. 2017. Peppers (Capsicum sp.). In: *Encyclopedia of Applied Plant Sciences* (Second Edition), 2017. <https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/capsicum-pubesens>
- NCSE. 2023. Capsicum annum. NC State Extension. <https://plants.ces.ncsu.edu/plants/capsicum-annuum/>
- Nwokem, C.O. 2021. Evaluation of capsaicin content in parts of some peppers grown in Nigeria. *Science World Journal*, 16(2): 90-93
- Padilha, H.K.M. and Barbieri, R.L. 2016. Plant breeding of chilli peppers (Capsicum, Solanaceae)- A review. *Australian Journal of Basic and Applied Sciences*, 10(15): 148-154
- Purkayastha, J., Alam, S.I., Gogoi, H.K. and Singh, L. 2012. Capsicum assamicum sp. Nov. (Solanaceae), from Assam, Northeastern India. *Biology*. @inproceedings {Purkayastha 2012CAPSICUMAS,
- Ramchiary, N., Kehie, M., Brahma, V., Kumaria, S. and Tandon, P. 2013. Application of genetics and genomics towards Capsicum translational research. *Plant Biotechnol. Report 2013*. © Korean Society for Plant Biotechnology and Springer Japan 2013
- Ramdev. 2023. Chili. Origin of Chilli. Ramdev Food Products Ltd...>
- Ratnala, T.N. 2023. Chilli. Singapore Infopedia. A Singapore Government Agency Website. https://eresources.nlb.gov.sg/infopedia/articles/SIP_203_2005-01-11.html
- Reddy, M.K., Srivastava, A., Kumar, S., Kumar, R., Chawda, N., Ebert, A.W. and Vishwakarma, M. 2014. Chilli (Capsicum annum L.) breeding in india: An overview. *SABRAO Journal of Breeding and Genetics*, 46 (2) : 160-173
- Roth, K. 2014. The Domesticated Species of Capsicum — Part of The Biochemistry of Peppers . https://www.chemistryviews.org/details/ezone/6113851/The_Domesticated_Species_of_Capsicum_Part_of_The_Biochemistry_of_Peppers/
- Roy, A. 2016. Bhut Jolokia (Capsicum chinense Jaqc): A Review. *International Journal of Pharmaceutical Sciences and Research*, 7(3): 882-889
- Sagar, V., Kaswan, V., Ranjan, J.K., Kumar, R. and Mishra, G.P. 2021. Advances in Breeding Strategies of Bell Pepper (Capsicum annum L. var. grossum Sendt.). In: (Eds. Al-Khayri, J.M., Jain, S.M., Johnson, D.V.) *Advances in Plant Breeding Strategies: Vegetable Crops* pp 3–58
- Sampaio, A.P.L., Angela, J.G.A., Mendes, M.S., Argente-Martínez, L., Zuffo, A.M. and Teodoro, P.E. 2023. The role of the genetic diversity of Capsicum spp. in the conservation of the species: Qualitative and quantitative characterization. *Ciência e Agrotecnologia*, 47:e009122, 2023. <https://www.scielo.br/j/cagro/a/PSxd4qm7Gp4GjNZBqccXbBy/>
- Sanghvi, V. 2017. Tracing the spice route. *Hindustan Times*, Jul 15, 2017 <https://www.hindustantimes.com/brunch/tracing-the-spice-route/story-KsBKbdnSERXOGCTX2h3ScN.html>
- Saxena, A., Raghuvanshi, R., Gupta, V.K. and Singh, H.B. 2016. Chilli anthracnose: The epidemiology and management. *Frontiers in Microbiology*, 30(7):1-18
- Selvakumar, R., Manjunathagowda, D.C. and Singh, P.K. 2022. Capsicum: Breeding Prospects and Perspectives for Higher Productivity. In: (Eds. Orlex B. Baylen Yllano) *Capsicum - New Perspectives* [Working Title]
- Soare, R., Dinu, M., Băbeanu, C., Popescu, M. and Popescu, A. 2017. Nutritional value and antioxidant activities in fruit of some cultivars of pepper (Capsicum annum L.). *Journal of Agroalimentary Processes and Technologies*, 23 (4), 217-222
- Sottosanti, K. 2023. Capsicum annum. The Editor of *Encyclopedia Britannica*. Last Updated: Feb 6, 2023. <https://www.britannica.com/plant/pepper-plant-Capsicum-genus>
- Swamy, S., Krupakar, A., Chandran, D.S. and Koshy, E.P. 2014. Direct regeneration protocols of five Capsicum annum L. varieties. *African Journal of Biotechnology*, 13(2): 307-312

- TPL. 2010. Capsicum . Species in Capsicum. The Plant List. <http://www.theplantlist.org/browse/A/Solanaceae/Capsicum/>
- Vedantu. 2023. Botanical Name of Chilli - Species, Phonetics, Usage and FAQs. <https://www.vedantu.com/biology/botanical-name-of-chilli>
- Verma, P. K, Rawat, K.K, Das, N. and Pradhan, B. A. 2013. A Botanical Enigma of India's Hottest Chilli 'Bhoot Jolokia' (*Capsicum chinense* Jacq.). New York Science Journal, 6(11): 49-51. <http://www.sciencepub.net/newyork>
- Vidhi, J. 2023. Capsicum: Origin, Flower Structure and Varieties | India. <https://www.biologydiscussion.com/vegetable-breeding/capsicum-origin-flower-structure-and-varieties-india/68453>
- Wikipedia. 2023. Chili history, origin & distribution. https://en.wikipedia.org/wiki/Chili_pepper#History <https://chili-plant.com/interesting-facts/chili-history-origin-distribution/>
- Wikipedia. 2023. Capsicum. From Wikipedia, the free encyclopedia. <https://en.wikipedia.org/wiki/Capsicum>
- Zeana. 2023. Five Main Species of Chile Peppers - ChilePeppers.com. <https://chilepeppers.com/p/about/chile-pepper-species/>
- Zhigila, D.A., Rahaman, A.A.A., Kolawole, O.S. and Oladele, F.A. 2014. Fruit Morphology as Taxonomic Features in Five Varieties of *Capsicum annuum* L. Solanaceae. Journal of Botany, Article ID 540868 | <https://doi.org/10.1155/2014/540868>
