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REVIEW ARTICLE

ORIGIN, DISTRIBUTION, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CROP IMPROVEMENT OF WATERMELON {*Citrullus lanatus* (Thunb.) Matsum and Nakai}

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ABSTRACT

Watermelon {*Citrullus lanatus* (Thunb.) Matsum & Nakai} is a flowering plant species of the Cucurbitaceae family and the name of its edible fruit. Watermelon is an ancient fruit. The ancestors of the watermelon called the *Tsamma* melon, which are still found in the Kalahari Desert even today. The sweet, juicy flesh is usually deep red to pink, with many black seeds, although seedless varieties exist. Common names in English areWatermelon, Wild watermelon, Sweet melon, Dessert watermelon. The common names in Indian languages areKumati palam (Tamil); Taramuj (Bengali); Tarabuucha (Gujarati); Kharbuza, Kharmuja, Tarabuuza, Tarbooz, Tarbuj, Tarbuz, Tarmuj (Hindi); Tarabuuja (Marathi); Tarabuuja (Pujabi); Kallangdi Hannu (Kannada). It is an excellent source of vitamins C and A, as well as a good source of vitamin B6 and vitamin B1 and various minerals. The seeds are eaten as a snack or added to other dishes, and may be roasted and seasoned. They are a good source of fat and protein. The Greeks and Romans considered watermelon to have medicinal properties. Notable Greek physicians Hippocrates and Dioscorides praised its healing properties and used it as a diuretic as well as a treatment for children who suffered a heatstroke. According to the National Institute of Industrial Research, watermelon is cultivated in Uttar Pradesh, Himachal Pradesh, Rajasthan, Orissa, Gujarat, Punjab, Haryana, Assam, West Bengal, Karnataka, Orissa, Andhra Pradesh, Maharashtra, and Tamil Nadu. In India there is approximately 25 commercial varieties. Watermelon comes into season during the summer months, usually from April to June. However, unusual weather patterns during planting sometimes introduce the fruit to cities as early as March. In this review article, Introduction, Origin and Distribution, Taxonomy, Botanical Description, Genetics, Genetic Diversity, Crop Improvement, Uses, Nutritional Value and Health Benefits of watermelon are dicussed.

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INTRODUCTION

Watermelon {*Citrullus lanatus* (Thunb.) Matsum & Nakai} is a flowering plant species of the Cucurbitaceae family and the name of its edible fruit. A scrambling and trailing vine-like plant, it is a highly cultivated fruit worldwide, with more than 1,000 varieties(WIKI, 2022). Watermelon refers to both fruit and plant originally from Southern Africa and one of the most common types of melon. This plant produces a special type of fruit known by botanists as a pepo, which has a thick rind (exocarp) and fleshy center (mesocarp and endocarp); pepos are derived from an inferior ovary and are characteristic of the Cucurbitaceae. The watermelon fruit, loosely considered a type of melon (although not in the genus *Cucumis*), has a smooth exterior rind (green and yellow) and a juicy, sweet, usually red or yellow, but sometimes orange, interior flesh. The flesh consists of highly developed placental tissue within the fruit (Bionity, 2022). Watermelons were originally cultivated for their high water content and were stored to be eaten during dry seasons, not only as a food source, but as a method of storing water (WIKI, 2022). The fruit species have gained major importance due to its lycopene content per cup that is found higher even than tomato (Whitaker and Davis, 1962). Watermelon is an ancient fruit. The ancestors of the watermelon called the *Tsamma* melon, which are still found in the Kalahari Desert even today (Venkateswarlu *et al*., 2013).The sweet, juicy flesh is usually deep red to pink, with many black seeds, although seedless varieties exist. The fruit can be eaten raw or pickled, and the rind is edible after cooking. It may also be consumed as a juice or an ingredient in mixed beverages (WIKI, 2022). The *C. lanatus* produces a fruit that is about 93% water, making it the majority of it water, hence the name "water" melon. The "melon" part came from the fact that the fruit is large and round and has a sweet, pulpy flesh. The scientific name of the watermelon derived from both Greek and Latin roots. The *Citrullus* part comes from a Greek word "citrus" which is a reference to the fruit. The *lanatus* part is Latin, and has the meaning of being wooly, referring to the small hairs on the stems and leaves of the plant (Bioweb, 2005). Watermelons originated in places that experienced very long dry spells. Although bitter tasting, the watermelons were like miniature water storage tanks. Archeologists even found evidence that King Tut's tomb had watermelons placed in it, as he would need some water for his journey into the afterlife. Therefore, watermelons were not harvested for their taste — they were harvested for their water. An uncut watermelon can store for weeks or even months in a cool, dry location (Szydlowski, 2021).

Common names in English areWatermelon, Wild watermelon, Sweet melon, Dessert watermelon (Long An, 2015). The common names in Indian languages areKumati palam (Tamil); Taramuj (Bengali); Tarabuucha (Gujarati); Kharbuza, Kharmuja, Tarabuuza, Tarbooz, Tarbuj, Tarbuz, Tarmuj (Hindi); Tarabuuja (Marathi); Tarabuuja (Pujabi); Kallangdi Hannu (Kannada) (Long An, 2015).

It is an excellent source of vitamins C and A, as well as a good source of vitamin B6 and vitamin B1 and various minerals. The seeds are eaten as a snack or added to other dishes, and may be roasted and seasoned. They are a good source of fat and protein(NWE, 2022). Watermelons are more than just sweet and juicy, and scientists are still discovering its health benefits. Its bright red color comes from the pigment lycopene which is a powerful antioxidant. Recent studies revealed that, when combined with a healthy lifestyle, watermelon consumption can reduce the risk of both cancer and diabetes. Additionally, watermelon is a potent source of the amino acid citrulline which may help lower blood pressure. Other studies indicate watermelon consumption might be helpful in reducing the onset of rheumatoid arthritis. Finally, while most do not consider it a "diet food," a cup of watermelon contains only about 45 calories. Plus, unlike other desserts, it's fat-free, low in cholesterol, and contains no sodium (Trinklein, 2020).The Greeks and Romans considered watermelon to have medicinal properties. Notable Greek physicians Hippocrates and Dioscorides praised its healing properties and used it as a diuretic as well as a treatment for children who suffered a heatstroke (Trinklein, 2020). Wild watermelon thrives in India's Northwestern plains, as well as India's South and Central regions. These two are the areas most conducive to growing commercial varieties. A number of India's states grow watermelon. Interestingly, these regions vary considerably in their climate, but the adaptability and versatility of watermelon allows the fruit to thrive in a number of soils. Watermelon simply desires heat: the hotter the better, in fact. According to the National Institute of Industrial Research, watermelon is cultivated in Uttar Pradesh, Himachal Pradesh, Rajasthan, Orissa, Gujarat, Punjab, Haryana, Assam, West Bengal, Karnataka, Orissa, Andhra Pradesh, Maharashtra, and Tamil Nadu. In India there is approximately 25 commercial varieties. Watermelon comes into season during the summer months, usually from April to June. However, unusual weather patterns during planting sometimes introduce the fruit to cities as early as March (Weebly, 2022).

ORIGIN AND DISTRIBUTION

The watermelon crop has been recorded in Central African, Egypt and the Middle East region for about 10,000 years and later launched in China, Europe and North America in tenth, thirteenth and seventeenth centuries, respectively (Whitaker and Davis, 1962). The watermelon originated in the deserts of Kalahari in Africa. Even today, it grows abundantly in this region. However, watermelon is an ancient fruit. The ancestors of the watermelon called the *Tsamma* melon, which are still found in the Kalahari Desert even today. Biologists claim that the fruit has to be the native of the African continent only. Some of the African slaves who went to the United States brought along the *Tsamma* melon, and that is how it started growing in Baja in California. Watermelon was being cultivated in the African continent as early as 2000 B.C. Some of the hieroglyphics found in the pyramids of Egypt show watermelon as a fruit. It was taken to china at the end of the 9th century. The Chinese also started cultivating it rapidly, and it soon became a preferred fruit. Watermelon have been cultivated at least as early as 2000 B.C. It appears this fruit was largely unknown in other Mediterranean cultures of the time, but they were certainly cultivated in Asia (China in particular) by the end of the 9th century, and the word "watermelon" was present in English dictionaries in 1615. Several other Asian regions have cultivated watermelons in ancient history. Watermelon has been introduced to North America and American Indians were found cultivating them by French explorers in the Mississippi valley (Venkateswarlu *et al*., 2013).

Watermelons have been with us for a long time, almost 5,000 years according to some data, and are believed to have originated in the deserts of Africa and the Middle East. Dr. Fei's team recently mapped a Sudanese melon that they believe to be the progenitor, or ancestor plant of the modern-day watermelon. Known as the Kordofan melon, this ancestor plant would have had a whitish pulp, demonstrating just how much the modern watermelon has evolved (Carey, 2021). Watermelon seeds were found in the Dead Sea region at the ancient settlements of Bab edh-Dhra and Tel Arad. Many 5000-year-old wild watermelon seeds (*Citrullus lanatus*) were discovered at Uan Muhuggiag, a prehistoric archaeological site located in Southwestern Libya. This archaeobotanical discovery may support the possibility that the plant was more widely distributed in the past. In the 7th century, watermelons were being cultivated in India, and by the 10th century had reached China. The Moors introduced the fruit into the IberianPeninsula, and there is evidence of it being cultivated in Córdoba in 961 and also in Seville in 1158. It spread Northwards through Southern Europe, perhaps limited in its advance by summer temperatures being insufficient for good yields. The fruit had begun appearing in European herbals by 1600, and was widely planted in Europe in the17th century as a minor garden crop. Early watermelons were not sweet, but bitter, with yellowish-white flesh and difficult to open. Through breeding, watermelons later tasted better and were easier to open. European colonists and enslaved people from Africa introduced the watermelon to the New World. Spanish settlers were growing it in Florida in 1576. It was being grown in Massachusetts by 1629, and by 1650 was being cultivated in Peru, Brazil and Panama. Around the same time, Native Americans were cultivating the crop in the Mississippi valley and Florida. Watermelons were rapidly accepted in Hawaii and other Pacific islands when they were introduced there by explorers such as Captain James Cook. In the Civil War era United States, watermelons were commonly grown by free black people and became one symbol for the abolition of slavery. After the Civil War, black people were maligned for their association with watermelon. The sentiment evolved into a racist stereotype where black people shared a supposed voracious appetite for watermelon, a fruit long correlated with laziness and uncleanliness. Seedless watermelons were initially developed in 1939 by Japanese scientists who were able to create seedless triploid hybrids which remained rare initially because they did not have sufficient disease resistance. Seedless watermelons became more popular in the 21st century, rising to nearly 85% of total watermelon sales in the United States in 2014 (WIKI, 2022).

The watermelon is thought to have originated in Southern Africa, where it is found growing wild. Watermelons originated in southern Africa but were already grown as a crop in Egypt 5000 years ago and are now planted throughout the world. China got them in the 10th century CE and is now the largest producer. They were brought to North America in the 16th century where California, Georgia, Arizona and Texas are the major producers. Watermelon is cultivated in all tropical and subtropical countries, as well as in temperate countries with a continental climate. It is widely naturalised (Long An, 2015). The diverse evidence, combined, indicates that Northeastern Africa is the centre of origin of the dessert watermelon, that watermelons were domesticated for water and food there over 4000 years ago, and that sweet dessert watermelons emerged in Mediterranean lands by approximately 2000 years ago (Paris, 2015). Watermelons (*Citrullus lanatus*) are native to Africa and have been cultivated since ancient times. The fruit flesh of wild watermelons is watery, but typically hard-textured, pale-coloured and bland or bitter. The familiar sweet dessert watermelons, *C. lanatus*, featuring non-bitter, tender, well-coloured flesh, have a narrow genetic base, suggesting that they originated from a series of selection events in a single ancestral population. Archaeological remains of watermelons, mostly seeds, that date from 5000 years ago have been found in Northeastern Africa. An image of a large, striped, oblong fruit on a tray has been found in an Egyptian tomb that dates to at least 4000 years ago. The Greek word *pepon*, Latin *pepo* and Hebrew *avattiah* of the first centuries CE (Common Era, Christian Era) were used for the same large, thick-rinded, wet fruit which, evidently, was the watermelon. Hebrew literature from the end of the second century CE and Latin literature from the beginning of the sixth century CE present watermelons. Wild and primitive watermelons have been observed repeatedly in Sudan and neighbouring countries of Northeastern Africa. It can be concluded that the diverse evidence, combined, indicates that Northeastern Africa is the centre of origin of the dessert watermelon, that watermelons were domesticated for water and food there over 4000 years ago, and that sweet dessert watermelons emerged in Mediterranean lands by approximately 2000 years ago (Paris, 2015). The dessert watermelon, *Citrullus lanatus*, is native to Northeastern Africa. Wild *C. lanatus* populations in Sudan, reported as bearing small, round, inferior-quality fruits, are living representatives of the wild ancestor of the sweet dessert watermelon. Ancient seeds, fruits and images of watermelons have been found in Sudan and Egypt and one image seems to depict the serving of a large, oblong, striped fruit which likely had non-bitter, tender flesh but was not sweet by modern standards. Hebrew-language literature from the first centuries CE indicates that, by Roman times, sweet dessert watermelons were esteemed in the Land of Israel and thus likely were present in other Mediterranean lands as well. The ripe fruit flesh, which was probably distinctly coloured rather than pale, was eaten raw and had sweetness comparable to that of figs, grapes and pomegranates. The seeds were not consumed. During or prior to the Roman era, the citron watermelon arrived in Mediterranean lands and its fruit flesh was consumed after being cooked (Paris, 2015).

It is thought that watermelon was first domesticated in central and southern Africa. Watermelon seeds and leaves have been found in ancient Egyptian tombs, suggesting it was cultivated there more than 5,000 years ago. The watermelon is thought to have originated in Southern Africa, where it is found growing wild. It reaches maximum genetic diversity there, with sweet, bland and bitter forms. In the 19th century, Alphonse de Candolle considered the watermelon to be indigenous to tropical Africa. *Citrullus colocynthis* is often considered to be a wild ancestor of the watermelon and is now found native in north and west Africa. However, it has been suggested on the basis of chloroplast DNA investigations, that the cultivated and wild watermelon diverged independently from a common ancestor, possibly *Citrullus ecirrhosus* from Namibia. Evidence of its cultivation in the Nile Valley has been found from the second millennium BC onward. Watermelon seeds have been found at Twelfth Dynasty sites and in the tomb of PharaohTutankhamun. In the 7th century, watermelons were being cultivated in India and by the 10th century had reached China, which is today the world's single largest watermelon producer. Moorish invaders introduced the fruit into Europe and there is evidence of it being cultivated in Córdoba in 961 and also in Seville in 1158. It spread northwards through Southern Europe, perhaps limited in its advance by summer temperatures being insufficient for good yields. The fruit had begun appearing in European herbals by 1600, and was widely planted in Europe in the 17th century as a minor garden crop. European colonists and slaves from Africa introduced the watermelon into the New World. Spanish settlers were growing it in Florida in 1576, and it was being grown in Massachusetts by 1629, and by 1650 was being cultivated in Peru, Brazil and Panama as well as in many British and Dutch colonies. Around the same time, Native Americans were cultivating the crop in the Mississippi valley and Florida. Watermelons were rapidly accepted in Hawaii and other Pacific islands when they were introduced there by explorers such as Captain James Cook (Long An, 2015). Aptly named, watermelon is 92 percent water and was first used by ancients as a source of water. Watermelon's history dates back 5000 years to Southern Africa where the tough, drought-tolerant ancestor of watermelon thrived. Although we don't know the exact identity of this plant, we do know it was prized for its ability to store water and was used by indigenous people in the Kalahari Desert region. Unlike today's watermelon, it had very bitter flesh. Speculation exists, in addition to taking advantage of its water content, people endemic to the region roasted and ate its seeds as a source of nourishment. Soon thereafter, watermelon found its way to Egypt where it was first improved. Both seeds and paintings of watermelon have been discovered in Egyptian tombs more than 4,000 years old. Some tomb paintings depict an oval-shaped watermelon, indicating the round wild type must have been improved by ancient plant breeders. Quite likely, it was during this period of early improvement that progress was made in developing melons with sweeter, more palatable flesh. Thus, watermelon was slowly transformed from a source of water to an enjoyable food. Watermelon was being cultivated in India by the 7th century, and by the 10th century it had found its way to China. The Moors introduced watermelon into the Iberian Peninsula in the 13th century and, from there, it spread throughout southern Europe. By the 17th century watermelon was widely planted throughout Europe and had become a familiar garden crop in warmer parts of the continent. European colonists as well as slave trade from Africa are thought to have introduced watermelon to the New World. It was found growing in Florida as early as 1576 and in Massachusetts by 1629. Thomas Jefferson grew watermelon at Monticello and, by the early part of our nation's history, it was being grown by Native American's from the Mississippi Valley South to Florida (Trinklein, 2020).

The primary centre of watermelon diversity lies in Southern Africa where wild forms are still found. Domestication is likely to have occurred in Egypt and India. Primary centre of diversity for watermelon is Southern Africa. The secondary centre is China and related species can be found in India (Vidhi, 2022). The wild watermelon is widely distributed in Africa and Asia, but originates from Southern Africa occurring naturally in South Africa, Namibia, Botswana, Zimbabwe, Mozambique, Zambia and Malawi. It is widely cultivated in warmer parts of the world. Watermelon is thought to have been domesticated at least 4,000 years ago, and the plant was grown as a crop in the Nile valley. The indigenous people of the Kalahari, in their search for water-containing foods, selected varieties with low glycoside content. From there followed the spread to the Mediterranean areas and in an eastern direction to India. Watermelons were developed as a crop in Egypt in ancient times and according to Encyclopedia Britannica " The history of watermelons is a long one; there is a Sanskrit word for watermelon, and fruits are depicted by early Egyptian artists, indicating an antiquity in agriculture of more than 4,000 years" (Weebly, 2022). It is indicated that watermelon (*Citrullus lanatus*) is of ancient cultivation in the Mediterranean and reached India in prehistoric times, but did not reach China until the eleventh century AD. Some websites suggest an introduction to India in 800 AD. Modern day cultivated varieties are a popular crop that can be cultivated in any climate that has warm summer, and are best suited to those climates that have long hot summers (Weebly, 2022). *Kordofan* melons from Sudan are the closest relatives and may be progenitors of modern, cultivated watermelons. Wild watermelon seeds were found in Uan Muhuggiag, a prehistoric site in Libya that dates to approximately 3500 BC. Watermelons were domesticated in North-east Africa, and cultivated in Egypt by 2000 BC, although they were not the sweet modern variety. Sweet dessert watermelons spread across the Mediterranean world during Roman times(WIKI, 2022). A melon from the *Kordofan* region of Sudan – the *kordofan* melon – may be the progenitor of the modern, domesticated watermelon. The kordofan melon shares with the domestic watermelon loss of the bitterness gene, while maintaining a sweet taste, unlike other wild African varieties from other regions, indicating a common origin, possibly cultivated in the Nile Valley by 4360 BP (before present) (WIKI, 2022). David Livingstone, an explorer of Africa, described watermelon as abundant in the Kalahari Desert in Southern Africa, where it is believed to have originated. There, the ancestral melon grows wild and is known as the *Tsamma* melon (*Citrullus lanatus* var *citroides*). It is recognizable by its pinnatifid leaves and prolific fruit, up to 100 melons on a single vine. For this reason it is a popular source of water in the diet of the indigenous people. The flesh is similar to the rind of a watermelon and is often known as citron melon (distinct from the actual citron, of the citrus family). It is used for making pickles, and because of its high content of pectin is popular as a constituent of jams, jellies, and other gelled preserves. It has established itself in the wild in Baja California. It is not known when the plant was first cultivated, but it has noted evidence of its cultivation in the Nile Valley from at least as early as the second millennium B.C.E. (Before the Common Era).

Finds of the characteristically large seed are reported in Twelfth dynasty sites; numerous watermelon seeds were recovered from the tomb of Pharaoh Tutankhamun. By the tenth century C.E., watermelons were being cultivated in China, which is today the world's single largest watermelon producer. By the thirteenth century, Moorish invaders had introduced the fruit to Europe; and, according to John Mariani's *The Dictionary of American Food and Drink*, "watermelon" made its first appearance in an English dictionary in 1615 (NWE, 2022; Bionity, 2022). In Vietnam, legend holds that watermelon was discovered in Vietnam long before it reached China, in the era of the Hùng Kings. According to legend, watermelon was discovered by Prince Mai An Tiêm, an adopted son of the 11th Hùng King. When he was exiled unjustly to an island, he was told that if he could survive for six months, he would be allowed to return. When he prayed for guidance, a bird flew past and dropped a seed. He cultivated the seed and called its fruit "dưa tây" or western melon, because the birds who ate it flew from the west. When the Chinese took over Vietnam in about 110 BC, they called the melons "dưa hảo" (good melon) or "dưa hấu". "dưa Tây", "dưa hảo", "dưa hấu" -- all words for "watermelon". An Tiêm's island is now a peninsula in the suburban district of Nga Sơn (Bionity, 2022).

TAXONOMY

The scientific classification watermelon is that it belongs to theFamily: Cucurbitaceae, Genus: *Citrullus,* Species: *Citrullus lanatus* (Venkateswarlu *et al*., 2013; TFNet, 2016; NWE, 2022; WIKI, 2022; Bionity, 2022). Watermelon has 22 chromosomes in the diploid form. This genus *Citrullus* contains a total of 4 species including *C. colocynthis, C. ecirrhosus, C. lanatus*, and *C. rehmii* (Bioweb. 2005; Long An, 2015**;** TFNet, 2016). The watermelon is given the name *lanatus* because of its pink/red or yellow flesh and black seeds, along with all of the above characteristics (Bioweb. 2005).

Synonyms: The former name *Citrullus vulgaris* (*vulgaris* meaning "common" — Shosteck, 1974), is now a synonym of the accepted scientific name for watermelon, *Citrullus lanatus*. (Bionity, 2022.). However 3 Synonyms,namely, *Anguria citrullus* Mill., *Citrullus amarus* Schrad. and *Citrullus anguria* (Duchesne) H.Hara (a full list of synonyms is available on The Plant List) have also been reported (Long An, 2015).

Cultivar Groups

Three cultivar groups have been identified (WIKI, 2022):

***Citroides* group:** (syn. *C. lanatus* subsp. *lanatus* var. *citroides*; *C. lanatus* var. *citroides*; *C. vulgaris* var. *citroides*) DNA data reveal that *C. lanatus* var. *citroides* Bailey is the same as Thunberg's bitter wooly melon, *C. lanatus* and also the same as *C. amarus* Schrad. It is not a form of the sweet watermelon *C. vulgaris* nor closely related to that species. The citron melon or *makataan* – a variety with sweet yellow flesh that is cultivated around the world for fodder and the production of citron peel and pectin.

***Lanatus* group:**(syn. *C. lanatus* var. *caffer*) *C. caffer* Schrad. is a synonym of *C. amarus* Schrad. The variety known as *tsamma* is grown for its juicy white flesh. The variety was an important food source for travellers in the Kalahari Desert. Another variety known as *karkoer* or *bitterboela* is unpalatable to humans, but the seeds may be eaten. A small-fruited form with a bumpy skin has caused poisoning in sheep.

***Vulgaris* group:** This is Linnaeus's sweet watermelon; it has been grown for human consumption for thousands of years. *C. lanatus mucosospermus* (Fursa) Fursa. This West African species is the closest wild relative of the watermelon. It is cultivated for cattle feed. Additionally, other wild species have bitter fruit containing cucurbitacin. *C. colocynthis* (L.) Schrad. ex Eckl. & Zeyh., *C. rehmii* De Winter, and *C. naudinianus* (Sond.) Hook.f

BOTANICAL DESCRIPTION

The plant: *Citrullus lanatus* can be recognized by its large fruit which is unique in the Cucurbitaceae of Southern Africa and also by the dense yellowish to brownish hairs on the younger plant parts. The watermelon is an annual plant with long, weak, trailing or climbing stems which are five-angled and up to 3 m (10 ft) long. The young parts are densely woolly with yellowish to brownish hairs while the older parts become hairless. The tendrils are rather robust and usually divided in the upper part (Long An, 2015; TFNet, 2016; Vidhi, 2022 ; NWE, 2022).

The leaves: Leaf stalks (petioles) up to about 19 cm long, more or less hairy. The leaves usually have three lobes which are themselves further divided into lobed or doubly lobed. Leafblades up to about 20 × 20 cm, more or less hairy, usually deeply 3-5 lobed, the central lobe being the largest. The leaves are herbaceous but rigid, becoming rough on both sides; 60 - 200 mm long and 40 -150 mm broad, ovate in outline, sometimes unlobed and entire, but usually deeply 3-lobed with the segments again lobed or doubly lobed; the central lobe is much the largest. The leaf stalks are somewhat hairy and up to 150 mm long (Long An, 2015; TFNet, 2016; Vidhi, 2022; NWE, 2022).

The flowers: The flowers grow singly in the leaf axils and the corolla is white or yellow inside and greenish-yellow on the outside. The flowers are unisexual, with male and female flowers occurring on the same plant (monoecious). The receptacle is up to 4 mm long, broadly campanulate and hairy, the lobes are as long as the tube. The corolla is usually green or green-veined outside and white to pale or bright yellow inside and up to 30 mm in diameter. Both male and female flowers are yellow, up to 3-4 cm in diameter, and borne on pedicels (flower stalks) up to 40 - 45 mm long and hairy. The male flowers predominate at the beginning of the season and the female flowers, which develop later, have inferior ovaries. The styles are united into a single column and the large fruit is a kind of modified berry called a pepo. This has a thick rind (exocarp) and fleshy center (mesocarp and endocarp). Watermelon flowers are small, 4-5 cm across, sulphur yellow in color, and less showy than other cucurbits. A few older varieties and accessions collected from the wild are andromonoecious, i.e having staminate and hermaphrodite flowers. Flowering begins at about eight weeks after seeding, with the production of staminate flowers and later followed by the production of pistillate flowers. In some varieties hermaphrodite flowers develop after the production of staminate flowers. Most varieties have a ratio of 7:1 staminate to perfect or pistillate flower. There are some varieties with a ratio of 4:1. There is no advantage of andromonoecious sex expression because even the perfect flowers must be cross-pollinated to set fruit. For successful seedless watermelon production, bees are especially important as seedless varieties do not produce pollen. The pollinator variety is planted in alternate or every third row, or as every third plant in the row. Use a distinctly different variety as pollinator in order to easily distinguish seedless fruit. Icebox varieties used as pollinators result in early yields; picnic varieties used as pollinators result in greater total yields. Icebox varieties usually flower 7–10 days earlier than picnic varieties, so delay icebox pollinator planting (Long An, 2015; TFNet, 2016; Vidhi, 2022; NWE, 2022) (Fig. 1).

The Fruits: The fruits of wild plants are subglobose, indehiscent and up to 20 cm (8 in) in diameter; the fruit stalk is up to 50 mm long. Fruits of cultivated plants are up to about 70 × 30 cm, rounded, oval or oblong. The most common rind (or skin) colors in watermelon are solid green (dark, medium, and light), striped (narrow, medium, and wide dark green stripes on a light green background), and gray (a light green background with a medium or dark green network of reticulations) or the rind is often concolorous (having a single colour) yellowish to pale or dark green, or mottled with darker green, or marbled with a darker shade (Fig. 2). The main flesh colors for watermelon are white, pale yellow, canary yellow, orange, pink, red, and scarlet dotted with black seeds. Seedless varieties are also available (Fig. 3). The flesh is somewhat spongy in texture but very juicy and soft. The fruit has the peel/skin, rind, pulp/flesh, and seeds (Fig. 4). There are more than 1,200 cultivars of watermelon range in weight from less than one to more than 90 kilograms (200 lb), The flesh of them can be red, orange, yellow or white (Long An, 2015**;** TFNet, 2016; Vidhi, 2022; NWE, 2022).

The seeds: The seeds are numerous, ovate in outline, sometimes bordered; in wild forms they are usually black or dark brown; in cultivated forms they are also white or mottled, mostly 6 - 12 mm long. Watermelons are grown from seed. Seedless Watermelons are not actually without seeds, but the seeds are all or mostly immature, white and very soft when the melon is ripe. The seeds are embedded in the edible pulp, small in size (4-6 cm), long and flattened. Seed color can be white, tan, brown, black, red, green, or mottled. Seed size also varies from small, medium, big , and also seedless (Fig. 5)(Long An, 2015; TFNet, 2016; Vidhi, 2022; NWE, 2022).

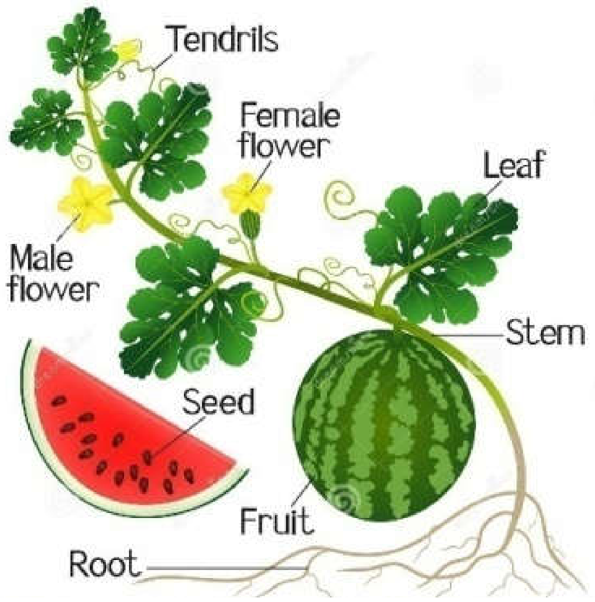


Fig. 1. Morphology of watermelon plant with fruits, flowers, green leaves, and root system

GENTICS

Watermelon traits such as yield and other agronomic traits are highly environmentally sensitive and regulated by multiple genes; therefore, by understanding the genetic structure, the heritability and genetic influence of different traits can improve them. Five watermelon lines were crossed in a full diallel parental design to estimate the genetic effect and heritability of fruit traits. Treatments were evaluated on the farm using a random complete block design. Analysis of the results showed a significant difference between genotypes, which was observed for all the studied traits at the probability level of 1%. Hayman's graphical method showed that the contribution of the non-additive effects was more important than that of the additive effect to control most of the traits. Fruit maturation and pericarp thickness traits were regulated by incomplete dominance gene effects, and other traits were regulated by over dominance effects. The trait heritability varied between at least 0.013 and 0.352 for the fruit weight and fruit number, respectively. Results demonstrated that some traits can be modified based on the heterozygosity and production of hybrid variety methods, while the hybrid and selection in an advanced generation method can be suggested in watermelon breeding programs to breed other traits. It is concluded that the role of over dominance and incomplete dominance effects in controlling studied traits was identified in this study. According to the results, the genetic control of the traits was different; therefore, a specific breeding strategy should be used for each trait. In most of the traits studied, genes with the over dominance effects had a dominant role in controlling the traits. In addition, the estimation of private heritability of traits indicated that most of the studied traits were of moderate private heritability and non-additive effects played a greater role in controlling them. Hence, the direct selection breeding method would not be very successful in improving the genetic value of the population for these traits, but using the heterosis phenomenon and the crossing the parents to produce hybrids or direct selection of lines in the last generations could improve these traits (Rahimi and Abdolinasab, 2022). We identified a locus for yellow skin through BSA-seq and GWAS. A segregation analysis in F_2 and BC_1 populations derived from a cross of two inbred lines '94E1' (yellow skin) and 'Qingfeng' (green skin) suggested that skin color is a qualitative trait. BSA-seq mapping confirmed the locus in the F_2 population, which was detected on chromosome 4 by GWAS among 330 varieties. Several major markers, namely, 15 CAPS markers, 6 SSR markers and 2 SNP markers, were designed to delimit the region to 59.8 kb region on chromosome 4. Utilizing the two populations consisting of 10 yellow and 10 green skin watermelons, we found a tightly linked functional SNP marker for the yellow skin phenotype. The application of this marker as a selection tool in breeding programs will help to improve the breeder's ability to make selections at early stages of growth, thus accelerating the breeding program (Junling Dou *et al*., 2018). Different species of edible seed watermelons (*Citrullus* spp.) are cultivated in Asia and Africa for their colorful nutritious seeds. Consumer preference varies for watermelon seed coat color. Therefore, it is an important consideration for watermelon breeders. In 1940s, a genetic model of four genes, *R*, *T*, *W* and *D*, was proposed to elucidate the inheritance of seed coat color in watermelon. In this study, we developed three segregating F_2 populations: Sugar Baby (dotted black seed, *RRTTWW*) × plant introduction (PI) 482379 (green seed, *rrTTWW*), Charleston Gray (dotted black seed, *RRTTWW*) × PI 189225 (red seed, *rrttWW*), and Charleston Gray (dotted black seed, *RRTTWWdd*) × UGA147 (clump seed, *RRTTwwDD*) to re-examine the four-gene model and to map the four genes. In the dotted black × green population, the dotted black seed coat color (*R_*) is dominant to green seed coat color (*rr*). In the dotted black × red population, the dominant dotted black seed coat color and the recessive red seed coat color segregate for the *R* and *T* genes, where the *R* gene is dominantly epistatic to the *T* gene. However, the inheritance of the *T* locus did not fit the four-gene model, thus we named it T^l . In the dotted black × clump population, the clump seed coat color and the dotted black seed coat color segregate for *W* and *D*, where *D* is recessively epistatic to *W*. The *R*, T^l , *W*, and *D* loci were mapped on chromosomes 3, 5, 6, and 8, respectively, using QTL-seq and genotyping-by-sequencing (GBS). Kompetitive Allele Specific PCR (KASP™) assays and SNP markers linked to the four loci were developed to facilitate maker-assisted selection (MAS) for watermelon seed coat color. To conclude, this is the first study to map seed color gene loci in watermelon and to report SNP markers associated with these loci. Most of the prior research related to the genetics of watermelon seed color was carried out before the advent of molecular tools. In this study, we mapped the *R*, T^l , *W* and *D* loci on chromosomes 3, 5, 6 and 8, respectively, and developed markers UGA3_5820134, UGA5_4591722, UGA6_7076766, and UGA8_22729513 for MAS of seed coat color in watermelon. Further research is necessary to determine whether T^l is a different allele or different locus than the previously described *T* locus. Moreover, identification of the T^l locus indicates that there are additional genes/alleles that confer seed coat color in watermelon. Our results also open future research opportunities to fine map genomic regions and identify the genes conferring seed coat color and to identify functional markers for MAS of seed coat color in watermelon (Paudel *et al*., 2019) (Fig. 6).

Two loci, *C* and *i-C*, were previously reported to determine flesh colors between canary yellow and red watermelon (*Citrullus lanatus*). Recently, lycopene β-cyclase (LCYB) was found as a color determinant gene for canary yellow (*C*) and a codominant cleaved amplified polymorphic sequence (CAPS) marker was developed to identify canary yellow and red alleles. The inhibitor of canary yellow (*i-C*), as reported in a previous work, was not detected in our original family derived from a cross between canary yellow and red parents. To identify additional genetic determinants such as *i-C*, we prepared a new family using 'Yellow Doll' (canary yellow) and 'Sweet Princess' (red), which was reported to carry the inhibitor gene *i-C* as parents. A new distinct class of flesh color, pale yellow, was identified in the progeny from the new canary yellow × red cross. The predominant carotenoid in canary yellow and pale yellow phenotypes was neoxanthin, followed by violaxanthin and neochrome; pale yellow contained less total carotenoids, but had more minor carotenoids compared with canary yellow. The chi-square goodness-of-fit test indicated that there are two genes involved in determining flesh color

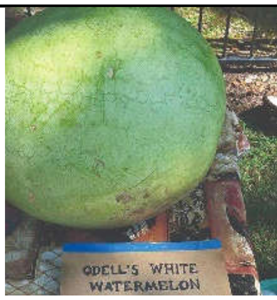
		
1. Green skin with yellow stripes 2. Green skin 3. Yellow skin with light green stripes	Light green skin	'Moon and Stars' watermelon
		
White/Ceam skin	White/Ceam skin With green stripes	Yellow skin

Fig. 2. Skin colors of watermelon

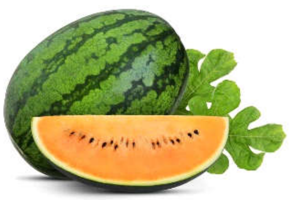
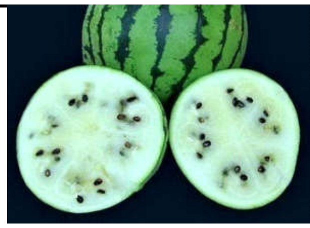
		
Pink flesh	Red flesh	salmon pink flesh
		
Orange flesh	yellow flesh	White flesh

Fig. 3: Flesh colors in watermelon

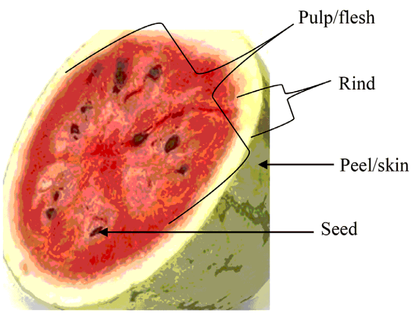


Fig.4. Transverse section of watermelon fruit showing the various parts

among canary yellow, pale yellow, and red, but the segregation pattern did not fit the pattern as reported for an *i-C* gene. When the genotype of the family 'Yellow Doll' × 'Sweet Princess' was analyzed with our LCYB CAPS marker, the flesh color of every individual perfectly cosegregated with the marker. The new pale yellow phenotype also cosegregated with the marker linked to the *C* allele, indicating that the recessive *py* phenotype (pale yellow) must carry at least one of the *C* alleles for expression. Therefore, we propose to designate *py* for a pale yellow determinant along with *C* as a canary yellow determinant.

A homozygous recessive *py* gene resulted in pale yellow flesh color in the presence of a dominant *C(Haejeen et al., 2010) (Fig. 7).* Watermelon [*Citrullus lanatus* (Thunb.) Matsum. &Nakai var. *lanatus*] is a diverse species, with fruits of different sizes, shapes, rind patterns, and flesh colors. This study measured the inheritance of novel rind phenotypes and verified the genetics of white, red, salmon yellow, and canary yellow flesh colors. For each of the 11 crosses, six generations (P_aS_1, P_bS_1, F_1, F_2, BC_1P_a, and BC_1P_b) were produced to form 11 families. Three new genes were identified and designated as follows:

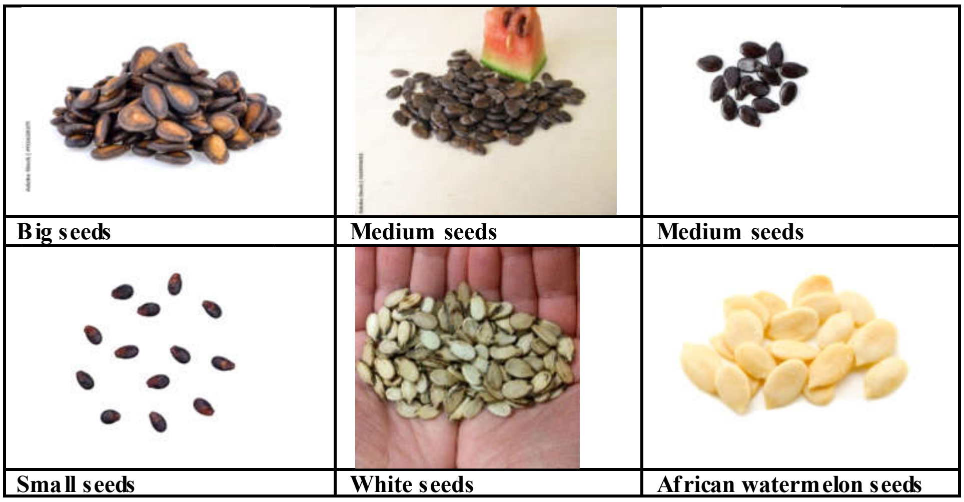


Fig. 5. Different sizes of seeds

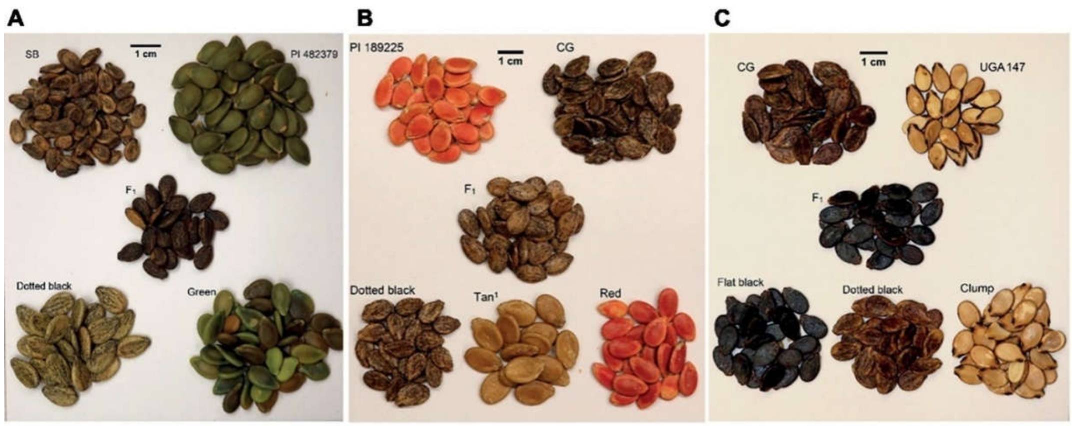


Fig. 6. Seed coat color of parents, F_1, and F_2 progenies in watermelon

In the dotted black × green population (A), seed of dotted black seeded Sugar Baby (SB), female parent, green seeded PI 482379, male parent. F_1 and F_2 individuals with dotted black and green phenotype. In the dotted black × red population (B), seed of red seeded PI 189225, female parent, dotted black seeded Charleston Gray (CG), male parent, F_1 and F_2 individuals with dotted black, tan[1] and red phenotype. In the dotted black × clump population (C), seed of dotted black seeded Charleston Gray (CG), female parent, clump seeded UGA147, a selection from PI 169233, male parent, F_1 and F_2 progenies with flat black, dotted black and clump phenotype.

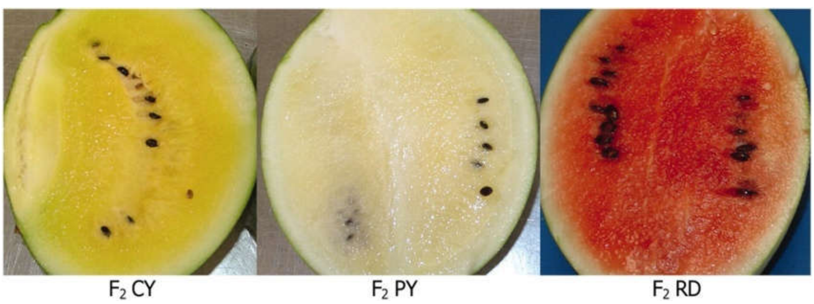


Fig. 7. Three representative flesh colors from F_2 progeny generated from the cross between 'Yellow Doll' (canary yellow) and 'Sweet Princess' (red) watermelon; CY = canary yellow, PY = pale yellow, RD = red

Table 1. Watermelon gene index

Preferred Symbol	Character
a	andromonoecious, recessive to monoecious
Ar_1^-, Ar_2^-	Anthracnose resistance, resistance to *Giomerella cingulata* var. *orbiculare*
C	Canary yellow flesh, dominant to pink
d	dotted seed coat, black dotted seed when dominant for r, t, and w
dw-1	dwarf-1, short internodes, due to fewer shorter cells than normal
dw-2	dwarf-2, short internodes, due to fewer cells
e	explosive rind,thin, tender rind, bursting when cut
f	furrowed fruit surface, recessive to smooth
g	light green skin, light green fruit, recessive to dark green
g^s	striped green skin, recessive to dark green but dominant to light green skin
go	golden, yellow colour of older leaves and mature fruit
gms*	glabrous male sterile, foliage lacking trichomes, male sterile
l	long seed, long recessive to medium length of seed ; interacts with s
m	mottled skin, greenish white mottling of fruit skin
nl	nonlobed leaves, leaves lack lobing, dominance incomplete
o	oval fruit
p	pencilled lines on skin, inconspicuous stripes, recessive to netted fruit
pm	powdery mildew susceptibility, susceptibility to *Sphaerotheca fuliginea*
r	red seed coat, interacts with w and t
s	short seeds, epistatic to l
Scr	Scarlet red flesh
su	suppressor of bitterness, nonbitter fruit
t	tan seed coat, interacts with r and w
w	White seed coat, interacts with r and t
Wf	White flesh, dominant to red
y^o	orange flesh
y	Coral red flesh

Scr for the scarlet red flesh color of Dixielee and Red-N-Sweet, *Yb* for the yellow belly (ground spot) of Black Diamond Yellow Belly, and *ins* for the intermittent stripes of Navajo Sweet. The inheritance of the *C* gene for the canary yellow flesh color was verified as single dominant, and a new inbred type line was developed possessing that gene. Aberrations in the segregation of red, white, and salmon yellow flesh colors were recorded, raising questions on the inheritance of these traits. Finally, the spotted phenotype from Moon and Stars was combined with light green and gray rind patterns for the development of novel cultivars with distinctive rind patterns (Gusmini and Wehner, 2006). Modern cultivated watermelons (*Citrullus lanatus*) are sweet tasting and tender, with intensely colored flesh that ranges in hue from yellow to deep red. These colors are produced by the accumulation of various carotenoids in the flesh cells. Red-fleshed watermelons that accumulate lycopene in their flesh cells have been selected and domesticated from pale-fleshed ancestors.

Red-fleshed watermelons contain even more lycopene per unit of fresh weight than tomato (*Solanum lycopersicum*) and this lycopene is easier for the body to absorb. By means of map-based cloning and transgenic analysis, identified a *lycopene b-cyclase* (*ClLCYB*) gene that controls the flesh color of watermelon. Down-regulation of *ClLCYB* caused the flesh color to change from pale yellow to red, and *ClLCYB* overexpression in the red-fleshed line caused the flesh color to change to orange. An analysis of over 200 watermelon accessions with different flesh colors revealed that two missense mutations between three haplotypes ($ClLCYB^{red}$, $ClLCYB^{white}$, and $ClLCYB^{yellow}$) were selected and largely fixed in domesticated watermelon. The plastid proteins derived from these three *ClLCYB* haplotypes catalyze the conversion of lycopene to b-carotene. Another important finding is that ClLCYB protein abundance, instead of *ClLCYB* transcript level, is negatively correlated with lycopene accumulation. Thus, natural missense mutations in *ClLCYB* apparently influence ClLCYB protein abundance and contribute to the red flesh color in domesticated watermelon (Minorsky, 2020).

The color of watermelon flesh is an important trait determined by a series of carotenoids. Herein, we used Cream of Saskatchewan (pale yellow flesh) and PI 186490 (white flesh) as parental materials for an F2 segregation and initial mapping using the bulked segregant analysis sequencing (BSA-seq) strategy. The BSA results revealed a flesh colorrelated QTL that spans approximately 2.45 Mb on chromosome 6. This region was preliminarily positioned in a 382-kb segment, and then narrowed down into a 66.8-kb segment with 1260 F2 individuals. A total of nine candidate genes were in the fine mapping interval, but only Cla007528 (encoding chlorophyllase) had non-synonymous mutations and was significantly expressed between the parental materials throughout flesh development. We also checked the expression patterns of the carotenoid metabolic pathway genes based on RNA-seq data and qRT-PCR validation. Three genes in the xanthophyll cycle (ClCHYB, ClNCED-1 and ClNCED-7) exhibited differential expression patterns between the two parental lines at different flesh color formation stages. ClPSY1, ClPDS, ClZDS, ClCHXE, ClCRTISO and ClLCYB also exhibited clearly different expression patterns accompanied by carotenoid accumulation (Chao-nan *et al*., 2021).

Watermelons used for seed consumption tend to have larger seeds, whereas watermelons used for flesh consumption often require relatively small seeds. Therefore, watermelon seed size has received extensive attention from consumers and breeders. However, the natural variation and genetic mechanism of watermelon seed size remain unclear. In the present study, 100-seed weight, seed hilum length, seed length, seed width, and seed thickness were examined in 197 watermelon accessions. Furthermore, association analysis was performed between seed size traits and high-quality SNP data. The results revealed that there were strong correlations among the five seed traits, and seed enlargement was an important feature during watermelon seed size domestication. The seed-consumed biological species *Citrullus mucosospermus* and the edible seed watermelon *Citrullus lanatus* had significantly larger seeds than the other species. Eleven non-repeating significant SNPs above the threshold line were obtained from GWAS analysis. Four SNPs on chromosome 5 were considered to be closely associated with seed size traits (S5:32250307, S5:32250454, S5:32256177, and S5:32260870) and could be used as potential molecular markers for the breeding of watermelon cultivars with a target seed size. In addition, based on gene annotation information and previous reports, five genes near the four significant SNPs may regulate seed size.qRT-PCR analysis showed that two genes that may be involved in abscisic acid metabolism, *Cla97C05G104360* and *Cla97C05G104380*, may play an important role in regulating watermelon seed size. Our findings provide molecular insights into natural variation in watermelon seed size and valuable information for molecular marker-assisted breeding (Gong *et al*., 2022). Here we conducted literature review on seed size QTL identified in watermelon, pumpkin/squash, cucumber and melon, and inferred 14, 9 and 13 consensus SS QTL based on their physical positions in respective draft genomes. Among them, four from watermelon (*ClSS2.2*, *ClSS6.1*, *ClSS6.2*, and *ClSS8.2*), were major-effect, stable QTL for seed size and weight. Whole genome sequence alignment revealed that these major-effect QTL were located in syntenic regions across different genomes suggesting possible structural and functional conservation of some important genes for seed size control in cucurbit crops. Annotation of genes in the four watermelon consensus SS QTL regions identified genes that are known to play important roles in seed size control including members of the zinc finger protein and the E3 ubiquitin-protein ligase families. The present work highlights the utility of comparative analysis in understanding the genetic basis of seed size variation, which may help future mapping and cloning of seed size QTL in watermelon (Yu Guo *et al*., 2020) (Fig. 8). Adjoumani *et al*. (2016) conducted a study to evaluate seed variability in different segregating populations, and determine heritability of traits of watermelon (*Citrulluslanatus*). Inter specific crosses were made between two cultivars of *C. lanatus* (Bebu and Wlêwlê Small Seeds (WSS) were performed. There was wide variability between parental, F_1, BC_1(first generation of back-crossing) and F_2 seeds. Seeds of all hybrid populations were in termediateversus those of the parents. Also, crossing did not affect $F_1$and F_2 seed characters, but affected those of BC_1 because of maternal effects. Thus, back-crossing on Bebu cultivar produced seeds which looked like those of Bebu; while back-crossing on WSS cultivar produced seeds similar to those of WSS. Principal Component Analysis (PCA) and individuals repartitioning revealed that Bebu and WSS cultivars were genetically distinct and showed three main groups: two groups from each parental line and one from are combinant line (hybrids) .F_2populationhadawide individual's dispersion, and contained seeds of all other populations. High heritability was observed for all evaluated characters. This study show large genetic variability between populations (parental and hybrid) seed. These populations were classed to 3 main groups: two parental types including each parental type with its offspring maternal backcross and some F_2 individuals and one recombinant type including all F_1 individuals and some BC_{1b}, BC_1w and F_2 individuals. Phenotypic similarity between BC_1 hybrids and their maternal parents suggests existence of sufficient parental genes than in F_1 hybrids during back crossing in expression of examined characters. These results are the evidence that cross direction is an important factor for *C.lanatus* genetic breeding. All characters examined, admitted a high large and strict heritabilities, suggesting that environment effects are less important than genetic effects. None of these characters were monogenic while others were polygenic (Fig. 9). *Citrullus colocynthis* (CC) is a viable source of genes for enhancing disease and pest resistance in common cultivated watermelon [*Citrullus lanatus* var. *lanatus* (CLL)] cultivars. However, there is little information about genetic diversity within CC or the relationship of CC accessions to *C. lanatus*. In this study, we examined genetic diversity and relationships among 29 CC accessions collected in northern Africa, the Middle East, and Asia, and their relationships to 3 accessions and 3 cultivars of CLL, 12 accessions of citron melon [*C. lanatus* ssp. *lanatus* var. *citroides* (CLC)], and 1 accession representing the desert perennial *Citrullus ecirrhosus* (CE). Twenty-three high-frequency oligonucleotides-targeting active gene (HFO–TAG) primers were used to produce a total of 431 polymorphic fragments that target coding regions of the genome. Cluster and multidimensional scaling plot analysis, separated the CC into five groups, in general agreement with their geographic origins. CC genotypes admixed with CLL and CLC also were identified. Major reproductive barriers resulted in significantly reduced fertility in CC × CLL hybridizations. However, several of the U.S. PIs of CC were successfully crossed with watermelon cultivars using traditional breeding procedures, and the seeds produced from these crosses were viable. This suggests that CC can be a viable source to introduce biotic and abiotic stress resistance genes into cultivated watermelon (Levi *et al*., 2017).

The science is at least more precise today, enabling breeders to test seedling for genetic markers such as sweetness, for instance. The other way to reintroduce some of these more durable traits—stress tolerance, drought resistance, disease resistance—is through new CRISPR technology, which essentially takes a snip of genetic material from one watermelon and inserts it into another. This technology is considered by some critics to be just as bad as other kinds of genetic manipulation, but many scientists argue that because foreign DNA is not used, this doesn't constitute GMO in the way we commonly understand it. Additionally, it is reported that this kind of technology can reduce traditional breeding times by years, and develops watermelons that are better able to handle challenges faster. Agriculture will need to embrace traditional sustainable practices and scientific innovations in order to survive our rapidly changing climate (Carey, 2021). Fruit quality traits of sweet watermelon (*Citrullus lanatus* var. *lanatus*) are crucial for new product development and commercialization. Sweet watermelon fruit quality traits are affected by the compositions of phytochemical compounds, phytohormones, and fruit flesh firmness which are affected by genes, the growing environment and their interaction. These compositions determine fruit ripening, eating quality, and postharvest shelf-life. Knowledge of the genetic profile and analyses of quality traits in watermelon is vital to develop improved cultivars with enhanced nutritional compositions, consumer-preferred traits, and extended storage life. This review aims to present the opportunities and progress made on the genetic analysis of fruit quality traits in watermelon as a guide for quality breeding based on economic and end-user attributes. The first section of the review highlights the genetic mechanisms involved in the biosynthesis of phytochemical compounds (i.e., sugars, carotenoids, amino acids, organic acids, and volatile compounds), phytohormones (i.e., ethylene and abscisic acid) and fruit flesh structural components (i.e., cellulose, hemicellulose, and pectin) elicited during watermelon fruit development and ripening. The second section pinpoints the progress on the development of molecular markers and quantitative trait loci (QTL) analysis for phytochemical compounds, phytohormones and fruit quality attributes. The review presents gene-editing technology and innovations associated with fruit quality traits for selection and accelerated cultivar development. Finally, the paper discussed gene actions conditioning fruit ripening in citron watermelon (*C. lanatus var. citroides* [L. H. Bailey] Mansf. ex Greb.) as reference genetic resources to guide current and future breeding. Information presented in this review is useful for watermelon variety design, product profiling and development to serve the diverse value chains of the crop. (Mashilo *et al*., 2022)

Inbred lines were evaluated for ten characters to determine variability, estimate heritability and correlation. Analysis of variance revealed highly significant ($P<0.05$) for all characters. The results indicated the presence of substantial variability among the genotypes. Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and broad Sense heritability (h2) estimates ranges from 14.05-72.98, 14.86-73.84 and 89.36-99.94% respectively. The high estimates of GCV and PCV in this study indicated the existence of variability and selection can be done. Whereas high estimate of h2 for the tested traits indicated that these characters were highly heritable and selection can be imposed. Significant phenotypic correlation for fruit diameter, fruit length, fruit weight and number of fruits per plant with total yield per plant revealed that, these characters were primarily influenced by their direct contribution to higher yield. Four inbred lines had best marketable yield and fruit quality as red and yellow watermelon inbred lines. Therefore, it is recommended for an effective selection of those characters which could be adopted for cultivar improvement and hybridization program and more research is needed to validate the findings. (Abd Rabou and El-Sayd, 2021)

Gene List of Watermelon: As per compilation by Robinson (1976) and some modifications, the qualitative genes of watermelon are listed in Table 1 **(**Vidhi, 2022**)**.

GENETIC DIVERSITY

There are more than **1,200** varieties or cultivars of watermelons range in weight from less than one to more than 90 kilograms (200 lb); the flesh can be red, orange, yellow or white. The 'Carolina Cross' produced the current world record watermelon, weighing 159 kilograms (351 pounds). It has green skin, red flesh and commonly produces fruit between 29 and 68 kilograms (65 and 150 lb). It takes about 90 days from planting to harvest. The 'Golden Midget' has a golden rind and pink flesh when ripe, and takes 70 days from planting to harvest. The 'Orangeglo' has a very sweet orange flesh, and is a large, oblong fruit weighing 9-14 kg (20-31 lb). It has a light green rind with jagged dark green stripes. It takes about 90-100 days from planting to harvest. The 'Moon and Stars' variety was created in 1926. The rind is purple/black and has many small, yellow circles (stars) and one or two large, yellow circles (moon). The melon weighs 9-23 kg (20-51 lb). The flesh is pink or red and has brown seeds. The foliage is also spotted. The time from planting to harvest is about 90 days. The 'Cream of Saskatchewan' has small, round fruits about 25 cm (9.8 in) in diameter. It has a thin, light and dark green striped rind, and sweet white flesh with black seeds. It can grow well in cool climates. It was originally brought to Saskatchewan, Canada, by Russian immigrants. The melon takes 80 - 85 days from planting to harvest **(**Long An**, 2015).**

Low polymorphism in cultivated watermelon has been reported in previous studies, based mainly on US Plant Introductions and watermelon cultivars, most of which were linked to breeding programmes associated with disease resistance. Since germplasm sampled in a putative centre of origin in Southern Africa may harbour considerably higher variability, DNA marker-based diversity was estimated among 81 seedlings from eight accessions of watermelon collected in Zimbabwe; five accessions of cow-melons (*Citrullus lanatus* var. *citroides*) and three of sweet watermelons (*C. lanatus* var. *lanatus*). Two molecular marker methods were used, random amplified polymorphic DNA (RAPD) and simple sequence repeats (SSR) also known as microsatellite DNA. Ten RAPD primers produced 138 markers of which 122 were polymorphic. Nine SSR primer pairs detected a total of 43 alleles with an average of 4.8 alleles per locus. The polymorphic information content (PIC) ranged from 0.47 to 0.77 for the RAPD primers and from 0.39 to 0.97 for the SSR loci. Similarity matrices obtained with SSR and RAPD, respectively, were highly correlated but only RAPD was able to provide each sample with an individual-specific DNA profile. Dendrograms and multidimensional scaling (MDS) produced two major clusters; one with the five cow-melon accessions and the other with the three sweet watermelon accessions. One of the most variable cow-melon accessions took an intermediate position in the MDS analysis, indicating the occurrence of gene flow between the two subspecies. Analysis of molecular variation (AMOVA) attributed most of the variability to within-accessions, and contrary to previous reports, sweet watermelon accessions apparently contain diversity of the same magnitude as the cow-melons (Mujaju *et al*., 2010).

The genetic relationships among 27 watermelon cultigens (*Citrullus lanatus* var. *lanatus*) from different countries of origin and with different horticultural characteristics and 5 related wild-type species and subspecies (*Citrullus colocynthis*, *Citrullus lanatus* var. *citroides*, and *Citrullus rehmii*) were assessed using amplified fragment length polymorphism (AFLP) and expressed sequence tag-simple sequence repeat (EST-SSR) markers. AFLPs were evaluated using 16 EcoRI-MseI primer combinations,, and 862 alleles (an average of 53.8 alleles per primer combination) were scored. Polymorphisms were found in 806 (93.4%) alleles, whereas 56 monomorphic alleles were identified. Using 16 EST-SSR primer sets, 103 alleles were scored, and all 103 alleles were polymorphic among the 32 genotypes with an average of 6.4 polymorphic alleles per primer pair. However, the high polymorphic ratio among the AFLPs and EST-SSRs was largely due to the wild-type species, while little diversity was observed among the adapted cultivars. Genetic similarity coefficients were calculated based on the 965 polymorphic AFLP and EST-SSR alleles, and a phenetic tree was constructed. The dendrogram contained 2 major clusters. Cluster I included all adapted watermelon cultivars, and the similarity among these cultigens was very high (0.94-0.98), demonstrating cross relationships and a narrow genetic background. Cluster II was composed of 4 wild-type species. The genetic distance between the nodes that comprise these 2 clusters was approximately 0.63, indicating a high level of genetic dissimilarity between the adapted watermelon species and the other related species. The low level of marker polymorphism among the adapted cultivars implies that a severe bottleneck in genetic diversity existed in watermelon during the initial breeding practices (Hwang *et al*., 2011).

Seed size is one of the important agronomic traits of watermelon and different watermelon germplasm resources would lead to great differences in seed size. Therefore, a comprehensive understanding of the natural variation in watermelon seeds is important for breeding cultivars with target seed sizes and may provide insights into the domestication process of different species. Through the Genome-Wide Association Study (GWAS), the research team examined five seed size traits, including 100-seed weight (100 SWT), seed hilum length (SHL), seed length (SL), seed width (SWD), and seed thickness (STH) in 197 watermelon accessions, according to a study published in the journal Horticulture Research. The researchers found that seed enlargement was an important feature during watermelon seed size domestication. The seed-consumed biological species *Citrullus mucosospermus* and the edible seed watermelon *Citrullus lanatus* had significantly larger seeds than the other species. The study also showed that watermelon seed size is mainly determined by 100-seed weight, seed length and seed width. The findings provide molecular insights into the natural variation in watermelon seed size, and valuable information for molecular marker-assisted breeding, the researchers said (Xinhua, 2022).

Genetic diversity in watermelon (*Citrullus lanatus*) was estimated among 213 seedlings from 22 accessions collected in Botswana, Namibia, South Africa, Zambia, and Zimbabwe. The accessions consisted of two types of watermelon landraces: sweet watermelon (*C. lanatus* var. *lanatus*) and cow-melon (*C. lanatus* var. *citroides*), also known as citron melon. In addition, three commercial varieties of *C. lanatus* var. *lanatus* from the USA were included for comparison. Ten simple sequence repeat (SSR; microsatellite) loci detected a total of 153 alleles. The polymorphic information content (PIC) ranged from 0.833 – 0.963, suggesting sufficient discriminatory power. Both a cluster analysis and a principal co-ordinate analysis produced two major clusters, one with the 13 cow-melon accessions and the other with the 12 sweet watermelon accessions. Within the sweet watermelon cluster, the three US cultivars grouped together with the Botswana accessions. Some of the other accessions also grouped according to their country of origin, but others did not. Within-accession diversity parameters showed that those sweet watermelon accessions found in traditional agrosystems were just as genetically variable as the cow-melon accessions (Mujaju *et al*., 2015).

Citron watermelon (*Citrullus lanatus* var. *citroides*), genetic resources are useful for dessert watermelon (*C. lanatus* var. *lanatus*) breeding. The objective of the present study was to assess the genetic diversity present among citron watermelon landrace collections of South Africa using simple sequence repeat (SSR) markers. Thirty four diverse citron watermelon landraces were genotyped using 10 SSR markers.
The markers amplified a total of 72 alleles from the sampled populations. Number of alleles ranged from 2 to 17 with a mean of 7.2 per locus. Number of effective alleles ranged from 1.03 to 6.74 with a mean of 3.54. The mean observed and expected heterozygosity were 0.48 and 0.60, respectively. The mean inbreeding coefficient was 0.18 suggesting high levels of heterozygosity among the collections. The mean polymorphic information content (PIC) of the SSR loci was 0.60 suggesting their value in genetic diversity analysis of watermelon. Analysis of molecular variance revealed highly significant difference ($P < 0.001$) among and within individuals. Among and within individuals variance contributed 21 and 78% of the total genetic variance. Cluster analysis separated the genotypes into three distinct genetic groups revealing the presence of wide genetic variation among the citron watermelon genotypes studied. The study identified 5 distinct genotypes from cluster I, 7 from cluster II and 5 from cluster III. These are recommended for further phenotyping using horticultural attributes for effective breeding and strategic conservation. The highlights are, Genetic diversity was assessed among diverse citron watermelon landraces using simple sequence repeats markers. Analysis of molecular variance revealed 21 and 78% of total genetic variance among and within individuals, respectively. Cluster analysis identified three distinct genetic groups. Considerable genetic diversity was detected among South African grown citron watermelon landraces useful for breeding and strategic conservation (Mashilo *et al*., 2017).

Nowadays, watermelon species are available in different shapes, sizes, rind thicknesses, skin textures, flesh colors and seed frequencies, but due to continuous cultivation practices and selection of varieties for particular traits, genetic base has narrowed leading to limited improvement in watermelon research and breeding. Nevertheless, morphological characteristics have a crucial role in species conservation and plant breeding, it needs to be associated with genetic information to obtain more definitive conclusion. Although several studies have been conducted throughout the world to estimate the morphological diversity of watermelon species, experiments on genetic diversity are still limited. The two most common species of watermelon are *C. lanatus* var. *citroides* and *C. lanatus* var. *lanatus* that are known as citron melon and dessert melon, respectively. On the one hand, where dessert melon is known for its narrow genetic base, citron melon possesses huge genetic diversity (Pandey *et al*., 2019).

Genetic polymorphism amid plant species is a crucial factor for plant improvement and maintaining their biodiversity. Evaluation of genetic diversity amongst plant species is significant to deal with the environmental stress conditions and their effective involvement in the breeding programs. Hence, in present study, an attempt has been made towards the genetic assessment of individual and bulked populations of 25 watermelon genotypes, belonging to *Citroides* (citron watermelon) and *Lanatus* (dessert watermelon) group from Konya, Thrace, Turkmenistan, Saudi Arabia and Turkey. The employed Random Amplified Polymorphic DNA (RAPD) and Inter-Simple Sequence Polymorphism (ISSR) marker systems provided 69.4 and 95.4% polymorphisms, respectively. Different clustering methods showed clear grouping of the genotypes based on the geographical origin and species. Citron genotypes from Turkmenistan stood apart from all the Turkish *Lanatus* genotypes. However, Saudi Arab *Lanatus* genotype grouped with native Turkish varieties indicating the genetic linkage. Among all the Turkmenistan Citron genotypes, Turkmenistan-11 was the most distinct form. Moreover, sufficient genetic variation was found between the commercial and native *Lanatus* genotypes of Turkey as well as Citron genotypes of Turkmenistan. Hence, it will be beneficial to include these genotypes in the future breeding programs to transfer disease-resistant alleles from Citron to *Lanatus* genotypes (Pandey *et al*., 2019). Genetic diversity assessed in watermelon genotypes in the present study can be used for the evolvement of diverse and disease-resistant sweet watermelon genotypes. In conclusion, we can say that in this advanced molecular era, still dominant markers such as RAPD and ISSR can be considered as approachable and justifying method in diversity studies. The variations revealed in this work can be utilized for future molecular and normal breeding programs that may exaggerate the efforts of watermelon betterment in Turkey as well as other parts of the world (Pandey *et al*., 2019). Without the genetic material that helps watermelons survive extreme conditions, this important crop will become increasingly difficult to grow as the climate crisis worsens. "During the time people have carried out domestication or breeding, for periods they only focused on the fruit quality, and people were taking care of the plants, so the fruit got kind of spoiled. It said to itself 'I don't need this diversity, I can give it up. I don't need this gene…' and so those genes were lost." It was found that centuries of domestication had drastically reduced the commercial watermelon's genetic diversity—especially its ability to survive disease. Without the genetic material that helps watermelons survive extreme conditions, this important crop will become increasingly difficult to grow as the climate crisis worsens. The centuries of breeding for sweeter, redder, juicier watermelons has meant many of the fruit's previous traits have disappeared. It was found that watermelon's country cousins— six wild species from continental Africa—are much hardier. While they may be less sweet, have tougher flesh, and have unfamiliar colours for a watermelon, these wild relatives can survive all sorts of harrowing situations—drought, disease, and extreme weather. "Maintaining wide genetic biodiversity is the key for crop improvement. " Sweet dessert watermelon (*Citrullus lanatus*) is among the most important vegetable crops grown and consumed throughout the world," and "it is considered a healthy fruit with a large number of phytochemicals beneficial for human health" (Carey, 2021).

The objective of this study was to characterize the diversity of six heirloom and open-pollinated watermelon cultivars that are popular among U.S. organic, direct market, and home gardeners. An additional evaluation was conducted to determine whether significant phenotypic and genotypic variation existed among seed lots sourced from different commercial seed vendors. Important horticultural traits such as days to germination, days to first flower, yield, and fruit quality were measured over two field seasons. Genetic diversity was estimated using 32 simple sequence repeat (SSR) markers. Significant differences in horticultural traits among seed lots in both years were observed only in days to germination and first male flower, which may be a consequence of vendor differences in seed storage and quality control. Heirloom 'Moon and Stars' and modern OP 'Sugar Baby' were the most genetically distinct from the other cultivars and heirloom 'Georgia Rattlesnake' was determined to be highly related to the modern OP 'Charleston Gray'. The two heirloom cultivars were observed to have lower average gene diversity than the modern cultivars. Heirloom 'Moon and Stars' contained significant genetic variation among seed lots, yet heirloom 'Georgia Rattlesnake' contained none. These findings suggest that genetic variation can be more accurately attributed to pedigree and foundation seed maintenance practices than to the ''heirloom'' designation per se. The variation reported in this study can be used to inform conservation and breeding efforts. (Stone *et al*., 2019)

Cucurbits (Cucurbitaceae family) include many economically important fruit vegetable crops such as watermelon, pumpkin/squash, cucumber, and melon. Seed size (SS) is an important trait in cucurbits breeding, which is controlled by quantitative trait loci (QTL). Recent advances have deciphered several signaling pathways underlying seed size variation in model plants such as Arabidopsis and rice, but little is known on the genetic basis of SS variation in cucurbits. Here we conducted literature review on seed size QTL identified in watermelon, pumpkin/squash, cucumber and melon, and inferred 14, 9 and 13 consensus SS QTL based on their physical positions in respective draft genomes. Among them, four from watermelon (*ClSS2.2*, *ClSS6.1*, *ClSS6.2*, and *ClSS8.2*), two from cucumber (*CsSS4.1* and *CsSS5.1*), and one from melon (*CmSS11.1*) were major-effect, stable QTL for seed size and weight. Whole genome sequence alignment revealed that these major-effect QTL were located in syntenic regions across different genomes suggesting possible structural and functional conservation of some important genes for seed size control in cucurbit crops. Annotation of genes in the four watermelon consensus SS QTL regions identified genes that are known to play important roles in seed size control including members of the zinc finger protein and the E3 ubiquitin-protein ligase families. The present work highlights the utility of comparative analysis in understanding the genetic basis of seed size variation, which may help future mapping and cloning of seed size QTL in cucurbits (Yu Guo *et al*., 2020).

Since germplasm sampled in a putative centre of origin in southern Africa may harbour considerably higher variability, DNA marker-based diversity was estimated among 81 seedlings from eight accessions of watermelon collected in Zimbabwe; five accessions of cow-melons (*Citrullus lanatus* var. *citroides*) and three of sweet watermelons (*C. lanatus* var. *lanatus*). Two molecular marker methods were used, random amplified polymorphic DNA (RAPD) and simple sequence repeats (SSR) also known as microsatellite DNA. Ten RAPD primers produced 138 markers of which 122 were polymorphic. Nine SSR primer pairs detected a total of 43 alleles with an average of 4.8 alleles per locus. The polymorphic information content (PIC) ranged from 0.47 to 0.77 for the RAPD primers and from 0.39 to 0.97 for the SSR loci. Similarity matrices obtained with SSR and RAPD, respectively, were highly correlated but only RAPD was able to provide each sample with an individual-specific DNA profile. Dendrograms and multidimensional scaling (MDS) produced two major clusters; one with the five cow-melon accessions and the other with the three sweet watermelon accessions. One of the most variable cow-melon accessions took an intermediate position in the MDS analysis, indicating the occurrence of gene flow between the two subspecies. Analysis of molecular variation (AMOVA) attributed most of the variability to within-accessions, and contrary to previous reports, sweet watermelon accessions apparently contain diversity of the same magnitude as the cow-melons (Mujaju *et al*., 2010).

CROP IMPROVEMENT

Genetic Resources of Watermelon: In India, watermelon germplasm are conserved at IIVR, Varanasi, NBPGR, New Delhi and a few SAUs and IIHR, Bangalore **(**Vidhi, 2022**).**

Watermelon breeding: At some point, somebody decided they could selectively breed the watermelon to change how it tastes. Some smart ancient scientists discovered that a single gene produced the bitter watermelon flavor. By purposefully breeding many generations of plants with certain characteristics, the gene for bitterness was eliminated. Soon after, ancient people continued the selective breeding of watermelons to make them easier to get into — no more pounding the hard shell with a rock. Then came the taste. The bitter taste was gone, but it still was quite bland. Farmers selectively bred watermelons that had a little sweetness until they became sweeter and sweeter like today. It turns out the color of watermelons was controlled by the same gene that controlled watermelon sweetness. Therefore, as the watermelon became sweeter it also changed color to the familiar deep red we now know and expect **(**Szydlowski, 2021**).**

Breeding Goals of Watermelon(Vidhi, 2022): The breeding goals of watermelon are Earliness, Pistillate flowers at lower node number, Tough skinned fruits for long distance transportation, Dark red flesh, Firm and non-fibrous flesh texture, Black seed, Proper sugar to acid ratio, TSS content not less than 10%, Fruits with smaller and fewer seeds with attractive deep red flesh, Firm flesh, Intermediate fruit shape between typical long and round ones as most elongated cultivars have a tendency to produce so called gourd neck fruit, whereas round-fruited cultivars tend to be susceptible to 'hollow heart', High yield, Resistance to diseases, viz., Virus, Fusarium wilt (race 0, 1,2), Anthracnose, gummy stem blight, Powdery mildew, and Resistance to insects (cucumber aphid, fruitfly, cucumber beetle, red pumpkin beetle).

Breeding Objectives (Wehner, 2011) Major objectives for watermelon breeding include proper fruit type, early maturity, high fruit yield, high sugar content, tough flexible rind, and proper seed type. It is important to determine breeding objectives carefully before starting variety development. For example, seed type changes significantly for different market classes. Parental lines for seedless hybrids should have small seeds, whereas confectionery seed types should have large seeds. For commercial varieties, black seeds are preferred because of their contrast with red, yellow, or orange flesh. Also, white seeds indicate immaturity to buyers, so white mature seed color can be a confusing trait for them. Most of the old varieties are diploid, open-pollinated or inbred lines, but hybrid diploid and hybrid triploid varieties are taking over the commercial market in the United States. After determining the breeding objectives, methods for measurement of the traits of interest should be developed, selection methods should be determined (specifying the operations to be carried out for each generation), and parents with high expression of the traits of interest should be chosen. Vine type should be long for commercial production and dwarf(bush) for home garden. It may also be possible to use the dwarf plant type for once-over harvest in commercial production. Sex expression should be monoecious, with a ratio of 7 staminate:1 pistillate flowers, or better (preferably 4:1). Andromonoecious sex expression and ratios of 15:1 are more typical of older varieties.

For production in most areas of the United States, watermelon must have resistance to fusarium wilt. Races 0 and 1 are common, and race 2 is becoming important, especially in Texas and Oklahoma where plastic mulch culture and fumigation are less common. Production areas in the southern United States usually have anthracnose race 1 and may also have problems with race 2. Gummy stem blight is a disease for which resistance is needed in most southern production areas. Powdery mildew is becoming a problem, especially in the western United States (possibly because of a new race), and should be a breeding objective for new varieties. Bacterial fruit blotch was a problem in the 1990s, and resistant accessions have been identified. The disease can be effectively controlled by genetic resistance and by large-scale seed testing followed by destruction of contaminated seed lots. Protection from viruses in the United States production areas should include resistance to papaya ringspot virus-watermelon strain (formerly watermelon mosaic virus-1), watermelon mosaic virus (formerly watermelon mosaic virus-2), and zucchini yellow mosaic virus.

Finally, breeding objectives should emphasize early maturity, high fruit yield, durability for shipping, high internal quality, freedom from internal defects (hollowheart and rind necrosis), and proper seed type in a diploid (seeded) or triploid (seedless) hybrid. Internal quality traits include dark red flesh, high sugar content, proper sugar to acid ratio, excellent flavor, high nutritional value (vitamins and lycopene), firm (not soft) and non-fibrous texture. Seeds should be black color, medium size (or small for inbreds to be made into tetraploids), and few to medium quantity per fruit (few for consumers, but medium to keep seed costs down). Flesh color should be dark red (*Y* gene with modifier genes) with uniform color throughout the fruit. For specialty types, flesh color could be bright orange (y^O gene), canary yellow (*C* gene), or white (*Wf* gene). Other colors such as salmon yellow (*y* gene) exist, but are not preferred because the flesh looks overmature. Older varieties have light red flesh, but dark red is becoming the preferred type. Diploid inbreds should be made into tetraploid inbreds and tested for fertility, seed yield, and ability to set fruit using controlled pollination. Tetraploid lines for use in triploid seedless hybrid production can be induced with colchicine. Finally, triploid hybrids should be tested for absence of seed coats in the fruit within a range of production environments.

Breeding Methods

Major objectives for watermelon breeding include proper fruit type, early maturity, high fruit yield, high sugar content, tough flexible rind, and proper seed type. For example, seed type changes significantly for different market classes. Parental lines for seedless hybrids should have small seeds, whereas confectionery seed types should have large seeds. For commercial cultivars, black seeds are preferred because of their contrast with red, yellow, or orange flesh. After determining the breeding objectives, methods for measurement of the traits of interest should be developed, selection methods should be determined (specifying the operations to be carried out for each generation), and parents with high expression of the traits of interest should be chosen. Vine type should be long for commercial production and dwarf(bush) for home garden. It may also be possible to use the dwarf plant type for once-over harvest in commercial production. Sex expression should be monoecious, with a ratio of 7 staminate: 1 pistillate flowers, or better (preferably 4:1). Andromonoecious sex expression and ratios of 15:1 are more typical of older cultivars. The main main breeding methods are as follows:

Recurrent Selection (Wehner, 2011)***:***Although watermelon is a cross-pollinated crop, population improvement methods popular in some cross-pollinated crops have not been used. The main reason for that appears to be the large size of the plants, and the low rate of natural outcrossing that occurs. Also, because there are few plant breeders working on watermelon, and because of the requirement for many qualitative traits to be present in the new varieties being tested for release, it is expensive to spend additional years in population improvement for quantitative traits. It may be possible to improve quantitative traits such as yield in watermelon using recurrent selection i.e. repeated selection and massing of selected plants, but the populations should probably be developed initially to have the necessary qualitative genes in them. Those would include proper flesh color, fruit size, and disease resistance. Due to large plant size and a 5-month generation time, recurrent selection methods should be those that have few generations per cycle, and few plants per family (or single-plant selection). One approach would be to develop an elite population by intercrossing two to four of the best red fleshed hybrids available, trying to choose a set that was genetically unrelated. A population with a wide genetic base could also be developed by intercrossing 20 or more elite varieties by hand for two or more generations, and using bees in an isolation block for two or more generations before beginning a mild selection pressure for important quantitative traits such as yield. Simple recurrent selection could be used for selection among single-plant hills for a set of highly heritable traits. A more complex method such as reciprocal recurrent selection would permit simultaneous improvement of two populations for combining ability for yield. This would be an expensive program to run, but would produce two populations that could be used to develop inbreds to be used as the female and male parents (respectively) of elite hybrids. During population development, it would be necessary to identify methods for yield testing that were efficient for use in large yield trials. The usual guidelines for recurrent selection are to test at least 200 individuals (or progenies of individuals) per population, and to select at least 20 to intercross for the next cycle of selection. A yield trial involving 200 replicated families would require more resources than many breeding programs could afford if the trial were done using current methods. Recurrent selection could be used to improve quantitative traits, such as yield, which are difficult to improve using qualitative methods such as pedigree and backcross breeding. Each year, the improved population would be used to begin the development of inbred lines to feed into other parts of the breeding program.

Pedigree Method of Breeding **(**Wehner, 2011; Vidhi, 2022**):** Probably the most common method for watermelon breeding is pedigree. In pedigree breeding, the breeder begins by choosing two or more adapted parents, which complement each other in their traits.

For example, one parent might be generally good (yield, earliness, type) except for disease resistance and the other might be generally good (yield, earliness, type) except for fruit quality. The objective would be to produce new lines with high yield, early maturity, proper type, high fruit quality, and good disease resistance. The varieties or breeding lines are crossed to form the hybrid (F1) generation, which is then self- or sib-pollinated to form a segregating (F2) population (Fig. 3.10). The F2 is self- or sib-pollinated while selecting for traits having high heritability to form the F3 generation. If multiple plants are tested from each selected F2 plant, then the breeder concentrates on selecting the best plants in each of the best F3 families. This might include selection in the seedling stage in the greenhouse in the F2 and F3 generations for disease resistance such as fusarium wilt races 0, 1, and 2 and anthracnose races 1 and 2. Beginning at the F4 generation, selection would begin to emphasize family-row performance for quantitative traits. Plants within family-rows that have excellent performance for qualitative traits should be selected for the next generation. As the families reach six generations of self-pollination (S6 or F5), they become more uniform, and can then be handled as inbred lines. This could include selection using eight-plant plots for early flowering, number of pistillate flowers, and fruit number. The number handled might decrease from 54 F2 plants of a cross to 36 F3 families, 24 F4 families, and 18 F5 lines. Single-seed-descent is a modification of pedigree breeding in which inbred lines are developed rapidly by self-pollination in greenhouses and winter nurseries, and selection is not practiced until later generations, such as S3 to S6. This method requires less record keeping and works better where the main objective is to improve quantitative traits such as yield and earliness, rather than qualitative traits such as flesh color and disease resistance. However, traditional pedigree breeding is probably the more useful method for watermelon since there are many qualitative traits that can be selected in early generations. In that way, plants or families having unsuitable traits that are simply inherited (such as poor fruit flesh color) can be eliminated in early generations. Otherwise, they would be carried along until the S3 to S6 generation when field-testing would be practiced in the single-seed-descent breeding method.

Backcross Method of Breeding (Wehner, 2011; Vidhi, 2022): Backcross breeding is used to transfer one qualitative (highly-heritable) trait into an otherwise superior inbred. The superior inbred is referred to as the recurrent parent. Often, six generations of selection and backcrossing to the recurrent parent are used to recover the genotype of the recurrent parent (except for the addition of the new trait) without the other undesirable traits from the non-recurrent (donor) parent. Two versions of the backcross method are used depending on whether the gene of interest is recessive or dominant. For the transfer of a trait controlled by a recessive gene, the recurrent parent is crossed with the donor parent, and the F1 backcrossed to the recurrent parent. In one scheme, the F1 is self-pollinated to produce the F2, which will segregate for the trait of interest. Individuals having the trait can then be backcrossed to the recurrent parent to produce the BC1. The BC1 generation is then tested for the trait, and individuals having it are self-pollinated once again to produce a segregating generation for selection and backcrossing to the recurrent parent. The process is repeated until the BC6 generation when the best individuals are self-pollinated and selected for the trait to produce the improved inbred. The inbred does not need to be tested extensively in trials, because it will be identical to the original inbred, but with one new trait. For the transfer of a trait controlled by a dominant gene, the recurrent parent is crossed with the donor parent, and the F1 backcrossed to the recurrent parent. The BC1 generation is then tested for the trait, and individuals having it are backcrossed to the recurrent parent. The process is repeated until the BC6 generation when the best individuals are self-pollinated and selected for homozygous expression of the trait using progeny testing.

Inbred Development and Hybrid Breeding **(**Wehner, 2011; Vidhi, 2022**):** The best selections from the recurrent selection program should be self-pollinated each cycle to begin inbred development. Pedigree selection, and backcross breeding result in the production of elite inbred lines. Each year, those inbred lines that are produced from the different parts of the breeding program should be increased by self-pollination, tested for useful horticultural traits, and used in the production of tetraploid inbred lines, as well as directly for the production of diploid hybrids based on the traits they have, and what is needed by the market. Isolation blocks or screen cages can be used to make large seed increases of the inbreds if that is needed. Isolation blocks should be away from other watermelon fields, requiring a separation of at least 1 mile. Bees should be provided in the isolation block or cage by bringing in one strong hive, unless there are sufficient numbers of wild bees. The final stage of breeding is to produce hybrids for testing. Hybrids are usually made between two monoecious inbreds. For triploid hybrid production, the seed parent should have a distinctive rind pattern that has recessive inheritance. For hybrid production with less labor input, the seed parent could be male sterile. The seed increase of the male sterile inbred would be accomplished by pollinating male sterile plants with the heterozygote (*Msms*) as the pollen parent. For seedless hybrid production, the seed parent would be a tetraploid inbred. Once they have been developed, all inbreds can be crossed in all possible combinations. However, that might produce too many entries to evaluate properly. For example, 20 inbreds could produce (20 x 19)/2 = 190 different hybrids, without including reciprocals. Thus, it may make more sense to make hybrids only from pairs of inbreds having complementing traits of the proper type. Testing of experimental hybrids should progress in stages, with fewer hybrids to test in later stages where more effort is spent on each hybrid. The first year trials might have two replications in each of two locations. In the second year, the best hybrids could be evaluated in 8 to 12 locations using the conditions available at each (grower fields, state university experiment stations). In the third year, the hybrids would be sent to grower trials throughout the production regions of interest for trials involving 0.25 to 1.0 acre using a total of 5-10 lb. of seeds for all trials. Seeds should be screened for bacterial fruit blotch before sending to growers. One can usually get good data from at least 10 of the 50 trials. Information from the 3 years of trialing should lead to the release of the best one or two hybrids in the fourth year.

Although there is not much advantage of hybrids over open-pollinated varieties for most traits, it is thought that the former are more uniform. Thus, it may be possible to get the same yield in fewer harvests because of more uniform growth and a more concentrated fruit set. Hybrids offer several advantages over open-pollinated varieties. A major advantage is the production of seedless triploids, which are produced by crossing a tetraploid female inbred with a diploid male inbred. Hybrids also can express heterosis, with the hybrid performing slightly better than the best parent in some cases. The amount of heterosis in watermelon is around 10%. Another advantage is the ability to get an intermediate fruit shape by crossing an elongate-fruited inbred with a round-fruited one. Inbreds can be used to combine dominant genes for resistance from each parent into a hybrid that has more dominant genes expressed than either parent. A hybrid that has large seeds for the grower to plant and small seeds in the fruit sold to the consumer can be produced by crossing a large-seeded female inbred with a small-seeded male inbred. Finally, hybrids provide a way for the seed company to protect their proprietary inbreds from theft. The disadvantages of hybrids are that they add an extra step to the breeding process, and increase the cost of seeds since they are produced by hand pollination rather than by bee pollination. Use of male sterile inbreds for seed production should help reduce the cost of hybrid seeds in the future.

Integration of New Biotechnologies into Breeding in Watermelon: (Vidhi, 2022) In watermelon, biotechnology is being used to propagate plants in tissue culture, to study genes at the molecular level, to develop molecular markers for selecting useful genes, to isolate the DNA of useful genes, and to incorporate useful genes into cultivars using genetic transformation.

***Tissue Culture*:** Tissue culture involves the production of cells or plants from plant parts. It offers a method for propagation of valuable plants such as tetraploid parental inbreds, or triploid seedless hybrids. With the increased demand for seedless cultivars, breeders are interested in producing tetraploids in quantities large enough for a hybrid seed production block. Since tetraploid watermelons have slow growth and low seed production, tissue culture can be useful for multiplying new tetraploid lines. Protocols have been developed for propagation of tetraploid plants. Methods have been developed for the production of tetraploid plants by the regeneration of cotyledons of seedlings cultured in vitro. It has been possible to produce tetraploid plants from different watermelon cultivars, as an efficient alternative to the standard method of using colchicines to double the chromosome number of diploid plants.

***Marker Assisted Selection**:* Molecular markers can be used as reference points in mapping genes on a chromosome. The information is useful in the selection of plants that carry a marked gene of interest. Plant breeders can discard plants from a segregating population that are missing the gene of interest. In that way, field testing can be done using only the plants having a particular set of traits. Markers can also be used to identify cultivars (DNA fingerprinting), and to estimate the genetic relatedness of a set of cultivars or individuals in a population. Over 40 genes have been described in watermelon. The genes are involved in disease resistance, flower type, fruit shape, and fruit quality. If molecular markers can be identified that are closely linked to those genes, then selection might be performed more rapidly, or earlier. For example, selection might be carried out in a seedling test instead of waiting for the plants to produce fruit.

Genetic Transformation: Genetic transformation provides methods for inserting single genes into plants while overcoming barriers to interspecific crossing. The soil-borne bacterium Agrobacterium tumefaciens is often used as the vehicle for transferring genes into plants. Plant cells can also be transformed using micro-particle bombardment, where DNA-coated particles are shot into plant cells. Several studies have reported transformation of watermelon using Agrobacterium or micro-particle bombardment. Transformed cells must by regenerated from sterile culture to produce plants containing the new gene to be used in a breeding program. Transformation of watermelon plants has been used to confer virus resistance. Several virus species cause disease in watermelon. These include squash mosaic virus (SQMV), cucumber mosaic virus (CMV), papaya ring-spot virus-watermelon strain (PRSV-W), zucchini yellow mosaic virus (ZYMV), and watermelon mosaic virus (WMV). Transfer of virus coat protein genes into watermelon plants may confer resistance to the virus disease, and provide plant breeders with new resistance genes.

Breeding Achievements: Considerable breeding effort has developed disease-resistant varieties. Many cultivars are available that produce mature fruit within 100 days of planting (WIKI, 2022). There are numerous cultivars of watermelon, which can differ in shape, rind color, fruit size, type of seed, and color of flesh. One may find 2 kilogram to 40 kilogram watermelons, watermelons with light green to very dark green rinds, and flesh color that is red, pink, yellow, orange, and white (Bionity, 2022). The following are some of the common varieties (ITFN 2016; Bionity, 2022).

Yellow Watermelon: variety of watermelon that has a yellow colored flesh. This particular type of watermelon has been described as "sweeter" and more "honey" flavored than the more popular red flesh watermelon.[9]

Orangeglo: This variety has a very sweet orange pulp, and is a large oblong fruit weighing 9-14kg (20-30 pounds). It has a light green rind with jagged dark green stripes. It takes about 90-100 days from planting to harvest.[10]

Moon and Stars**:** This variety of watermelon has been around since at least the 1930s. The rind is purple/black and has many small yellow circles (stars) and one or two large yellow circles (moon). The melon weighs 9-23kg (20-50 pounds). The flesh is pink or red and has brown seeds. The foliage is also spotted. The time from planting to harvest is about 90 days.

Cream of Saskatchewan: This variety consists of small round fruits, around 25cm (10 inches) in diameter. It has a quite thin, light green with dark green striped rind, with sweet white flesh and black seeds. It can grow well in cool climates. It was originally brought to Saskatchewan, Canada by Russian immigrants. These melons take 80-85 days from planting to harvest.

***Melitopolski**:* This variety has small round fruits roughly 28-30cm (11-12 inches) in diameter. It is an early ripening variety that originated from the Volga River region of Russia, an area known for cultivation of watermelons. The Melitopolski watermelons are seen piled high by vendors in Moscow in summer. This variety takes around 95 days from planting to harvest.

Seedless watermelon: Seedless watermelon has made our lives easier, adding to the convenience of taking watermelon on the go as a snack or a refreshing post-workout fuel but also adding to the versatility we now have to play with watermelon in a huge variety of recipes. But the question is frequently asked (and often incorrectly assumed) about where seedless watermelons came from? Seedless watermelons were invented over 50 years ago, and they have few or no seeds. When we say seeds, we are talking about mature seeds, the black ones. Oftentimes, the white seed coats where a seed did not fully mature are assumed to be seeds. But this isn't the case! They are perfectly safe to swallow while eating, and don't worry – no watermelons will grow in your stomach despite the old wives' tale. So, how are seedless watermelons grown? Chromosomes are the building blocks that give characteristics, or traits, to living things including plants and watermelons. Watermelon breeders discovered that crossing a diploid plant (bearing the standard two sets of chromosomes) with a tetraploid plant (having four sets of chromosomes) results in a fruit that produces a triploid seed. (Yes, it has three sets of chromosomes.) This triploid seed is the seed that produces seedless watermelons! In other words, a seedless watermelon is a sterile hybrid which is created by crossing male pollen for a watermelon, containing 22 chromosomes per cell, with a female watermelon flower with 44 chromosomes per cell. When this seeded fruit matures, the small, white seed coats inside contain 33 chromosomes, rendering it sterile and incapable of producing seeds. This is similar to the mule, produced by crossing a horse with a donkey – simple cross-breeding. And to be clear on the subject, this is not genetic modification**.** Cross-breeding is two parents and their offspring. Importantly and interestingly, seedless watermelon still need to be pollinated by their seeded parent, so oftentimes growers will plant seeded and seedless in their field. However, the seeded commercial harvest and retail sales only add up to about 8%, meaning seedless watermelon makes up for 92% of all watermelon sales. Seedless watermelon is hugely popular in the United States and it is here to stay (FAQ, 2022). Although so-called "seedless" watermelons have far fewer seeds than the seeded varieties, they generally contain at least a few soft, pale, edible seeds. They are the product of crossing a female tetraploid plant (itself the product of genetic manipulation, using colchicine) with diploid pollen. The resulting triploid plant is sterile, but will produce the seedless fruit if pollenized by a diploid plant. For this reason, commercially available seedless watermelon seeds actually contain two varieties of seeds; that of the triploid seedless plant itself (recognizable because the seed is larger), and the diploid plant, which is needed to pollenize the triploid. Unless both plant types are grown in the same vicinity, no seedless fruit will result (NWE, 2022). Although so-called "seedless" watermelons have far fewer seeds than the seeded varieties, they generally contain at least a few soft, pale seeds. They are the product of crossing a female tetraploid plant (itself the product of genetic manipulation, using colchicine) with diploid pollen. The resulting triploid plant is sterile, but will produce the seedless fruit if pollenized by a diploid plant. For this reason, commercially available seedless watermelon seeds actually contain two varieties of seeds; that of the triploid seedless plant itself (recognizable because the seed is larger), and the diploid plant which is needed to pollenize the triploid. Unless both plant types are grown in the same vicinity, no seedless fruit will result (Bionity, 2022).

Cube/Ice Box/Cube Watermelons: In Japan, farmers of the Zentsuji region found a way to grow cubic watermelons, by growing the fruits in glass boxes and letting them naturally assume the shape of the receptacle. The square shape supposedly makes the melons easier to stack and store, but the square watermelons are often more than double the price of normal ones. Pyramid-shaped watermelons have also been developed (NWE, 2022).For starters, many people have needed to downsize due to rising electricity costs and these square watermelons can easily be stacked beneath or above something else in a small refrigerator. In their country of origin, Japan, being space smart really is important. The shape of these watermelons also allows them to be easily stacked for transportation. Furthermore, these watermelons have been grown for their ornamental value. In Japan, many people display these unusual cube watermelons in their restaurants and homes to be observed by others. These cube watermelons are not left on the ground to grow into their natural shape. The vine is trained into large square boxes where the melon grows to maturity. The young watermelon is left in the box to naturally grow and take shape of the cube. The boxes these fruits are grown in are generally made of glass so that the sunlight can still reach them.

Varieties of Watermelon in India (Vidhi, 2022**)** ***Sugar Baby***: This is a variety originally introduced by M Hardin, Geary, Oklahoma, USA in the year 1956. It is early and resistant to drought. From USA, it was introduced to India by 1ARI. The vines are medium long. Fruits are smaller (3-5 kg), round in shape. The rind is bluish black. Flesh is sweet (11-13% TSS) with deep pink colour. Seeds are brown and small. Yield potential is 150 q/ha.

Asahi Yamato*:* It is a mid-season Japanese introduction by IARI. Fruits are medium weighing 6-8 kg. The fruits are round oblong, non-striped with light green rind. Flesh is deep pink with 11-13% TSS. Fruits ripen in about 95 days. Yield is 225 q/ha.

Pusa Bedana*:* It is a seedless triploid variety of watermelon developed at IARI, from a cross of Tetra-2 (4X) x PusaRasaal (2X). The fruits have dark green skin with faint stripes. Fruits are somewhat triangular in shape with tough rind, red flesh and white remnants of false seed. TSS is 12-13%. Average fruit weight is 5-6 kg. The number of fruits per vine varies from 3 to 6. It takes 115-120 days for first fruit harvest. It could not become popular due to irregular fruit shape and high cost of seed. Now it is not available.

Arka Manik*:* This has been bred at IIHR, Bangalore from a cross of IIHR 21 x Crimson Sweet. Fruits are round to oval with green rind, dark green stripes and weight is about 6 kg. The flesh is deep crimson, with granular texture. It is very sweet with 12-15% TSS. It has multiple resistance to powdery mildew, downy mildew and anthracnose. Yield potential is 500 q/ha.

Arka Jyoti*:* It is a mid-season F_1 hybrid cultivar evolved at IIHR, Bangalore by crossing a local watermelon of Rajasthan (IIHR 20) with Crimson Sweet. Fruit are oval and deep blue angular stripes. Average fruit weight is 5-6 kg. Flesh is bright crimson, sweet with 11-13% TSS. Yield potential is 600 q/ha.

Durgapura Meetha*:* It is a late maturing cultivar (125 days). Fruit is round and light-green. Rind is thick with good keeping quality. Flesh is sweet with TSS around 11% and dark-red colour. Average fruit weight is 6-8 kg. Seeds have black tip and margin. Yield is 40-45 tonnes/ha. It is released by Agricultural Research Station, Durgapura, Rajasthan.

Durgapura Kesar*:* It is a late cultivar. Fruit weight is 4-5 kg. Skin is green with stripes. Flesh is yellow in colour, and moderately sweet. Seeds are large. It is released by Agricultural Research Station, Durgapura, Rajasthan. There are several cultivars, locally grown which are named after the region in which they are grown, such as Farrukhabadi, Moradabadi of Uttar Pradesh. Most of them have fruits with dark- green colour or pale-green with black stripes, oblong to round shape weighing 8-10 kg with thick rind. The flesh colour could be variable from pale-pink to pink with big flat black to brown seeds. In Rajasthan, Mateera cultivar is grown in rainy season around Bikaner. There is local cultivar of Jamuna river-bed called Katagolan whose flesh is not sweet but it keeps well for over 2-3 months at ambient temperature during July-September. The flesh becomes dry and fibrous instead of fermentation and rotting. Prominent hybrids by private seed companies in India are NS 295, Tambola, Madhuri (all Jubilee segment, oval, 6-10 kg fruits, striped rind, red flesh), Black Magic, Black Sugar, Augusta (spherical, 6-8 kg, black rind, Sugar Baby type) and Kiran and Rasraj (3-4 kg, oblong, green skin/striped skin, ice box type). All these hybrids are sweet, juicy (12-13% TSS) and have high shelf- life and transportability. With the introduction of these hybrids, Indian consumers are enjoying delicious watermelons round the year. This is the impact of hybrid technology for anybody to see.

Advances in Watermelon Breeding: The continuous discovery of best possible combiners and their outcome has replaced the superior varieties by hybrids in watermelon. Nowadays several types of watermelons are being marketed-some are having red flesh, some with yellow, some with white flesh. Even with the differences in its shape and size, some are round, some are oval, some are square. Some are with seeds some are seedless. This all happened because of the efforts of crazy mind and fast changing market needs. The introduction of new watermelon genes and marker genes have equipped us to deal with pest and pathogens. Beyond that, using the genes of a rootstock of a related cucurbit, we can combat soil pests as well as adverse environmental conditions. Use of male sterility can reduce the cost of hybrid seed. But watermelons haven't always been so popular. They started out as small, hard, bitter fruits, somewhere in Southern or Western Africa. As generations of people selectively planted seeds from fruits that were larger and tastier, they created the sweet, red watermelon we know today. In the process, however, watermelon plants lost much of their genetic diversity. Breeders depend on this diversity to create desirable traits such as the ability to resist infections and withstand droughts. The cultivated watermelon has very, very narrow genetic diversity that causes problems for breeding. It was concluded that as people bred sweeter watermelons with better fruit quality, they inadvertently lost genes that give watermelons resistance to common pests and diseases. It was also identified regions of the chromosome that are involved in sugar production, create bitterness and give resistance to Fusarium wilt, a common fungal disease. It was also investigated the metabolic pathway for citrulline, an amino acid found in the flesh and rind that helps to regulate blood pressure and may even have a Viagra-like effect. Watermelons also contain large amounts of lycopene, a red pigment that acts as an antioxidant and may provide additional health benefits (Waldron, 2016).

USES

Food Uses- Watermelons are collected from the wild for local use, notably as a source of water in the Kalahari region of southern Africa. The flesh comprises about 65% of the whole fruit and contains over 90% water. Watermelon contains carotenes and vitamin C. One particularly useful species is watermelon, *Citrullus lanatus*. An important source of water in the Kalahari region over the dry season, it also provides food and medicines. Watermelons are cultivated commercially for their refreshing, sweet fruits. They are mostly consumed as fresh fruit, alone or as part of fruit salads or other desserts. In some African cuisines the fruit and leaves are cooked as a vegetable. Watermelon rinds are also edible, but most people avoid eating them due to their unappealing flavor. They are used for making pickles, and sometimes used as a vegetable. The rind is stir-fried, stewed or more often pickled, which is sometimes eaten in the Southern US. Small, white-fleshed cultivars are used in the production of preserves. Watermelon fruits are made into syrup in Eastern Europe. The rind may be consumed in pickled or candied form. Watermelon rind preserves are made by boiling chunks of watermelon rind with sugar and other ingredients. The mixture is then canned in glass jars. According to some recipes, the rind is pared to only the white portion, strips or cubes of which are soaked overnight in a solution of lime or salt and water, then rinsed. It is then boiled, combined with sugar and flavorings such as ginger and lemon, and cooked until the rind is clear. In the United States, these preserves are typical of Southern cuisine. A Serbian variety is called slatko od lubenice. In parts of the former Soviet Union, and elsewhere, watermelon juice is fermented to produce an alcoholic beverage. Watermelon juice can be made into wine or blended with other fruit juices. An alcoholic treat called a "hard watermelon" is made by pouring liquor into a hole in the rind of a whole fruit, and then eating the alcohol-permeated flesh. Watermelon has been used to make many kinds of Watermelon Wines. The seeds have a nutty flavor and can be dried and roasted, or ground into flour. In China, the seeds are esteemed and eaten with other seeds at Chinese New Year celebrations. In Vietnamese culture, watermelon seeds are consumed during the Vietnamese New Year's holiday, *Tết*, as a snack. Watermelon seeds are used in some traditional African cuisines. They are eaten dry or roasted as a snack food or as an ingredient in soups, in the Middle East, China and other Asian countries. Watermelon seeds are rich in edible oils and protein. They are ground into flour and baked as bread in some parts of India. Watermelon seeds are sold in West African markets as *egusi* (a name also used for *Cucumeropsis mannii*, another member of the cucurbit family). They are chiefly used as a masticatory, but also for medicine, food and oil. They are roasted and ground to a pulp, which is added to soup or made into sauce or porridge. Seed oil is extracted for use in cooking (Long An, 2015). Watermelon is a sweet, commonly consumed fruit of summer, usually as fresh slices, diced in mixed fruit salads, or as juice. Watermelon juice can be blended with other fruit juices or made into wine. The seeds have a nutty flavor and can be dried and roasted, or ground into flour. Watermelon rinds may be eaten, but their unappealing flavor may be overcome by pickling, sometimes eaten as a vegetable, stir-fried or stewed. *Citrullis lanatus*, variety *caffer*, grows wild in the Kalahari Desert, where it is known as tsamma. The fruits are used by the San people and wild animals for both water and nourishment, allowing survival on a diet of *Tsamma* for six weeks.(WIKI, 2022)

All parts of a watermelon fruit—fleshy interior, seeds, and rind—can be used. Asians love the seeds roasted and that in many parts of the world the pickled rind is a favorite. Fresh watermelon may be eaten in a variety of ways and is also often used to flavor summer drinks and smoothies. In the United States and South Africa, one may also find an alcoholic novelty known as a hard watermelon, or a watermelon that has been enhanced with an alcoholic beverage. This process involves boring a hole into the watermelon, then pouring the liquor inside and allowing it to mix with the flesh of the fruit. The watermelon is then cut and served as normal. Watermelon seeds are rich in fat and protein, and are widely eaten as a snack, added to other dishes, or used as an oilseed. Specialized varieties of watermelon are grown that have little watery flesh but concentrate their energy into seed production. In China, watermelon seeds are one of the most common snack foods, popular especially with women, competing with sunflower seeds, and sold roasted and seasoned. In West Africa, they are pressed for oil, and are popular in egusi soup and other dishes. There can be some confusion between seed-specialized watermelon varieties and the colocynth, a closely-related species with which they share many characteristics, uses, and similar or identical names. Watermelon rinds are also edible, and sometimes used as a vegetable. In China, they are stir-fried, stewed, or more often pickled. When stir-fried, the de-skinned and de-fruited rind is cooked with olive oil, garlic, chili peppers, scallions, sugar and rum, providing a way to utilize the whole watermelon. Pickled watermelon rind is also widespread in Russia, Ukraine, and Romania. Grilled watermelon, known as watermelon steak due to its visual similarity to raw steak, has started to become a popular item in restaurants (NWE, 2022). Fresh watermelon may be eaten in a variety of ways and is also often used to flavor summer drinks and smoothies. Grilled watermelon, known as watermelon steak due to its visual similarity to raw steak, has started to become a popular item in restaurants. Watermelon rinds are also edible, and sometimes used as a vegetable. In China, they are stir-fried, stewed, or more often pickled. When stir-fried, the de-skinned and de-fruited rind is cooked with olive oil, garlic, chili peppers, scallions, sugar and rum (and provides a great way to utilize the whole watermelon). Pickled watermelon rind is also commonly consumed in the Southern US, Russia, Ukraine, and Romania. Watermelon seeds are rich in fat and protein, and are widely eaten as a snack, added to other dishes, or used as an oilseed. Specialized varieties are grown which have little watery flesh but concentrate their energy into seed production. In China watermelon seeds are one of the most common snack foods, popular especially with women, competing with sunflower seeds, and sold roasted and seasoned. In West Africa, they are pressed for oil, and are popular in egusi soup and other dishes. There can be some confusion between seed-specialized watermelon varieties and the colocynth, a closely-related species with which they share many characteristics, uses, and similar or identical names. Watermelon is 92 percent water by weight. Throughout the western world, one may also find an alcoholic novelty known as a hard watermelon, or a watermelon that has been enhanced with an alcoholic beverage. This process involves boring a hole into the watermelon, then pouring the liquor inside and allowing it to mix with the flesh of the fruit. The watermelon is then cut and served as normal (Bionity, 2022).

Medicinal Uses- Watermelon fruit pulp, juice and seeds have been used as a diuretic. Fruit pulp has been used as a purgative, particularly that from bitter-forms. A preparation of watermelon seed has been used to lower blood pressure. Watermelon seeds have been used to expel intestinal worms in Senegal (Long An, 2015). The Greeks and Romans considered watermelon to have medicinal properties. Notable Greek physicians Hippocrates and Dioscorides praised its healing properties and used it as a diuretic as well as a treatment for children who suffered a heatstroke. The latter was accomplished by placing a wet, cool watermelon rind on their heads. Later, the Roman naturalist Pliny the Elder described watermelon as a cooling food in his first century publication, *Historia Natualis.* The latter was an encyclopedic work covering many subjects including botany and medicine (Trinklein, 2020).

Other Uses- Bitter forms of watermelon and the cake left over after expressing the seed oil are used as cattle-feed. The leaves and fruit provide grazing for stock. Watermelon has been used as an ingredient in sun-lotions and other cosmetics. The amino acid citrulline is produced in watermelon rind. Watermelon pulp contains carotenoids, including lycopene(Long An, 2015).

NUTRITIONAL VALUE AND HEALTH BENEFITS

Watermelon is characterized by several bioactive compounds, showing different chemical structures, such as carotenoids, xanthophylls, phenolic compounds, citrulline, and unsaturated fatty acids. The good amount of total polyphenols, vitamin C, citrulline and the excellent supply of lycopene, about 40% compared to raw tomatoes, give a measure of the importance of this fruit respect to the other crops considering the beneficial effects of these compounds on human health.

Nutritional Value: The nutrition content of red fleshed, yellow fleshed, orange fleshed, and white fleshed watermelons are mentioned in Fig.10. Watermelon is rich source of carotenoids. Some of the carotenoide in watermelon include lycopene, phytofluene, phytoene, beta-carotene, lutein, and neurospirene. Lycopene makes up the majority of the carotenoids in watermelon. The carotenoid content in red fleshed watermelon varies from 37-121 mg/kg fresh weight, where as lycopene varies from 32-112 mg/kg fresh weight (Venkateswarlu *et al*., 2013). Watermelon fruit is 91% water, contains 6% sugars, and is low in fat (table). In a 100-gram (3+$\frac{1}{2}$-ounce) serving, watermelon fruit supplies 125 kilojoules (30 kilocalories) of food energy and low amounts of essential nutrients (see table). Only vitamin C is present in appreciable content at 10% of the Daily Value (table). Watermelon pulp contains carotenoids, including lycopene. The amino acid citrulline is produced in watermelon rind(WIKI, 2022).

It is an excellent source of vitamins C and A, as well as a good source of vitamin B6 and vitamin B1 and various minerals. The seeds are eaten as a snack or added to other dishes, and may be roasted and seasoned. They are a good source of fat and protein(NWE, 2022). A one-cup serving of watermelon will provide around 48 calories. Watermelon is an excellent source of vitamin C and vitamin A. Watermelon also provides significant amounts of vitamin B6 and vitamin B1, as well as the minerals potassium and magnesium. Pink watermelon is also a source of the potent carotenoid antioxidant, lycopene. Watermelon is 92 percent water by weight, the highest percentage of any fruit (NWE, 2022). A one-cup serving of watermelon will provide around 48 Calories. Watermelon is an excellent source of vitamin C and vitamin A, with one serving containing 14.59 mg of vitamin C and 556.32 IU of vitamin A. Watermelon also provides significant amounts of vitamin B6 and vitamin B1, as well as the minerals potassium and magnesium. Pink watermelon is also a source of the potent carotenoid antioxidant, lycopene. The amino acid citrulline was first extracted from watermelon and analysed. Watermelons contain a significant amount of citrulline and after consumption of several kg an elevated concentration is measured in the blood plasma, this could be mistaken for citrullinaemia or other urea cycle disorder (Bionity, 2022.)

Health Benefits: Carotenoids have antioxidant activity due to the free radical scvenging property. Several researches have reported an association between dietary lycopene consumption and lower incidence in diseases such a sprostrate and oral cancers. Lycopene may also help reduce risks of cardiovascular disease. Watermelon seeds are excellent sources of protein (both essential and non-essential amino acids) and oil. Watermelon seed is about 35% protein, 50% oil, and 5% dietary fiber. Watermelon seed is also rich in micro and macro – nutrients such as magnesium, calcium, potassium, iron, phosphorous, zinc etc (Venkateswarlu *et al*., 2013)

As mentioned earlier, watermelons are more than just sweet and juicy, and scientists are still discovering its health benefits. Its bright red color comes from the pigment lycopene which is a powerful antioxidant. Recent studies revealed that, when combined with a healthy lifestyle, watermelon consumption can reduce the risk of both cancer and diabetes. Additionally, watermelon is a potent source of the amino acid citrulline which may help lower blood pressure. Other studies indicate watermelon consumption might be helpful in reducing the onset of rheumatoid arthritis. Finally, while most do not consider it a "diet food," a cup of watermelon contains only about 45 calories. Plus, unlike other desserts, it's fat-free, low in cholesterol, and contains no sodium (Trinklein, 2020).

Despite popular belief that watermelon is made up of only water and sugar, watermelon is actually considered a nutrient dense food, a food that provides a high amount of vitamins, minerals and antioxidants for a low amount of calories. Many studies have suggested that increasing consumption of plant foods like watermelon decreases the risk of obesity and overall mortality, diabetes, heart disease and promotes a healthy complexion and hair, increased energy, overall lower weight:

1. Cardiovascular & Bone Health: The lycopene in watermelon is especially important for our cardiovascular health and is now being recognized as an important factor in promoting bone health. Consuming large amounts of watermelon has also been correlated with improved cardiovascular function because it improves blood flow via vasodilation (relaxation of blood pressure). Dietary lycopene (from foods like watermelon or tomatoes) reduces oxidative stress which normally reduces the activity of osteoblasts and osteoclasts (the two major bone cells involved in the pathogenesis of osteoporosis) - this means stronger bones for those consuming lycopene-rich foods. Watermelon is also rich in potassium which helps to retain calcium in your body, resulting in stronger bones and joints.

2. Reduces Body Fat: The citrulline in watermelon has been shown to reduce the accumulation of fat in our fat cells. Citrulline is an amino acid which converts into arginine with help from the kidneys. When our bodies absorb citrulline it can take the step of converting into arginine if so required. Citrulline, when consumed, has the ability to (through a series of steps) block the activity of TNAP (tissue-nonspecific alkaline phosphatase) which makes our fat cells create less fat, and thus helps prevent over-accumulation of body fat.

3. Anti-inflammatory & Antioxidant Support: Watermelon is rich in phenolic compounds like flavonoids, carotenoids, and triterpenoids. The carotenoid lycopene in watermelon is particularly beneficial in reducing inflammation and neutralizing free radicals. The tripterpenoid cucurbitacin E is also present in watermelon, which provides anti-inflammatory support by blocking activity of cyclo-oxygenase enzymes which normally lead to increased inflammatory support. Make sure you pick ripe watermelons, because they contain higher amounts of these beneficial phenolic compounds.

4. Diuretic & Kidney Support: Watermelon is a natural diuretic which helps increase the flow of urine, but does not strain the kidneys (unlike alcohol and caffeine). Watermelons helps the liver process ammonia (waste from protein digestion) which causes strain on the kidneys while getting rid of excess fluids.

5. Muscle & Nerve Support: Rich in potassium, watermelon is a great natural electrolyte and thus helps regulate the action of nerves and muscles in our body. Potassium determines the degree and frequency with which our muscles contract, and controls the excitation of nerves in our body.

6. Alkaline-forming: Watermelons have an alkaline-forming effect in the body when fully ripe. Eating lots of alkaline-forming foods (fresh, ripe, fruit and vegetables) can help reduce your risk of developing disease and illness caused by a high-acid diet (namely, meat, eggs and dairy.

7. Improves Eye Health: Watermelon is a wonderful source of beta-carotene (that rich red hue of watermelon = beta carotene) which is converted in the body to vitamin A. It helps produce the pigments in the retina of the eye and protects against age-related macular degeneration as well as prevents night blindness. Vitamin A also maintains healthy skin, teeth, skeletal and soft tissue, and mucus membranes.

8. Immune Support, Wound Healing & Prevents Cell Damage: The vitamin C content in watermelon is astoundingly high. Vitamin C is great at improving our immune system by maintaining the redox integrity of cells and thereby protecting them from reactive oxygen species (which damages our cells and DNA). The role of vitamin C in healing wounds has also been observed in numerous studies because it is essential to the formation of new connective tissue. The enzymes involved in forming collagen (the main component of wound healing) cannot function without vitamin C. If you are suffering from any slow-healing wounds, up your intake of vitamin C heavy.

CULTURAL SIGNIFICANCE (Bionity, 2022)

- Watermelons are used in many parts of the world as symbols and during various celebrations. Art related to the Mexican holiday Dia de los Muertos commonly depicts watermelons being eaten by the dead or shown in close conjunction with the dead. This theme appears regularly on ceramics and in other art from the holiday. Watermelons also appear as a subject in Mexican still life art.
- In Vietnam watermelon is used as part of the Vietnamese New Year's holiday, Tết, because it is considered a lucky colour. The seeds are also consumed during the holiday as a snack.
- In the 19th and early 20th centuries, African Americans often were depicted in racist caricatures as being inordinately fond of watermelon. The same depiction of the African American people's fondness of watermelon is used in some Eastern states in Mexico. However, it's not considered racist due to the great African heritage of the people from those areas.
- The fruit is extremely popular in the southern United States and has also led to self-parody in the annual watermelon seed-spitting

contests Georgia's Redneck Games. Country music singer Tracy Byrd released a single called "Watermelon Crawl", a song about a dance at a fictional watermelon festival. The Oklahoma State Senate passed a bill on 17 April, 2007 declaring watermelon as the official state vegetable, with some controversy as the watermelon is considered by many to be a fruit.

- A carved watermelon is worn as a hat by fans of the CFL's Saskatchewan Roughriders in imitation of the players' helmets as a symbol of their 'Rider Pride' due the team's official colors of green, white, black, and silver. R. Lee Ermey often uses watermelons as targets during his weapons demonstrations on his television show Mail Call because the watermelon has approximately the same tensile strength as a human head (Bionity, 2022)

WATERMELON TRIVIA (Trinklein, 2020)

- The first recorded watermelon harvest occurred in Egypt nearly 5000 years ago. Because of its great water content, early explorers used watermelons as canteens.
- The first cookbook published in the United States in 1796 contains a recipe for pickled watermelon rinds.
- According to Guinness World Records, the world's heaviest watermelon ever produced weighed 350.5 pounds and was grown in Sevierville, Tennessee.
- In Japan, a technique for growing square watermelons has been perfected. There, square melons sell for between $75 and $100 (U.S. dollars) each.
- Over 1,200 varieties of watermelon are grown across 96 countries worldwide. China is 1st in worldwide watermelon production, while the United States ranks 7th.

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