ISSN: 2230-9926

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

IJDR

International Journal of Development Research
Vol. 13, Issue, 02, pp. 61542-61559, February, 2023
https://doi.org/10.37118/ijdr.26219.02.2023

REVIEW ARTICLE OPEN ACCESS

ORIGIN, DISTRIBUTION, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS, GENETIC DIVERSITY AND BREEDING OF CUCUMBER (*Cucumis sativus* 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 11th January, 2023
Received in revised form
29th January, 2023
Accepted 10th February, 2023
Published online 25th February, 2023

KeyWords:

Origin, Distribution, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value, Health Benefits Cucumber.

ABSTRACT

Cucumber belongs to the Family Cucurbitaceae, Subfamily Cucurbitoideae, Tribe Melothrieae, Subtribe Cucumerinae, Genus *Cucumis* and Species *Cucumis sativus* L. The Common Names of Cucumber are garden cucumber, apple cucumber, gherkin and *khira.* Cucumber (*Cucumis sativus* L. 2n = 2x = 14) is one of the Asiatic species. Cultivated for at least 3,000 years, the cucumber originated from India, where a great many varieties have been observed, along with its closest living relative, *Cucumis hystrix*. It was probably introduced to Europe by the Greeks or Romans. Records of cucumber cultivation appear in France in the 9th century, England in the 14th century, and in North America by the mid-16th century. Cucumber (*Cucumis sativus*) is a widely-cultivated creeping vine plant that bears usually cylindrical fruits, which are used as culinary vegetables. Considered an annual plant, there are three main types/varieties of cucumber—slicing, pickling, and seedless—within which several cultivars have been created. It is high in beneficial nutrients, as well as certain plant compounds and antioxidants that may help treat and even prevent some conditions. Also, cucumbers are low in calories and contain a good amount of water and soluble fiber, making them ideal for promoting hydration and aiding in weight loss. Cucumber is also frequently used in cosmetology, where it is used as a skin moisturizer, due to its large amount of water, which can make up ninety-seven percent of its composition. It is also used in naturopathic medicine as a diuretic and depurative, in order to treat some pictures of cystitis or urinary tract infections. Cucumbers have a mild, refreshing taste and a high water content. They can help relieve dehydration and are pleasant to eat in hot weather. People eat cucumber as a savory food. It also features in some beauty products. Mature uncooked cucumbers bring relief for individuals suffering from celiac disease, and promote skin health. The seeds can be used to expel parasitic worms. Cucumber juice has significant amounts of potassium and is high in vitamin A. It also contains significant amounts of silicon. It also contains sterol. Cucumber juice is used as an ingredient in cosmetics, soaps, shampoos, and lotions, and in Eau de toilette and perfumes. The juice from the leaves induce vomiting and aid digestion. The cucumber blessing is an *adhiṣṭhāna* practised at Shingon Buddhist temples in summer. In a cucumber blessing meeting, the priest and believers together pray that they can pass the season of hot summer in good health like fresh cucumbers. Classical genetics and traditional breeding techniques have made great contribution in better understanding and genetic improvement of cucumber crop for several qualitative and quantitative traits. In this review article origin, distribution, taxonomy, botanical description, genetics, genetic diversity, breeding, uses, nutritional value, and health benefits of cucumber are discussed.

Citation: ***Swamy, K.R.M. 2023.*** "Origin, distribution, taxonomy, botanical description, genetics, genetic diversity and breeding of Cucumber (Cucumis Sativus L.)*", International Journal of Development Research*, 13, (02), 61542-61559.

INTRODUCTION

Bitter gourd belongs to the Family Cucurbitaceae, Subfamily Cucurbitoideae, Tribe Melothrieae, Subtribe Cucumerinae, Genus *Cucumis* and Species *Cucumis sativus* L. (Long An, 2015). *Cucumis* in Latin means 'cucumber', the word was derived from Greek for cucumber, *kykyon*. The epithet *sativus*, also Latin, means 'that is sown', referring to the common agricultural use of the species (Santanna and Bradtke, 2022). The Common Names of Cucumber are garden cucumber, apple cucumber, gherkin, *concombre* (French), *cornichon* (French), *pepino* (Spanish and Portuguese), *huang gua* (pinyin, China), *khira* (Pakistan) (1,2,6,8) (Santanna and Bradtke, 2022). Cucumber (*Cucumis sativus* L. 2n = 2x = 14) is one of the Asiatic species and member of the Cucurbitaceae. The African group has diploid chromosome number of 24 (Vidhi, 2022). Main sex types of cucumber are (i) Monoecious plants: Staminate and pistillate flowers, (ii) Androecious plants: Only staminate flowers, (iii) Gynoecious plants: Only pistillate flowers, (iv) Hermaphrodite plants:

Only hermaphrodite flowers, and (v) Andromonoecious plants: Staminate and hermaphrodite flowers (Vidhi, 2022). Cucumber (*Cucumis sativus*) is a widely-cultivated creeping vine plant in the Cucurbitaceae family that bears usually cylindrical fruits, which are used as culinary vegetables. Considered an annual plant, there are three main types/varieties of cucumber—slicing, pickling, and seedless—within which several cultivars have been created (Long An, 2015; Anon., 2016; Felix, 2021). Cultivated for at least 3,000 years, the cucumber originated from India, where a great many varieties have been observed, along with its closest living relative, *Cucumis hystrix*. It was probably introduced to Europe by the Greeks or Romans. Records of cucumber cultivation appear in France in the 9th century, England in the 14th century, and in North America by the mid-16th century (WIKI, 2023). Cucumbers have a mild, refreshing taste and a high water content. They can help relieve dehydration and are pleasant to eat in hot weather. People eat cucumber as a savory food. It also features in some beauty products (Megan Ware, 2019). Cucumbers are consumed raw or pickled (gherkin). Mature uncooked cucumbers bring relief for individuals suffering from celiac disease, and promote skin health. Edible oil can be extracted from the seeds and used for cooking. Immature cucumbers can be cooked and consumed to treat dysentery. The fruit is also valued in the cosmetic industry, used to soften the skin. A poultice made from fresh cucumbers can be applied to burns and open sores. The seeds can be used to expel parasitic worms. The juice from the leaves induce vomiting and aid digestion. The seedlings are toxic and should not be consumed (Santanna and Bradtke, 2022).

Cucumbers provide various nutrients but are low in calories, fat, cholesterol, and sodium (Megan Ware, 2019). Cucumber juice is used as an ingredient in cosmetics, soaps, shampoos, and lotions, and in Eau de toilette and perfumes. It was used in Russian traditional medicine to aid in the treatment of respiratory tract inflammation and to reduce lingering cough. In other traditions it was used to soothe heartburn and reduce acid in the stomach. For skin, it has been used to soothe burns and rashes. Cucumber juice has been described as a repellent against wood lice and fish-moths (WIKI, 2023). It's high in beneficial nutrients, as well as certain plant compounds and antioxidants that may help treat and even prevent some conditions. Also, cucumbers are low in calories and contain a good amount of water and soluble fiber, making them ideal for promoting hydration and aiding in weight loss (Momaya, 2022). Cucumber is also frequently used in cosmetology, where it is used as a skin moisturizer, due to its large amount of water, which can make up ninety-seven percent of its composition**.** It is also used in naturopathic medicine as a diuretic and depurative, in order to treat some pictures of cystitis or urinary tract infections (Phoneia, 2019). Cucumber juice is the juice derived from cucumbers produced by squeezing or pressing it. Cucumbers are 98% water. Cucumber juice is used in beverages such as cocktails like the Bloody Mary, dishes such as cucumber soup, and in dips and salad dressings, such as green goddess dressing. Cucumber juice has significant amounts of potassium and is high in vitamin A. It also contains significant amounts of silicon. It also contains sterol (WIKI, 2023).

The cucumber blessing is an *adhiṣṭhāna* practised at Shingon Buddhist temples in summer. In a cucumber blessing meeting, the priest and believers together pray that they can pass the season of hot summer in good health like fresh cucumbers. Kūkai, the founder of Shingon Buddhism, is said to have initiated this practice of blessing (WIKI, 2023). Classical genetics and traditional breeding techniques have made great contribution in better understanding and genetic improvement of cucumber crop for several qualitative and quantitative traits, understanding of phylogenetic relationship and taxonomy (Jat *et al*., 2021). Using traditional breeding methods, cucumber breeder have identified a number of genes associated with economic traits and used this information to develop early and high yielding cultivars (Jat *et al*., 2021). Advancement of some quantitative characters using traditional methodology is difficult and time consuming process. Therefore molecular markers technology offers an avenue to overcome the hurdles associated with traditional breeding. Molecular breeding has played a significant role in better understanding of cucumber genetics, and has been directly responsible for some of the improvement made in modern cucumber cultivars in different market classes (Jat *et al*., 2021).

ORIGIN AND DISTRIBUTION

Wild cucumbers exist in India and a closely related species lives in the Eastern Himalayas. Using DNA sequences from plastid and nuclear markers for some 100 *Cucumis* accessions from Africa, Australia, and Asia, we show here that melon and cucumber are of Asian origin and have numerous previously overlooked species-level relatives in Australia and around the Indian Ocean. Southeast Asian *Cucumis hystrix* is the closest relative of cucumber. Range reconstruction under maximum likelihood suggests Asia as the ancestral area for the most recent common ancestor of melon and cucumber, fitting with both having progenitor populations in the Himalayan region (Sebastian *et al*., 2010). The cucumber is originally from Southern Asia, but now grows on most continents. Many different varieties are traded on the global market (Long An, 2015). The cucumber is originally from India but is now grown on most continents. Many different varieties are traded on the global market (Anon., 2016). Cucumber is one of the most important member of cucurbitaceae family. It is thought to be originated from India and China, is considered as secondary center of diversity. Inspite of being native of Indian sub-continent and endowed with enormous variability for various plant characters, cucumber remain underutilized in context of its economic potential and breeding value. There is huge scope to work on cucumber improvement in India (Kathayat *et al*., 2018). Cucumber is originally from India and known to humanity at least three thousand years ago (Phoneia, 2019). Cucumber has been cultivated in India for at least 3,000 years. It spread eastward to China and westward to Europe around 2,000, and 700–1500 years ago, respectively (Yiqun Weng *et al*., 2020).

Cucumber is originated from India, particularly southern foot-hills of Himalayan region. It was domesticated in India from its wild relative, Cucumis sativus var. hardwickii 3000 years ago. It is commercially grown in the tropical and subtropical regions of the world. The fruits are widely consumed as salad at immature stage (Jat *et al*., 2021). Cucumber probably originated in India from where it seems to have spread Eastwards to China and Westwards to Asia Minor, North Africa and Southern Europe and subsequently to entire Europe. It was introduced to the New World by Columbus who planted it in Haiti in 1494 and perhaps soon afterwards it was brought to the USA. Cucumber was domesticated about 3000 years ago and is indigenous to India, (primary centre of diversity). *C. sativus* var *hardwickii* is a wild relative of *C. sativus* var *sativus* and grows in the foothills of the Himalayas and used by native peoples of Northern India as a laxative. This botanical variety is sympatric and cross-compatible with *Cucumis sativus* var *sativus* and has multiple fruiting and branching habit which is uncommon in cucumber. As against India which is the primary centre of diversity of cucumber, China is considered as secondary centre of diversity (Vidhi, 2022). The cucumber originates from South Asia, but now grows on most continents, as many different types of cucumber are traded on the global market (WIKI, 2023). Cultivated for at least 3,000 years, the cucumber originated from India, where a great many varieties have been observed, along with its closest living relative, Cucumis hystrix. It was probably introduced to Europe by the Greeks or Romans.

Records of cucumber cultivation appear in France in the 9th century, England in the 14th century, and in North America by the mid-16th century (WIKI, 2023). Cucumber is indigenous to India and likely originated from the foothills of the Himalayan Mountain. Cucumber was cultivated ~3000 years ago in India, and it seems to spread rapidly to Western Asia, and then to Southern Europe. Cucumber was introduced respectively to North China through the Silk Route and to South China from Burma and India-China border, and subsequently spread to East Asia (Jia and Wang, 2021). Cucumber may also be referred to as gherkin and originates from the foothills of the Himalayas, likely in India (Anon., 2023).

Cucumber is thought to have originated in the Indian subcontinent (Anon., 2023).

History: Since that pivotal moment over 4000 years ago, cucumber was spread beyond Indian borders, moved through Ancient Greece, Rome, Europe, New World, China, and eventually becoming fourth most widely cultivate vegetable in the world. This journey was filed with golden periods when they were viewed as integral parts of many culture's cuisines, and sometimes they were treated as bringers of disease. Home for cucumbers (which have three main varieties - "slicing", "pickling", and "burpless") originated from Ancient India where it grew in the wild. Around 2-3 millennia BC, early Indian civilization managed to domesticate cucumber and start infusing it into their rich cuisine. As time went by, their manufacturing capabilities expanded, and in 1st millennia BC they started trading with Middle Eastern civilization and Europe. The most famous example of cucumber finding home in Middle East can be found in the legends of the ancient Ur and the sagas of Gilgamesh. Later on, Greek civilization embraced cucumbers and started calling them síkyon (σίκυον). During those times, cucumbers also reached Turkey, Bulgaria, Africa, Modern-day Serbia and Italy. Roman Empire was the place where cucumbers were truly embraced by both nobility and lower classes. The ease of production and wide variety of types and tastes ensured that cucumbers remained popular in Italy for several centuries. In addition to eating, cucumbers were also widely used as a source of several medicinal remedies (both cultivated and wild cucumbers of cucumbers were used for creation of over various 40 remedies). They treated everything from bad eyesight, scared mices, cured scorpion bites, and carried around wastes by wives who wished to have children.

The most famous example of cucumbers fascination in Ancient Rome came during the short reign of Emperor Tiberius (14 – 16 AD) who demanded to eat cucumber on every day of the year. During summer special gardens were tended just for his vegetables, and in winter cucumber was grown on moveable bed frames that were moved to be exposed to the sun, or illuminated with the mirror-stones. After the fall of Rome, cucumbers receded from popularity for long amounts of time. They resurfaced on the court of Charlemagne in 8th and 9th century, and arrived in England in 14th century. That first interaction with English population was not successful, but cucumbers returned there in mid-17th century when they managed to take hold. Age of Discovery proved to be a very important factor of spreading cucumber all across the word. Christopher Columbus brought cucumbers to Haiti in 1494 where they were grown by Spanish settlers and distributed further across New World. During 16th century, European trappers in North America introduced cucumbers to the native Indians in the region of Great Plains and the Rocky Mountains. Those tribes quickly saw the potential and nutritious value of cucumbers, integrating them into immediately into their fields. The best Native American cucumber farmers were located on the lands of modern North and South Dakota. During 18th century, expansion of cucumbers across North America suddenly stopped when several medicinal journals started reporting that cucumbers and all similar vegetables that were not cooked represented serious health risk. Discouraged by those misconceptions, cucumber use plummeted across the continent, which was reversed only in 19th century (Anon., 2023a).

Recent research, however, has shown this water-laden vegetable contains significant amounts of phyto-nutrients which have a wide array of human health benefits. Cave excavations have revealed that cucumber has been grown as a food source for over 3000 years. Early cucumbers were robably very bitter because of compounds they contained called cucurbitacins. These natural defense compounds act to repel insects and other pests. Cucumbers were cultivated and eaten in ancient Egpyt as evidenced by the Bible. Evidently the Egyptians made weak liquor from cucumber by cutting a hole in the ripe fruit, stirring the inside with a stick to liquefy it, plugging the hole and then burying it in the ground for several days. The resultant concoction was unearthed and consumed. The Greeks also cultivated cucumbers as (later) did the Romans. The Emperor Tiberius was said to have demanded that they be on his table every day. To meet that demand, his gardeners fashioned some of the first plant forcing structures, constructing portable containers which they moved from place to place. Later, the Romans advanced plant forcing structure technology (and cucumber production) by fashioning frames covered with translucent panes of silicates—not unlike our modern cold frames. Later, Charlemagne was said to have grown cucumbers in his gardens in Italy in the 8th and 9thcentury. Cucumber later spread to Western Europe. It was during the reign of King Henry VIII that cucumber made its way to England. The Age of Discovery proved to be very important to the spread of cucumber. Columbus is credited for taking cucumber to the New World, along with many other vegetables. He introduced it to Haiti in 1494. From there it spread.

As mentioned previously, scientists recently have found cucumber to contain a number of beneficial phyto-nutrients. The lack of that knowledge did not keep cucumber from being used medicinally earlier in our history. The cucumber's water retentive ability earned it the reputation for never losing its cool. As a result, 17th Century physicians prescribed placing fever patients on a bed of cucumbers so they would become "cool, as a cucumber." Additionally, it was thought that if cucumbers were eaten three times daily, red noses would be healed and pimples on the face would disappear. Cucumber's popularity was bolstered considerably when, in 1876, Henry J. Heinz added pickles to the list of products made by the food processing company that bears his name. Others followed, and by the end of the 19th century pickles were a tasty addition to the monotonous diet of meat and potatoes consumed by most Americans. Today, pickles can be found in 70 percent of all households. Cucumbers are placed into one of two major categories based on their use: slicing or pickling. Slicing cucumbers are eaten fresh from the garden. They range in size from about four to 12 inches and have skin that is relatively smooth. If "spines" are present, they normally are white. Pickling cucumbers are much smaller, ranging in size from one to five inches; the latter reserved for making dill pickles. Unlike the slicers, pickling cucumbers usually have bumps on their skin along with "spines" that are black. Gerkins are a type of immature pickling cucumber. They are noted for their small size and warty skin.In the middle of the 20th century, "burpless" cucumbers were introduced that eliminated this problem. Today there are several burpless varieties available. Their fruit usually is long, somewhat narrow and thin-skinned. Non-burpless types can be made a bit more socially acceptable by cutting off about one inch of the stem-end and peeling the skin off the fruit. Most cucumbers varieties reach maturity in 50 to 65 days. The fruit will be firm to the touch and the skin will have a uniform dark green color. Cucumbers enlarge (mature) rapidly and should be checked/harvested daily. If left on the vine too long, the fruit becomes over-mature and less desirable. Slicing types are mature when about six to eight inches long; larger slicing varieties should be picked before they are ten inches long. Pickling varieties should be harvested after reaching a length of one to four inches. In either case, refrigerate harvested fruit as soon as possible to preserve flavor and avoid desiccation (IPM, 2014).

TAXONOMY

Bitter gourd belongs to Family: Cucurbitaceae, Subfamily: Cucurbitoideae, Tribe: Melothrieae, Subtribe: Cucumerinae, Genus: *Cucumis* and Species: *Cucumis sativus* L. (Long An, 2015; WIKI, 2023). *Cucumis* in Latin means 'cucumber', the word was derived from Greek for cucumber, *kykyon*. The epithet *sativus*, also Latin, means 'that is sown', referring to the common agricultural use of the species (Santanna and Bradtke, 2022). Common Names of cucumber are garden cucumber, apple cucumber, gherkin, *concombre* (French), *cornichon* (French), *pepino* (Spanish and Portuguese), *huang gua* (pinyin, China), *khira* (Pakistan) (Santanna and Bradtke, 2022).

Accepted Species of Cucumis (WIKI, 2023**)**

1. *Cucumis aculeatus* Cogn.
2. *Cucumis aetheocarpus* (C. Jeffrey) Ghebret. & Thulin

3. *Cucumis africanus* L.f.
4. *Cucumis althaeoides* (Ser.) P.Sebastian & I.Telford
5. *Cucumis anguria* L.
6. *Cucumis argenteus* (Domin) P.Sebastian & I.Telford
7. *Cucumis asper* Cogn.
8. *Cucumis baladensis* Thulin
9. *Cucumis bryoniifolius* (Merxm.) Ghebret. & Thulin
10. *Cucumis canoxyi* Thulin & Al-Gifri
11. *Cucumis carolinus* J.H.Kirkbr.
12. *Cucumis cinereus* (Cogn.) Ghebret. & Thulin
13. *Cucumis clavipetiolatus* (J.H.Kirkbr.) Ghebret. & Thulin
14. *Cucumis costatus* I.Telford
15. *Cucumis debilis* W.J.de Wilde & Duyfjes
16. *Cucumis dipsaceus* Ehrenb. ex Spach
17. *Cucumis engleri* (Gilg) Ghebret. & Thulin
18. *Cucumis ficifolius* A.Rich.
19. *Cucumis globosus* C.Jeffrey
20. *Cucumis gracilis* (Kurz) Ghebret. & Thulin
21. *Cucumis hastatus* Thulin
22. *Cucumis heptadactylus* Naudin
23. *Cucumis hirsutus* Sond.
24. *Cucumis humifructus* Stent (as *Cucumis humofructus*)
25. *Cucumis hystrix* Chakrav.
26. *Cucumis indicus* Ghebret. & Thulin
27. *Cucumis insignis* C.Jeffrey
28. *Cucumis javanicus* (Miq.) Ghebret. & Thulin
29. *Cucumis jeffreyanus* Thulin
30. *Cucumis kalahariensis* A.Meeuse
31. *Cucumis kelleri* (Cogn.) Ghebret. & Thulin
32. *Cucumis kirkbridei* Ghebret. & Thulin
33. *Cucumis leiospermus* (Wight & Arn.) Ghebret. & Thulin
34. *Cucumis maderaspatanus* L.
35. *Cucumis meeusei* C.Jeffrey
36. *Cucumis melo* L.
37. *Cucumis messorius* (C.Jeffrey) Ghebret. & Thulin
38. *Cucumis metuliferus* E.Mey. ex Naudin
39. *Cucumis myriocarpus* Naudin
40. *Cucumis omissus* Thulin
41. *Cucumis picrocarpus* F.Muell.
42. *Cucumis prophetarum* L.
43. *Cucumis pubituberculatus* Thulin
44. *Cucumis pustulatus* Naudin ex Hook.f.
45. *Cucumis queenslandicus* I.Telford
46. *Cucumis quintanilhae* R.Fern. & A.Fern.
47. *Cucumis reticulatus* (A.Fern. & R.Fern.) Ghebret. & Thulin
48. *Cucumis rigidus* E.Mey. ex Sond.
49. *Cucumis ritchiei* (C.B.Clarke) Ghebret. & Thulin
50. *Cucumis rostratus* J.H.Kirkbr.
51. *Cucumis rumphianus* (Scheff.) H.Schaef.
52. *Cucumis sacleuxii* Paill. & Bois
53. *Cucumis sagittatus* Wawra & Peyr.
54. *Cucumis sativus* L., cucumber
55. *Cucumis setosus* Cogn.
56. *Cucumis silentvalleyi* (Manilal, T.Sabu & P.Mathew) Ghebret. & Thulin
57. *Cucumis thulinianus* J.H.Kirkbr.
58. *Cucumis umbellatus* I.Telford
59. *Cucumis variabilis* P.Sebastian & I.Telford
60. *Cucumis zambianus* Widrl., J.H.Kirkbr., Ghebret. & K.R.Reitsma
61. *Cucumis zeyheri* Sond.

There are three wild or semi-wild varieties of cucumber: C. sativus L. var. hardwickii, C. sativus L. var. sikkimensis, C. sativus L. var. xishuangbannanesis (Jia and Wang, 2021). Botanical synonyms are 1) *Cucumis esculentus* Salisb., 2) *C. hardwickii* Royle, 3) *C. muricatus* Willd., 4) *C. rumphii* Hassk., 5) *C. setosus* Cogn., 6) *C. sphaerocarpus* Gabaev, and 7) *C. vilmorinii* Sprenger (Santanna and Bradtke, 2022).

According to Santanna and Bradtke (2022) the subspecies/botanical varieties of cucumber are as follows:

1) *C. sativus* subsp. *agrestis* Gabaev,
2) *C. sativus* var. *albus* Ser.,
3) *C. sativus* var. *anatolicus* Gabaev,
4) *C. sativus* var. *anglicus* L.H. Bailey,
5) *C. sativus* var. *arakis* Forssk.,
6) *C. sativus* var. *battich-djebbal* Forssk.,
7) *C. sativus* var. *brullos* Forssk.,
8) *C. sativus* var. *chatte* Forssk.,
9) *C. sativus* var. *chiar* Forssk.,
10) *C. sativus* var. *cilicicus* Gabaev,
11) *C. sativus* var. *ennemis* Forssk.,
12) *C. sativus* var. *europaeus* Gabaev,
13) *C. sativus* var. *fakus* Forssk.,
14) *C. sativus* var. *falcatus* Gabaev,
15) *C. sativus* var. *fastigiatus* Ser.,
16) *C. sativus* var. *flavus* Ser.,
17) *C. sativus* subsp. *gracilior* Gabaev,
18) *C. sativus* var. *hardwickii* (Royle) Gabaev,
19) *C. sativus* var. *indo-europeus* Gabaev,
20) *C. sativus* var. *irano-turanicus* Gabaev,
21) *C. sativus* var. *izmir* Gabaev,
22) *C. sativus* var. *pallidus* Gabaev,
23) *C. sativus* subsp. *rigidus* Gabaev,
24) C. sativus var. *sativus,*
25) *C. sativus* var. *schemmam* Forssk.,
26) *C. sativus* var. *sikkimensis* Hook. f.,
27) *C. sativus* var. *squamosus* Gabaev,
28) *C. sativus* var. *testudaceus* Gabaev,
29) *C. sativus* var. *tuberculatus* Gabaev,
30) *C. sativus* var. *usambarensis* Zimm.,
31) *C. sativus* var. *variegatus* Ser.,
32) *C. sativus* var. *viridis* Ser.,
33) *C. sativus* var. *vulgatus* Gabaev.

Following main sex types are reported in cucumber (Vidhi, 2022): (i) Monoecious plants: Staminate and pistillate flowers, (ii) Androecious plants: Only staminate flowers, (iii) Gynoecious plants: Only pistillate flowers, (iv) Hermaphrodite plants: Only hermaphrodite flowers, (v) Andromonoecious plants: Staminate and hermaphrodite flowers (Vidhi, 2022). The sex expression in cucumber is determined by three major genes, namely, F (also known as Acr), M and A. The F locus determines degree of femaleness (FF > Ff > ff). M locus determines whether flowers are unisexual (M-) or bisexual (mm). The A locus conditions increased male tendency if the plant is homozygous recessive for aa and ff. Interaction between these three loci is responsible for producing basic sex types in cucumber. Along with three major genes, there are several modifying genes and environmental factors influencing sex types in cucumber.

The existence of sex modifying genes is supported by the observations that gynoecious plants differ in the level of gynoecy and their ability to confer femaleness in F_1 hybrids. Monoecious plants also vary quantitatively in sex expression ranging from predominantly staminate to predominantly pistillate. There are at least five genes that modify the expression of gynoecy in cucumber. The hybrids between monoecious and gynoecious lines can manifest considerable variation in frequency of female flowers depending upon the level of gynoecy in the parents. This variation in the level of gynoecy in the gynoecious x gynoecious and gynoecious x monoecious hybrids remain a potential deficiency in many commercial cultivars. Development of stable gynoecious lines is of commercial interest to produce F_1 hybrids of cucumber. Roguing of monoecious segregates during increases of gynoecious lines is important in this context. Gynoecious lines are suggested to be grown at high plant density, high temperature and long days to promote male tendencies so that really stable gynoecious lines could be selected (Vidhi, 2022).

Although cucumber is known as only a cultivated plant, a *Cucumis* form *Cucumis sativus* var. *hardwickii* R. (Alex.), with 2n = 2x = 14 crosses readily with cultivated cucumber. Sir Joseph Hooker has collected specimens of var. *hardwickii* along the Southern foot-hills of the Himalayas and found that its range of variability fell within that

of *C. sativus*. This has led to conclusion that var. *hardwickii* is either a feral or progenitor form of the cultivated cucumber i.e., *C. sativus* L. Examined the Indian wild cucumber (*C. sativus*. L. var. *hardwickii* Kitamura) and 81 accessions of cultivated cucumber for six isozymes, viz., malate dehydrogenase, 6-phosphogluconic dehydrogenase, phosphoglucomutase, phosphoglucoisomerase, shikimate dehydrogenase and isocitrate dehydrogenase and concluded that Indian wild cucumber is a distant relative of cultivated cucumber (Vidhi, 2022). There are two market classes or cultivar groups in cucumber viz., 1) Eaten fresh or slicing market types and 2) . Processing or pickling types (Vidhi, 2022). In human cultivation, the varieties of cucumbers are classified into three main groups: "slicing", "pickling", and "burpless"/"Seedless". Within these groups, several different cultivars have emerged (Long An, 2015; Anon., 2016; Felix, 2021).

Slicing: Cucumbers grown to eat fresh are called *slicing cucumbers*. The main varieties of slicers mature on vines with large leaves that provide shading. Slicers grown commercially for the North American market are generally longer, smoother, more uniform in color, and have much tougher skin. In contrast, those in other countries, often called European cucumbers, are smaller and have thinner, more delicate skin, often with fewer seeds, thus are often being sold in plastic skin for protection. This variety may also be called a telegraph cucumber. in Australasia.

Pickling: Pickling with brine, sugar, vinegar, and spices creates various flavored products from cucumbers and other foods. Although any cucumber can be pickled, commercial pickles are made from cucumbers specially bred for uniformity of length-to-diameter ratio and lack of voids in the flesh. Those cucumbers intended for pickling, called picklers, grow to about 7 to 10 cm long and 2.5 cm wide. Compared to slicers, picklers tend to be shorter, thicker, less-regularly shaped, and have bumpy skin with tiny white or black-dotted spines. Color can vary from creamy yellow to pale or dark green. Gherkins, also called cornichons, or baby pickles, are small cucumbers, typically those 2.5 to 12.5 cm in length, often with bumpy skin, which are typically used for pickling.

Burpless/Seedless: Burpless cucumbers are sweeter and have a thinner skin than other varieties of cucumber. They are reputed to be easy to digest and to have a pleasant taste. They can grow as long as 60 cm, are nearly seedless, and have a delicate skin. Most commonly grown in greenhouses, these parthenocarpic cucumbers are often found in grocery markets, shrink-wrapped in plastic. They are marketed as either burpless or seedless, as the seeds and skin of other varieties of cucumbers are said to give some people gas.

Cucumber Types (Ferre, 2022**)**

Armenian: Also known as a "snake cucumber," they are extra long, have thin skin, a mild flavor, are crunchy, and not bitter. Skins are light green color or a striped light and dark green color. Examples are Striped Armenian and Sweet Green Armenian.

Burpless: Varieties are reported to be slightly less bitter even when grown in conditions that may cause bitterness (excessive heat and or drought conditions.)

English: Also known as "hothouse," English cucumbers are mild, thin, have smooth skin, and a low seed count.

Gherkin: A small, bumpy skin variety great for pickles.

Asian: A slender cucumber with tiny bumps on dark green thin skin.

Lemon: A pale yellow, round, cucumber picked at lemon size. Lemon cucumbers have a delicate, crisp, not bitter, flavor.

Persian: Persian cucumbers are similar to English cucumbers. A mild type, that grows to various lengths.

Fig. 1. Types of cucumber

BOTANICL DESCRIPTION

Plant: The cucumber, Cucumis sativus, is a creeping vine (climbing or sprawling) that roots in the ground and grows up trellises on other supporting frames, wrapping around ribbing with thin, spiraling tendrils. Cucumber plants are annual plants, surviving only one growing season and the vines can reach up to 5 m in length. The plant may have 4 or 5 main stems from which the tendrils branch (Long An, 2015).

Leaves: The plant has large leaves that form a canopy over the fruit. The leaves of the plant are arranged alternately on the vines, have 3-7 pointed lobes and are hairy; branched tendrils at leaf axes support climbing (Long An, 2015).

Flowers: Cucumber plants are tendril bearing vines with triangular prickly hairy leaves and yellow flowers which are either male or female. The male flowers are in clusters with short, slender pedicels. The female flowers are usually solitary with stout, short pedicels**.** Female flowers are yellow with 5 petals, and develop into a cylindrical fruit, which may be as large as 60 cm long and 10 cm in diameter. The color ranges from green to yellow to whitish; in many varieties, fruits are bicolored with longitudinal stripes from stem to apex. The female flowers are recognized by the swollen ovary at the base which will become the edible fruit. Traditional varieties produce male blossoms first, then female, in about equivalent numbers. New gynoecious hybrid cultivars produce almost all female blossoms. However, since these varieties do not provide pollen, they must have a pollenizer variety interplanted with them, and the number of beehives per unit area is increased (Long An, 2015).

Fruits: Having an enclosed seed and developing from a flower, cucumbers are scientifically classified as fruits. It should be noted that vegetable is a purely culinary term and as such there is no conflict in classifying cucumber as both a fruit and a vegetable. Cucumbers are usually more than 90% water. The flesh of cucumbers is firm and crisp, and really not very sweet, but delicious nevertheless. Cucumbers grown to be eaten fresh (called slicers) and those intended for pickling (called picklers) are similar (Long An, 2015).

Seeds: Cucumber seeds are much smaller than Pumpkin seeds, relatively narrower and thicker and with almost no marginal groove (Long An, 2015). The cucumber is a creeping vine that roots in the ground and grows up trellises or other supporting frames, wrapping around supports with thin, spiraling tendrils. The plant has large leaves that form a canopy over the fruit. The fruit of the cucumber is roughly cylindrical, elongated with tapered ends, and may be as large

as 60 cm long and 10 cm in diameter. Having an enclosed seed and developing from a flower, botanically speaking, cucumbers are classified as Accessory fruits. It is a creeping vine which bears cylindrical edible fruit when ripe (Anon., 2016). Cucumber is an annual climbing herbaceous plant. The root system is shallow and mainly distributed in the cultivated land layer of 30 cm. The stem is vine with different degree of apical dominance. The cross section of the stem is rhombus, and the epidermis of the stem has burrs. The axillae on the stem have the ability of branching, and the number of branching varies greatly among varieties. The cotyledons of cucumber are opposite and long elliptic; leaves are alternate, simple, pentagonal palmate or cordate in outline, and the blades are 3–7 lobed. The flower is axillary, unisexual and occasionally hermaphrodite. The calyx is green with bristles, and the corolla is yellow. The colour of young fruit changes from white to pale green, while mature fruit is yellow or brown when ripened. The shape of the fruit is diverse, such as clublike, cylindrical and spherical. Each fruit has 100–400 seeds. The weight of 1000 seeds is about 20–40 g (Jia and Wang, 2021). Cucumber is an annual plant species and is found to be day neutral. Basically, it is monoecious, trailing or climbing vine with angled, hirsute or rough stems. Leaves are triangular-ovate, somewhat three lobed with mostly acute curves. The staminate flowers are in clusters with short, slender pedicels. The pistillate flowers are usually solitary with stout, short pedicels. The calyx and corolla of staminate, pistillate and even hermaphrodite flowers are five lobed. The staminate flowers have three stamens. Two stamens have two locules each and the third is unilocular. Filaments are free, but the stamens are more or less united by their anthers. The pistillate flowers are epigynous and hermaphrodite flowers are perigynous. The pistil consists of from one to five (but usually three) carpels which in turn, produce ovaries with a corresponding number of locules. The pistillate flowers contain up to five stigmas. The main stem of monoecious cucumber is usually characterized by three phases of sex expressions.

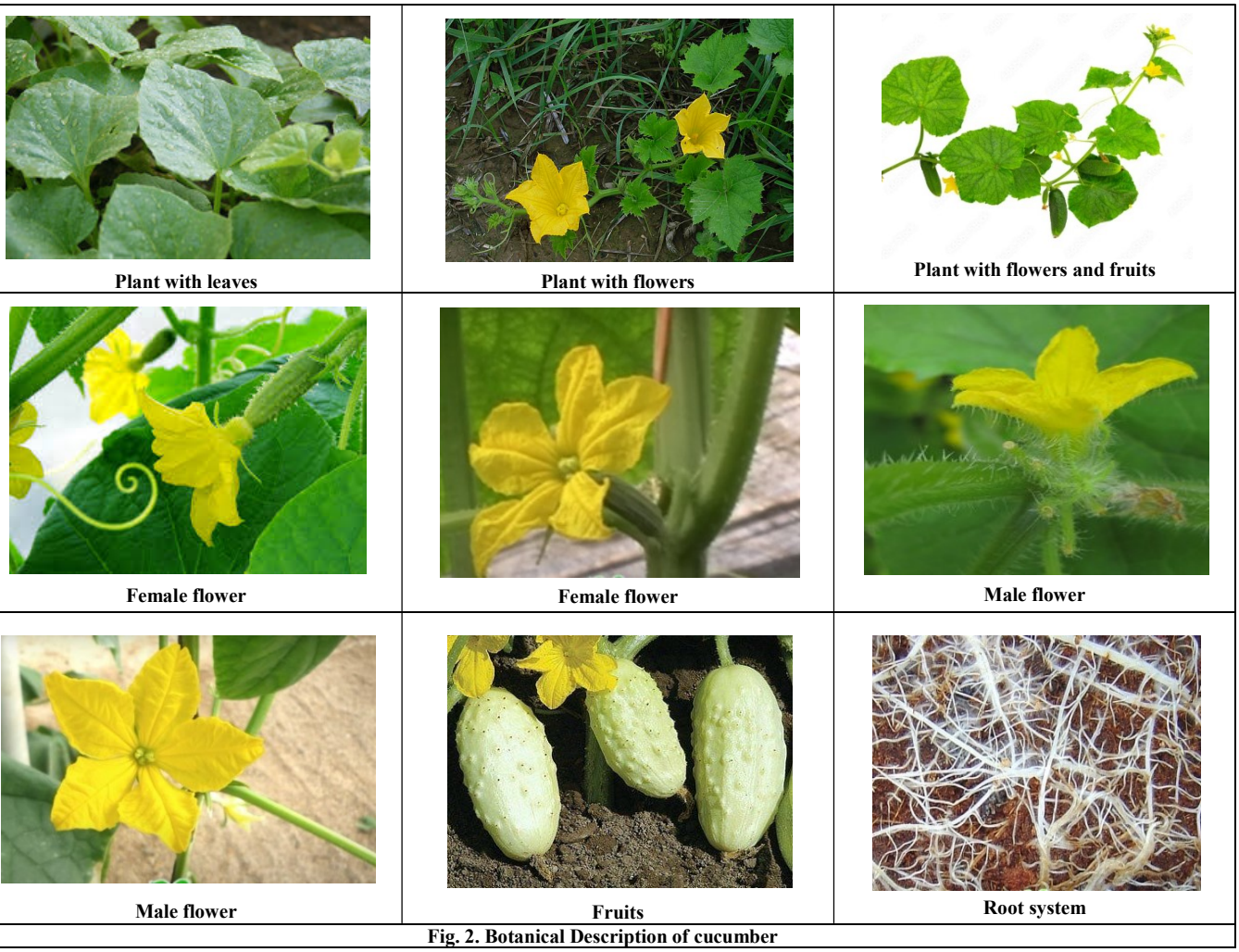

Fig. 2. Botanical Description of cucumber

Fig. 3. A farmer's cucumber field

Only staminate flowers are produced in the first phase followed by a phase of irregularly alternating female, male or mixed nodes and finally a phase of only pistillate flowers. Lateral shoots of monoecious cultivars usually have stronger female tendencies. Fruits from perigynous flowers are more rounded as opposed to elongated ones from epigynous ones. The rounded fruits are horticulturally poor due to large seed cavity. Sex expression is generally influenced by environment. Under long day and high light intensities staminate flowers predominate, whereas under short day and low light intensities female flowers predominate (Vidhi, 2022). Cucumber is a morphologically variable annual herbaceous climber. The stems are prostrate, angular, and covered in white pubescence. Stipules are absent, and the plant bears unbranched axillary tendrils up to 30cm. The pubescent leaves are alternately arranged on 10-16 cm long petioles, simple, basally cordate, and apically acute with 3-7 palmate lobes. The palmately-veined leaves are nearly orbicular, 7-20 cm long and broad. Cucumbers use their simple tendrils to climb over structures or other vegetation. Cucumber is monoecious (separate male and female flowers on the same plant) and its axillary flowers are actinomorphic and rarely bisexual. Both staminate and pistillate flowers have a pubescent 5-parted calyx composed of 0.5-1cm long white pubescent sepals. The sepals are long, narrow, and acute; on pistillate flowers, the calyx is fused to the ovary and forms a hypanthium. The corolla is approximately 2 cm long, yellow, fused less than half of its length, campanulate, 5-parted with oblong to lanceolate lobes. Staminate flowers are solitary or 3-7 on pubescent pedicels (0.5-2 cm long), bearing 3 stamens, of which two have 2-celled anthers (0.3-0.4 cm long) and one a 1-celled anther. Pistillate flowers are solitary or paired on pedicels shorter than the staminate (< 0.5 cm long) before fruit development, whereas during fruit development the pedicels can elongate up to 5 cm long.

The pistilate flowers have 3 staminodes, a pubescent, ellipsoid, unilocular ovary 2-5 cm long, with a short style and 3 stigmas. The blooming period of cucumbers is July-September. Staminate flowers open before pistillate flowers. Cucumber is pollinated by bees that harvest the nectar produced by the flowers; honey bees are more effective than wild bees. The pollen is sticky, which makes wind pollination improbable. The fruit is an indehiscent cylindrical berry with many seeds. Cucumbers are glabrous, and can be smooth or warty, yellow or green, ranging from 5-100 cm long and weigh 50g to 4kg. Each plant produces up to 25 fruits. The white seeds range from 0.5-1.8cm in length, and are emarginate and elliptical with pointed ends. A gram of seed includes 33-40 seeds (Santanna and Bradtke, 2022). The cucumber plant is a sprawling vine with large leaves and curling tendrils. The plant may have 4 or 5 main stems from which the tendrils branch. The leaves of the plant are arranged alternately on the vines, have 3–7 pointed lobes and are hairy. The cucumber plant produces yellow flowers that are 4 cm in diameter. The cucumber fruit varies in shape but is generally a curved cylinder rounded at both ends that can reach up to 60 cm in length 10 cm in diameter. Cucumber plants are annual plants, surviving only one growing season and the vines can reach up to 5 m in length (Anon., 2023). The cucumber is a creeping vine that roots in the ground and grows up trellises or other supporting frames, wrapping around supports with thin, spiraling tendrils. The vine has large leaves that form a canopy over the fruits. The fruit of typical cultivars of cucumber is roughly cylindrical, but elongated with tapered ends, and may be as large as 62 cm long and 10 cm in diameter (WIKI, 2023).

Pollination: Most cucumber cultivars are seeded and require pollination. For this purpose, thousands of honey beehives are annually carried to cucumber fields just before bloom. Cucumbers may also be pollinated via bumblebees and several other bee species. Most cucumbers that require pollination are self-incompatible, thus requiring the pollen of another plant in order to form seeds and fruit. Some self-compatible cultivars exist that are related to the 'Lemon' cultivar. A few cultivars of cucumber are parthenocarpic, the blossoms of which create seedless fruit without pollination, which degrades the eating quality of these cultivar. In the United States, these are usually grown in greenhouses, where bees are excluded. In Europe, they are grown outdoors in some regions, where bees are likewise excluded. Traditional cultivars produce male blossoms first, then female, in about equivalent numbers. Newer gynoecious hybrid cultivars produce almost all female blossoms. They may have a pollenizer cultivar interplanted, and the number of beehives per unit area is increased, but temperature changes induce male flowers even on these plants, which may be sufficient for pollination to occur (WIKI, 2023).

Selfng and Crossing: For crossing purpose, pistillate flowers are closed with a rubber band/wrapped with cotton pad or covered by paper bag to protect against unwanted pollen 1 day prior to opening in the afternoon. Unopened male flowers are also covered similarly at the same time. Anthesis takes place around 5.30 – 7.00 hr. Dehiscence occurs around 4.30-5.00 hr. Pollen fertility is up to 14 hr. Next day morning, pollination is carried out from pollen of protected staminate flower. A thread is tied on selfed flowers and a label is tied on the crossed flowers. Selfed and crossed flowers are again covered by paper bag/wrapped in cotton pad. After about 4 weeks, the fruits are harvested and allowed to further ripening by about another week (Vidhi, 2022). For seed collection, the fruits are cut open and seeds are collected in a glass jar with water and left as such for two days to remove gelatinous mass. Then they are washed in a sieve and dried. Seeds should not be left in water for more than two days otherwise they may start germinating. Sixty days after pollination are usually preferred for optimum maturity of seeds. The success of controlled pollination may be enhanced by removal of any previously set fruit as first fertilized flower inhibits the development of subsequent fruits. Therefore, controlled pollination should be done as soon as possible after flowering begins (Vidhi, 2022).

Fruit development and morphology: Numerous studies in recent years have added greatly to our understanding of cucumber fruit development and have identified a variety of genetic factors leading to extensive diversity. Candidate genes influencing floral organ establishment, cell division and cell cycle regulation, hormone biosynthesis and response, sugar transport, trichome development, and cutin, wax, and pigment biosynthesis have all been identified as factors influencing cucumber fruit morphology (Grumet *et al*, 2023). Cucumber fruits, which are formed from an inferior ovary, are generally harvested toward the end of the period of exponential growth, approximately two weeks post-floral anthesis. Flesh tissue of the fruit at this stage is crisp, and seeds remain small and tender, allowing for consumption of the full fruit. Unlike fruits that are eaten ripe, where metabolic attributes such as sweetness, flavor, and aroma are key quality determinants, the predominant characteristics that drive cucumber fruit quality are morphological: size and shape; external features, such as waxiness, spines and warts; and internal features, such as flesh thickness and seed cavity size (Grumet *et al*., 2023) (Fig. 4).

Fruit Development, Size, and Shape: The fruit, or pericarp, is composed of exocarp (outer layer, i.e., skin or rind); mesocarp (flesh); and endocarp surrounding the ovules or seeds (Fig. 5). Cucumber ovaries, which carry the seeds, are typically comprised of three fused carpels. Superimposed on this basic structure, numerous factors during floral and fruit development confer the observed diversity of fruit size and shape (Grumet *et al*., 2023), (Fig. 5).

GENETICS AND CYTOGENETICS

Cucumber (*Cucumis sativus* L.; 2n = 2x = 14) is one of the Asiatic species and member of the Cucurbitaceae. The African group has diploid chromosome number of 24 (Vidhi, 2022). Genome variation analysis showed cucumber core germplasms were divided into four geographic groups including India, Eurasia, East Asia, and Xishuangbanna (Jia and Wang, 2021). Among the ~66 species in the genus *Cucumis*, cucumber is the only one with $2n = 2x = 14$ chromosomes. The rest, including its sister species, *C. hystrix*, have $2n = 2x = 24$ chromosomes or multiples of 12 chromosomes. Cucumber evolved from its extinct $2n = 24$ ancestor through dysploid chromosome reduction, in which many chromosome rearrangement

events (inversions, fusions, and translocations) were involved with the exception of cucumber Chromosome 7, which remained largely intact during the entire evolution of *Cucumis*.

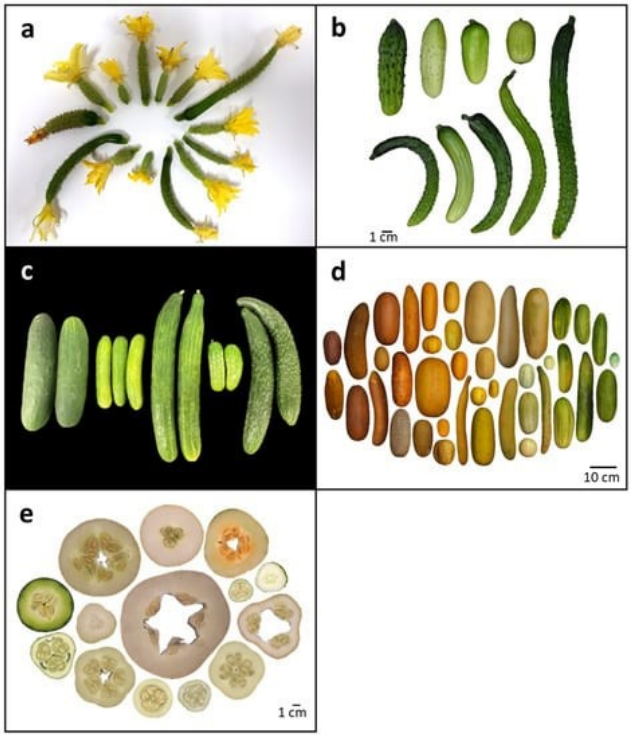

Fig. 4. Examples of diversity in cucumber ovary and fruit morphology at different stages of development as observed in cucumber core collection. (a) Cucumber ovaries at anthesis or one day post-anthesis exhibit differences in size, shape, presence/absence/number of spines, spine color, warts, and ribs.(b) Variation in cucumber fruit development during early exponential growth 5–8 days post pollination (dpp). (c) Examples of cucumber market types. Left to right: Western fresh market (slicing); Beit Alpha/Mediterranean; parthenocarpic greenhouse; Western pickling; Chinese Long. (d) Mature cucumber fruit vary in shape, size, color, surface texture, and netting. (e) Variation in internal properties at maturity (flesh thickness, seed cavity size, color, and hollows)

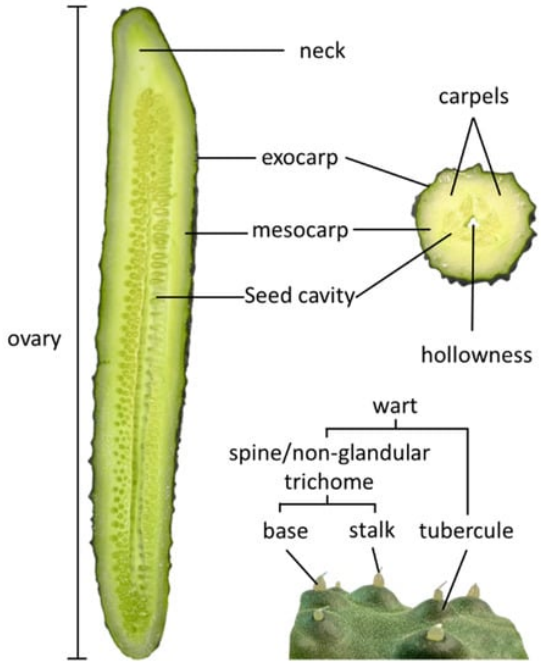

Fig. 5. Structural features of cucumber fruit in longitudinal and cross-section

There are four cross-compatible botanical varieties in *C. sativus*, including the wild cucumber (*C. s*. var. *hardwickii*), the semi-wild Xishuangbanna cucumber (*C. s*. var. *xishuangbannesis*), the Sikkim cucumber (*C.s*. var. *sikkimensis*), and the cultivated cucumber (*C.s*. var. *sativus*). The wild cucumber is the progenitor of cultivated cucumber, but differentiated from the other three taxa in the amount and distribution of heterochromatin, as well as several large inversions (Yiqun Weng *et al*., 2020). Most cucumber varieties have fruits with white flesh, which is devoid of ß-carotene and has a low concentration of total carotenoids. Carotenoids are important nutrients for humans and animals. Thus, developing cucumber varieties with orange flesh could provide a new nutritionally enhanced food source. Some cucumbers with yellow and orange flesh have been described, but there are others that have not been studied. Here, we used three cucumber PI lines, reported to produce colored fruits, from the USDA National Plant Germplasm System to generate three F_2 populations. Fruits from the F_2 populations with colored flesh (green, yellow, or orange) were pooled, and an equal number of fruits with white flesh were pooled. RNA was isolated from the pools and used for RNA sequencing to determine gene expression differences and to identify SNPs in each pool. The orange color of the cucumber fruits was confirmed to be due to ß-carotene. There were no clear expression patterns for genes of the carotenoid biosynthesis pathway that would suggest that their expression controlled the coloration of fruits. Mutations in carotenoid biosynthesis genes also did not explain the variation. However, we detected a SNP in the homolog of the *Or* gene that is responsible for ß-carotene accumulation in orange cauliflower. This genetic basis is different from that of previously studied orange cucumbers, but our results suggest that *Or* is not the only factor. These results provide the basis for future studies for breeding orange cucumbers for commercial or home garden production (Fig. 6).

Fig. 6. Diversity of cucumber fruit size, shape, and color. A, Photograph of several fruits from each F_2 population. B, Cross-section photograph of orange, green, and white fruits used for HPLC analysis of beta-carotene

Genetics of quantitative and qualitative characters: The deep understanding about cucumber crops biology was only possible due to mendelian's classical genetics which have made possible for the cucumber breeders to develop improved varieties and F_1 hybrids. The knowledge about different genes which affects economic traits

facilitated breeders to develop proper genetic resources for the development of trait specific genetic stock for further use for genetic improvement of cucumber. For example, the size of the population will be much smaller if a breeder is selecting for a trait controlled by a single gene, than if the trait is controlled by multiple genes with a large environmental influence. The application of Mendelian genetics using classical techniques in cucumber has facilitated the discovery of a number of genes for yield, quality, plant architecture, and disease and pest resistance in both slicing and pickling cucumber. The yield in cucumber is enhanced by utilizing gynoecious as one of the parent in breeding programme which promote higher female to male sex ratio. Sex ratio (female: male), fruit weight and fruit size are the direct yield components in cucumber breeding (Jat *et al*., 2021).

Sex expression: In commercial cucumber cultivars, the type of sex forms (gynoecious or monoecious) and the amount of their expression is important because these have a direct effect on harvesting date, production and productivity of this crop. Flowering time in cucumber played a critical role in fetching early market price and increase in fruit yield for the growers. In cucumber, the type of sex from (gynoecious or monoecious) and the amount of their expression have direct effect on harvesting time, production and productivity. The sex expression also played a vital role in seed production as well as development of new plant types. The flowering traits like node number at which first female flower appear, days to first pistillate flower opening, and male: female (♂:♀) flower ratio (sex ratio) are the important traits for determination of earliness and fruit yield. The sex expression in cucumber is controlled by three genes, F, M, and A. The degree of female flower expression is controlled by F/f gene. The F locus determines the amount of femaleness (FF > Ff > ff). Gynoecious sex expression in F_1 hybrid of cross of gynoecious × monoecious is governed by partial dominance; where as in gynoecious × subandroecious, it was governed by multiple genes. Single gene with dominant or incomplete dominance, single dominant gene and oligogene with some modified genes, three major QTLs conferring subgynoecy in cucumbers. Seven gynoecious QTLs were detected on chromosomes 5 and 6 in backcross population. These studies suggested that gynoecious is an important economic trait for determinant of earliness and yield in cucumber (Jat *et al*., 2021).

Parthenocarpy: The discovery of parthenocarpy in cucumber has led to the development of seedless fruit in combination with gynoecious trait. Gynoecy coupled with parthenocarpy is a yield and quality related parameter and a high value vegetable crop suited for protected cultivation because these varieties do not require pollination for fruit setting. The fruits of greenhouse parthenocarpic cucumber varieties are also mild in flavor, seedless and have a thin skin that does not require peeling. Still the genetics of parthenocarpy is not well understood in cucumber which is utmost important for efficient breeding procedure. An incomplete dominant gene is responsible for parthenocarpic fruit development. Single recessive gene is responsible for parthenocarpy in cucumber. The growing environmental conditions and epistatic interactions influence the parthenocarpy trait and two additive dominant epistatic major genes and additive dominant polygenes. Seven QTLs for parthenocarpy were detected on chromosome 5 and 7 (parth5.1 and parth7.1) and two on chromosome 6 (parth6.1 and parth6.2). One major effect QTL (parth 2.1) was identified controlling parthenocarpy. The identification of QTLs is a valuable resource for cucumber breeders for development of parthenocarpic cultivars (Jat *et al*., 2021).

Fruit characters*:* The improvement in fruit traits including shape, size, and color is an important target in cucumber breeding. The fruit traits like fruit weight, length diameter and number of fruit per plant are directly related to yield. The other traits like shape index (length: diameter and length/stalk ratio), fruit skin (size of spines, dull or uniform fruit color) and fruit bitterness decides the market value of fruits which are important particularly for slicing cucumber. A single recessive gene controls fragrance in cucumber, fruit color traits were controlled by two major genes, single recessive gene, (**w**), was identified that controls white immature fruit color, single recessive gene controlled the inheritance of quantity of beta-carotene. Green flesh color is one of the most important and commercial trait of cucumber fruit was controlled by a major effect QTL. The bent characters of the fruit were quantitative inheritance controlled by multiple genes and major genes. Twin fused fruits were controlled by single recessive gene. Two loci controlling fruit bitterness in cucumber. The QTLs were also identified in cucumber for several economic traits including fruit spine, skin colors, fruit netting, fruit size, hollow size, flesh thickness variation, fruit carpel number, sex expression, fruit length, fruit diameter, fruit shape, fruit number, and powdery mildew resistance (Jat *et al*., 2021)

Genetic Diversity: The shape of the fruit is diverse, such as clublike, cylindrical and spherical (Jia and Wang, 2021). Cucumbers are glabrous, and can be smooth or warty, yellow or green, ranging from 5-100 cm long and weigh 50g to 4kg (Santanna and Bradtke, 2022). The cucumber fruit varies in shape but is generally a curved cylinder rounded at both ends that can reach up to 60 cm in length 10 cm in diameter (Anon., 2023). Knowing the extent and structure of genetic variation in germplasm collections is essential for the conservation and utilization of biodiversity in cultivated plants. Previous isozyme studies revealed a low genetic diversity in cucumber, but detailed insights into the crop's genetic structure and diversity are largely missing.

Fingerprinted 3,342 accessions from the Chinese, Dutch and U.S. cucumber collections with 23 highly polymorphic Simple Sequence Repeat (SSR) markers evenly distributed in the genome. The data reveal three distinct populations, largely corresponding to three geographic regions. Population 1 corresponds to germplasm from China, except for the unique semi-wild landraces found in Xishuangbanna in Southwest China and East Asia; population 2 to Europe, America, and Central and West Asia; and population 3 to India and Xishuangbanna. Admixtures were also detected, reflecting hybridization and migration events between the populations. The genetic background of the Indian germplasm is heterogeneous, indicating that the Indian cucumbers maintain a large proportion of the genetic diversity and that only a small fraction was introduced to other parts of the world (Jing Lv *et al*., 2012). Cucumber (*Cucumis sativus* L.) is one of the most economically important plants in many countries of the world. Thirty-eight cucumber accessions were evaluated for their genetic diversity using eight agro-economic traits (yield, fruit weight, flesh pith width, flesh pith length, fruit length, harvesting period, number of fruits per plant, and fruit color) and 20 microsatellite markers. Phenotypic data were collected in field for nine crop cycles. The correlation analysis of phenotypic data revealed that yield significantly correlated with fruit weight, flesh pith length, fruit length, harvesting period, and number of fruits per plant. Genotypic data from SSR markers identified 36 polymorphic loci. The polymorphism information content (PIC) averaged at 0.33 and ranged from 0 to 0.62. Genetic diversity and principal component analysis showed three main clusters corresponding to cucumber country of origin. Interestingly, these clusters can also be grouped by several phenotypic traits including yield and number of fruits per plant. The data obtained from this study can be used to select the best parental lines for plant breeding program and for genetic improvement in cucumber (Innark *et al*., 2013). The demand for good quality and high yield cucumber varieties is high. Unfortunately, previous study by Staub *et al*. (2005) showed that cucumber has a very narrow gene pool which limits development of new cucumber varieties by cross-breeding. In order for cucumber breeder to produce new cucumber varieties with higher yield and better quality, the knowledge of genetic diversity of cucumber germplasm is extremely essential. This genetic diversity data will play an important role in cucumber breeding program and for the cucumber germplasm management (Innark *et al*., 2013). Comparative genetic mapping revealed the origin of *Xishuangbanna* cucumber through diversification selection after domestication. QTL mapping provided insights into the genetic basis of traits under diversification selection during crop evolution. The *Xishuangbanna* cucumber, *Cucumis sativus* L. var. *xishuangbannanesis* Qi et Yuan (XIS), is a semi-wild landrace from the tropical southwest China with some unique traits that are very useful for cucumber breeding, such as tolerance to low

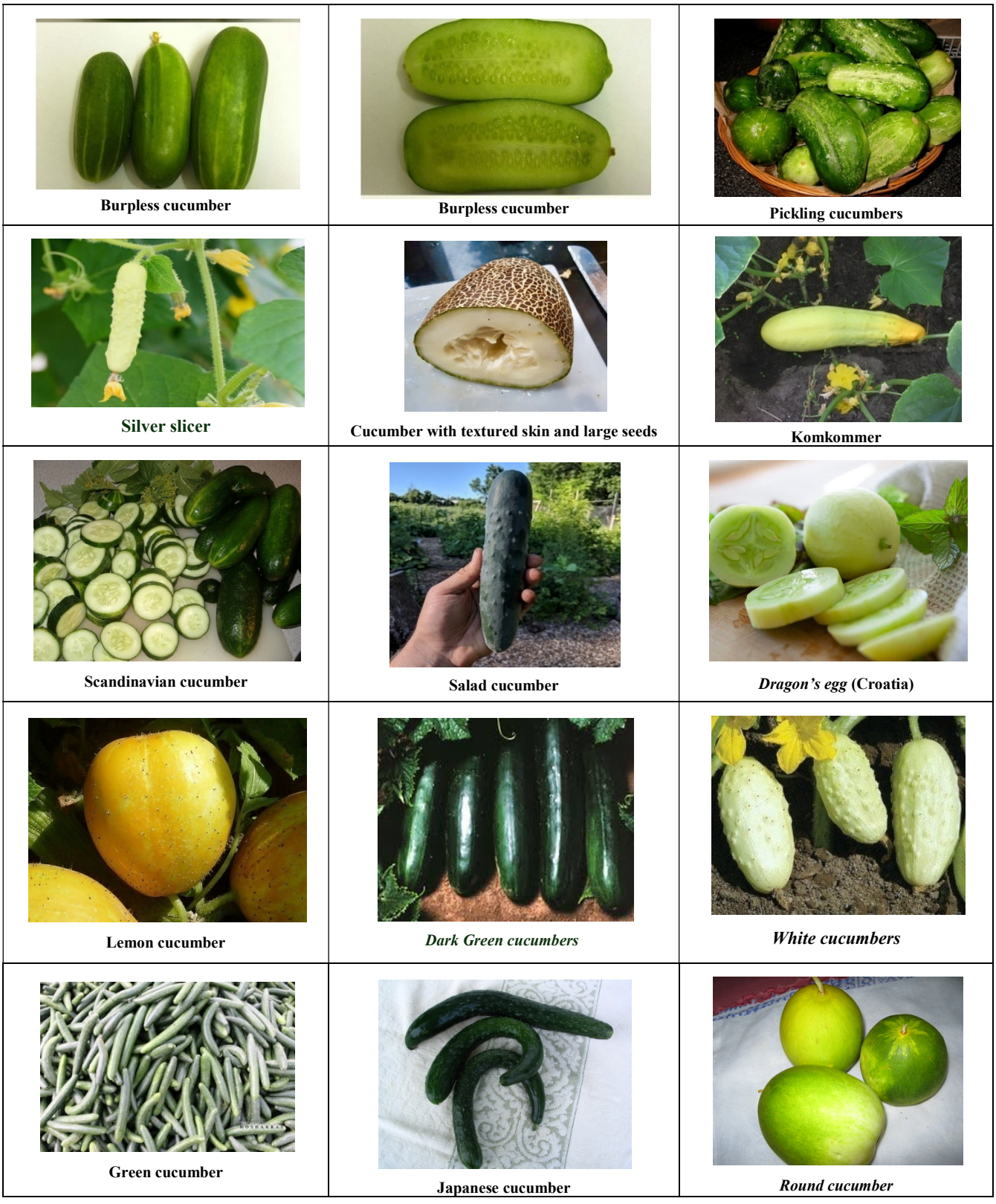

Fig. 7. Variability for fruit color, shape and size in cucumbers

light, large fruit size, heavy fruit weight, and orange flesh color in mature fruits. In this study, using 124 recombinant inbred lines (RILs) derived from the cross of the XIS cucumber with a cultivated cucumber inbred line, we developed a linkage map with 269 microsatellite (or simple sequence repeat) markers which covered 705.9 cM in seven linkage groups. Comparative analysis of orders of common marker loci or marker-anchored draft genome scaffolds among the wild (*C. sativus* var. *hardwickii*), semi-wild, and cultivated cucumber genetic maps revealed that the XIS cucumber shares major chromosomal rearrangements in chromosomes 4, 5, and 7 between the wild and cultivated cucumbers suggesting that the XIS cucumber originated through diversifying selection after cucumber domestication. Results from this study provide insights into the cytological and genetic basis of crop evolution leading to the XIS cucumber. The molecular markers associated with the QTLs should be useful in exploring the XIS cucumber genetic resources for cucumber breeding (Kailiang Bo *et al*., 2015). In this study, we conducted QTL mapping of fruit size in cucumber using F2, F2-derived F3 families and recombinant inbred lines (RILs) from a cross between two inbred lines Gy14 (North American picking cucumber) and 9930 (North China fresh market cucumber). Phenotypic data of fruit length and diameter were collected at three development stages

(anthesis, immature and mature fruits) in six environments over 4 years. QTL analysis was performed with three QTL models including composite interval mapping (CIM), Bayesian interval mapping (BIM), and multiple QTL mapping (MQM). Twenty-nine consistent and distinct QTLs were detected for nine traits from multiple mapping populations and QTL models. Synthesis of information from available fruit size QTLs allowed establishment of 12 consensus QTLs underlying fruit elongation and radial growth, which presented a dynamic view of genetic control of cucumber fruit development. Results from this study highlighted the benefits of QTL analysis with multiple QTL models and different mapping populations in improving the power of QTL detection. Discussion was presented in the context of domestication and diversifying selection of fruit length and diameter, marker-assisted selection of fruit size, as well as identification of candidate genes for fruit size QTLs in cucumber (Yiqun Weng *et al*., 2015).

Here we reported QTL mapping results on fruit size with segregating populations derived from the cross between WI7238 (long fruit) and WI7239 (round fruit) inbred cucumber lines. Phenotypic data of fruit length and diameter were collected at anthesis, immature and mature fruit stages in four environments. Ten major-effect QTL were detected for six traits; synthesis of information from these QTL supported two genes, FS1.2 and FS2.1, underlying fruit size variation in the examined populations. Under the two-gene model, deviation from expected segregation ratio in fruit length and diameter among segregating populations was observed, which could be explained mainly by the interactions between FS1.2 and FS2.1, and segregation distortion in the FS2.1 region. Genome-wide candidate gene search identified CsSUN, a homolog of the tomato fruit shape gene SUN, as the candidate for FS1.2. The round-fruited WI7239 had a 161-bp deletion in the first exon of CsSUN, and its expression in WI7239 was significantly lower than that in WI7238. A marker derived from this deletion was mapped at the peak location of FS1.2 in QTL analysis. Comparative analysis suggested the melon gene CmSUN-14, a homolog of CsSUN as a candidate of the fl2/fd2/fw2 QTL in melon. This study revealed the unique genetic architecture of round fruit shape in WI7239 cucumber. It also highlights the power of QTL analysis for traits with a simple genetic basis but their expression is complicated by other factors (Yupeng Pan *et al*., 2017). In the present study, genetic variation among 40 cucumber genotypes was analyzed by means of morpho-physiological traits and 21 EST-SSR markers. Diversity was observed for morpho-physiological characters like days to 50% female flowering (37-46.9, number of fruits/plant (1.33-5.80), average fruit weight (41-333), vine length (36-364), relative water content (58.5-92.7), electrolyte leakage (15.9-37.1), photosynthetic efficiency (0.40-0.75) and chlorophyll concentration index (11.1-28.6). The pair wise Jaccard similarity coefficient ranged from 0.00 to 0.27 for quantitative traits and 0.24 to 0.96 for EST-SSR markers indicating that the accessions represent genetically diverse populations. With twenty-one EST-SSR markers, polymorphism revealed among 40 cucumber genotypes, number of alleles varied 2-6 with an average 3.05. Polymorphism information content varied from 0.002 to 0.989 (mean = 0.308). The number of effective allele (Ne), expected heterozygosity (He) and unbiased expected heterozygosity (uHe) of these EST-SSRs were 1.079-1.753, 0.074-0.428 and 0.074-0.434, respectively. Same 21 EST-SSR markers transferability checked in four other Cucumis species: snapmelon (*Cucumis melo* var. *momordica*), muskmelon (*Cucumis melo* L.), pickling melon (*Cucumis melo* var. *conomon*) and wild muskmelon (*Cucumis melo* var. *agrestis*) with frequency of 61.9, 95.2, 76.2, and 76.2%, respectively. Present study provides useful information on variability, which can assist geneticists with desirable traits for cucumber germplasm utilization. Observed physiological parameters may assists in selection of genotype for abiotic stress tolerance also, EST-SSR markers may be useful for genetic studies in related species (Pandey *et al*., 2018).

The genetic diversity among 78 cucumber (*Cucumis sativus* L.) accessions was analyzed using 8 morphological traits and 60 SSR markers under two environmental (open field and protected cultivation) conditions. D 2 analysis had grouped the 78 accessions in five major clusters. Cluster I comprised 51 accessions followed by 14, 5, 7 and 1 in cluster II, III, IV, and V respectively. The variation was observed for morphological characters like days to first female flower anthesis (37.53-58.64), days to first fruit harvest (47.28-67.43), fruit length (9.47-26.84 cm), average fruit weight (67.46-417.56 g) and vine length (96.23-170.13 cm). The first four principal components explained 87.72% of the total variation. A total of 171 alleles were amplified with a mean of 2.85 alleles per locus. The polymorphism information content (PIC) varied from 0.05 (UW084478) to 0.59 (UW084186) with a mean value of 0.36. The major allele frequency, gene diversity, and heterozygosity of these SSR markers were 0.36-0.97, 0.05-0.67 and 0.00-0.68, respectively. The dendrogram based on SSR marker analysis classified the 78 genotypes into two major groups those were subdivided into ten subgroups. Collectively, the information obtained will provide a valuable resource for germplasm conservation, genetic analyses and gene discovery in cucumber breeding (Rahul Kumar *et al*., 2020). Conventional genetic breeding has played an essential role in cucumber cultivar innovation over the past decades. However, its progress is slow due to the long breeding period, and difficulty in selecting stable genetic characters or genotypes, prompting researchers to apply molecular biotechnologies in cucumber breeding. Here, we first summarize the achievements of conventional cucumber breeding such as crossing and mutagenesis, and then focus on the current status of molecular breeding of cucumber in China, including the progress and achievements on cucumber genomics, molecular mechanism underlying important agronomic traits, and also on the creation of high-quality multi-resistant germplasm resources, new variety breeding and ecological breeding. Future development trends and prospects of cucumber molecular breeding in China are also discussed (Shengjun Feng *et al*., 2020).

Molecular characterization and genetic diversity among fourteen cucumber genotypes were carried out by using eleven Inter Simple Sequence Repeat (ISSR) markers. All the eleven ISSR markers used were found polymorphic having 97.72% polymorphism among fourteen cucumber genotypes comprising pathenocarpic, gynoecious and monoecious cucumbers. These eleven polymorphic markers produced a total of 69 alleles, of which 4 were unique alleles. The allele number for each ISSR locus varied between 4 to 10 with an average of 6.27 alleles per marker. Polymorphic information content values of ISSRs ranged from 0.43 to 0.84 with an average of 0.68. Jaccard's similarity coefficient was employed to study the molecular diversity of 14 cucumber genotypes. The pair wise genetic similarity among 14 cucumber genotypes varied from 0.36 to 0.83. The dendrogram constructed based on genetic similarities among 14 cucumber genotypes identified two major clusters. The four major parthenocarpic genotypes viz., PCUCP-2, PCUCP-4, PCUCP-6 and PCUCP-8 having high genetic resemblance (80-83%) and two major gynoecious genotypes viz., PGYC-3 and PGYC-2 with 68% similarity value were grouped in a single cluster and three monoecious genotypes viz., PCUC-8, PCUC-25 and Pant Khira-1 were grouped in another cluster with 76-78% similarity value. This study provides information about diversity among pathenocarpic, gynoecious and monoecious cucumber genotypes and remains helpful in future exploration and utilization of diverse germplasm for developing cultivars and hybrids (Sahoo *et al*., 2020). The available genetic diversity within the cultivated cucumber is very low which is the major impediment in the genetic improvement of various cucumber market classes. Thus, increasing the genetic diversity of cultivated cucumber is an important task for public sector research.The cultivated cucumber has narrow genetic base with 3–8% polymorphism within the cultivated genotypes, and 10–25% between botanical varieties (Jat *et al*., 2021). The purpose of this paper is to reveal the molecular research progress of fruit color and spines as key quality traits of cucumber. The markers and genes identified so far could help for marker-assisted selection of the fruit color and spine trait in cucumber breeding and its associated nutritional improvement. Based on the previous studies, peel color and spine density as examples, we proposed a comprehensive approach for cucumber fruit quality traits improvement. Moreover, the markers and genes can be useful to facilitate cloning-mediated genetic breeding in cucumber.

However, in the era of climate change, increased human population and high-quality demand of consumers, studies on molecular mechanisms of cucumber fruit quality traits are limited (Kiros Gebretsadik *et al*., 2021). To a large extent, cultivated cucurbits are beneficial to human health for providing necessary minerals and fibers.Therefore, this review portrays the current status of advances made by using Genotyping-by-sequencing --GBS and its combination with other tools in various studies of cucumber such as the use of GBS and single nucleotide polymorphism (SNP) markers, GBS and GWAS, also with QTL and marker-assisted selection (MAS) are applied to display and detect explicit genetic architecture complex traits in crops and chromosome rearrangements. Cucumber breeding programs have undoubtedly benefited from genotyping-by-sequencing. Using the GBS method, research discovered lots of new candidate genes that control various traits including spine color, fruit stalk-end color, and disease resistance in cucumber lines (Fildaus *et al*., 2022).

BREEDING

Plant Genetic Resources of Cucumber: The scope of improvement of any crop depends upon the magnitude of genetic variability present in the available germplasm. Greater the variability in the available germplasm better would be the chances of selecting superior genotypes (Sandeep Kumar Dhatwalia and Ramesh Kumar Bhardwaj, 2012). Germplasm collections are a crucial resource to conserve natural genetic diversity and provide a source of novel traits essential for sustained crop improvement. Optimal collection, preservation and utilization of these materials depends upon knowledge of the genetic variation present within the collection. Here we use the high-throughput genotyping-by-sequencing (GBS) technology to characterize the United States National Plant Germplasm System (NPGS) collection of cucumber (*Cucumis sativus* L.). The GBS data, derived from 1234 cucumber accessions, provided more than 23 K high-quality single-nucleotide polymorphisms (SNPs) that are well distributed at high density in the genome (~1 SNP/10.6 kb). The SNP markers were used to characterize genetic diversity, population structure, phylogenetic relationships, linkage disequilibrium, and population differentiation of the NPGS cucumber collection. These results, providing detailed genetic analysis of the U.S. cucumber collection, complement NPGS descriptive information regarding geographic origin and phenotypic characterization. We also identified genome regions significantly associated with 13 horticulturally important traits through genome-wide association studies (GWAS). Finally, we developed a molecularly informed, publicly accessible core collection of 395 accessions that represents at least 96% of the genetic variation present in the NPGS. Collectively, the information obtained from the GBS data enabled deep insight into the diversity present and genetic relationships among accessions within the collection, and will provide a valuable resource for genetic analyses, gene discovery, crop improvement, and germplasm preservation (Wang *et al*., 2018). International Plant Genetic Resources Institute (IPGRI) coordinates institutional germplasm holdings of cucumber in Europe. In USA, the U.S. National Plant Germplasm System (NPGS) maintains and evaluates cucumber germplasm. The regional plant introduction station of NPGS, Ames, Iowa has about 1350 C. sativus accessions from all parts of world. In India, cucumber germplasm are conserved at NBPGR, New Delhi and IIVR, Varanasi and several SAUs. Cucumber plant introductions (Pls) have contributed enormously to cucumber improvement (Vidhi, 2022).

Breeding Objectives of Cucumber: With increasing consumption demand of cucumber, more new varieties with excellent comprehensive properties are in need, and we might make some efforts from the following aspects: (i) expanding collection and utilization of cucumber germplasm resources; (ii) establishing highly efficient gene editing and genetic transformation technologies in cucumber; (iii) identifying new loci or genes associated with key agronomic traits of cucumber and combining multiple molecular markers of excellent traits into one variety; (iv) realizing rapid accumulation of omics genotypes and phenomics (Jia and Wang, 2021). Earliness, high yield, uniform fruit shape, size, color and better quality are prerequisites for the release of the cucumber varieties and F_1 hybrids for open field condition. In addition to these characters, gynoecious and parthenocarpic traits are desirable for green house cucumber production. Identification of genotypes tolerance to drought is also one of important breeding objective in cucumber. Cucumber is a monoecious vegetable crops species. However, several gynoecious varieties and F_1 hybrids have been developed by introgression of F locus (gynoecious gene) in the background of different market classes of the cucumber for commercial production. The utilization of gynoecious lines are economical and easier for hybrid seed production by reducing the cost of male flower pinching and hand pollination. The present day cucumber F_1 hybrids for open field production derived from the cross between gynoecious × monoecious and monoecious × monoecious where as green house grown F_1 hybrids are the result of the cross of gynoecious × gynoecious lines with parthenocarpic traits (Jat *et al*., 2021). Quantitatively inherited trait, has low heritability, mainly influenced by genotype and environment and to a lesser extent by g x e interaction, hence selection for yield should occur during intermediate stages of selection, yield evaluation should be based on plot basis rather than on individual plants, yield may be effectively evaluated on small (one row, single replication and harvest), multi-locations (two-three) trials over seasons/years, several methods of yield measurement (fruit volume, mass, number, market value) compared and investigated (Vidhi, 2022).

- The most efficient measurement of yield in plant breeding trials seems to be the total number of marketable and oversized fruits/plant, as it is highly heritable, more stable over time, is easier to measure.
- Increase in number of harvests/plant, stem length, number of branches/plant, number of flowing nodes/plant, time to anthesis, percentage of pistillate flowers and percentage of fruit set.
- Predominantly gynoecious types.
- Earliness (days to first harvest).
- More number of lateral branches
- Desirable fruit size, shape and colour as per need of consumers/processing industry. In India there are two main segments from consumers point of view. There are long, green with light stripes particularly in north India and medium long, white with mild spines like Gypsy in western and south India.
- Parthenocarpic cucumber, controlled by single recessive gene/several incompletely recessive genes/single dominant gene expressing incomplete dominance, desirable for glasshouse cultivation.
- Better keeping quality of fruits with less shrinkage, non-bitter, crispy taste, free from carpel separation without hollow spots.

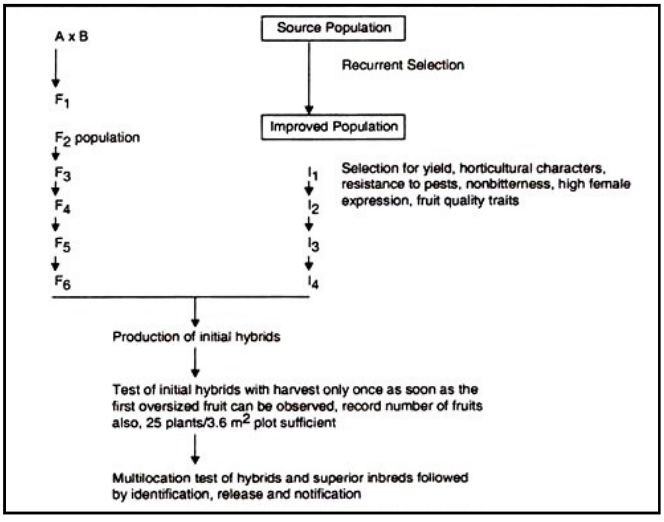

Fig. 8. Hybrid breeding in cucumber

Breeding Methds of Cucumber: Ihe top five breeding methods applicable to cucumber are: 1. Routine Backcross Programme

Method; 2. Pedigree Method; 3. Use of Sex Inheritance and Chemicals in Breeding Method and 4. Population Improvement and Extraction of Inbred Lines Method and 5. Hybrid Breeding (Vidhi, 2022). Hybrid varieties of cucumber are becoming predominant day by day. Their number is continuously increasing in USA, Germany, Southeast Asia etc. and thus, extraction of superior inbreds and determination of best hybrid combinations appears to be of great importance. This scheme is diagrammatically illustrated in Fig. 8 as adapted from Tatlioglu (1993). According to Staub (2008) hybrids are usually made as: gynoecious x gynoecious lines or monoecious x monoecious lines. Molecular markers technology could be exploited to overcome the obstacle of traditional breeding by accelerating the breeding cycle and selection of desirable traits. The high density genetic maps for various traits have been constructed in cucumber to detected quantitative traits loci (QTLs) for genetic enhancement in different market classes of cucumber. (Jat *et al*., 2021).

Cultivar Description (Vidhi, 2022).

1. Plant: Growth type: determinate or indeterminate; Vigour: weak, medium or strong; Total length of first 15 internodes: short, medium or long; Length of internodes of side shoots: short, medium or long.

2. Leaf: Size of blade: small, medium or large; Intensity of green colour: light, medium or dark; Blistering: absent or very weak, weak, medium, strong or very strong; Undulation of margin: absent or very weak, weak, medium, strong or very strong; Length of terminal lobe: short, medium or long; Width of terminal lobe: narrow, medium or broad; Ratio length/width of terminal lobe: less than 1, equal to 1, or more than 1.

3. Plant: Sex expression: male and female flowers approximately equally present, mainly female flowers, or almost exclusively female; Number of female flowers per node: one to three, or more than three

4. Young fruit: Type of vestiture: hairs only, prickles only or hairs and prickles; Density of vestiture: sparse, medium or dense; Colour of vestiture: white or black; Size of warts: absent or very small, small, medium, large or very large.

5. Parthenocarpy: absent or present

6. Fruit: Length: very short, short, medium, long or very long; Diameter: small, medium or large; Ratio length/diameter: small, medium or large; Core diameter in relation to diameter of fruit: small, medium or large; Predominant shape of stem end at market stage: necked, acute or obtuse; Length of neck: short, medium or long; Shape of calyx end at market stage: acute or obtuse; Ground colour of skin at market stage: white, yellow or green; Intensity of ground colour of skin: light, medium or dark; Ribs: absent or present; Prominence of ribs: weak, medium or strong; Colouration of ribs compared to ground colour: lighter, equal or darker; Vestiture: absent or very sparse, sparse, medium, dense or very dense; Warts: absent or present; Stripes (ribs excluded): absent or present; Length of stripes: short, medium or long; Mottling: absent or present; Predominant type of mottling: small and round, or large and irregular; Intensity of mottling: weak, medium or strong; Length of peduncle: short, medium or long; Thickness of peduncle: thin, medium or thick; Ground colour of skin at physiological ripening: white, yellow, green, orange or brown.

7. Time of development of female flowers (80% of plants with at least one female flower): early, medium or late

8. Cotyledon bitterness: absent or present

9. Fruit bitterness: absent or present.

Cucumber Varieties in India (Vidhi, 2022).

Straight Eight: This is a variety of cucumber having cylindrical, very symmetrical fruits introduced by Ferry- Morse Seed Co., Detroit, Michigan, USA, in 1935. It was introduced to India and released by IARI, Regional Station, Katrain, Kullu Valley. It is early, suited for hills, and has dark green leaves, 20-25 cm long thick straight fruits with round ends. The fruits are light green. It is a heavy yielder.

Japanese Long Green: This is a temperate variety specifically suited to hills and lower hills. It is extra-early with 45 days maturity. Fruits are 30-40 cm long, with white skin, white spines and light green crisp flesh. It has been released by IARI, Regional Station, Katrain.

Poinsette: This is an American variety initially introduced and multiplied by National Seeds Corporation of India. Fruits are 20-30 cm long, dull dark green in colour. It is resistant to downy mildew, powdery mildew, anthracnose and angular leaf spot. It has been originally bred at Charleston, South Carolina, USA.

Pusa Sanyog: This is an F_1 hybrid between a Japanese gynoecious line and Green Long Naples. It matures in 50 days. Fruits are 28-30 cm long, cylindrical and have dark green skin with yellow spines. It has been released by IARI, Regional Station, Katrain. This hybrid could never reach to market in India as seed could not be produced and marketed.

Pant Khira 1 (PCUC 28): This is a selection from inbreds of indigenous germplasm at Pantnagar, released in 2001. The fruits are 20 cm long, cylindrical with light, white stripes. Yield is approximately 150 q/ha.

Pant Sankar Khira 1: This hybrid (PCUC 28 X PCUC 8) developed at Pantnagar was released in 1999. Fruits are about 20 cm long. Yield potential is about 200 q/ha. Predominant hybrids in market by seed industry in India are Gypsy (white fruits), Malini (green fruits) and Harshini (green fruits).

USES

Cucumbers have a mild, refreshing taste and a high water content. They can help relieve dehydration and are pleasant to eat in hot weather. People eat cucumber as a savory food. It also features in some beauty products (Megan Ware, 2019). Cucumber is one of the freshest and most nutritious foods on the planet**,** being frequently used for the preparation of salads, soups and even refreshing juices (Phoneia, 2019). Cucumber has versatile uses in culinary, therapeutic and cosmetic purposes. Nutritional and epidemiological researches have shown various benefits of cucumber. For example, cucumber contains abundant nutrients and has crunchy texture and unique flavor, so it is a quintessential vegetable used for a variety of dishes, and it is also indispensable for salad, soup and smoothie (Jia and Wang, 2021). Cucumbers are a vegetable with many uses in both cooking and skin care. These members of the gourd family are a healthy, flavorful addition to salads and are often served along with spicy Asian dishes to help cool off the diner's palate. Many people make pickled cucumbers as a side dish with a mixture of salt and sugar or preserve them in a brine for later use. Some of the most important uses of cucumber are in food preparation. They are used in cuisines around the world for their mild flavor and texture. In Thai cuisine, cucumbers are often served with extremely spicy dishes to help soothe a burning mouth and tongue. The lightness of the vegetable provides a strong contrast to more powerful flavors in many cuisines. Cultures around the world also use cucumbers as a healthy, low-calorie snack. In Western cuisine, fresh cucumbers are often sliced and placed in salads along with a mixture of other vegetables or as a garnish. They also are one of the most commonly pickled vegetables, so much so that the word "pickle" is essentially a synonym for pickled cucumber in many countries. Pickles provide a salty condiment for use on various types of sandwiches. Fresh, lightly pickled cucumbers are often served as a side dish, either alone or mixed with onions, peppers and tomatoes (Bishop, 2022).

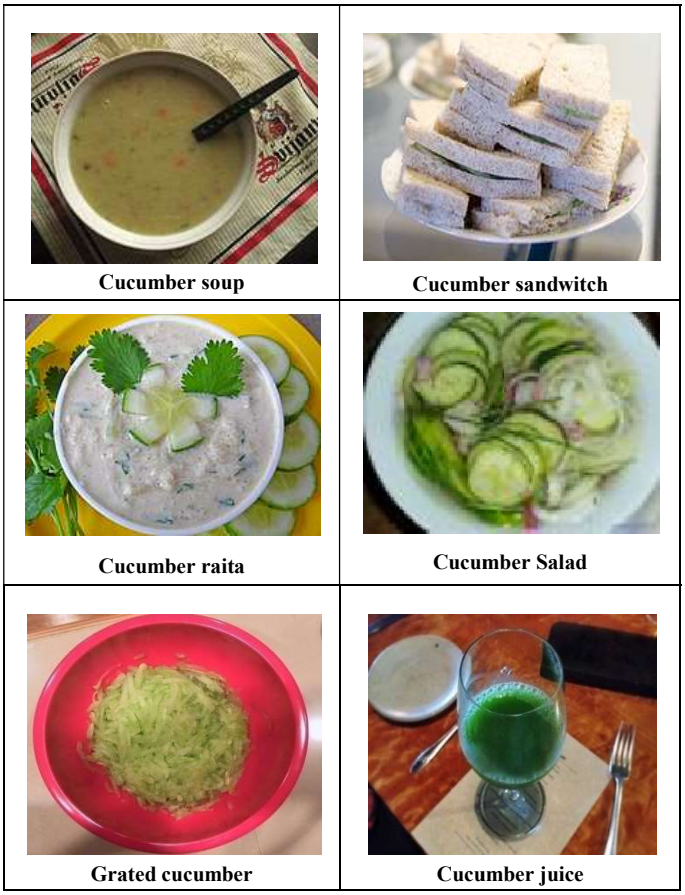

Fig. 9. Various preparations made from cucumber

Cucumber is used in many ways:

Cucumber cake: Cucumber cake is a cake prepared using cucumber as a primary ingredient. Additional ingredients may include typical cake ingredients such as flour, sugar, eggs and leavening. It may be served as a dessert cake, and some versions are topped with an icing (WIKI, 2023).

Cucumber Raita: Cucumber Raita is a variation of raita that can be used as a dip or a salad. It is made by mixing together freshly chopped cucumber, green chillies, and dahi (yogurt), and optionally finely chopped tomato and onion. It is especially popular in the summer months as it helps to beat the heat. It is often served as a side accompaniment with the main course in Indian cuisine (WIKI, 2023).

Cucumber sandwich: The traditional cucumber sandwich is a crustless tea sandwich (or finger sandwich) composed of thin slices of cucumber situated between two thin slices of lightly buttered white bread. The sandwich originated in the United Kingdom, and modern variants, largely of United States origin, introduce cream cheese, mayonnaise, chopped dill or spices, and salmon, and may substitute brown bread. One specific US variant includes benedictine, a green soft spread made from cucumbers and cream cheese. Cucumber sandwiches are most often served for a light snack or for afternoon tea, a formal light meal served in the late afternoon, or in the early evening before the main supper. Cucumber sandwiches are also traditionally served in the tea break at club cricket matches in England (WIKI, 2023).

***Cucumber soup*:** Cucumber soup is a traditional Polish and Lithuanian soup sometimes simply ogórkowa). It is made from sour, salted cucumbers and potato. Occasionally rice is substituted for the potatoes. Cucumber soup is also any soup using cucumbers as a primary ingredient, and is present in various cuisines. The two major varieties are fresh cucumber soup and pickled cucumber soup (WIKI, 2023).

Use in Perfumery: The peculiarly refreshing odour of Cucumber has found application in perfumery. Various products belonging under this head requiring the odour of Cucumber - it being used in blending certain bouquet perfumes - this plant is to be included among the aromatic plant in a wider sense (Grieve, 2022).

Ethnobotanical Uses: Cucumbers are consumed raw or pickled (gherkin). Mature uncooked cucumbers bring relief for individuals suffering from celiac disease, and promote skin health. Edible oil can be extracted from the seeds and used for cooking. Immature cucumbers can be cooked and consumed to treat dysentery. The fruit is also valued in the cosmetic industry, used to soften the skin. A poultice made from fresh cucumbers can be applied to burns and open sores. The seeds can be used to expel parasitic worms. The juice from the leaves induce vomiting and aid digestion. The seedlings are toxic and should not be consumed (Santanna and Bradtke, 2022).

Other Uses: Cucumbers have been recommended as an emergency shoe polish, breath freshener and ink eraser. Some advocate the vegetable as a green alternative for chemical products when cleaning sinks and bathrooms (Bishop, 2022).

Cutural Significance/Cucumber blessing: The cucumber blessing is an adhiṣṭhāna practised at Shingon Buddhist temples in summer. In a cucumber blessing meeting, the priest and believers together pray that they can pass the season of hot summer in good health like fresh cucumbers. Kūkai, the founder of Shingon Buddhism, is said to have initiated this practice of blessing (Fig. 10) (WIKI, 2023).

Fig. 10. Cucumbers being blessed at a Shingon Buddhist temple in Kailua, Hawaii County, Hawaii

NUTRITIONAL VALUE

Cucumbers are low in calories but high in many important vitamins and minerals. One 300-g unpeeled, raw cucumber contains the following: Calories: 45, Total fat**:** 0 grams, Carbs**:** 11 g, Protein: 2 g, Fibe**r:** 2 g, Vitamin C**:** 14% of the RDI, Vitamin K**:** 62% of the RDI, Magnesium**:** 10% of the RDI, Potassium**:** 13% of the RDI, Manganese**:** 12% of the RDI. Although, the typical serving size is about one-third of a cucumber, so eating a standard portion would provide about one-third of the nutrients above. Additionally, cucumbers have a high water content. In fact, cucumbers are made up of about 96% water. To maximize their nutrient content, cucumbers should be eaten unpeeled.

Peeling them reduces the amount of fiber, as well as certain vitamins and minerals. Antioxidants are molecules that block oxidation, a chemical reaction that forms highly reactive atoms with unpaired electrons known as free radicals. The accumulation of these harmful free radicals can lead to several types of chronic illness. In fact, oxidative stress caused by free radicals has been associated with cancer and heart, lung and autoimmune disease. Cucumbers, are especially rich in beneficial antioxidants that may reduce the risk of these conditions (Link, 2017).

According to Long An (2015) Nutritional value per 100 g of Cucumber, with peel, raw are as follows:

Energy	65 kJ (16 kcal)
Carbohydrates	3.63 g
Sugars	1.67
Dietary fiber	0.5 g
Fat	0.11 g
Protein	0.65 g
Vitamins	:
Thiamine (B1)	0.027 mg (2%)
Riboflavin (B2)	0.033 mg (3%)
Niacin (B3)	0.098 mg (1%)
Pantothenic acid (B5)	0.259 mg (5%)
Vitamin B6	0.04 mg (3%)
Folate (B9)	7 µg (2%)
Vitamin C	2.8 mg (3%)
Vitamin K	16.4 µg (16%)
Trace minerals	:
Calcium	16 mg (2%)
Iron	0.28 mg (2%)
Magnesium	13 mg (4%)
Manganese	0.079 mg (4%)
Phosphorus	24 mg (3%)
Potassium	147 mg (3%)
Sodium	2 mg (0%)
Zinc	0.2 mg (2%)
Other constituents	:
Water	95.23
Fluoride.	1.3 µg

According to the USDA, one 142-g cup of unpared, raw, chopped cucumber contains the following nutrients (Megan Ware, 2019): water: 137 g, calories: 17, protein: 0.8 g, fat: 0.2 g, carbohydrate: 3.1 g, including 2.0 g of sugar, fiber: 1.0 g, calcium: 19.9 g, iron: 0.3 mg, magnesium: 17 mg, phosphorus: 29.8 mg, potassium: 193 mg, sodium: 2.8 mg, vitamin C: 4.5 mg, folate: 19.9 mcg, beta carotene: 44 mcg, lutein + zeaxanthin 22.7 mcg and vitamin K: 10.2 mcg. Cucumber also contains a range of B vitamins, vitamin A, and antioxidants, including a type known as lignans. Antioxidants help remove substances from the body known as free radicals. Some free radicals come from natural bodily processes, and some come from outside pressures, such as pollution. If too many collect in the body, they can lead to cell damage and various types of disease. Studies have suggested that the lignans in cucumber and other foods may help lower the risk of cardiovascular disease and several types of cancer. Cucumbers are not especially nutritious. Due to their high water content, they are perfect for hydrating you, but not so good at packing much nutritional punch. Despite this, there are some smaller amounts of some important nutrients including potassium, vitamin K and vitamin C (Fruitsmart, 2012). Cucumbers provide various nutrients but are low in calories, fat, cholesterol, and sodium (Megan Ware, 2019**).** Cucumbers are rich in vitamins A, C, E, and K, as well as protein, dietary compounds, folate, niacin, pyridoxine, riboflavin, thiamine, sodium, potassium. It also contains important healthy minerals such as calcium, iron, magnesium, manganese, phosphorus, zinc (Anon., 2023). Raw cucumber (with peel) is 95% water, 4% carbohydrates, 1% protein, and contains negligible fat. A 100-gram ($3+\frac{1}{2}$-ounce) reference serving provides 65 kilojoules (16 kilocalories) of food energy. It has a low content of micronutrients: it is notable only for vitamin K, at 16% of the Daily Value. Depending on variety, cucumbers may have a mild melon aroma and flavor, in part resulting from unsaturated aldehydes, such as (E,Z)-nona-2,6-dienal, and the *cis*- and *trans*- isomers of 2-nonenal.[8] The slightly bitter taste of cucumber rind results from cucurbitacins (WIKI, 2023).

HEALTH BENEFITS

Long An (2015) reported the following health benefits:

Redrates body and replenishes daily vitamins**:** Cucumbers are 95 percent water, keeping the body hydrated while helping the body eliminate toxins. Cucumbers have most of the vitamins the body needs in a single day. Don't forget to leave the skin on because the skin contains a good amount of vitamin C, about 10 percent of the daily-recommended allowance.

Skin and hair care: If you don't like to eat the skin, it can be used for skin irritations and sunburns as aloe would be used. Place a slice over puffy eyes and its anti-inflammatory properties help reduce puffiness. The silicon and sulfur in cucumbers help to stimulate hair growth.

Fight cancers**:** Cucumber are known to contain lariciresinol, pinoresinol, and secoisolariciresinol. These three lignans have a strong history of research in connection with reduced risk of several cancer types, including breast cancer, ovarian cancer, uterine cancer and prostate cancer.

Relieves bad breath**:** Take a slice of cucumber and press it to the roof of your mouth with your tongue for 30 seconds, the phytochemcials will kill the bacteria in your mouth responsible for causing bad breath.

Hangover cure**:** To avoid a morning hangover or headache; eat a few cucumber slices before going to bed. Cucumbers contain enough sugar, B vitamins and electrolytes to replenish many essential nutrients, reducing the intensity of both hangover and headache.

Aids in weight loss and digestion**:** Due to its low calorie and high water content, cucumber is an ideal diet for people who are looking for weight loss. The high water content and dietary fiber in cucumbers are very effective in ridding the body of toxins from the digestive system, aiding digestion. Daily consumption of cucumbers can be regarded as a remedy for chronic constipation.

Cures diabetes, reduces cholesterol and controls blood pressure**:** Cucumber juice contains a hormone which is needed by the cells of the pancreas for producing insulin which has been found to be beneficial to diabetic patients. Researchers found that a compound called sterols in cucumbers may help reduce cholesterol levels. Cucumbers contain a lot of potassium, magnesium and fiber. These work effectively for regulating blood pressure. This makes cucumbers good for treating both low blood pressure and high blood pressure.

Promotes joint health, relieves gout and arthritis pain: Cucumber is an excellent source of silica, which is known to help promotes joint health by strengthening the connective tissues. They are also rich in vitamin A, B1, B6, C & D, Folate, Calcium, Magnesium, and Potassium. When mixed with carrot juice, they can relieve gout and arthritis pain by lowering the uric acid levels.

Other benefits**:** It eliminates a foggy mirror. Before taking a shower, rub a cucumber slice along a mirror and it will eliminate the mirror fogging up. Instead of WD40, take a cucumber slice and rub it along a squeaky hinge and your door will stop squeaking (Long An, 2015).

According to Megan Ware (2019) the health benefits are as follows:

Hydration: Cucumbers consist mostly of water, and they also contain important electrolytes. They can help prevent dehydration in hot weather or after a workout. For people who do not enjoy drinking water, adding cucumber and mint can make it more attractive. Staying hydrated is essential for maintaining a healthy intestine, preventing constipation, avoiding kidney stones, and more. Cucumber is one of the most hydrating foods. What other foods are good for hydration?

Bone health**:** Vitamin K helps withTrusted Source blood clotting, and it may support bone health.

Vitamin K helps improve calcium absorption. Together, these nutrients can contribute to good bone health.

Vitamin D is also important for bone health. Find out more.

Cancer**:** As a member of the Cucurbitaceae family of plants, cucumbers contain high levels of bitter-tasting nutrients known as

cucurbitacin. Cucurbitacins may help prevent cancer by stopping cancer cells from reproducing.

***Cardiovascular health*:** The American Heart AssociationTrusted Source (AHA) note that fiber can help manage cholesterol and prevent related cardiovascular problems. Reducing sodium intake and increasing potassium intake may help prevent high blood pressure. The cucurbitacins in cucumber may also help prevent atherosclerosis.

***Diabetes*:** Cucumbers may play a roleTrusted Source in controlling and preventing diabetes. It contains substances that may help lower blood sugar or stop blood glucose from rising too high. One theory is that the cucurbitacins in cucumber help regulate insulin release and the metabolism of hepatic glycogen, a key hormone in the processing of blood sugar. Fiber, too, may help prevent and manage type 2 diabetes. Cucumbers score low score on the glycemic index (GI). This means they provide essential nutrients without adding carbohydrates that can increase blood glucose.

Inflammation: Cucumbers may have anti-inflammatory benefits Trusted Source. Inflammation is a function of the immune system. Experts believe inflammation may help trigger the development of various health conditions, viz., cardiovascular disease, diabetes, autoimmune conditions, depression and cancer.

Skin care: Some research has suggested that cucumber's nutrients may provide benefits for skin health. Applying sliced cucumber directly to the skin can help cool and soothe the skin and reduce swelling and irritation. It can alleviate sunburn. Placed on the eyes, they can help decrease morning puffiness.

According to Momaya (2022) the health benefits are as follows:

***Cucumber Fights Dehydration*:** Water is considered to be a life-giving fluid that is essential for your body. Having less than the required amount of water in the body results in dehydration, causing you to be susceptible to several diseases. Cucumbers are 95% water. Including cucumber in your daily diet replenishes the lost water in your body, keeping you perfectly hydrated. Owing to the minerals and vitamins present in cucumber, it is known to hydrate the same as twice the amount of water. Do remember to eat a few slices of cucumber after a strenuous round of workout or exhausting physical activity, especially during the height of summer.

***Fiber-Rich*:** Cucumber is considered a good source of nutritious fibre that helps your body function properly. The combination of fibre and water in cucumbers prevents constipation and can increase the regularity of bowel movements. Dieticians advise diabetics to consume it regularly, as it causes the pancreas to secrete the right amount of insulin, thus helping in regulating the sugar produced. Keep the peels on or you might lose most of the cucumber's fibre content.

***Cucumber Boosts Bone Health*:** Cucumbers are also a source of calcium that eliminates the risks of low bone density and fractures. Cucumber also helps to improve the absorption of calcium, enhancing the repair of bone muscles. Cucumber contains silica in its skin which works together with calcium and Vitamin D to boost collagen production and prevent bone deterioration which is a leading cause of conditions like osteoporosis. Do not fail to add cucumber to your diet, as you will enjoy having strong bones and cartilages despite advancing in years.

***Cucumber Prevents Growth of Cancer Cells*:** Cucumber is known for its anti-cancer properties. It can reduce the spread of cancerous cells throughout the body and decrease the risk of cancer developing in your body. Oncologists or cancer specialists ask their patients to consume cucumbers to restore the damaged cells in their body that also aids blood circulation.

***Cucumber Reduces Chronic Inflammation*:** The water content and Vitamin C present in cucumber can arrest the spread of damaged cells in your body, thus saving you from multiple chronic inflammatory conditions, including heart ailments. The antioxidants in cucumber will fight inflammation by boosting the immune effects of your body.

***Beautifies Hair*:** Eating cucumber hydrates your scalp preventing hair loss due to dryness. It further makes the hair lustrous and healthy. The hair will be supple and not break easily either. Cucumber is rich in several minerals and vitamins like silica, magnesium, potassium etc. Applying cucumber juice to the scalp reduces and repairs thinning of hair. It strengthens the hair and encourages hair growth.

***Cucumber Prevents Constipation*:** An insufficient amount of water and dietary fibres in your body may cause constipation, causing you great discomfort. A cucumber every single day will replenish the water and fibres in your body so that the passage of stool becomes smooth and painless.

***Natural Treatment for Kidney Stones*:** The water content of cucumber can flush out all toxins from your body. This can go a long way in preventing kidney stones while the existing stones and debris present in the bladder get removed from the body by urination. Cucumber also plays a major role in regulating uric acid levels in your body and thus prevents the crystallisation that leads to stone formation.

***Relief from Migraine*:** Migraine can be excruciating, and you will get no relief unless you sleep it off. No worries! Including cucumber in your diet can have a miraculous effect. The magnesium in cucumber, helping you keep your blood pressure in control, provides a boost to your immunological system.

***Healthifies Skin*:** Forget expensive skin treatments by application of pricey lotions and oils. Consume cucumbers instead to ensure healthy and glowing skin that remains blemish-free, with wrinkles and lines becoming a thing of the past. Cucumber can also be applied topically for skin lightening and revitalising.

***Relieves Pain*:** Cucumber contains flavonoids, tannins and other antioxidants—this helps to bring down the pain by controlling the number of free radicals released in the body. You do not have to suffer excessive pain because of chronic ailments either. Eat cucumbers every day to reduce the pain if you cannot eliminate it completely.

***Fights Bad Breath*:** You have to brush your teeth twice a day and maintain proper oral hygiene. Unfortunately, you may still be plagued with a bad breath that makes people shun you. No! You do not have to opt for costly treatments to get rid of stinking breath. Have as much cucumber as you want to wash the accumulated bacteria off your gums and teeth.

It's high in beneficial nutrients, as well as certain plant compounds and antioxidants that may help treat and even prevent some conditions. Also, cucumbers are low in calories and contain a good amount of water and soluble fiber, making them ideal for promoting hydration and aiding in weight loss (Link, 2017). Cucumber is also frequently used in cosmetology, where it is used as a skin moisturizer, due to its large amount of water, which can make up ninety-seven percent of its composition**.** It is also used in naturopathic medicine as a diuretic and depurative, in order to treat some pictures of cystitis or urinary tract infections (Phoneia, 2019). Cucumber is rich in superior hydration and phytochemicals, which have diverse health benefits including weight loss, anti-inflammation, remedy for multiple diseases of eczema, constipation, hypertension, atherosclerosis, cancer, etc. Recent studies found that the presence of kaempferol in cucumber is an important antidiabetic agent. Furthermore, cucumber is popularly used for natural beautification and for skin treatments (Jia and Wang, 2021). Cucumber is high in water content and low in calories, fat, cholesterol, and sodium and good source of mineral nutrients (Ca, Mg, P & K) and medicinal properties such as antioxidant, anti-inflammatory, and anti-cancer benefits. Cucumbers

are also used for digestive benefits and mood stability when modulating stress. Cucumbers fortify cells so they may retain hydrated and work at the highest levels, and may slow age-related cellular deteriorations (Jat *et al*., 2021).

Cucumber seeds possess similar properties to those of the allied Pumpkin (*Cucurbita Pepo*, Linn.) which are distinctly diuretic, but mainly employed as a very efficient taeniacide, 1 to 2 oz. of the seed, thoroughly ground and made into an electuary with sugar, or into an emetic with water, being taken fasting, followed in from 1 to 2 hours by an active purge. The resin has been given in doses of 15 grains. Cucumber seeds are much smaller than Pumpkin seeds, relatively narrower and thicker and with almost no marginal groove. The emulsion made by bruising Cucumber seeds and rubbing them up with water was formerly thought to possess considerable virtue and was much used in catarrhal affections and diseases of the bowels and urinary passages (Grieve, 2022). *As a cosmetic*, Cucumber is excellent for rubbing over the skin to keep it soft and white. It is cooling, healing and soothing to an irritated skin, whether caused by sun, or the effects of a cutaneous eruption, and Cucumber juice is in great demand in various forms as a cooling and beautifying agent for the skin. Cucumber soap is used by many women, and a Cucumber wash applied to the skin after exposure to keen winds is extremely beneficial (Grieve, 2022). The uses of cucumber also extend to skin care, from helping to reduce the swelling of puffy eyes to serving as an ingredient in facial masks. Skin care is one of the main uses of cucumber. As an economical home remedy, people often place sliced cucumbers over their eyes to reduce swelling and improve their appearance. Cucumbers also can be blended in the home along with other ingredients to make a moisturizing facial mask or a skin toner. Many commercial skin care products advertise cucumber as an active ingredient, and the vegetable is often used in day spas (Bishop, 2022).

Magical Properties of Cucumber are (Moone, 2019)

***Beauty* (inner and outer):** Empower this green fruit for beauty and use it as a face mask, eye compress, or in beauty spells. You can also use its juice as part of a beauty potion! Because this fruit is so hydrating, it's great for beauty spells that work from the inside out, as well!

Fertility: Carry a cucumber with you when trying to conceive to help balance your feminine energies with masculine energies. You can also use this in sympathetic magic.

Healing: In ancient times, these were used to heal swelling, exhaustion, hangovers, scorpion bites, and much more! Place this fruit on your altar during healing spells or eat when you are feeling ill. Pickles also work well for healing.

Youth: Similar to beauty work, use this as part of your beauty regimen or in beauty and youth spells.

Cucumber juice is the juice derived from cucumbers produced by squeezing or pressing it. Cucumbers are 98% water. Cucumber juice is used in beverages such as cocktails like the Bloody Mary, dishes such as cucumber soup, and in dips and salad dressings, such as green goddess dressing. Cucumber juice has significant amounts of potassium and is high in vitamin A. It also contains significant amounts of silicon. It also contains sterol (WIKI, 2023). Cucumber juice is used as an ingredient in cosmetics, soaps, shampoos, and lotions, and in Eau de toilette and perfumes. It was used in Russian traditional medicine to aid in the treatment of respiratory tract inflammation and to reduce lingering cough. In other traditions it was used to soothe heartburn and reduce acid in the stomach. For skin, it has been used to soothe burns and rashes. Cucumber juice has been described as a repellent against wood lice and fish-moths (WIKI, 2023). Since cucumber juice contains significant amounts of iron, it is very useful for the nervous system, bone and blood health. By helping red blood cells healthily perform their tasks, they can contribute significantly to facilitating circulation and oxygen uptake in the body. This is also important for heart health. It is especially important for skin and hair care helps to moisturize and cleanse the skin. Protects bone health, eliminates this problem with nails that tend to break. This reduces the risk of diseases caused by iron deficiency, also helps in anemia problems. Reduces the risk of developing cancer. This juice that removes constipation is also beneficial for the digestive system (Anon., 2023).

REFERENCES

Ahirwar, C.S., Singh, D.K. and Kushwaha, M.L. 2017. Assessment of Genetic Variation in Cucumber (*Cucumis sativus* L.) Germplasm on Correlation, Path analysis and Cluster Analysis. *Chemical Science Review and Letters,* 6(23): 1886-1893

Ahmed, I., Rohman, M.M., Hossain, M.A., Molla, M.R., Azam, M.G., Hasan, M.M., Gaber, A., Albogami, B. and Hossain, A. 2022. A Study on the Phenotypic Variation of 103 Cucumber (Cucumis sativus L.) Landraces for the Development of Desirable Cultivars Suitable for the Changing Climate. Life, 12: 1235. Pp1-28

Anonymous. 2023a. History of Cucumbers. Vegetablefacts http://www.vegetablefacts.net/vegetable-history/history-of-cucumbers/

Anonymous. 2023b. Cucumber. Plantvillage. https://plantvillage.psu.edu/topics/cucumber/infos

Anonymous. 2023c. 14 Proven Health Benefits & Uses of Cucumber: Try It Now !. plantshospital. https://plantshospital.com/benefits-of-cucumber/

Bhagwat, A., Bhammanakati, S., Srinivasa, V., Bhammanakati, A.S., Shubha and Devaraju, H. M. 2018. Genetic variability studies in cucumber (Cucumis sativus L.) genotypes under hill zone of Karnataka. International Journal of Chemical Studies, 6(5): 925-928

Bishop, D. 2022. What Are the Different Uses of Cucumber?. delightedcooking. https://www.delightedcooking.com/what-are-the-different-uses-of-cucumber.htm

Doddamani, M.S., Satish, D., Nishani, S., Masuthi, D.A., Seetaramu, G.K. and Tatagar, M.H. 2018. Assessment of Genetic Variability in Local Collections of Cucumber (Cucumis sativus L.) Genotypes for Productivity Traits. International Journal of Genetics, 8(1): 01-05

Felix. 2021. Cultural practices for growing cucumber. Agrigist. https://www.agrigist.com/cultural-practices-for-growing-cucumber

Ferre, J. 2022. How to Grow Cucumbers: A Growing Guide. Groworganic. https://www.groworganic.com/blogs/articles/how-to-grow-cucumbers-a-growing-guide

Fildaus, N., Flavien Shimira, Ghassan Zahid and Ilknur Solmaz. 2022. Recent status of Genotyping by Sequencing (GBS) Technology in cucumber (Cucumis sativus L.): a review. Mol Biol Rep., 49(6):5547-5554

Fruitsmart. 2012. In Veggie Veritas? Cucumbers are Actually Fruit. Fruitsmart. https://www.fruitsmart.com/blog/in-veggie-veritas-cucumbers-are-actually-fruit/

Golabadi, M., Golkar, P. and Eghtedary, A.R. 2012. Assessment of genetic variation in cucumber (Cucumis sativus L.) genotypes. *European Journal of Experimental Biology,* 2 (5):1382-1388

Grieve, M. 2022. Cucumber. https://www.botanical.com/botanical/mgmh/c/cucum123.html. 2021

Grumet, R., Lin, Y.C., Rett-Cadman, S., Malik, A. 2023. Morphological and Genetic Diversity of Cucumber (*Cucumis sativus* L.) Fruit Development. Plants, 12(1): 23. https://doi.org/10.3390/plants12010023

Innark, P., Chanulak Khanobdee, Sompid Samipak, Chatchawan Jantasuriyarat. 2013. Evaluation of genetic diversity in cucumber (*Cucumis sativus* L.) germplasm using agro-economic traits and microsatellite markers. Scientia Horticulturae, 162: 278-284

IPM. 2014. Cucumber: A Brief History. ipm.missouri https://ipm.missouri.edu/meg/2014/3/Cucumber-A-Brief-History/

Jat,G.S., Behera, T.K., Lata, S. and Kumar, S. 2021. Classical Genetics and Traditional Breeding in Cucumber (Cucumis sativus L.). In: (Edr. Haiping Wang) Cucumber Economic Values and Its Cultivation and Breeding. DOI: 10.5772/intechopen.97593

Jia, H. and Wang, H. 2021. Introductory Chapter: Studies on Cucumber. In: (Eds. Wang, H.) Cucumber Economic Values and Its Cultivation and Breeding

Jing Lv, Jianjian Qi, Qiuxiang Shi, Di Shen, Shengping Zhang, Guangjin Shao, Hang Li, Zhanyong Sun, Yiqun Weng, Yi Shang, Xingfang Gu, Xixiang Li, Xiaoguo Zhu, Jinzhe Zhang, Robbert van Treuren, Willem van Dooijeweert, Zhonghua Zhang, and Sanwen Huang. 2012. Genetic diversity and population structure of cucumber (*Cucumis sativus* L.). PLoS One, 7(10):e46919.10.1371/journal.pone.0046919

Kailiang Bo, Zheng Ma, Jinfeng Chen, and Yiqun Weng. 2015. Molecular mapping reveals structural rearrangements and quantitative trait loci underlying traits with local adaptation in semi-wild Xishuangbanna cucumber (*Cucumis sativus* L. var. *xishuangbannanesis* Qi et Yuan). Theor Appl Genet., 128(1):25-39

Karthick, K., Arumugam, T., Rajasree, V., Ganesan, K.N. and Karthikeyan, M. 2019. Evaluation and assessment of genetic variability of cucumber (Cucumis sativus L.) genotypes. Pharma Innovation , 8(11):156-160.

Kathayat, K., Rawat, M., Kandpal, G., Pandey, G., Chauhan, P. and Tiwari, R. 2018. Genetic variability in cucumber (*Cucumis sativus* L.): a review. Plant Archives, 18(2): 1223-1228

Kiros Gebretsadik , Xiyan Qiu, Shaoyun Dong , Han Miao and Kailiang Bo. 2021. Molecular research progress and improvement approach of fruit quality traits in cucumber. Theor Appl Genet., 134(11):3535-3552

Link, R. 2017. 7 Health Benefits of Eating Cucumber. Healthline https://www.healthline.com/nutrition/7-health-benefits-of-cucumber

Long An. 2015. *Cucumis sativus*-Cucumber. The Worldwide Vegetables. http://theworldwidevegetables.weebly.com/cucumis-sativus-cucumber.html

Megan Ware, M. 2019. Health benefits of cucumber. Medicalnewstoday https://www.medicalnewstoday.com/articles/283006

Momaya, A. 2022. Cucumber – Benefits, Nutrition, Recipes and more. Healthifyme https://www.healthifyme.com/blog/cucumber/

Moone, A. 2019. Magical Properties of Cucumber | Materia Magicka. Plentiful Earth. https://plentifulearth.com/magical-properties-of-cucumber-cucumber-materia-magicka/

Pandey , S., Waquar Akhter Ansari , Maneesh Pandey and Bijendra Singh. 2018. Genetic diversity of cucumber estimated by morpho-physiological and EST-SSR markers. Physiol Mol Biol Plants, 24(1):135-146.

Patents. 2022. CN103461132A - Method for cultivating cucumber breeding material by utilizing macrospore culture technique. patents.google.com/patent/CN103461132A/en

Phoneia. 2019. Surprising uses of cucumber https://phoneia.com/en/education/surprising-uses-of-cucumber/

Rahul Kumar, Munshi, A. D., Behera, T.K., Jat, G.S., Choudhary, H., Singh, M. and Talukdar, A. 2020. Genetic diversity of cucumber (Cucumis sativus) accessions differing in quantitative traits and microsatellite markers. Indian Journal of Agricultural Sciences, 90(11):2161-2168

Sahoo, T.R., Singh, D.K. and Singh, N.K. 2020. Genetic diversity analysis of cucumber (Cucumis sativus L.) genotypes based on ISSR markers. Journal of Pharmacognosy and Phytochemistry, 9(2): 2131-2136

Sandeep Kumar Dhatwalia, S.K. and Ramesh Kumar Bhardwaj, R.K. 2012. Genetic variability: Basis for cucumber improvement Paperback. LAP LAMBERT Academic Publishing (May 10, 2012)

Santanna, C.V. and Bradtke, J. 2022. Cucumis sativus. Climbers. https://climbers.lsa.umich.edu/?p=252

Sebastian, P., Schaefer, H., Telford, I.R.H. and Renner, S.S. 2010. Cucumber (Cucumis sativus) and melon (C. melo) have numerous wild relatives in Asia and Australia, and the sister species of melon is from Australia. Proc Natl Acad Sci U S A, 107(32):14269-73.

Shengjun Feng , Juping Zhang[1], Zihan Mu , Yuji Wang , Changlong Wen, Tao Wu , Chao Yu , Zheng Li and Huasen Wang. 2020. Recent progress on the molecular breeding of Cucumis sativus L. in China. Theor Appl Genet., 133(5):1777-1790

Staub, J.E., Chung, S.M. and Fazio, G. 2005. Conformity and genetic relatedness estimation in crop species having a narrow genetic base: the case of cucumber (*Cucumis sativus* L.). Plant Breed., 124 (1): 44-53

Staub, J.E., Serquen, F.C. and Mccreight, J.D. 1997. Genetic diversity in cucumber (cucumis sativus L.): Iii. An evaluation of Indian germplasm. Genetic Resources and Crop Evolution , 44: 315–326

Vidhi, J. 2022. Top 4 Breeding Methods Applicable to Cucumber | India https://www.biologydiscussion.com/vegetable-breeding/top-4-breeding-methods-applicable-to-cucumber-india/68529

Wang, X., Bao, K., Reddy, U.K. *et al.* 2018. The USDA cucumber (*Cucumis sativus* L.) collection: genetic diversity, population structure, genome-wide association studies, and core collection development. Hortic. Res., 5: 64 (2018). https://doi.org/10.1038/s41438-018-0080-8

Waters, B.M., Kim, H.J. and Amundsen, K. 2023. New genetic sources for orange color in cucumber (Cucumis sativus L.) fruit flesh. bioRxiv. https://www.biorxiv.org/content/10.1101/685289v1.article-metrics

WIKI. 2023. *Cucumis.* From Wikipedia, the free encyclopedia. https://en.wikipedia.org/wiki/Cucumis

Yiqun Weng , Marivi Colle, Yuhui Wang, Luming Yang, Mor Rubinstein, Amir Sherman, Ron Ophir, Rebecca Grumet. 2015. QTL mapping in multiple populations and development stages reveals dynamic quantitative trait loci for fruit size in cucumbers of different market classes. Theor Appl Genet., 128(9):1747-63.

Yiqun Weng, Y. 2020. Chapter 4: *Cucumis sativus* Chromosome Evolution, Domestication, and Genetic Diversity. In: (Edr. Irwin Goldman) Plant Breeding Reviews, Volume 44

Yupeng Pan, Xinjing Liang, Meiling Gao, Hanqiang Liu, Huanwen Meng, Yiqun Weng and Zhihui Cheng. 2017. Round fruit shape in WI7239 cucumber is controlled by two interacting quantitative trait loci with one putatively encoding a tomato SUN homolog. Theor Appl Genet., 130(3):573-586

****