ISSN: 0975-833X

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

International Journal of Current Research

Vol. 16, Issue, 09, pp.29799-29825, September, 2024
DOI: https://doi.org/10.24941/ijcr.47771.09.2024

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

REVIEW ARTICLE

ORIGIN, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETIC DIVERSITY, BREEDING AND CULTIVATION OF SAFFRON

***Swamy, K.R.M.**

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

ARTICLE INFO

Article History:
Received 20th June, 2024
Received in revised form
19th July, 2024
Accepted 19th August, 2024
Published online 30th September, 2024

Key words:
Saffron, Origin, Taxonomy, Botanical Description, Genetic Diversity, Breeding.

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

ABSTRACT

Saffron belongs to the family Iridaceae, genius Crocus and species *Crocus sativus.* The word "saffron" immediately stems from the Latin word *safranum* via the 12th-century Old French term safran. The French was borrowed from Arabic *za'farān*, and ultimately from Persian zarparān which literally means "golden leaves". The Latin form *safranum* is also the source of the Catalan safrà, Italian zafferano, but Portuguese açafrão, and Spanish azafrán come from the Arabic *az-zaferán*. The Latin term *crocus* is certainly a Semitic loanword. It is adapted from the Aramaic form *kurkema* via the Arabic term *kurkum* and the Greek intermediate κρόκος *krokos*, which once again signifies "yellowish". The Sanskrit *kunkumam* might be ultimately the origin, or in some way related to the Semitic term. The common names are in Hindi - kesar, zaffran; Sanskrit - avarakta, saurab, mangalya, agnishikha, kumkuma, mangal, kusrunam; English- saffron; Arab and Persian - zafrah, zipharana; Ben - jafran; Bom - safran, kessar; Mah - kecara; Guj - keshar; Tel - kunkuma-purva, kunkumma-purru; Tam. and Mal. - kunkumappu; Can. and Kon. - kunkuma-kesara; Fr.and Ger. – safran. Saffron has been mentioned in many ancient mythologies and has a long history of use in various cultures. In Greek mythology, saffron is said to have been first used by the god Hermes to cure his injuries. It is also said to have been used by the goddess Aphrodite in her bath to enhance her beauty. In Hindu mythology, saffron is associated with Lord Vishnu and is believed to symbolize purity, courage, and sacrifice. It is also used in various religious ceremonies and rituals. In Persian mythology, saffron is believed to have been created from the tears of the legendary hero Kaveh, who led a revolt against an evil king. It is also said to have been used by the goddess Anahita to heal the sick and the wounded. In ancient Egyptian mythology, saffron was used in medicine and was believed to have healing powers. It was also used in perfumes, cosmetics, and other beauty products. Saffron also appears in the Bible, where it is referenced as a valuable spice. In the Song of Solomon, the bridegroom praises his bride's lips as being like a thread of scarlet, which some scholars interpret as a reference to saffron. Overall, saffron has been highly valued throughout history and has been associated with various spiritual, cultural, and medicinal properties. Its mention in mythology further reflects its importance and significance in different cultures (Wikipedia, 2024b). Saffron's cultural significance spans centuries, evident in various traditions and culinary practices: **Greek Mythology**: Celebrated for both its color and supposed healing properties. **Ancient Rome**: Used in perfumes, medicines, and as an aphrodisiac. **Indian Ayurveda**: Known for its therapeutic attributes, used in Ayurvedic medicine to treat ailments like arthritis and menstrual discomfort. One of the legacies of saffron farming practice for centuries in and around the Pampore Karewas of Kashmir in India is that this ancient farming system continues to inspire family farmers and local communities through their livelihood security that it provides for more than 17,000 farm families. Kashmiri village women contribute to this agriculture heritage site through traditional tilling to flower picking over 3,200 hectares dedicated to the legendary saffron crop cultivation at Pampore. Saffron is the bright red stigmas of the saffron crocus, a lilac-colored flower that primarily grows in a geographical band that stretches from Spain through the Mediterranean region and into the Middle East and Asia. However, many people may know of saffron from the times they've enjoyed Indian food, which makes a lot of sense since the cuisine features the spice prominently in many dishes. In this review article on Origin, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding and Cultivation of Saffron are discussed.

Citation: K.R.M. Swamy. 2024. "Origin, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding and Cultivation of Saffron*". International Journal of Current Research*, 16, (09), 29799-29825.

INTRODUCTION

Saffron belongs to the family Iridaceae, genius *Crocus* and species *Crocus sativus* (Srivastava *et al*., 2010;Dar *et al.,* 2017; Wikipedia, 2024c). Saffron is the dried stigma from the *Crocus sativus* flower. The name "saffron" derives from an Arabic word meaning "to become yellow" which refers to saffron's use as a bright yellow dye. The Latin name "*crocus*" most likely stems from an ancient Sanskrit word for saffron. In different languages saffron is called: *zafran* (Arabic & Hebrew), *za'afaran* (Farsi), *fan hong hua* (Chinese Mandarin), *safran* (French, German), *zaffarano* (Italian), *azafrán* (Spanish), *krokos* (Greek), and *kesar* (Hindi) (Resources, 2024). A degree of uncertainty surrounds the origin of the English word "saffron". It might stem from the 12th-century Old French term *safran*, which comes from the Latin word *safranum*, from the Persian (زعفران, *za'farān*), from the Persian word *zarparān* meaning "gold strung" (implying either the golden stamens of the flower or the golden colour it creates when used as flavour) (Wikipedia, 2024). The word "saffron" immediately stems from the Latin word *safranum* via the 12th-century Old French term *safran*. The French was borrowed from Arabic *za'farān*, and ultimately from Persian زَرپَران which literally means "golden leaves". The Latin form *safranum* is also the source of the Catalan *safrà*, Italian *zafferano*, but Portuguese *açafrão*, and Spanish *azafrán* come from the Arabic *az-zaferān*. The Latin term *crocus* is certainly a Semitic loanword. It is adapted from the Aramaic form *kurkema* via the Arabic term *kurkum* and the Greek intermediate κρόκος *krokos*, which once again signifies "yellowish". The Sanskrit *kunkumam* might be ultimately the origin, or in some way related to the Semitic term (Wikipedia. 2024a). The common names are in Hindi - kesar, zaffran; Sanskrit - avarakta, saurab, mangalya, agnishikha, kumkuma, mangal, kusrunam; English- saffron; Arab and Persian - zafrah, zipharana; Ben - jafran; Bom - safran, kessar; Mah - kecara; Guj - keshar; Tel - kunkuma-purva, kunkumma-purru; Tam. and Mal. - kunkumappu; Can. and Kon. - kunkuma-kesara; Fr.and Ger. – safran (Srivastava *et al.,* 2010). Saffron or *Crocus sativus* L. as is belongs to Iridaceae family and is well known as 'King of Spices'. The spice well known for its unforgettable taste and aroma is commonly known as "zaffran" in Urdu, "kesar in Sanskrit, azaffran in Arabic and Azafran in Spanish. The name saffron was used by Gerarde in 1597 in the first edition of his book 'The Herball or Generall Histories of Plants' (Verma *et al*., 2024).

Saffron has been mentioned in many ancient mythologies and has a long history of use in various cultures. In Greek mythology, saffron is said to have been first used by the god Hermes to cure his injuries. It is also said to have been used by the goddess Aphrodite in her bath to enhance her beauty. In Hindu mythology, saffron is associated with Lord Vishnu and is believed to symbolize purity, courage, and sacrifice. It is also used in various religious ceremonies and rituals. In Persian mythology, saffron is believed to have been created from the tears of the legendary hero Kaveh, who led a revolt against an evil king. It is also said to have been used by the goddess Anahita to heal the sick and the wounded. In ancient Egyptian mythology, saffron was used in medicine and was believed to have healing powers. It was also used in perfumes, cosmetics, and other beauty products. Saffron also appears in the Bible, where it is referenced as a valuable spice. In the Song of Solomon, the bridegroom praises his bride's lips as being like a thread of scarlet, which some scholars interpret as a reference to saffron. Overall, saffron has been highly valued throughout history and has been associated with various spiritual, cultural, and medicinal properties. Its mention in mythology further reflects its importance and significance in different cultures (Wikipedia, 2024b). Saffron's cultural significance spans centuries, evident in various traditions and culinary practices: Greek Mythology: Celebrated for both its color and supposed healing properties. Ancient Rome: Used in perfumes, medicines, and as an aphrodisiac. Indian Ayurveda: Known for its therapeutic attributes, used in Ayurvedic medicine to treat ailments like arthritis and menstrual discomfort (Zar, 2024).

Crocus sativus L. belonging to the family Iridaceae (syn - kesar) comprises the dried red stigma and is widely cultivated in Iran and other countries such as India and Greece (Srivastava *et al.,* 2010). Saffron contains more than 150 volatile and aroma-yielding compounds mainly terpenes, terpene alcohol, and their esters. The bitter taste and an iodoform or hay-like fragrance are caused by chemicals picrocrocin and safranal (Srivastava *et al*., 2010). *C. sativus* possesses a number of medicinally important activities such as antihypertensive, anticonvulsant, antitussive, antigenototoxic and cytotoxic effects, anxiolytic aphrodisiac, antioxidant, antidepressant, antinociceptive, anti-inflammatory, and relaxant activity. It also improves memory and learning skills, and increases blood flow in retina and choroid (Srivastava *et al*., 2010). *Crocus sativus* L. (Iridaceae), commonly known as saffron, is a perennial stemless herb that is widely cultivated in Iran and other countries such as India and Greece. Commercial saffron comprises the dried red stigma with a small portion of the yellowish style attached (Srivastava *et al.,* 2010). A definite identification of saffron crocuses dates from about 1700-1600 BC, in the form of a fresco painting in the Palace of Minos at Knossos in Crete. The wild precursor of domesticated saffron crocus was *Crocus cartwrightianus* (Srivastava *et al*., 2010). Experts believe saffron was first documented in a 7th century BC Assyrian botanical reference compiled under Ashurbanipal. Since then, documentation of saffron's use over the span of 4000 years in the treatment of some 90 illnesses has been uncovered (Srivastava *et al.,* 2010). It is in leaf from October to May, and in flower in October. The flowers are hermaphrodite (have both male and female organs) and are pollinated by bees and butterflies (Srivastava *et al.,* 2010). The flower has three stigmas, which are the distal ends of the plant's carpels. Together with the style, the stalk connecting the stigmas to the rest of the plant are often dried and used in cooking as a seasoning and coloring agent (Srivastava *et al*., 2010). Saffron blooms only once a year and should be collected within a very short duration. It is picked during 3-4 weeks in October-November (Srivastava *et al*., 2010). According to some reports, this species is a sterile triploid and so does not produce fertile seeds. Germination can take 1-6 months at 18°C.] It takes 3 years for plants to flower from seed (Srivastava *et al.,* 2010). Saffron is characterized by a bitter taste and an iodoform or hay-like fragrance, which are caused by chemicals picrocrocin and safranal (Srivastava *et al.,* 2010). The value of saffron (stigmas of *C. sativus* L.) is determined by the existence of three main secondary metabolites: crocin, picrocrocin, and safranal (Srivastava *et al*., 2010). Saffron is used for depression in Persian traditional medicine. Pistils of saffron are generally used in traditional Indian medicine as analgesics and cardio-protective agents, as well as in the treatment of various kinds of mental illnesses (Srivastava *et*

al., 2010). A crude extract of pistils of saffron improves recovery in ischemia/reperfusion injury and learning and memory in rats. In traditional medicines, saffron is recommended as an aphrodisiac agent (Srivastava *et al*., 2010). Saffron (*Crocus sativus* Kashmirianus) covers about 4% of the total cultivated area of the Kashmir valley and provides about 16% of total agricultural income (Husaini *et al*., 2010). Saffron is chiefly grown in the following districts: Pulwama (74.64%) comprising Pampore, Balhuma, Wayun, Munpur, Mueej, Konibal, Dus, Zundhur, Letpur, Sombar, Baras, Ladu and Khrew; Badgam (16.13%) comprising Chadura, Nagam, Lasjan, Ompora and Kralpura; Srinagar (6.68%) comprising Zewan, Zawreh and Ganderbal; Doda (2.50%) comprising Poochal, Namil, Cherrad, Huller, Blasia, Gatha, Bandakoota and Sangrambatta, and some areas of Anantnag district comprising Zeripur, Srechan, Kaimouh, Samthan and Buch (Husaini *et al*., 2010). Saffron cultivation forms an important sector for the livelihood security of more than 16,000 farm families located in 226 villages. The limited size of land holdings makes cultivation less profitable, with over 61% of holdings below 0.5 ha, and only 26% of holdings between 0.5-1.0 ha and 13% of holdings > 1.0 ha (Husaini *et al*., 2010). The total area under this crop in the State of Jammu & Kashmir has shown a decrease of 83% in the last decade, a 215% decrease in production and a 72% decrease in productivity (Husaini *et al*. 2010).

.

Saffron, highly prized as a spice and dye, is derived from the stigma and styles of the saffron crocus, or *Crocus sativus*. It is a perennial plant that flowers in the fall and is often mistaken for its wild cousin, the common autumn crocus called meadow saffron, sometimes with deadly results (Azafran, 2011). Each year, the saffron crocus grows from one corm that in turn produces as many as ten "cormlets". It is from these cormlets the new plants sprout after they have been dug up, divided and replanted. The parent corm will die off after one year, leaving the cormlets to carry on the plant (Azafran, 2011). Saffron is comprised of over 150 volatile compounds, along with many nonvolatile active components. The glucoside picrocrocin compound, which is responsible for the flavor of saffron, has insecticidal and pesticidal properties and can account for up to 4% of the volume of dried saffron (Azafran, 2011).

Saffron is considered the most valuable, renowned and intriguing spice. Much of this intrigue derives from several fabulous myths and legends regarding its origin, which are frequently disputed between the current production areas (Alonso *et al.,* 2012). Saffron is the only known plant that uses its own stigmas for spreading. Unable to reproduce naturally, this mutant plant with its tiny stigma (2.5 cm) is dependent on human handling and care for its survival (Alonso *et al.,* 2012). Hundreds of animal and plant species, with complete reproductive systems, have disappeared from our planet, yet this tiny, sterile plant has been maintained for centuries, without the least evolution, thanks to an uninterrupted chain of gardeners, farmers, travellers and merchants who used it for its colouring and medicinal properties, as well as for its flavour (Alonso *et al.,* 2012). Another explanation for the intrigue inspired by saffron is that, despite the plant's inability to reproduce sexually, it has retained its beautiful colour, heady perfume and abundant pollen production, all of which are evolutionary tools to ensure its perpetuation by pollinating bees. The saffron plant blooms in mid-autumn when other plants are preparing for the winter. It can flourish when no other plant does in the most hostile edaphic and weather conditions, but only for a very short period of time (Alonso *et al*., 2012). Saffron is valued not only for its price, but also for its attributes; it is the only spice capable of giving food colour, flavour and aroma. The most expensive spice in the world, the high price of saffron is due to its production costs (Alonso *et al*., 2012). Beginning with the Sumerians, saffron has played an important role in religious practices and rituals in various cultures throughout history. Often adopted as a symbol of light, wisdom and spirituality, monarchs, as well as political and religious leaders (including the Dalai Lama), wore, and still wear, saffron yellow tunics (Alonso *et al.,* 2012).

One of the legacies of saffron farming practice for centuries in and around the Pampore Karewas of Kashmir in India is that this ancient farming system continues to inspire family farmers and local communities through their livelihood security that it provides for more than 17,000 farm families (GIAHS, 2012). Kashmiri village women contribute to this agriculture heritage site through traditional tilling to flower picking over 3,200 hectares dedicated to the legendary saffron crop cultivation at Pampore (GIAHS, 2012).

Saffron is one of the important species, because its dried red stigma is the most expensive spice in the world with numerous applications in medicine and food industries. It is used as anti-cancer agent, antidepressant, antioxidant component, enhancer of learning ability and as a coloring and flavoring substance in food industry. In addition, *C. sativus* has been adapted to cold winters and warm summers with low rainfall (Babaei *et al*., 2014). Nine species of saffron have been reported from Iran including *C. sativus*, *C. pallasii*, *C. cancellatus*, *C. caspius*, *C. speciosus*, *C. almehensis*, *C. gilanicus*, *C. michelsonii*, and *C. biflorus*. It has been determined that *C. sativus* was derived from wild species, *C. cartwrightianus* cv. Albus, which is diploid ($2n = 16$) and domesticated in Crete since olden times. Saffron (*C. sativus*) is a perennial and stemless plant, with purple flowers and autumnal and grass-like leaves that appear along or shortly after flowering (Babaei *et al.,* 2014). It is triploid ($2n = 24$; $x = 8$) and male infertile species, therefore, proliferated vegetatively by corm. Nowadays, saffron is widely cultivated in Iran (especially Khorasan province, known as origin of saffron), Spain and other countries such as Greece, Italy and France (Babaei *et al*., 2014).

Saffron is an autumn flowering cormose plant, cultivated for numerous properties ascribed to the stigmatic lobes and used as spice, condiment and for medicinal purposes. The corms reproduce annually, only vegetatively as the plant is sterile autotriploid (2n=3x=24) and seeds are unknown (Mir *et al*., 2015). Studies have revealed that the sterility is related to meiotic abnormalities producing both pollen grains, which display low/defective germination, and partially nonfunctional macrospores. Sterility in saffron limits the application of conventional breeding approaches for its further improvement (Mir *et al*., 2015). All over the world saffron is known as one cultivar, a descent of certain triploid sterile plant arisen once spontaneously in nature which was caught by sight of man and involved into cultivation. It has been propagated and still continues to be propagated vegetatively. There is a supposition that saffron as a clone can be scarcely changed genetically and its improvement is hardly possible through clonal selection (Mir *et al*., 2015). It is supposed that saffron, a sterile clone of triploid origin that has been cultivated from times immemorial (the period about 3.5 to 4.5 thousand years) has passed an original evolution. Growing in the various countries under

various soil climatic conditions, during many centuries, saffron has been influenced by various stressful factors and has undergone different sorts of mutations. Despite of sterility, genetic changes could partly happen as a result of somatic recombination, deletions, inversions, translocations, polyploidy, incomplete segregation, segregation distortion, mutations, trans-versions, transitions (Mir *et al*., 2015).

Crocus sativus L. is small perennial plant, considered as king of the spice world. It belongs to Iridaceae. The genus Crocus consists of about 90 species and some are being cultivated for flower. The flowers (three stigmas-distal end of the carpel) of the *C. sativus* contain three key components, known as crocin, picrocrocin and safaranal (Dar *et al*., 2017). These three components are reported to be responsible for the colour, taste and aroma of the saffron. The flowering time in case of *C. sativus* during autumn (Dar *et al.,* 2017). The tradition methods of saffron cultivation and flower harvesting are very tedious and labour extensive and leads to increase the cost of the saffron. Due to its high demand and low production, it is the most expensive spice and is called as red gold in the present scenario (Dar *et al.,* 2017).

Crocus sativus L. is an autumn-flowering geophyte extensively grown in the Mediterranean basin and Near East since the Late Bronze Age (Javan and Gharari, 2018). *Crocus sativus* L., a member of the family Iridaceae, is a sterile autotriploid or of hybrid origin (2n= 3x= 24) plant. C. Cartwrightianus is considered to be one of the parents (Javan and Gharari, 2018). *Crocus sativus* is traditionally grown from Spain in the west to Kashmir and China in the east. There is evidence and archaeological indications of Crocus stigma collection by human as early as about 2300 BC (Javan and Gharari, 2018). The cultivation of saffron dates back to 1500-2500 BC in Iran, Greece, India, China, the Mediterranean basin, and Eastern Europe (Javan and Gharari, 2018). Iran is the largest producer, accounting for almost 80% of the total world production. Ranked first in the world, Khorasan province, Iran, is specifically the ideal place for the growth and production of cultivated saffron. (Javan and Gharari, 2018). Iran is also the native habitat of eight Crocus species besides *C.sativus*, four of which are exclusively indigenous to this country (Javan and Gharari, 2018). Morphological comparisons of cultivated saffron ecotypes have revealed some differences in intensity of flower color, viability, pollen size, and number of style branches and stamens (Javan and Gharari, 2018).

The origin of *C. sativus* has long been the subject of speculation and research, as this knowledge would enable breeders to introduce genetic diversity into the otherwise genetically uniform plant species. Two new studies have now shown that the saffron crocus originated from a Greek ancestor (PRP, 2019). Since ancient times, saffron has been giving dishes a golden-yellow hue and an aromatic flavour. The use of the stigmas of the saffron crocus (*Crocus sativus*) is depicted in frescos from Crete and Santorini, which are as old as 3600 years. Nowadays, the valuable plant is mainly cultivated in Iran accounting for more than 90% of the saffron production (PRP, 2019). The saffron crocus is a triploid and male-sterile plant. This means that the plant can only be propagated vegetatively. In this case, parts of the corms (bulb-like structures of the stem) of the saffron plants are broken off and then these daughter-corms are used to grow new adult plants (PRP, 2019). A consequence of this form of reproduction is that there is no room for improving saffron quality by crossing different cultivars. Thus all modern saffron plants are genetically nearly identical. Knowing the origin, in particular the originating plant species, would enable saffron breeders to use new genotypes to broaden the diversity of the saffron crocus (PRP, 2019).

The wild crocus species *C. cartwrightianus* from Greece was identified as the sole progenitor of the modern saffron plant, and the area in the vicinity of the Greek capital Athens as the region where it evolved. *C. cartwrightianus* had already been postulated as a possible progenitor of *C. sativus*, however the high intra-specific genetic diversity present in *C. cartwrightianus* had led to unclear results during previous investigations (PRP, 2019). A slight surprise for all of the involved researchers was that the main growing regions for saffron are clearly located outside the distribution area of its progenitor *C. cartwrightianus*, with *C. sativus* prospering in drier regions and at higher elevations. They suspect that the explanation to this also lies within the origin story of saffron - it was probably the genome-fusing autopolyploidisation event that led to ecological shift of saffron, away from the habitats in the Mediterranean vegetation zone of Greece (PRP, 2019).

Against the backdrop of towering snow capped mountains and a road lined by willow trees sits a field as big as a football pitch, bursting with purple blooms. Villagers in traditional *pherans*, or woolen gowns, pick the delicate flowers, filling their wicker baskets (Sunder, 2020). A small village known as the "saffron capital of India" that is a 30-minute drive from Srinagar, the capital of the northern state of Jammu and Kashmir (Sunder, 2020). Grown in Kashmir at an altitude of over 1,600 meters, saffron is tightly woven into the local economy, with more than 20,000 families engaged in related businesses, mostly in the districts of Pulwama, Srinagar and Budgam. The prized spice is extracted as threads from the stigma and style of the flower (Sunder, 2020). While there are conflicting accounts about how the spice came to India, most agree that Iranians spread it across the subcontinent as their influence there grew from the 13th century onward, culminating in the Mughal Empire. Iran still produces 90% of the world's saffron (Sunder, 2020). According to Kashmiri legend, in the 12th century, two Sufi saints presented a local chieftain with a saffron crocus bulb after he cured them of an illness. Today, a golden-domed shrine and tomb dedicated to the saints can be found in the saffron-trading village of Pampore (Sunder, 2020). Saffron has always captured the imagination of the rich and famous. The legendary Egyptian ruler Cleopatra is said to have indulged in saffron baths for their cosmetic and aphrodisiacal qualities. Egyptians also used the spice for embalming and in poultices. Minoan goddesses would dye their gowns with it. Antioxidants found in the spice -- crocin, picrocrocin and safranal -- are said to reduce inflammation, build immunity and aid in fighting Alzheimer's and depression (Sunder, 2020). "The petals, stigmas and styles have yellow strands and red strands," explains Sunil Mahnoori, a Kashmiri chef who operates a restaurant in Kolkata. "Only the red strands give saffron" (Sunder, 2020). As a child, Mahnoori accompanied his grandfather, a saffron trader, on collection rounds in Kashmir during harvest season. The floors of farmers' huts would be covered with crimson saffron. "Local women used to grind the leftover petals after harvest with spices like cardamom and dry it in the sun to use in the winter to season their food," Mahnoori recalls (Sunder, 2020). Saffron is said to be worth its weight in gold. A kilogram of the spice can cost up to $4,000 -- partly because it takes many

as 150,000 flowers to produce that amount. Because the seeds produced by the flower are sterile, farmers propagate the flowers asexually using bulbs, called corms (Sunder, 2020). The spice is also a culinary star used by Kashmiris for stews, broths and kebabs, as well as in milk to break the Ramadan fast. It was under Mughal rule in India that saffron was first used to flavor flatbreads like *sheermal*, lamb curries and fruit sherbets (Sunder, 2020). A farmer weighs dried saffron at his home in Pampore. The labor-intensive nature of saffron farming pushes prices higher, with a kilogram of the spice sometimes fetching up to $4,000 (Sunder, 2020). But my favorite is the Kashmiri saffron-infused green tea called *kahwa*, or *kehwa*, that I fell in love with on my first trip to the valley. This elixir is brewed slowly in a copper *samovar* with spices such as cardamom and cinnamon, served with a dash of honey and sometimes garnished with slivers of almond (Sunder, 2020). Sanjay Raina, an award-winning Kashmiri celebrity chef who runs Mealability, a restaurant in Delhi, says saffron was an integral part of his life while growing up. His signature desserts, like *shufta* -- dry fruits and spices coated with sugar syrup -- and *phirni* -- rice pudding -- are coated in fine Kashmiri saffron. "The best way to know if the saffron you are using is genuine is to taste it. It should never be sweet, but it should smell like sweet hay," Raina says (Sunder, 2020). Monica Dhar, a Kashmiri human resources professional based in Mumbai, says saffron is traditionally used as a prized ingredient that is mixed with yogurt and offered to new brides or grooms on their first visit home. Milk with saffron is a staple for pregnant mothers in Kashmir. Dhar says she still has kahwa tea every day, and "thanks to e-commerce, it's available online now in lovely packaging" (Sunder, 2020).

Saffron is a delicate plant that thrives only in moist soils rich in humus -- the dark, organic material that forms when plant and animal matter decays. Harvesting the crop is laborious and time-consuming. Noor Mohammad, a saffron farmer in the village of Lethpora, 15 km from Srinagar, says most of the work on his 2 hectares of land is done by his family, with the peak harvest season falling between Oct. 20 and Nov. 20 each year (Sunder, 2020). Over the years, the cultivation of saffron in Kashmir has suffered because of civil strife and the heavy military presence there. According to Kashmir's Department of Agriculture, saffron output fell by 65% over the 22 years through 2018 (Sunder, 2020). "Saffron manufacture is also besieged by the problem of spurious substitutes in the market, with an inferior grade of saffron from Iran being passed off as Kashmiri," says Mohammad, the saffron farmer (Sunder, 2020). In 2010, the central government launched the National Saffron Mission with a budget of $57 million to revive production and study new cultivation methods. The government has also opened a Saffron Trading Centre in Pampore with high-tech post-harvesting facilities. On July 25, Kashmir-grown saffron was given the prestigious international Geographical Indication, a designation that, by certifying its origin, helps protect it from adulteration and enables farmers to fetch higher prices (Sunder, 2020).

Kashmir valley represents one of the major saffron growing areas of the world. The time of introduction of saffron in Kashmir is not precisely known, though evidences from '*Rajatarangini*', written by a 12th century poet-historian (Kalhana) indicate its presence in Kashmir even before the reign of King *Lalitaditya* in 750 AD. This golden spice is known as '*Kesar*' in Sanskrit, and '*Koung*' in Kashmiri language (Husaini, 2020).

Saffron is cultivated in J&K over an area of 3715 ha. It is chiefly grown in the districts Pulwama (86.13%) comprising of areas in Pampore, Balhuma,Wayun, Munpur, Mueej, Konibal, Dus, Zundhur, Letpur, Sombar, Baras, Ladu and Khrew; Badgam (8.03%) comprising area of Chadura, Nagam, Lasjan, Ompora and Kralpura; Srinagar (4.41%) comprising areas in Zewan, Zawreh and Ganderbal; Kishtwar (1.34%) comprising Poochal, Namil, Cherrad, Huller, Blasia, Gatha, Bandakoota and Sangrambatta, and some areas of Anantnag district comprising Zeripur, Srechan, Kaimouh, Samthan and Buch (Husaini, 2020). Saffron cultivation forms an important sector for livelihood security of more than 17,000 farm families located in 80 villages (Salwee *et al*. 2018). The limited size of land holdings makes the cultivation less profitable, with over 61% of holdings below 0.5 ha, and only 26% size of holdings between 0.5-1.0 ha and 13% holdings of size above 1.0 ha (Husaini, 2020). Saffron global production is estimated at 418 t y^{-1} on 121,338 ha. Stigma yield, depending on many factors, ranges between 2 and 28 kg ha^{-1}. Saffron is suitable for low-input and sustainable cropping systems. New research focuses on the improvement of stigma yield and quality. Valorisation of saffron by-products can increase the profitability of the spice (Cardone *et al*., 2020). Saffron is obtained from the dried red stigmas of *Crocus sativus* L., an autumnal herbaceous flowering plant belonging to the Iridaceae family. It is largely cultivated in Iran, India, Afghanistan, Greece, Morocco, Spain and Italy (Cardone *et al*., 2020). Saffron global production is estimated at 418 t y^{-1} on 121,338 ha. It is known as the most expensive spice in the world and as beneficial for human health due to three main bioactive compounds: crocin, picrocrocin and safranal (Cardone *et al.,* 2020). The demand for saffron is increasing worldwide for its interesting role in cuisine, medicine and cosmetics. Due to the reduction of its production, recent investigations have been conducted to study how to improve stigma yield, quality and antioxidant activity by selecting of corm geographical origin and climatic conditions, using biostimulants such as mycorrhizal fungi as well as choosing irrigation regimes, drying methods and storage processes (Cardone *et al*., 2020). Saffron is one of the most expensive cash crops among medicinal plants in the world and thus it has been called "the red gold" (Cardone *et al.,* 2020).

It has been known for more than 4000 years and was used mostly in traditional medicine as a tonic agent and antidepressant drug (Cardone *et al*., 2020). This spice is obtained from dried red stigmas of *Crocus sativus* L. flower and it is appreciated in the food industry to dye and perfume different dishes and alcoholic beverages due to its colouring, flavouring and aroma capacity (Cardone *et al*., 2020). Recently, the use of spices and functional foods has increased in the everyday diet for the prevention of chronic diseases or cancer. In particular, saffron is attracting attention from consumers thanks to its beneficial properties for human health (Cardone *et al*., 2020). To increase crop profitability, many researchers have focused their attention on the valorisation of saffron by-products, such as tepals, stamens, styles, leaves and corms (Cardone *et al*., 2020). Saffron is a very ancient spice and for almost four millennia it has been used in the treatment of 90 medical indications. Its dyeing, food and medicinal properties were mentioned by Homer, Virgil, Hippocrates, Pliny, Ovid and in the Old Testament's "Song of Solomon" (Cardone *et al*., 2020). It is largely cultivated in Iran, India, Afghanistan, Greece, Morocco, Spain and Italy. Iran is considered as the largest producer in the world, with 90 % of

the global production (Cardone *et al*., 2020). Saffron, originating from the Arabic word "Zafaran" meaning yellow, has an uncertain site of origin. Some authors indicated the Middle East (Iran) or Greece (southern Aegean islands Crete and Santorini) and later widespread in India, China, the Mediterranean basin and Eastern Europe (Cardone *et al*., 2020). After harvesting follows the "mondatura", a very delicate and laborious phase which consists in opening the flower and cutting the stigma at the base of the three filaments and removing the white-yellow part of the style without separating them. During this process, the stigmas plus the uppermost 2 mm of style are separated from the rest of the organs (Cardone *et al.,* 2020). Saffron quality is determined chemically by three main secondary metabolites: crocin, picrocrocin, and safranal which are responsible for the colour, bitter taste and odour, respectively (Cardone *et al*., 2020). Its sterility limits the application of breeding improvements and so biotechnological approaches as micropropagation could be an alternative way to increase the corm production and to improve the spice quality (Cardone *et al*., 2020).

Amidst the towering snow-capped mountains of Pampore, Kashmir, lie fields covered in a blanket of purple crocus flowers. This is the flower that produces the precious spice known as saffron. Pampore, a small village located around 14 kilometres from the state capital, Srinagar, is known as the 'saffron capital of India', with more than 20,000 families associated with saffron cultivation (Pandit, 2021). The saffron produced in the region is of superior quality and can fetch as much as Rs 2,50,000 per kilogram in the market. The laborious task of cultivating saffron is what makes the spice so valuable (Pandit, 2021). The process begins with the villagers picking the delicate flowers and collecting them in wicker baskets. Each flower is then sorted according to its three parts — the petals, the yellow strands and the red strands. Pure saffron is derived from the red strands. More than 1,50,000 flowers are sifted and scanned for a kilogram of the crimson spice. After this, the strands are dried over a charcoal fire (Pandit, 2021). Across India, this spice has many names — *zafran* in Urdu, *kesar* in Hindi, *kong posh* in Kashmiri and *kungumapoo* in Tamil. Alongside the multiple names it is known by, there are numerous accounts of how the spice came to India (Pandit, 2021). One such legend dates back to the 12th century, which says that while travelling through the country, two Sufi saints presented a local chieftain with a saffron bulb after he cured them of an illness. Another claims that the Persians brought it to the country from Iran in 500 B.C during their trades. A third dates the spice back to the Mughal Empire, and says the spice was used extensively in cooking (Pandit, 2021).

The name Saffron has its origins in the Arabic word Zafaran which means yellow. Botanically, wild saffron is known as *Crocus cartwrightianus*, while the commercially cultivated saffron is botanically called *Crocus sativus*, which is also the name of the flower (Hanief, 2022). One of the most expensive spices in the world, saffron is also referred to as "Red Gold". Its history spans over more than 3500 years. The Romans used it as a deodorizer, the Egyptian healers used it to treat gastrointestinal ailments and it is said that Cleopatra used saffron for cosmetic value (Hanief, 2022). Saffron crocus has been predominantly cultivated in Iran and Kashmir. A very labour intensive crop, Saffron is a highly coveted spice and is often considered to be more valuable than gold! (Hanief, 2022). It is a spice that comes from the stigmas of the purple flowers of the plant *Crocus sativus*. Each flower contains three stigmas that are handpicked and then dried to make the saffron spice (Hanief, 2022). It takes thousands of flowers to produce a few grams of saffron. The stigmas are typically of an orange-red colour, which is due to the content of crocetin, a type of acid and crocin (Hanief, 2022). While buying saffron, it is important to keep in mind that the best kind of saffron has a deep red colour, a honey-like aroma with a delicate but musky taste (Hanief, 2022). It is late autumn in Kashmir, and villagers around Pampore – also known as the saffron town of Kashmir in Pulwama district of Jammu and Kashmir are picking the delicate flowers to fill their wicker baskets. Kashmir's saffron (*Crocus sativus* Kashmirianus), known for its flavour and colour, is harvested just once a year from late October till mid November (Hanief, 2022). Out of total 5,707 hectares of land under saffron cultivation in Kashmir, more than 90 per cent is in Pampore tehsil of Pulwama district in South Kashmir while the rest is in central Kashmir's Budgam and Srinagar districts. Known for its special aroma, saffron is a powerful flavouring and colouring agent (Hanief, 2022). Owing to its long and dark red hues, Kashmiri saffron is regarded as the best variety of saffron available in the market. High-quality and pure saffron can always be recognized by the unique aroma and features of the stigmas it contains. Best Quality Raw and Organic Natural Kashmiri Saffron (Kesar) (Hanief, 2022). The three components of each flower—petals, yellow strands, and red threads—are arranged in order of importance. Pure saffron is extracted from the red strands. More than 1,50,000 flowers are sifted and scanned for a kilogram of the crimson spice. After this, the strands are dried over a charcoal fire. Saffron, one of the most expensive spices in the world, is also referred to as the "crop of gold" (Hanief, 2022). Pampore meadows attract tourists from everywhere to witness the yellow, marron, and purple hues of the blossoms that bloom beside giant chinars and harvest time resembles a festival for villages in the area. On the first day of the harvest, saffron farmers head to the shrine of Hazrat Sheikh Sharif-ud-Din in Namblabal Pampore to offer some saffron (Hanief, 2022). These fragrant red strands have even featured in the poems and songs of the 16th-century poet Habba Khatoon. Known as the Nightingale of Kashmir, Khatoon hailed from Pampore (Hanief, 2022). This spice is known by various names in India, including zafran in Urdu, kesar in Hindi, kong posh in Kashmiri, and kungumapoo in Tamil. Saffron is used in different ways. There's kahwa – the green tea laced with saffron from Kashmir. Beloved by many, it will make you fall in love with it at one sip. With spices like cardamom and cinnamon, this elixir is slowly brewed in a copper samovar. It is then served with a touch of honey and often garnished with almonds. It is also an important part of wazwan, the lavish Kashmiri supper platter (Hanief, 2022). Saffron is used in cooking, but it also offers many health advantages. The oil from which safranal is produced reduces growth in cancer cells and functions as an anticonvulsant and antidepressant. The carotenoid alfa-crocin also has a similar effect. Minerals are also abundant in it, including potassium, manganese, iron, calcium, selenium, copper, zinc, and magnesium. Additionally, it is high in folic acid, niacin, riboflavin, and vitamins A and C (Hanief, 2022). Every year, the government of Jammu and Kashmir organises a three-day Saffron Festival with cultural events. Held from the last week of October, it gives tourists a chance to see saffron fields and buy the spice directly from producers (Hanief, 2022). Kashmiri saffron was given a geographical indication tag by the geographical indications registry. The request was filed by the Directorate of Agriculture, Government of Jammu and Kashmir, and facilitated by the

Sher-e-Kashmir University of Agriculture Sciences and Technology, Kashmir, and Saffron Research Station, Dussu (Pampore) with the aim to make it illegal for someone outside the valley to make and sell a similar product under the "Kashmiri saffron" name (Hanief, 2022). However, despite all the difficulties and tribulations, the saffron business still employs thousands of people in Kashmir. The government is taking several steps to resurrect the sector and restore it to its former glory. The central government has started the National Saffron Mission in 2010 to revive the valley's production of the most costly spice in the world (Hanief, 2022).

Saffron belongs to the family Iridaceae, is globally the most expensive spice, and is commonly referred to as the "Golden Condiment." (Irfan *et al.,* 2022). It is a legendary crop of Jammu and Kashmir, grown on well-drained karewa soils with climatic conditions conducive to obtaining higher yield (Irfan *et al*., 2022). Saffron is a male-sterile, triploid flower crop, and source of the spice and colorant saffron. For over three millennia, it was cultivated across the Mediterranean, including ancient Greece, Persia, and other cultures, later spreading all over the world (Shahandashti *et al*., 2022). *Crocus sativus* L. is a globally used expensive spice. There are a few countries like Iran, Greece, Morocco, Spain, Italy, Turkey, France, Switzerland, Pakistan, China, Japan and Australia where this spice is cultivated and exported to other countries (Kumar *et al*., 2022). India contributes 5% of the world's total production of which 90% is supplied only from its Jammu and Kashmir (J&K) regions. In India, the production of saffron from J&K is 3.83 tonnes whereas its annual demand is approximately 100 tonnes. In this country, there are geographical regions that have similar environmental and ecological conditions to J&K and possess the possibility of introducing this crop. Identification of such regions can be made using Ecological Niche Modelling (ENM) (Kumar *et al*., 2022). The saffron was sowed in these new modelled locations in India representing its various states such as Himachal Pradesh, Uttarakhand, Arunachal Pradesh, Sikkim, Manipur and Tamil Nadu. The quality, as well as yield of saffron produced in some of these regions, were evaluated and found at par with the saffron grown traditionally in India (Kumar *et al.,* 2022). *Crocus sativus* L. (saffron) or Golden spice or Red gold or 'Kesar' belongs to the family 'Iridaceae' and is one of the most expensive spices in the world (Kumar *et al*., 2022). Saffron has several medicinal properties such as aphrodisiac, antispasmodic, antimicrobial, antibacterial, antifungal, antiseptic, and antiinflammatory. It has anticancer medicinal properties also, which has elevated its cost (Kumar *et al*., 2022). Its stigma is used in food, pharmaceutical, cosmetic, perfumery and textile dyes industries in various ways (mostly in dry form) (Kumar *et al.,* 2022). Saffron cultivation is labour intensive requiring hand labour in the various stages of its cultivation. Its stigma needs to be carefully picked from its flower manually. Thus harvesting followed by processing requires trained work hands (Kumar *et al.,* 2022). Therefore, saffron is costly due to its high labour requirement, low yield, careful handling and limited worldwide distribution (Kumar *et al*., 2022). Saffron is mainly cultivated in Iran, India, Greece, Morocco, Spain, Italy, Turkey, France, Switzerland, Pakistan, China, Japan and Australia (Kumar *et al*., 2022). Iran ranks first in its production and almost 80% of the world demand for saffron is met by Iran. India contributed only 5% of the world's total production. 90% of the country's saffron is produced in Jammu and Kashmir (J&K) and here it is mainly confined to Pulwama and Budgam districts. Saffron production in J&K has been reported to decrease year by year (Kumar *et al*., 2022).

Saffron is the bright red stigmas of the saffron crocus, a lilac-colored flower that primarily grows in a geographical band that stretches from Spain through the Mediterranean region and into the Middle East and Asia. However, many people may know of saffron from the times they've enjoyed Indian food, which makes a lot of sense since the cuisine features the spice prominently in many dishes (Field, 2023). It would then stand to reason that India would be a big producer in the global saffron market. And while the country certainly contributes — the village of Pampore in Kashmir has a magical saffron harvest in particular — there is another place that is miles ahead of India when it comes to producing the spice (Field, 2023). Iran is actually the leading exporter of saffron. According to data from 2018, they produced 616,430 pounds. The next closest country was China at 329,776 pounds while India came in at ninth on the list with 46,423 pounds. In just two months, March to April of 2023, Iran reported exports of 24,619 pounds, and that's not even during the busy season since saffron harvesting primarily occurs in October and November. With these kinds of numbers, the odds are extremely high that most of the saffron used in the United States originated in Iran (Field, 2023). In conjunction with production numbers, it's also relevant to talk about cost of saffron since it's known as the most expensive spice in the world; in fact, just 2 pounds of the real stuff can cost upwards of $10,000. However, there are several factors that account for its hefty price tag (Field, 2023). Each flower has only three of the tiny particles called stigmas that create saffron, which means it takes a monumental amount of flowers to produce even a small amount of the spice; approximately 150,000 flowers are needed for 2 pounds of saffron (Field, 2023). Due to the delicate nature of the saffron crocus and the fact that only a small part of the flower is used to create the spice, all harvesting is done by hand, which adds to the labor cost. After the flowers are picked, the stigmata are carefully removed from the flower's center and left to dry. After the drying, they are processed and packaged for export. It's a large amount of work for such a small amount of product, exacerbated by the fact that saffron harvesting primarily occurs in the span of a month, all of which adds to the price tag (Field, 2023). The cultural significance of saffron extends far beyond the cuisine of India as well; every country that cultivates and harvests the flower has a historical tradition of using the spice in their food. With Iran being the primary producer of saffron, it makes sense that many Iranian recipes use it. The national dish Chelow kebab is commonly served with saffron rice, and Iran's version of crispy rice — called tahdig — often includes the spice, as well as many popular stews that can be categorized as a khoresh (Field, 2023). The saffron-infused dessert zerde is another Iraqi classic that has become very popular in Turkey as well. A wide variety of pilaf dishes also are a staple of Turkish cuisine, many of which are seasoned with the spice. Saffron is also an essential element of the Spanish paella, which in turn influenced the Kapampanagan cuisine of the Philippines with their chicken saffron rice called nasing biringyi. These examples are just a sampling of the countless uses of the spice in international food traditions (Field, 2023).

Saffron, the stamen of the crocus flower, is often claimed to be the world's most expensive spice. As such, it stands as an especially salient example of people's longstanding desire for visually-appealing food colours, given that the bitter taste of

saffron stamens, caused by the presence of picrocrocin. The aroma of high quality saffron is often described as smelling sweet, floral, and spicy. Sometimes, it is also described as having a hay-like aroma and a metallic note. Saffron has long been used as a dye, as a medicine, and also as a cosmetics/perfumery ingredient (Spence, 2023). However, the spice would appear to have fallen out of favour in the 19th Century (possibly due to its expense), its use being restricted to a relatively small number of dishes. There are, however, signs of a resurgence of interest in this natural colorant with a range potentially beneficial functional properties attributable to the stigma, as well as to other parts of the plant. Minimal exposure to heat during cooking is recommended though to help preserve the aroma/flavour (Spence, 2023). Saffron spice, the dried stigma of *Crocus sativus* L., has been appreciated since Mesopotamian times up to the present time not only for its biological, aromatic, and flavoring properties, but particularly due to its color (Spence, 2023). The history of saffron's use dates back nearly 3000 years, spanning many continents, civilizations, and cultures. Colorants have been used as additives since ancient times to make food more attractive and possibly also healthier. It is frequently suggested that saffron is the most expensive spice in the world. The spice is derived from the dry stigmata of the saffron crocus *Crocus sativus* L., a member of the family *Iridaceae* (Spence, 2023). It is one of the 85 members of the genus *Crocus.* The evidence points to saffron's origin (*i.e.,* emergence and domestication) in early Greece, most likely in Attica possibly from *C. Cartwrightianus* (Spence, 2023). The oldest evidence of the use of the crocus flower by humans comes from a 50,000-year-old prehistoric cave painting in today's Iraq depicting beasts in a cave, where saffron-related pigments (including crocin) were used (Spence, 2023). The first mention of the crop of saffron dates back to 2300 BC. Sargon, founder of the Accadian empire, was born at an unknown village, the City of Saffron, 'Azupirano', near the river Euphrates in Babylon. The first mention of saffron—*azupiranu* (saffron) from *C. sativus (azupiru)*—appears in an Assyrian dictionary of botany written during the reign of Ashurbanipal (Spence, 2023). The first signs of the cultivation and domestication of crocus flowers date from c. 1700 BC, during the time of the Minoan civilization in Crete. As saffron's various medicinal uses and antioxidant potential became recognized, its commercial value as a spice increased over the following eras/periods, and this resulted in the flowers spread across the Mediterranean (Spence, 2023).

Plant breeding techniques have produced a wide variety of crocuses. Most have cup-shaped flowers, but some produce star-shaped ones instead. The flowers may be purple, blue, lavender, pink, orange, yellow, red, or white in colour. My favourite types are the striped varieties (Crampton, 2023). The spice known as saffron is produced from an autumn-flowering plant with the scientific name *Crocus sativus.* The common name of this plant is saffron crocus. The species is unknown in the wild. It's thought to have been developed by selective breeding of other crocuses that do exist in the wild. It's believed to have originated in Greece or possibly in Southwest Asia. Saffron has been harvested and used since ancient times (Crampton, 2023). The flowers are purple, blue, pink, or white. They have yellow stamens and three long, red stigmas branching from a single yellow style. The flowers are sterile, however (Crampton, 2023). Propagation has to be carried out by corms instead of by pollination and fruit development. The corm can be divided to make new corms (Crampton, 2023). The stigma, style, and ovary make up the female part of the flower, which is known as the pistil. The stamen is made of the anther and filament and is the male part of a flower (Crampton, 2023). The stigmas of the saffron crocus are used to make the spice. About 75,000 crocus flowers or 225,000 stigmas (three per flower) are needed to make one pound of saffron (Crampton, 2023). Saffron is appreciated for its flavour, aroma, and colour. It's used as a fabric dye as well as a spice and may have medicinal benefits. The stigmas are generally picked by hand, which makes producing saffron a very labour-intensive endeavour. It also makes the spice very expensive. In fact, it's often said to be the most expensive spice in the world. Only a small amount is needed to flavour food, however (Crampton, 2023). Once the stigmas are collected, they're dried. They are sold as threads or are ground into a powder first. The dried stigmas are red, but the spice turns yellow when added to food. Some people add the stigmas to water before using them, creating an infusion sometimes known as saffron water (Crampton, 2023). Saffron is very popular in some cuisines, including traditional Persian, Arabic, Turkish, Indian, and Spanish ones. The spice is used to flavour bouillabaisse, curry, paella and other rice dishes, beverages, ice cream, puddings, and baked goods (Crampton, 2023).

Human cultivation and use of saffron spans more than 3,500 years and extends across cultures, continents, and civilizations. Saffron, a spice derived from the dried stigmas of the saffron crocus (*Crocus sativus*), has through history remained among the world's most costly substances. With its bitter taste, hay-like fragrance, and slight metallic notes, the apocarotenoid-rich saffron has been used as a seasoning, fragrance, dye, and medicine (Wikipedia, 2024a). The wild precursor of domesticated saffron crocus was likely *Crocus cartwrightianus*, a plant native to mainland Greece, Euboea, Crete, Skyros and some islands of the Cyclades. This species has been used as a wild source of saffron. A study reported in 2019 that the authors considered that a cross between two cytotypes of *Crocus cartwrightianus* was responsible for the emergence of *Crocus sativus*. This was probably a unique or very rare event as there is no genetic diversity in commercial saffron today. Another study in 2019 showed that a population of *Crocus cartwrightianus* near Athens in Attica was the closest match to the theoretical ancestors of *Crocus sativus* (Wikipedia, 2024a). *C. thomasii* and *C. pallasii* have previously been suggested as possible ancestors. There has been much theorising about its origin, with suggestions that saffron originated in Iran (Persia), Greece, Mesopotamia and even Kashmir (Wikipedia. 2024a). Several wild species of *Crocus* are known to have been harvested for use as saffron. *Crocus ancyrensis* was used to make saffron in Sivas in Central Turkey, the corms were also eaten. *Crocus cartwrightianus* was harvested on Andros in the islands of the Cyclades, for medicinal purposes and the stigmas for making a pigment called Zafran. *Crocus longiflorus* stigmas were used for saffron in Sicily. *Crocus thomasii* stigmas were used to flavour dishes around Taranto, South Italy. In Syria the stigmas of an unknown wild species were collected by women and children, sun-dried and pressed into small tablets which were sold in the Bazaars (Wikipedia. 2024a). The saffron crocus is now a triploid that is "self-incompatible" and male sterile; it undergoes aberrant meiosis and is hence incapable of independent sexual reproduction—all propagation is by vegetative multiplication via manual "divide-and-set" of a starter clone or by interspecific hybridisation. If *C. sativus* is a mutant form of *C. cartwrightianus*, then it may have emerged

via plant breeding, which would have selected for elongated stigmas, in late Bronze Age Crete (Wikipedia, 2024a). Humans may have bred *C. cartwrightianus* specimens by screening for specimens with abnormally long stigmas. The resulting saffron crocus was documented in a 7th-century BC Assyrian botanical reference compiled under Ashurbanipal, and it has since been traded and used over the course of four millennia and has been used as treatment for some ninety disorders. The *C. sativus* clone was slowly propagated throughout much of Eurasia, later reaching parts of North Africa, North America, and Oceania (Wikipedia, 2024a).

Ancient Greek legends tell of brazen sailors embarking on long and perilous voyages to the remote land of Cilicia, where they traveled to procure what they believed was the world's most valuable saffron. The best-known Hellenic saffron legend is that of Crocus and Smilax: The handsome youth Crocus sets out in pursuit of the nymph Smilax in the woods near Athens; in a brief dallying interlude of idyllic love, Smilax is flattered by his amorous advances, but all too soon tires of his attentions. He continues his pursuit; she resists. She bewitches Crocus: he is transformed—into a saffron crocus. Its radiant orange stigmas were held as a relict glow of an undying and unrequited passion. The tragedy and the spice would be recalled later (Wikipedia, 2024a). In another variation, Crocus was the lover of the messenger god Hermes. Hermes accidentally killed his lover during a game with the discus, and thus turned the dying Crocus into a saffron flower, in an aetiological myth explaining the origin of the plant (Wikipedia, 2024a). For the ancient Mediterraneans, saffron gathered around the Cilician coastal town of Soli was of top value, particularly for use in perfumes and ointments. Herodotus and Pliny the Elder, however, rated rival Assyrian and Babylonian saffron from the Fertile Crescent as best—to treat gastrointestinal or renal upsets. Greek saffron from the Corycian Cave of Mount Parnassus was also of note: the color offered by the Corycian crocus is used as a benchmark in the Argonautica of Apollonius Rhodius and similarly with its fragrance in the epigrams of Martial (Wikipedia, 2024a). Cleopatra of late Ptolemaic Egypt used a quarter-cup of saffron in her warm baths, as she prized its colouring and cosmetic properties. She used it before encounters with men, trusting that saffron would render lovemaking yet more pleasurable. Egyptian healers used saffron as a treatment for all varieties of gastrointestinal ailments: when stomach pains progressed to internal hemorrhaging, an Egyptian treatment consisted of saffron crocus seeds mixed and crushed together with *aager*-tree remnants, ox fat, coriander, and myrrh. This ointment or poultice was applied to the body. The physicians expected it to "[expel] blood through the mouth or rectum which resembles hog's blood when it is cooked". Urinary tract conditions were also treated with an oil-based emulsion of premature saffron flowers mixed with roasted beans; this was used topically on men. Women ingested a more complex preparation (Wikipedia, 2024a). In Greco-Roman times saffron was widely traded across the Mediterranean by the Phoenicians. Their customers ranged from the perfumers of Rosetta, in Egypt, to physicians in Gaza to townsfolk in Rhodes, who wore pouches of saffron in order to mask the presence of malodorous fellow citizens during outings to the theatre. For the Greeks, saffron was widely associated with professional courtesans and retainers known as the *hetaerae*. Large dye works operating in Sidon and Tyre used saffron baths as a substitute; there, royal robes were *triple*-dipped in deep purple dyes; for the robes of royal pretenders and commoners, the last two dips were replaced with a saffron dip, which gave a less intense purple hue (Wikipedia, 2024a). The ancient Greeks and Romans prized saffron as a perfume or deodoriser and scattered it about their public spaces: royal halls, courts, and amphitheatres alike. When Nero entered Rome they spread saffron along the streets; wealthy Romans partook of daily saffron baths. They used it as mascara, stirred saffron threads into their wines, cast it aloft in their halls and streets as a potpourri, and offered it to their deities. Roman colonists took saffron with them when they settled in southern Roman Gaul, where it was extensively cultivated until the AD 271 barbarian invasion of Italy. Competing theories state that saffron only returned to France with 8th-century Moors or with the Avignon Papacy in the 14th century (Wikipedia, 2024a). There, Persian saffron threads have been found interwoven into ancient Persian royal carpets and funeral shrouds. Saffron was used by ancient Persian worshippers as a ritual offering to their deities, and as a brilliant yellow dye, perfume, and a medicine. Thus, saffron threads would be scattered across beds and mixed into hot teas as a curative for bouts of melancholy. Indeed, Persian saffron threads, used to spice foods and teas, were widely suspected by foreigners of being a drugging agent and an aphrodisiac (Wikipedia, 2024a). These fears grew to forewarn travelers to abstain from eating saffron-laced Persian cuisine. In addition, Persian saffron was dissolved in water with sandalwood to use as a body wash after heavy work and perspiration under the hot Persian sun. Later, Persian saffron was heavily used by Alexander the Great and his forces during their Asian campaigns. They mixed saffron into teas and dined on saffron rice (Wikipedia, 2024a).

Saffron is one of the most expensive spices in the world. It is made from the dried pistils of the saffron crocus, a flower native to the Middle East. But how did saffron originate and how was it used by ancient civilizations? In this article, we go back in time and discover the fascinating history of this golden spice (Wikipedia, 2024b). The ancient Greeks used saffron for its aromatic properties and for its color properties. The majority of the population of ancient Greece had black hair, and because the favorite hair color was blond, they used yellow dyes to dye their hair. They used a mixture of saffron and potassium water. In Greece, frescoes depicting the saffron harvest were also found, dating from 1600-1500 BC, such as the famous fresco in the palace of Knossos on the island of Crete (Wikipedia, 2024b). Saffron was also known to the ancient Egyptians. Pharaohs used saffron as a flavoring and as an aphrodisiac. Also, they used it to perfume their baths, houses and temples. In late Hellenistic Egypt, Cleopatra used saffron in her baths so that lovemaking would be even more pleasurable (Wikipedia, 2024b). In ancient Persia, the cultivation of saffron expanded considerably. It was grown in Derbena and Isfahan in the 10th century BC. There, saffron threads had been discovered woven into ancient royal Persian carpets and shrouds (Wikipedia, 2024b). Darius the Great of Persia (500 BC) ordered his governors to ensure that saffron crocus was planted in the far northern regions of the Persian Empire (in the Caucasus) (Wikipedia, 2024b). Because of its value, saffron has always been a symbol of wealth and elegance. The ruling classes of the ancient empires used it to add flavor to their food, to dye their robes and perfume their ballrooms. Saffron was also used by the ancient Persians as medicine, as an offering to the gods and as currency (Wikipedia, 2024b). During the Black Death period in Europe in the 14th century, the demand for saffron was skyrocketing. It was coveted by victims of the plague for medical purposes.

Since many of the farmers able to grow saffron had also died of the Black Death, saffron was imported by ship from Mediterranean islands such as Rhodes. When one such shipload, worth €420,000 in today's money, was stolen by a group of nobles, a period of saffron piracy followed, resulting in the 14-week "Saffron War" and the establishment of Basel as a safe saffron production center that was also closer (Wikipedia, 2024b). Later, the European production and trade center moved to Nuremberg, where the rampant counterfeiting of saffron led to the "Safranschou code. Under this law, saffron counterfeiters could be punished, imprisoned or even face the death penalty (Wikipedia, 2024b). Saffron cultivation was introduced to England around 1350. The story goes that bulbs from the Levant, the historical-geographical name for part of southwest Asia, were smuggled into England in a special hollow of a pilgrim's staff. Saffron was initially grown only in monastery gardens for medical use. The light, well-drained calcareous soil and climatic conditions of northern Essex caused saffron cultivation to be concentrated in eastern England beginning in the 16th century. The town of "Cheppinge Walden" in Essex was renamed "Saffron Walden" because at the time it was located in the main saffron growing area and had become the saffron trading center of England (Wikipedia, 2024b).

Saffron, often hailed as the world's most precious spice, has a rich history rooted in various cultures. Derived from the vivid crimson stigmas of the saffron crocus (*Crocus sativus*), this spice not only imparts a unique flavor but also holds significant cultural and culinary importance (Zar, 2024). The saffron crocus plant, *Crocus sativus*, stands out in the botanical world for its unique ability to produce saffron, one of the most expensive spices globally. This plant is characterized by its vibrant crimson stigmas and styles, which are meticulously harvested and dried to create saffron threads. *Crocus sativus* has several distinctive features: Height: Typically grows between 20-30 cm. Flowers: Each plant can produce up to four flowers, ranging from light pastel lilac to dark mauve. Stigmas: The flowers contain three-pronged styles with crimson stigmas, the part harvested for saffron. The plant thrives in Mediterranean climates, enduring temperatures from -10°C to 40°C. Successful cultivation involves planting corms (bulb-like organs) around June in well-drained clay soils enriched with organic matter (Zar, 2024). Saffron is often referred to as the *world's most expensive spice*, with prices reaching $5,000 per kilogram or higher. Several factors contribute to this high market value: Labor-Intensive Harvesting: Each saffron flower produces only three stigmas, which are hand-picked and then dried. It takes around 150,000 flowers to produce just one kilogram of saffron. This meticulous process requires extensive manual labor. Limited Growing Conditions: Saffron crocus (Crocus sativus) thrives in specific climates, particularly those with hot summers and cold winters. Regions like Iran, Spain, and India are ideal, but the plant's environmental needs restrict large-scale cultivation. Time-Consuming Cultivation: The saffron crocus blooms for a short period each year, usually in October. The planting, growing, and harvesting cycles are lengthy and require careful timing. High Quality Control: Authentic saffron must meet stringent quality standards to ensure its rich color, aroma, and flavor. This quality assurance adds to the production costs (Zar, 2024). *Crocus sativus*, commonly known as saffron crocus or autumn crocus, is a species of flowering plant in the iris family Iridaceae. A cormous autumn-flowering cultivated perennial, unknown in the wild, it is best known for the culinary use of its floral stigmas as the spice saffron. Human cultivation of saffron crocus and the trade and use of saffron have endured for more than 3,500 years and span different cultures, continents, and civilizations (Wikipedia, 2024c).

Saffron, golden-colored pungent stigmas (pollen-receiving structures) of the autumn crocus (*Crocus sativus*), which are dried and used as a spice to flavor foods and as a dye to color foods and other products (Rogers, 2024). Saffron has a strong exotic aroma and a bitter taste and is used to color and flavor many Mediterranean and Asian dishes, particularly rice and fish, and English, Scandinavian, and Balkan breads. It is an important ingredient in bouillabaisse soup (Rogers, 2024). Saffron is cultivated chiefly in Iran but is also grown in Spain, France, Italy (on the lower spurs of the Apennines Range), and parts of India (Rogers, 2024). A labor-intensive crop, the three stigmas are handpicked from each flower, spread on trays, and dried over charcoal fires for use as a food flavoring and coloring. A pound (0.45 kg) of saffron represents 75,000 blossoms. Saffron contains 0.5 to 1 percent essential oil, the principal component of which is picrocrocin. The coloring matter is crocin (Rogers, 2024). Believed to be native to the Mediterranean area, Asia Minor, and Iran, the saffron crocus has long been cultivated in Iran and Kashmir and is supposed to have been introduced into Cathay (China) by the Mongol invasion (Rogers, 2024). A golden-colored water-soluble fabric dye was distilled from saffron stigmas in India in ancient times. Shortly after the Buddha died, his priests made saffron the official color for their robes. The dye has been used for royal garments in several cultures (Rogers, 2024). Saffron is named among the sweet-smelling herbs in Song of Solomon. As a perfume, saffron was strewn in Greek and Roman halls, courts, theaters, and baths. It became especially associated with the hetairai, a professional class of Greek courtesans. The streets of Rome were sprinkled with saffron when Nero made his entry into the city (Rogers, 2024). Saffron is a spice derived from the flower of *Crocus sativus*, commonly known as the "saffron crocus". The vivid crimson stigma and styles, called threads, are collected and dried for use mainly as a seasoning and colouring agent in food (Wikipedia, 2024). The saffron crocus was slowly propagated throughout much of Eurasia and was later brought to parts of North Africa, North America, and Oceania (Wikipedia, 2024). Saffron's taste and iodoform-like or hay-like fragrance result from the phytochemicals picrocrocin and safranal. It also contains a carotenoid pigment, crocin, which imparts a rich golden-yellow hue to dishes and textiles (Wikipedia, 2024). Its recorded history is attested in a 7th-century BC Assyrian botanical treatise, and it has been traded and used for thousands of years (Wikipedia, 2024).

Saffron is an autumnal herbaceous flowering plant belonging to the Iridaceae family. It is considered the most expensive spice in the world and a valuable medicinal herb (Shokrpour, 2019). The origin of saffron is unclear. The probable center of origin of the plant is Asia Minor (Greece) and/or the Middle East (Iran). From the historical point of view, use of saffron for medical treatment, perfume, food and dye dates back 4000 years (Shokrpour, 2019). Saffron stigmas contain three important secondary metabolites, crocin, picrocrocin and safranal that are responsible for the saffron color, taste and aroma, respectively (Shokrpour, 2019). In this review article on Origin, Taxonomy, Botanical Description, Genetics and Cytogenetics**,** Genetic Diversity, Breeding and Cultivation of Saffron are discussed.

ORIGIN AND DIRTIBUTION

There are several proposals concerning the origins of saffron. It may have originated in Egypt since it is represented in hieroglyphs, which experts have dated as being from approximately 4000 bc. Saffron is also cited by Salomon in the 'Canticle of Canticles' (1100–1000 bc) under the name of 'karkom', a word of Indian derivation, leading some authors to locate its origin in the region of Kashmir, where its cultivation has traditionally been most significant. Other authors propose Greece as the birthplace of saffron due to the large quantity of species from the *Crocus* genus that grow in this area and also because of the important Minoic archaeological remains, which are in an excellent state of preservation. Wall paintings in the palace of Minos date back to 1700–1600 bc and those at Akrotiri, on the island of Thera are dated at 1500 bc and depict saffron fields and young women harvesting the flower (Alonso *et al*., 2012). Saffron belongs to the class Liliatae (monocotyledons), sub-class Liliidae, order Liliales, *Iridaceae* family and genus *Crocus.* The *Crocus* genus comprises about 85 species distributed throughout Mediterranean Europe and Western Asia. The plants of this genus are well adapted to areas with cold winters and warm, dry summers. Saffron is considered an undemanding plant due to its enormous capacity for adaptation. It tolerates an enormous variety of ecological edaphic, as well as climatic, conditions. As a cultivated plant, saffron can be found in altitudes ranging from sea level to almost 2000 m, although it is more acclimatized to hillsides, plateaux and mountain valleys in altitudes between 600 and 1200 m, supposedly its original conditions. This plant can be cultivated in arid or semi-arid areas where the water deficit is extreme in summer. As far as temperature is concerned, it can withstand rigorous environmental temperatures of − 15 °C or − 20 °C in winter and 35–45 °C in summer, which does not mean it is insensitive to them (Alonso *et al.,* 2012). Although saffron's origin has been under debate for over a century, with a large body of work attempting to clarify its genetic and geographic origin, the history of saffron domestication remained unresolved until recently (Kazemi-Shahandashti *et al*., 2022).

The origin of *C. sativus* is not clearly known, some suggest eastern Mediterranean as its endemic place and some consider its Iranian origin. As per the archaeological and historical data, the domestication of *C. sativus* is very old (2,000 to 1,500 years BC). The *C. Sativus* is reported to be cultivated in Afghanistan, Azerbaijan, China, Egypt, France, Greece, India, Iran, Iraq, Israel, Italy, Japan, Pakistan, Morocco, Spain, Switzerland, Turkey, United Arab Emirates since ancient times, and recently Australia also have started its cultivation (Dar *et al*., 2017). Despite saffron crocus' early omnipresence, its origin has been the matter of a century-old debate, in terms of area and time as well as parental species contribution. While remnants of the ancient arts, crafts, and texts still provide hints on its origin, modern genetics has the potential to efficiently follow these leads, thus shedding light on new possible lines of descent. In this review, we follow ancient arts and recent genetics to trace the evolutionary origin of saffron crocus. We focus on the place and time of saffron domestication and cultivation, and address its presumed autopolyploid origin involving cytotypes of wild *Crocus cartwrightianus*. Both ancient arts from Greece, Iran, and Mesopotamia as well as recent cytogenetic and comparative next-generation sequencing approaches point to saffron's emergence and domestication in ancient Greece, showing how both disciplines converge in tracing its origin (Shahandashti *et al.,* 2022). A wide diversity of germplasm is essential for any breeding program. Mulberry basically originated in the Himalayan foothills but distributed to continents like Asia, Europe, North and South America, and Africa and presently, mulberry is under cultivation in almost all Asian countries, including India (Manjunath *et al.,* 2023).

Previously, it was theorised that saffron originated in Iran, Greece, Mesopotamia, or Kashmir. Harold McGee states that it was domesticated in or near Greece during the Bronze Age. *C. sativus* is probably a triploid form of *Crocus cartwrightianus*, which is also known as "wild saffron". Saffron crocus was slowly propagated by humans throughout much of Eurasia and was later brought to parts of North Africa, North America, and Oceania (Wikipedia, 2024). Conflicting theories explain saffron's arrival in South Asia. Kashmiri and Chinese accounts date its arrival anywhere between 2500 and 900 years ago. Historians studying ancient Persian records date the arrival to sometime prior to 500 BC, attributing it to a Persian transplantation of saffron corms to stock new gardens and parks. Phoenicians then marketed Kashmiri saffron as a dye and a treatment for melancholy. Its use in foods and dyes subsequently spread throughout South Asia. Buddhist monks wear saffron-coloured robes; however, the robes are not dyed with costly saffron but turmeric, a less expensive dye, or jackfruit. Monks' robes are dyed the same colour to show equality with each other, and turmeric or ochre were the cheapest, most readily available dyes. Gamboge is also used to dye the robes (Wikipedia, 2024). According to the herbalist Wan Zhen, "the habitat of saffron is in Kashmir, where people grow it principally to offer it to the Buddha". Wan also reflected on how it was used in his time: "The flower withers after a few days, and then the saffron is obtained. It is valued for its uniform yellow colour. It can be used to aromatise wine" (Wikipedia, 2024).

The history of the saffron crocus is not entirely certain. Many people believe that *Crocus sativus* is a mutation of *Crocus cartwrightianus*, a crocus species that occurred wild in Greece at the time, and was selected and domesticated in Crete during the late Bronze Age. What is certain is that saffron cultivation is more than 4,000 years old. Around 500 BC, saffron cultivation had also spread from Persia to eastern India. There, after Buddha's death, it was decided that the robes of the title class of Buddhist priests should forever be colored with saffron. Later, Persian saffron was widely used by Alexander the Great and his troops during their campaigns through Asia. They drank saffron tea and ate rice colored with saffron. Alexander himself used saffron mainly in his warm bath water, believing that the beneficial effects of saffron would heal his wounds sustained on the battlefield. During 100 BC, saffron was also exported to China from Persia, along with cucumbers, onions, jasmine and vines. The Roman Empire, of course, also imported its saffron from Persia. With the fall of the Roman Empire, saffron cultivation was introduced to Europe by the Moors, first in Spain and later in parts of France and southern Italy (Wikipedia, 2024b). Historical evidence suggests that saffron's origins trace back to ancient Iran, then known as Persia. Ancient texts and archaeological findings indicate that Persian saffron was highly valued for its medicinal properties and use as a dye. Iran remains the world's largest producer of saffron, contributing around 88% of the global supply. Its dominance can be attributed to optimal growing conditions and centuries of cultivation expertise (Zar, 2024). Saffron's journey

through history is as vibrant as its deep crimson threads. In ancient civilizations like Assyria and Greece, saffron was highly prized not only as a spice but also as a dye. Assyrians used it in their rituals and medicines, while Greeks wove it into their mythologies and artistic expressions. The Greeks valued saffron so much that it was often depicted in frescoes, showcasing its importance in their culture. During the Middle Ages, the Moors played a crucial role in the spread of saffron cultivation across Europe. Their advanced agricultural techniques helped reintroduce saffron to Spain, which became a significant hub for its production. This period saw the spice being transported by Crusaders returning from the Holy Land, further embedding saffron into European culinary and medicinal practices. The influence of saffron is also evident in art and literature. Michelangelo, for instance, utilized saffron as a pigment in some of his masterpieces, demonstrating its versatility beyond culinary uses. Understanding the historical significance of saffron provides valuable context for its enduring allure today. The threads of this golden spice weave through centuries, cultures, and traditions, making it an irreplaceable element in both history and modern times (Zar, 2024). Saffron has been cultivated as a spice for at least 5,000 years in Egypt and the Middle East. The first mention of saffron dates back to the Accadian empire (2300 BC). The harvesting of saffron appeared in Minoan pottery and frescoes from the Palace of Minos in Knossos, Crete (1700–1600 BC). *Kroko*s was the ancient Greek word for saffron and appears in songs IX and XII of Homer's Iliad. In Greek mythology, Krokos, the lover of nymph Esmilax, was transformed into the plant saffron by Hermes. Ancient Greek & Roman physicians Hippocrates, Theophrastus, and Galen considered saffron as an appetite stimulant and digestive aid. Saffron was also known in ancient Egypt and mentioned in the *Eber's papyrus* as an ingredient in a cure for kidney problems. It is thought that saffron was introduced to India *via* Persian rulers' efforts to stock their newly built gardens and parks. In India, saffron is highly regarded in Ayurvedic medicine to heal a variety of diseases ranging from arthritis to impotence and infertility. The Romans introduced saffron into Great Britain, while the Arabs brought saffron to Spain. In the ancient world, textiles dyed with saffron were rare, extremely expensive, and considered as royal status symbols. The saffron mantle of the kings of Ireland and saffron-dyed material supplied by the Phoenicians to the kings of Assyria are examples. In modern times, the use of saffron as a dye has been replaced by synthetics due to cost. Due to its high price, adulteration and cheating have been pervasive in the saffron trade. Additional parts of the flower can be included such as the stamen, which is yellow in color and low in flavour (Resources, 2024). It is thought that the domesticated saffron crocus most likely arose as a result of selective breeding from the wild *C. cartwrightianus* in the southern portion of mainland Greece. An origin in Western or Central Asia, although often suspected, is not supported by botanical research (Wikipedia, 2024c).

TAXONOMY

Saffron belongs to the family Iridaceae, genius *Crocus* and species *Crocus sativus* (Srivastava *et al*., 2010;Dar *et al*., 2017; Wikipedia, 2024c). Saffron is produced from the dried styles of *Crocus sativus* L. (Iridaceae) which is unknown as wild plant, representing a sterile triploid. These belong to subgenus *Crocus* series *Crocus sativus* – series are closely related species; and are difficult to be separated taxonomically and have a complex cytology. The genus *Crocus* (family Iridaceae) comprises some 85–100 species having an old world distribution, primarily in the Mediterranean – Europe and Western Asia. The limits of the entire genus lie within the longitude 10°W to 80°E and latitude 30°N to 50°N (Saxena, 2010). The genus *Crocus* consists of about 85 different species. *Crocus sativus* is the only species widely utilized as a spice. Many of the other *Crocus* species are cultivated for ornamental purposes. The major saffron cultivating countries for trade are Spain, Iran, Greece, India, China, and Morocco. Spain and Iran are the largest producers, accounting together for more than 80% of the world's production. The best quality saffron is said to be harvested in the Spanish region of La Mancha (Resources, 2024).

Synonyms (Saxena, 2010).

C. sativus var. *officinalis* Linn. (1762)
Crocus officinalis var. *sativus* Huds (1778)
Crocus autumnalis Smith (1796)
Crocus sativus var. *casbmiruanus* Royle (1836)
Crocus orsinii parl (1856)
Crocus sativus var. *crsinii* (1881)

Synonyms (Wikipedia. 2024c)

Crocus autumnalis Sm. nom. illeg.
Crocus officinalis (L.) Honck.
Crocus orsinii Parl.
Crocus pendulus Stokes
Crocus setifolius Stokes
Geanthus autumnalis Raf.
Safran officinarum Medik

BOTANICAL DESCRIPTION

When nuclear DNA of *Crocus sativus* L. is compared to that of diploid allies species, it indicates that the most probable ancestor of saffron is *C. cartwrightianus* Herb., although *C. thomasii* Ten and *C. pallasii* Goldb. have been considered other possible parents of saffron (Caiola, 2004). Saffron is male sterile, self-incompatible and if crossed with pollen of *C. cartwrightianus* or *C. thomasii* it seed sets and matures capsules. Self-incompatibility is not mediated by RNase, peroxidise or calcium. Moreover, experiments on stigmatic and intraovarian pollination between *C. sativus* and *C. cartwrightianus*, *C. thomasii* or *C. hadriaticus* indicate that embryo development is not related to apomixis or somatic embryogenesis. This has been verified both in vitro as well as in field (Caiola, 2004). Corms to c. 5 cm in diameter, depressed globose, flattened at the base; tunica fibrous, the fibers very slender and finely reticulated, extended at the apex of the corm into the neck upto 5 cm long. Cataphylls 3–5, white, membranous. Leaves 5–11, normally synanthous, exect, green, 1.5–2.5 mm wide, glabrous or ciliate. Flowers autumnal, fragrant, 1–4, deep lilac-purple with darker veins and a darker violet stain in the throat; throat white or lilac, pubescent. Prophyll present. Bract and bracteole present, very unequal white, membranous with long-tapering, rather flaccid tips. Perianth tube 4–5 (–8) cm long; segments subequal, 3.5–5 cm long, 1–2 cm wide, oblanceolate or obovate, obtuse. Filaments 7–10 mm long, purplish, glabrous; anther 15–20 mm long, yellow. Style divided into three deep red clavate branches, each branch 25–32 mm long, much exceeding the anthers and, at least half the length of the perianth segments,

arising at a point well below the base of the anthers in the throat of the flowers. Capsules and seeds rarely produced (a triploid of low fertility) (Saxena**,** 2010). Anthers with extrose dehiscence, Section *Crocus*: Scape subtended by a membranous prophyll, Series *Crocus*: Corm tunics finely fibrous, usually reticulate; flowers autumnal; leaves rather numerous, usually 5–30, appearing with the flowers or shortly after; bracts flaccid, usually not closely sheathing the perianth-tube, membranous, white or transparent with no marking; anther yellow; style branches 3, usually red and often expended at the apex, entire or at most fimbriate; seed coats covered with dense mat of papillae (Saxena**,** 2010).

Saffron is a perennial, herbaceous, 10–25 cm high plant that develops from corms. From a botanical point of view, a corm is a short, thick shoot, similar to an onion, except that it is a solid structure, which does not consist of numerous concentric layers. It is a subsoil organ that measures 5–7 cm in diameter and is protected by fibrous reticulated leaf tunics coming from the degeneration of various foliar structures that constituted the sprouts from which it was formed. As previously mentioned, saffron multiplies by vegetative reproduction (Fig. 1) (Alonso *et al*., 2012).

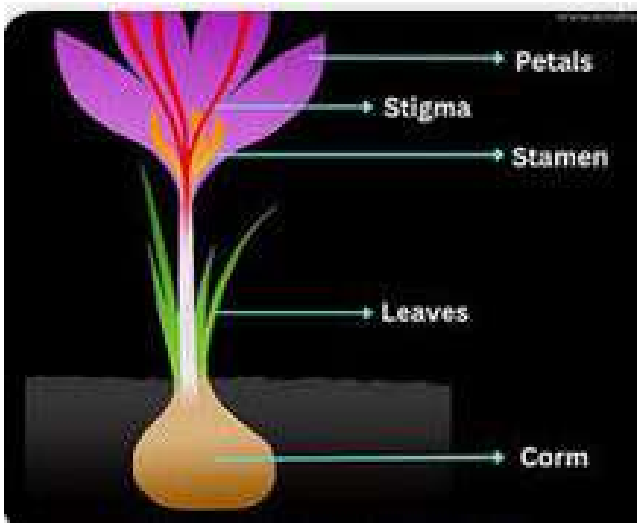

Fig. 1. Partsa of Crocus sativus L

When the corm is activated and buds begin to protrude, three to five structures of foliar origin, called cataphylls, form a tube of a whitish colour and membranous consistency (from 5–20 cm) which surrounds and protects the other foliar and floral structures that grow longitudinally and simultaneously in their interior. Between five and 11 green leaves or nomophylls are found per sprout and are usually called bristles, horsehair or esparto grass. They are very narrow, between 1.5 and 2.5 mm wide, dark green in colour, linear, with a white band on their inner side and a vein on the outer side. They can measure about 50 cm although excessive irrigation and certain types of management can make them reach 1 m in length. Flowers, known as the saffron rose, sprout from the bractea axils. They consist of six tepals, three inner and three outer ones, united in a long tube that starts at the top of the ovary. Tepals are violet-coloured with darker veins. Flowers are erect and regular in form and, depending on water availability, the flowers can appears before or simultaneously to green leaves. There are one to three flowers per stem and two or three stems per plant. Three yellow stamens emerge from the upper part of the afore-mentioned tube (Alonso *et al.,* 2012). The long, yellowish-white, filiform style starts at the subsoil ovary apex, crossing through the perianth tube and ending in a sole stigma of three bright red branches or filaments, the part of the plant for which man cultivates it. The filaments, 25–32 mm each, are tubular in appearance and somewhat rolled up. They become progressively thicker from their base, to end in wide papils in the form of a scalloped trumpet, where grains of pollen are usually found. Their length is disproportionate in comparison to the other floral organs, so they rest on the tepals or hang outside the flower (Alonso *et al*., 2012).

The *C. sativus* is a perennial plant and attains maximum height of 30 cm, with erect, ciliate margined leaves. It flowers during the month of the November and December. The flowers of the *C. sativus* reported to have two bracts at the base, pale-violent veined calyx, yellow and white coloured anthers and filament with color and filament with white colour. Although *C. sativus* don't bear any fruit but its shade dried red-stigma is the most important and highly consumed part. Among the 85 reported species of the genus *Crocus*, *C. sativus* is the only species which attract the special attention because of its medicinal potential, colouring property and spice usage (Dar *et al.,* 2017). Saffron is a spice derived from the flower of Crocus sativus, commonly known as the saffron crocus. Crocus is a genus in the family Iridaceae. Saffron crocus grows to 20-30 cm and bears up to four flowers, each with three vivid crimson stigmas, which are the distal end of a carpel. Together with the styles, or stalks that connect the stigmas to their host plant, the dried stigmas are used mainly in various cuisines as a seasoning and colouring agent. Saffron, long among the world's most costly spices by weight, is native to Greece or Southwest Asia and was first cultivated in Greece. As a genetically monomorphic clone, it was slowly propagated throughout much of Eurasia and was later brought to parts of North Africa, North America, and Oceania. Saffron's taste and iodoform or hay-like fragrance result from the chemicals picrocrocin and safranal. It also contains a carotenoid pigment, crocin, which imparts a rich golden-yellow hue to dishes and textiles. Its recorded history is attested in a 7th-century BC Assyrian botanical treatise compiled under Ashurbanipal, and it has been traded and used for over four millennia. Iran now accounts for approximately 90% of the world production of saffron (NLM, 2021).

It is a sterile triploid form, which means that three homologous sets of chromosomes make up each specimen's genetic complement; *C. sativus* bears eight chromosomal bodies per set, making for 24 in total. Being sterile, the purple flowers of *C. sativus* fail to produce viable seeds; reproduction hinges on human assistance: clusters of corms, underground, bulb-like, starch-storing organs, must be dug up, divided, and replanted. A corm survives for one season, producing via vegetative division up to ten "cormlets" that can grow into new plants in the next season. The compact corms are small, brown globules that can measure as large as 5 cm in diameter, have a flat base, and are shrouded in a dense mat of parallel fibres; this coat is referred to as the "corm tunic". Corms also bear vertical fibres, thin and net-like, that grow up to 5 cm above the plant's neck (Wikipedia, 2024). The plant sprouts 5–11 white and non-photosynthetic leaves known as cataphylls. These membrane-like structures cover and protect 5 to 11 true leaves as they bud and develop on the crocus flower. The latter are thin, straight, and blade-like green foliage leaves, which are 1–3 mm, in diameter, which either expand after the flowers have opened ("hysteranthous") or do so simultaneously with their blooming ("synanthous"). *C. sativus* cataphylls are suspected by some to

manifest prior to blooming when the plant is irrigated relatively early in the growing season. Its floral axes, or flower-bearing structures, bear bracteoles, or specialised leaves, that sprout from the flower stems; the latter are known as pedicels. After aestivating in spring, the plant sends up its true leaves, each up to 40 cm in length. Only in October, after most other flowering plants have released their seeds, do its brilliantly hued flowers develop; they range from a light pastel shade of lilac to a darker and more striated mauve. The flowers possess a sweet, honey-like fragrance. Upon flowering, the plants are 20–30 cm in height and bear up to four flowers. A three-pronged style 25–30 mm in length, emerges from each flower. Each prong terminates with a vivid crimson stigma, which is the distal end of a carpel (Wikipedia, 2024). *Crocus sativus* is a perennial herb that grows about 10 to 30 cm high. It develops as an underground corm, which produces leaves, bracts, bracteole, and the flowering stalk. It generally blooms with purple flowers in the autumn. Flowers are sterile, have six petals and three red to orange colored stigmas. Leaves are simple, rosulate in arrangement with entire margins (Wikipedia, 2024c).

Saffron is planted as a corm, an underground plant stem that is similar to a bulb. It is a perennial crop which can be maintained for up to 6–10 years although in some areas it is planted annually. In the Northern hemisphere, the planting season is from July to September. Each corm produces 1-3 small purple flowers with violet colored petals. The leaves of the plant are long, slender, and grass-like. Saffron is hand-harvested in late October-early November when flowers are fully bloomed and the saffron strand (stigma) is at its reddest. Harvesting begins shortly after dawn since picked saffron quickly loses its color and flavor and withers under the sunlight (2-3). Shortly after harvest, the stigma is carefully hand-separated from the flowers and dried. In Spain, the traditional drying method involves gently roasting the stigma over the embers of a charcoal fire. Harvesting the flowers and separation of stigmas is time consuming and laborious which makes saffron the most expensive spice in the world (over $4,000/pound). About 2,00,000 saffron stigmas (picked from ~70,000 flowers) yields ½ kg of saffron and this can take roughly 200 man hours (Resources, 2024). Mulberry has different varieties with male, female or androgynous flowers. Among the varieties with androgynous flowers, there are predominantly staminated, predominantly pistillated and even hermaphrodite types. Mulberry plants with anemophilous flowers cross each other easily and naturally (Machii *et al*., 2024). Botanical description is given in Fig.2 and growth cycle of Saffron is given in Fig. 3.

Pollination: Saffron pollen grains have dimensions too large to be airborne, but its conspicuous flowers and nectar are useful tools for attracting insects. Among these *Apis mellifica* is considered a collector of pollen of saffron. However, other insects have been reported active in transport pollen in Crocus species, such as bumble-bees or wild moths in *C. Cartwrightianus*. However is difficult to establish the role of the cited insects in pollination of saffron because when flowers open saffron stigmas bend downward making it difficult to come into contact with the insects. Also in saffron the nectar origins are in the ovary canals, and it is improbable that it get up along the flower tube, which is over 10 cm long making it impossible for bees, bumble-bees or wild moths to collect it. There are no specific studies appearing in literature on insect saffron pollination being the plant considered unable of seed and fruit maturation. Our direct observations of saffron and allied Crocus species have evidenced that during flowering many *Bombus silvestris* fly from flower-to-flower collecting pollen. Usually *Bombus* appears at noon of sunny days when the temperature rises facilitating the opening of the anther and the optimum amount of pollen is available and intense perfume. Similar behaviour has been reported for other pollinators of Crocus. In these environmental conditions both intraspecific and interspecific pollination could occur but only scarce seeds production was detected by free pollination, compared to the high production of seed from saffron after a massive hand pollination with pollen of *C. cartwrightianus* or *C. thomasii*. Crocuses are cited as "flowers for bees" because only bees collect pollen from Crocus flowers. However we have never observed bees in our saffron cultivation. This could depend on the particularly restricted area of cultivation or temperature, or there was a distinct absence of bee in the research area (Caiola, 2004).

The growth cycle (Cardone *et al.*, 2020)

- The bulb is in its dormant phase
- Sprout and root formation
- Flowering and leaf production
- Flowering and leaf development
- Further development of the leaves
- Growth of the leaves and production of new bulbs
- Further growth of the leaves and the new bulbs
- Reaching maximum leaf length and continued growth of the new bulbs
- Initiate leaf wilting and further growth of new bulbs
- The leaves are completely wilted. The new bulbs have reached their maximum growth and return to dormancy.

GENETICS AND CYTOGENETICS

According to Saxena (2010) the chromosome number $3n = 24$. Meiosis processes in saffron showed that *Crocus sativus* L. is an autotriploid species with 2n=3x=8+8+8=24 chromosomes. The results obtained from the meiosis behavior indicated that the major role in the sterility of saffron is autotriploidy in this crop. Arrangement of chromosomes as trivalents in meiosis and formation of these trivalents in the forms of frying pan, chain type, Y type, V type, and triangle type at metaphase I, causes their imbalance junction at anaphase I. Unbalance disjunction of chromosomes at anaphase I and II with the occurrence of the lagging chromosomes in these phases, causes sterile gametes. Also, the formation of chromatid bridges at anaphase I and II with the occurrence of micronuclei at telophase II and tetrad stage are the other reasons for the sterility (Ghaffari, 2022). Meiosis processes in saffron showed that *Crocus sativus* L. is an autotriploid species with $2n$=3x=8+8+8=24 chromosomes. The results obtained from the meiosis behavior indicated that the major role in the sterility of saffron is autotriploidy in this crop. Arrangement of chromosomes as trivalents in meiosis and formation of these trivalents in the forms of frying pan, chain type, Y type, V type, and triangle type at metaphase I, causes their imbalance junction at anaphase I. Unbalance disjunction of chromosomes at anaphase I and II with the occurrence of the lagging chromosomes in these phases, causes sterile gametes. Also, the formation of chromatid bridges at anaphase I and II with the occurrence of micronuclei at telophase II and tetrad stage are the other reasons for the sterility (Ghaffari, 2022).

		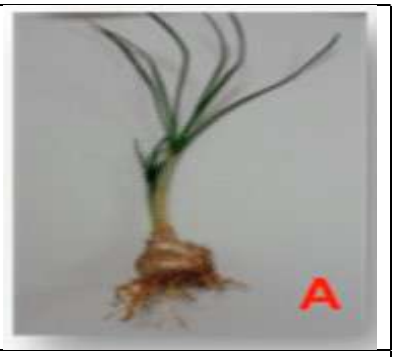
Corms	**Corms**	**Saffron plant**
		
Types of roots	**Saffron flower.**	**Field**
		
Harvesting	**Carrying the Harvested flowers**	**Just opened flower**
		
Separating the stigmas	**Saffron**	**Saffron**

Fig. 2: Botanical Description

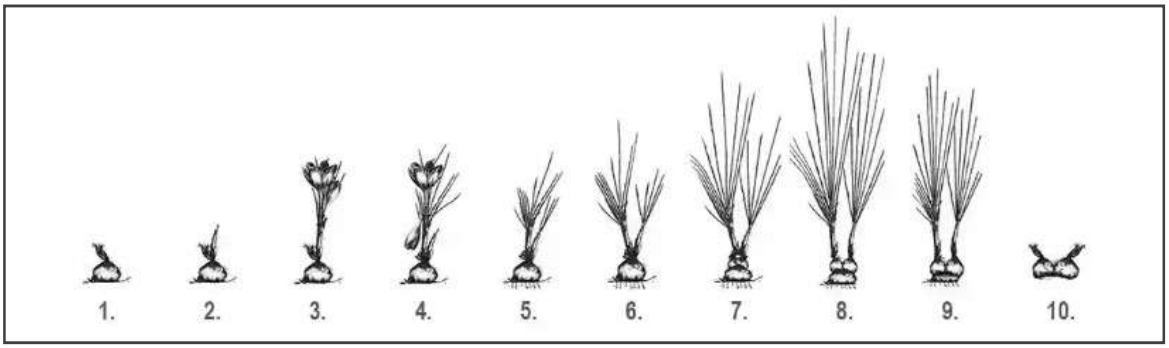

Fig. 3. The growth cycle of Saffron

Instead of chromosome pairs, saffron has eight chromosome triplets with a chromosome configuration of 2n = 3x = 24 and a triploid genome size of 10.5 Gb. Saffron's triploidy is the cause for many genetic peculiarities of saffron (Kazemi-Shahandashti *et al*., 2022).

Saffron crocus is a triploid with 24 chromosomes (2*n* = 3*x* = 24), making the plant sexually sterile due to its inability to pair chromosomes during meiosis (Wikipedia, 2024c). Generally, mulberry is a diploid plant with 28 chromosomes (2n=28). However, it is rich in ploidy and many triploid varieties have been found especially among *M. bombysis* Koidz. It is said that *M. cathayana* Hemsl. has tetraploid, pentaploid and hexaploid varieties. Both *M. serrata* Roxb., indigenous to India, and *M. tiliaefolia* Makino, originally from Japan and Korea, are known to be hexaploid. *M. boninensis* Koidz is a tetraploid that is being endangered through cross-contamination with *Morus acidosa* Griff. *M. nigra* L. is dexaploid (2n=308), the largest number of chromosomes among phanerogams (Machii *et al*., 2024).

GENETIC DIVERSITY

Plant breeding techniques have produced a wide variety of saffron. Most have cup-shaped flowers, but some produce star-shaped ones instead. The flowers may be purple, blue, lavender, pink, orange, yellow, red, white and are the striped varieties (Crampton, 2023).

Lavender

Pink, Yellow, White

Striped

In Kashmir, the cultivated population of saffron is *Crocus sativus* 'Kashmirianus', which is recognized by its extremely dark maroon-purple hue, and is among the world's darkest, suggesting strong flavour and colourative effects. Surveys undertaken to study the extent of variation revealed a wide spectrum of variability in saffron flowers and corm samples collected from saffron-growing areas of Kashmir (Dhar *et al.* 1998). Stigma length varied from 1.75-3.72 cm and style length ranged from 1.70-4.25 cm. The average number of daughter corms per mother corm ranged from 2.37-7.05 and their average weight ranged from1.59-8.49 g. Crocin content ranged from 8.55-17.10% (Husaini *et al.,* 2010).

Variability in respect of sprouting time, plant height, induction of flowering, shape of petals and number of filaments in a stigma was noted. Plants exhibiting mutations were identified and bulbs produced from mutants were harvested separately to further the generations. An outstanding mutant which was isolated was, a mutant with five branched stigma, instead of three as in normal plants. On evaluating this mutant, it was found superior in respect of number of branches in stigma. Average length of filaments in five branched stigma noted to be 2.75 cm whereas in three branched stigma it is 2.70 cm. Dry weight of normal three branched stigma is 5 mg. whereas in five branched stigma it was noted to be 6.950 mg which is higher than control. Development of 5 branched stigmas is the result of gene mutation due to induction effect (Khan, 2007). Two hundred saffron genotypes collected from saffron growing areas of Kashmir subjected toMahalanobis D2 analysis revealed high amount of diversity. Out of 200 genotypes, 171 genotypeswere grouped in cluster I, 9 in cluster V and 7 in cluster VI whereas the other 13 clusters weremonogenotypic. Maximum intracluster distance (6.50) was recorded for cluster V accommodatingSH-21, SH-123, SH-200, SH-51, SH-30, SH-81, SH-69, SH-03, SH-98 genotypes collected fromKushbal, Wuyan, Khrew, Kashbal, Wulan nadh, Kruncho, Dusso, Tang and Darbagh. Maximumintercluster distance (18.14) was recorded between cluster XV and XVI showing maximum geneticdivergence among the population for SH-67 collected from Chandhara and SH- 89 collected formKhrew area of Kashmir valley. Fresh stamen weight (20.86%) followed by plant height (17.77%), fresh flower weight (15.31%) and pistil length (9.98%) had contributed significantly towardsdiversity (Qadri *et al*., 2013).

Genetic diversity among 28 saffron accessions collected from different regions of Iran was evaluated using sequence-related amplified polymorphism (SRAP) markers. Nineteen SRAP primer combinations amplified a total of 147 polymorphic fragments with an average of 7.74 fragments per each primer combination and average of polymorphic information content (PIC) of 0.15. Cluster analysis using Neighbor-Joining method divided the accessions into four groups with most of them clustered in a major group. The principal component analysis (PCA) showed that cluster analysis is more appropriate for revealing genetic relationship of saffron accessions. The close relationships among saffron accessions revealed in this study can be due to vegetative propagation, human selection of superior genotypes and existence of narrow genetic base of saffron. The results confirmed that the SRAP markers are powerful tools and effective marker system for evaluation of genetic diversity among saffron accessions (Babaei *et al.,* 2014). Due to the importance of saffron as a commercial plant, evaluation of its genetic diversity among accessions is critically important for breeding and germplasm conservation.

During the last three decades, classical strategies for the evaluation of plant genetic variability, such as comparative anatomy, morphology, embryology and physiology, have increasingly been complemented by molecular techniques. Morphological comparison of saffron flower from different countries revealed variations in the pollen size and viability, intensity of flower coloring, size of the flowers and the shape of the petals. Since the DNA markers show the variation at DNA level and are not affected by environmental conditions, they are more reliable than morphological markers. Some of the molecular markers such as random amplified polymorphic DNA (RAPD), inter simple sequence repeat (ISSR) and microsatellite markers have been used to assess the genetic diversity of 43 *C. sativus* isolates from 11 different countries, which showed that saffron is a monomorphic species (Babaei *et al.,* 2014). In this study genetic diversity among 28 saffron accessions collected from different regions of Iran was evaluated using sequence-related amplified polymorphism (SRAP) markers. Nineteen SRAP primer combinations amplified a total of 147 polymorphic fragments with an average of 7.74 fragments per each primer combination and average of polymorphic information content (PIC) of 0.15. Cluster analysis using Neighbor-Joining method divided the accessions into four groups with most of them clustered in a major group. The principal component analysis (PCA) showed that cluster analysis is more appropriate for revealing genetic relationship of saffron accessions. The close relationships among saffron accessions revealed in this study can be due to vegetative propagation, human selection of superior genotypes and existence of narrow genetic base of saffron. The results confirmed that the SRAP markers are powerful tools and effective marker system for evaluation of genetic diversity among saffron accessions (Babaei *et al*., 2014).

Clonal selection plays an important role with reference to improving the traits of cultivated saffron. There is a specific belief among some researchers that clonal selection of saffron will not result in large scale success with respect to improving the productivity of saffron because saffron, as a cloned species, does not have sufficient genetic variability for use in plant selection programs. In addition, mutations that have been identified as resulting from experimental or natural mutagenesis are not maintained as they are not heritable; consequently, they disappear in subsequently vegetative generations. There is also the problem of sterility, caused by the triploid nature of saffron, which prohibits its use in hybridization programs. Therefore, methods of conventional breeding are not relevant in terms of saffron breeding programs, and others believe that experimental mutagenesis and *in vitro* techniques must be focused upon. However, to date, both experimental mutagenesis and procedures aimed at doubling a chromosome set of saffron have not lead to encouraging results. Moreover, the decrease of land surface dedicated to saffron crop in many areas has possibly resulted in corresponding genetic erosion that adds up to the limited genetic variation suspected for *C. sativus* due to its sterile habit. Thus, the situation seems dramatic at present time and compromises any attempt of genetic improvement regarding this highly-valued crop. Consequently, the creation of a germplasm bank consisting of superior elite clonal selections can be considered as a great achievement in the first place. In addition, the identification of selections as sources of variation with respect to some valuable traits like apocarotenoid biosynthetic potential, stigma length variation, variation in stigma number and yield can play an important role in improvement of this crop. Therefore superior clones showing better stigma characteristics need to be selected and mass multiplied (Mir *et al*., 2015).

To determine the effective traits to improve saffron yield, a split plot design based on RBCD was done in Mashhad region in Iran for three years (2012–2014). The results showed that all traits except number of daughter corm, fresh weight of daughter corm and dry leaf weight had low general heritability. Results of genotypic and phenotypic coefficients of variation and genetic advance demonstrated that the majority of traits had a low diversity and the selection did not have any effect in improving the traits. As a result, the best way to increase saffron yield is improvement of farm management. It was also found that saffron yield had the highest phenotypic and genotypic correlations with fresh and dry weight of daughter corm and dry and fresh flower weight. Therefore, the efforts to improve these traits will increase saffron yield. According to the present study 5-Jun to 5-Jul was found to be the best sowing date for planting saffron. Also, the Mashhad and Torbat ecotypes were the best ecotypes in this study. Phenotypic and genotypic path analysis showed that in the first step three traits number of daughter corm, fresh flower weight and flower number and in the second step traits fresh weight of daughter corm, dry flower weight and dry leaf weight interred to the regression model and had the highest positive direct and indirect effects on saffron yield. Mainly, it can be derived that the implementation of correct farm management including appropriate sowing date, saffron ecotypes, proper density, bigger and higher quality saffron corm can play an important role in improving yield components and subsequently increasing saffron yield (Bayat *et al*., 2016). Current study aimed to determine the molecular characterization of saffron and its close relative species using inter-primer binding site (iPBS)-retrotransposon markers. Eighty-three iPBS-retrotransposon primers were used in 28 C. sativus genotypes and 17 close relative species of saffron to identify their genetic diversity. Sixteen polymorphic iPBS-retrotransposon primers generated a total of 401 polymorphic scorable bands. The mean PIC value, Nei's genetic diversity and Shannon's information index (I) were calculated as 0.85, 0.16 and 0.29, respectively. The results of the Unweighted Pair Group Method with Arithmetic mean UPGMA dendrogram and Principal Coordinates Analysis PCoA analysis indicated a spatial representation of the relative genetic distances among 28 saffron samples and the 17 close relative species were categorized under two distinct groups. Saffron genotypes showed very limited genetic variation and according to the iPBS-retrotransposon data, its close relatives were *C. cartwrightianus* and *C. pallasii* subsp. *Pallasii* (Gedik *et al*., 2017).

A collection of twenty-two cultivars of saffron grown in different regions of Iran was screened with 25 SSR and 5 SNP primers in order to determine genetic identities and genetic diversity in these cultivars. On an average, 50 alleles were amplified using SSR primers with scorable fragment sizes ranging from approximately 160 to 400 bp. Among these, 33 alleles were polymorphic thus revealing 72% of polymorphism. The genetic similarity estimated according to SSR data was scaled between 9.5 and 87.8%. In determination of genetic diversity, five polymorphic SNP markers were used. Since SNP markers are mainly bi-allelic, all SNPs showed two alleles only, suggesting the potential of SSR and SNP markers in discriminating among plants of distant genetic backgrounds.

Un-weighted pair group method with arithmetic mean clustering grouped the cultivars into four groups. In this study, we tried to expand the genetic diversity of *C. sativus* in Iran despite their asexual reproduction. Due to the similarity of climatic conditions in Iran, a certain genetic variation was observed in saffron plants (Javan and Gharari, 2018). The existence of genetic diversity in *Crocus sativus* has globally remained a mystery till date. The study investigated PCR based DNA amplification profile of saffron using ISSR and RAPD based primers. A total of 38 amplicons were generated by ISSR primers in the range from 7 to 12 with an average of 9.50 bands per primer. 20 bands were found to be polymorphic and 18 were monomorphic with an average percentage of polymorphism as 52.48%. RAPD based amplification revealed a total 161 amplicons, 107 as polymorphic and 54 as monomorphic with an average percentage of polymorphism as 66.44%. Cumulative results of RAPD and ISSR demonstrated that Nei-Li's similarity index ranged between 0.70 and 0.97. The results of AMOVA has revealed 9% of variance among populations and 91% of variance within populations, Φ PT was found as 0.089, which indicates existence of genetic differences though limited. In conclusion, the results indicate that saffron accessions are minimally genetically differentiated, which could be capitalized in future breeding programmes to ameliorate this precious crop (Mir *et al*., 2021). In this study, genetic diversity among 14 saffron accessions collected from different ancestral geographic areas in Morocco, Greece and France, has been assessed using inter-simple sequence repeats (ISSRs) markers system. Ten ISSR primers were amplified, a total of 143 fragments of which 44.05 % are polymorphic with an average of 6.3 polymorphic fragments per each primer and average of polymorphic information content (PIC) of 0.236. ISSR markers proved to be a powerful tool for assessment of genetic diversity among saffron accessions. Cluster analysis using unweighted pair group method with arithmetic mean (UPGMA), based on Jaccard's similarity coefficient and supported by the principal coordinate analysis (PCoA), divided the studied accessions into three major groups, and showed that genetic distance is independent of geographical distance (Lachheb *et al*., 2021).

The genetic divergence among selected lines was thoroughly investigated for the identification of elite divergent traits showing economic gains along with their contribution towards yield. Significant differences were observed among populations for all traits, including the multiplication index (MI) (3.0-5.0) with a mean of 3.8, the number of days to 50% sprouting (22-134) with a mean of 128 days, and the Big Corm Index (BCI) (6-15) with a mean of 10.42g, indicating the presence of a high level of variability and therefore imply considerable scope for saffron improvement via proper corm selection. Bigger corm size (8-12cm) indicates earlier and more persistent flowering, as well as big flower size, implying a direct effect on saffron yield, however, there was no effect on saffron quality. It was also observed that phenotypic variance estimation was greater than corresponding estimates of genotypic variance, indicating an environmental influence on trait expression. Genetic variability studies are critical for understanding the degree of variability and the potential for its future use in subsequent breeding programs (Irfan *et al*., 2022). Saffron is a unique plant in many aspects, and its cellular processes are regulated at multiple levels. The genetic makeup in the form of eight chromosome triplets ($2n = 3x = 24$) with a haploid genetic content (genome size) of 3.45 Gbp is decoded into different types of RNA by transcription. The RNA then translates into peptides and functional proteins, sometimes involving post-translational modifications too. The interactions of the genome, transcriptome, proteome and other regulatory molecules ultimately result in the complex set of primary and secondary metabolites of saffron metabolome. These complex interactions manifest in the form of a set of traits 'phenome' peculiar to saffron. The phenome responds to the environmental changes occurring in and around saffron and modify its response in respect of growth, development, disease response, stigma quality, apocarotenoid biosynthesis, and other processes. Understanding these complex relations between different yet interconnected biological activities is quite challenging in saffron where classical genetics has a very limited role owing to its sterility, and the absence of a whole-genome sequence. Omics-based technologies are immensely helpful in overcoming these limitations and developing a better understanding of saffron biology. In addition to creating a comprehensive picture of the molecular mechanisms involved in apocarotenoid synthesis, stigma biogenesis, corm activity, and flower development, omics-technologies will ultimately lead to the engineering of saffron plants with improved phenome (Husaini *et al*., 2022). As saffron is effectively sterile, it cannot generate genetic variation through recombination during sexual reproduction. Intriguingly, phenotypic differences are still accumulating in today's saffron accessions. After clonal selection, select a population of corms that was characterized by very different phenotypes. The majority of studies only detected insignificant amounts of genetic variability among saffron accessions, if at all, using molecular marker technologies (Kazemi-Shahandashti *et al.,* 2022).

A total of 272 saffron genotypes using multivariate analysis were analysed. We carefully observed and recorded information about the floral, morphological and corm attributes. Significant variations were observed among the genotypes for all the traits, indicating a high level of variability and suggesting a great potential for saffron improvement. The phenotypic variances were found to be greater than the estimated genotypic variances. Descriptive data on various morphological traits revealed significant differences in the frequency of phenotype classes as well as a wide distribution range. The high heritability estimates were observed in average number of daughter corms per plant (ANDCPP), initial weight of corms (IWC g), no. of buds/corm (NBPC), – no. of leaves in main sprout, (NLMS), number of sprouted buds per corm (NSBpC) and total number of leaves (TNL), whereas average weight of daughter corms per plant (AWBCPP), corm diameter (CDcm), pistal length (PL) cm, style length (STYLcm), fresh weight of pistals per plant (FWOPPPmg) and stigma length (STML cm), revealed medium sense of heritability. The traits dry weight of pistals per plants (DWOPPP mg), inner tepal width (ITW cm), leaf length (LLcm), number of flowers per corm (NFpC), outer tepal length (OTLcm), parianth length with tube (PLWT cm) and weight of stigma (WSTG mg) exhibited low broad-sense heritability. Principal component analysis (PCA) divulged that the first eight component characters had an eigenvalue greater than one with a contributory cumulative variance of 66.15% to the total variance, while as rest of the 16 components contributed 33.85% of total variation in a set of 272 genotypes of saffron. The eigenvalues for yield attributing traits for significant PCs ranged from 5.48 (PC1) to 1.03(PC8). The current study has revealed that there was a sufficient variability in a set of saffron germplasm lines which forms the

basis for performance-based clonal selection. Moreover, identified elite genotypes based on saffron yield and corm attributes could be used in the saffron breeding programme for the development of saffron varieties (Iqbal *et al*., 2023).

The investigation comprised of 35 germplasm lines of saffron *(Crocus sativus L.)* conducted. Observations were recorded on morphological, yield, and quality traits for the assessment of genetic variability and other parameters. The findings revealed significant differences among germplasm lines, indicating substantial variability across all traits. Phenotypic coefficient of variation consistently exceeded the genotypic coefficient of variation (GCV) for all characters, with stigma length exhibiting the highest PCV (25.24%) and GCV (24.08%), while the number of days taken to first flush demonstrated the lowest PCV (1.84%) and GCV (1.66%). The study reported high broad-sense heritability for all traits, ranging from 75.1% for corm diameter to 99.2% for the number of leaves. Notably, safranal content, stigma length, and fresh weight of pistil displayed the highest heritability and genetic advance over mean. Correlation analysis revealed significant associations, with dry weight of stigma exhibiting positive correlations with various traits, including pistil length, stigma length, and safranal content, while displaying negative correlations with outer tepal width, inner tepal width, and number of leaves per corm/plant. Path coefficient analyses underscored the importance of traits such as pistil length, fresh weight of pistil, stigma length, and style length and the UPGMA clustering method categorized saffron genotypes into five clusters. The study reports the morphological characterization and genetic variability of diverse saffron genotypes, which could be used for future saffron breeding programs especially clonal selection from the available germplasm resources is of prime importance (Fazil *et al.,* 2024).

BREEDING

Germplasm

Recentlya consortium, composed of 14 groups of 9 EU and non-EU countries has taken the responsibility of creating and maintaining the genetic variability of saffron.The, European Commission has approved a projecton “Genetic Resources of Saffron and Allies (*Crocus* spp.): CROCUS- BANK” to reate, characterize and exploit a germplasm col- lection (bank) in *Crocus* species. There is a need to establish a germplasm bank of saffron in India (preferably in the state of J&K) for collection and reproduction of saffron bulbs from all the areas that cultivate saffron in India. This plant material can then be used in selection programmes all over the country and serve as sources of resistance and other agronomically interesting traits to be transferred between saffron clones through appropriate breeding programmes and technological tools. These objectives can be achieved by a four-pronged strategy (Husaini *et al*., 2010):

- The collection of *Crocus* material by means of re- quests to different regional centres growing the plants and visiting specific locations at appropriate dates to collectboth cultivated saffron species and sub-species;
- Multiplication of collected plant material for conservation in the Plant Germplasm Bank using tissue culture techniques;
- Preparation of a list of descriptors for primary characterisa- tion of the collected material;
- Providing material to potential users by distribution of corms, tissue culture and DNAsamples

Breeding

Saffron is a triploid species with 3n=24, x=8 chromosomes. Its triploid nature allows for vegetative multiplication, but not regular sexual reproduction. This is because meiosis and gamete development in triploids are irregular, resulting in many anomalies in sporogenesis and gametophyte development. Manipulating seed to produce better plants has not been successful in cultivated saffron as meiotic abnormalities result in abnormal chromosome assortment and formation of an abnormal number of genetically imbalanced spores which vary in shape and size, leading to complete sterility. Moreover, corm multiplication does not induce genome variations with the exception of some mutations, which are not easily detectable in a triploid saffron population (Husaini *et al.,* 2010). Breeding for desirable features is much easier in fertile plants. 1) Although the plant is not self-fertile, some wild relatives can be successfully cross-pollinated with saffron pollen *in vitro* and form seeds. This creates fertile diploid plants containing genomic material from *C. sativus*, allowing new traits to be explored via further cross-pollination. 2) Chromosome doubling could in principle also create a fertile hexaploid plant. Such a change may be possible via colchicine. Corms of saffron crocus should be planted 10 cm apart and in a trough 10 cm deep. The flower grows best in areas of full sun in well-drained soil with moderate levels of organic content. The corms will multiply after each year, and each corm will last 3–5 years (Wikipedia, 2024c). Corms with different doses of gamma rays (Co^{60}) were subjected to induce the variability in Saffron. Five sets, each consisting of 100 uniform corms of 5-6 g in weight, were irradiated with 0.5, 1.0, 1.5, 2.0 and 2.5 krad doses of gamma rays (Khan, 2007). Throughout its history being cultivated for human use, saffron was selectively bred to produce longer stigmas. This breeding has resulted in a sterile plant that cannot reproduce without human assistance. The flowers do not produce seeds; the bulbs of the saffron crocus must be dug up and separated, then transplanted to begin new plants (Azafran, 2011). Phytochemically saffron is composed of volatile, non-volatile, and aromatic compounds, namely, crocin, crocetin, picrocrocin and safranal. Saffron is used as a spice for essence improvement and food preservative. The stigmas of saffron have good proportion of vitamin B2, which also adds to it yellow color besides the highly water-soluble compound crocin. It also contains many nonvolatile constituents like carotenoids, α and β- carotene, lycopene, and zeaxanthin. Saffron stigmas are characterized by a bitter taste and an iodoform or straw-like smell caused by chemicals picrocrocin and safranal .The major volatile compound of *C. sativus* is a carboxaldehyde called safranal produced by deglucosylation of picrocrocin. All these compounds of saffron find their prime importance in the field of medical sciences, yet the total potential of these compounds has not been ascertained completely. To unfold the medical powers of saffron, the bioactive attributes such as metabolomics, genomics, transcriptomics and proteomics provide an efficient way (Shafat, 2021). The genetic base of natural saffron populations around the world is very narrow and no significant improvement in productivity is expected through recurrent selection. Still, it would be worthwhile to continuously select well developed corms from a population for improved economically important characteristics like long red stigmas.

This method offers an advantage in maintaining the genetic characteristics of the plant, but it does not allow for making any genetic improvement (Husaini *et al.,* 2010).

Hybridization

C. sativus was generally assumed to be of autotriploid or hybrid origin. Now we have several data that support the alloploidy of *C. sativus* being the parents *C.cartwrightianus* and *C. hadriaticus*, both with 2n=16 and present currently in Greece but not in overlapping areas. Other possible parents, *e.g., C. thomasi*, from Italy and Croatia, *C. mathewii* from Turkey, and *C. pallasii* ssp. *haussknechtii* from Iran-Iraq-Jordan, cannot be excluded. The complexity of the evolutionary history of the genus crocus suggests an intensive species hybridisation and explosive speciation in crocus evolution that could be on the basis of the origin of saffron. We now are sure that saffron is an allopolyploid but the localization of the hybridisation event has not been ascertained so far. If the event took part several times could have generated different amphiploids and, in consequence, different saffron lines. In saffron the potential of the spore mother cells is limited by their triploid genome which causes meiotic abnormalities, followed by variations in sporogenesis and gametogenesis, as a result, abnormal gametophytes are generated. However, the reproductive system of the saffron, like that of fertile crocus species, supports inter-specific crosses with related species. This potential cross-compatibility opens the door to breeding programmes for genetic improvement of the saffron. It is therefore possible to transfer the traits from other species into the saffron through hybridization or change the ploidy level of this species through hybridization with close diploid relatives. History suggested that such events led to the development of this crop therefore those events can now further be used to intensify the improvement of this crop (Mir *et al.,* 2015).

Saffron Quality

According to the definition given by the Food and Agricultural Organisation (FAO), saffron forms "a loosely matted mass of dark, reddish-brown flattened threads, amongst which a few narrower yellow ones can be distinguished. The upper, enlarged part of the flattened threads is the stigma of the flower, the lower narrower portion is the style". The quality and consequently the commercial value of saffron are based on an estimation of colouring power, bitter taste and aroma. The quality of saffron is certified in the international trade market following the International Organisation for Standardisation (ISO) 3632 Normative since 1993. The ISO issued a specific standard for saffron ISO 3632 in 1975, revised it in 1980 and technically im- proved it in 1993. In ISO 3632 1&2 (1993) trade standard definitions as well as requirements for saffron quality and methods of analysis are given as follows (Husaini *et al*., 2010):

- Saffron in filaments are the stigmas of *Crocus sativus* Linneaus, dried, dark red in colour and trumpet shaped, serrated or indented at the distal end. The length is between 20 and 40 mm. The stigmas may be isolated or joined in pairs or threes at the end of the portion of the style, which is white/yellow in colour;
- Saffron in cut filaments are the stigmas of *C. sativus* with styles removed and completely detached from each other;
- Colouring strength is mainly due to its crocin content, as measured by its optical density at about 440 nm;
- Bitterness is mainly due to its picrocrocin content, as measured by its optical density at about 257 nm;
- Flavour is mainly due to its safranal content, as measured by its optical density at about 330 nm.

In India, the agency that sets up and guards the quality standards of saffron products is the Bureau of Indian Standards (BIS), and 'saffron specification' is defined in IS5453: Part 1 (1996), which is equivalent to ISO 3632-1 of 1993, and 'saffron methods of test' are defined in IS 5453: Part1(1996),which is identical to ISO 3632-2 of 1993. Following the saffron test method as defined in IS 5453: Part 1 (1996), various samples of saffron from Kashmir have been analyzed, which indicated a wide range of test values for various parameters (Husaini *et al*., 2010).

Uses

In milk and milk desserts, saffron is used as a flavour and coluring component. It's used as season cheese, mayonnaise, and meat, among other things. In Mughlai cuisine, they are utilized as a flavoring and seasoning agent. It is used to treat arthritis, infertility, liver enlargement, and fever in Ayurveda. It's a common ingredient in perfumes and cosmetics (Staff , 2021). Saffron is a temperate, medicinal and low growing herb. Its dried stigma is used as bio-medicine, dyes and perfumes. All allies of genus *Crocus* are diploid but *Crocus sativus* L. is a triploid in genetic makeup (2n = 3x = 24). Due to triploidy, meiosis in *C. sativus* is highly erratic and genetically unbalanced gametes are formed which lead to the formation of sterile gametes and ultimately no sexuality is involved which is an essential phenomenon for seed production. Due to absence of sexuality in Saffron, a non conventional mutation breeding was initiated to develop improved mutants of Saffron at Horticulture Research Centre, Chaubatia, Almora, India, located in the Himalayan region. As per reports, since the pre-historic times, the medicinal potential of the *C. sativus* are well documented. In the present scenario, saffron water extract (carotenoid) have proven with medicinal potential to treat cancer, cerebrovascular and cardiovascular complications . It is also reported to have various other activities in different parts of the world *e.g.* in Middle East, it is reported to be used as antispasmodic, aphrodisiac, carminative, cognition enhancer, emmenagogue and thymoleptic in traditional Chinese system of medicine, saffron was used to treat amenorrhea, high-risk deliveries, menorrhagia and postpartum lochiostasis. In Indian system of medicines, saffron was used to treat the disease of bronchitis, fever, headache, sore throat and vomiting. Various pharmacological activities are also reported in saffron *viz.* antihypertensive activity, anticonvulsant activity, antitussive activity, anti-inflammatory action of saffron, antioxidant activity of saffron. Besides the medicinal importance, saffron is being used as a spice (regarded as all-time king of spice world), as a dye, as perfume, in food industry (Manjunath *et al*., 2023).

Saffron is used extensively in the cuisines of various cultures. For instance, the spice is commonly found in the cuisines of Arabia, Central Asia, Europe, India, Iran, and Morocco. Nowadays, saffron is used to add colour and taste/flavour to dishes such as paella in Spain, bouillabaisse in France, *Risotto alla Milanese* in Italy. and to traditional Cornish saffron cakes

and loaves in England. In India, saffron is an essential commodity that is found in high-quality, milk/cream-based confectionaries and Mughlai dishes where it imparts a rich colour and distinctive flavour. Saffron is also used in Indian milk-based sweets such as *gulab* jamun, *kulfi*, *double ka meetha*, and saffron *lassi*, a spicy yogurt-based drink originally from Jodhpur . Meanwhile, in Japan, saffron is typically used to enhance the taste and appearance of fish (giving the latter a golden-yellow hue) (Spence, 2023). Nowadays, however, the growing interest in natural (colouring) ingredients has led to something of a resurgence in the spice's popularity. For instance, there has been a recent growth of interest in the use of saffron to provide a natural colour to a wide range of processed foods (*e.g.,* such as wheat flour pasta) and dairy products. Given that the only parts of the crocus flower that is currently used are the tiny stigma, a number of researchers have understandably turned their attention to the question of whether other parts of the flower, such as the terpals, can also be processed to deliver bioactively valuable products such as flavonoids and anthocyanins (Spence, 2023).

Saffron is used both to flavor and color a wide range of foods and is popular in many European and Asian cuisines. In Europe, it is the key flavoring ingredient in Spanish *paella* , French *bouillabaisse*, Italian *risotto alla Milanese*, English saffron cakes, and Swedish holiday breads. In central and Northern Asia, saffron flavors rice dishes such as North Indian *biryani* and Persian *tachin*. Popular Indian sweets such as *kheer* (rice pudding), *ras malai* (cheese curd balls in spice sweetened cream), *kulfi* (India frozen dessert), and *zarda* (boiled sweet rice dish) are often flavored with saffron. In Arabic countries, visitors are welcomed with a drink prepared from coffee, saffron, and cardamom. In Japan, it is employed to enhance the taste of fish and give it a golden-yellow color (Resources, 2024). Saffron has a long history of use in traditional medicine. Saffron has also been used as a fabric dye, particularly in China and India, and in perfumery. It is used for religious purposes in India. Saffron's aroma is often described by connoisseurs as reminiscent of metallic honey with grassy or hay-like notes, while its taste has also been noted as hay-like and sweet. Saffron also contributes a luminous yellow-orange colouring to foods. Saffron is widely used in Persian, Indian, European, and Arab cuisines. Confectioneries and liquors also often include saffron. Saffron is used in dishes ranging from the jewelled rice and *khoresh* of Iran, the Milanese *risotto* of Italy, the *paella* of Spain, the *bouillabaisse* of France, to the *biryani* with various meat accompaniments in South Asia. Saffron is also used in the preparation of the *Golden Ham*, a precious dry-cured ham made with saffron from San Gimignano. Common saffron substitutes include safflower (*Carthamus tinctorius*, which is often sold as "Portuguese saffron" or "açafrão"), annatto, and turmeric (*Curcuma longa*). In Medieval Europe, turmeric was also known as "Indian saffron" because of its yellow-orange colour Saffron has a long history of use in traditional medicine. Saffron has also been used as a fabric dye, particularly in China and India, and in perfumery. It is used for religious purposes in India (Wikipedia, 2024). In the culinary world, saffron is a prized ingredient: Middle Eastern Cuisine: Integral to dishes like Persian *Tahdig* and Moroccan *Tagine*. Spanish Paella: Infusing the rice with its distinct flavor and vibrant hue**.** Italian Risotto alla Milanese: Enhancing the dish with its unique taste. Saffron's versatility makes it a staple in many kitchens worldwide, reflecting its rich history and diverse applications (Zar, 2024). The stigmas of the flower are used as the culinary spice saffron. It is also used for health purposes, especially in traditional Asian medicine - owing to biologically active chemical compounds (mainly alkaloids, anthocyanins, carotenoids, flavonoid, phenolic, saponins, and terpenoids) saffron causes among others mood-enhancing effect (including persons with major depressive disorder). Depending on the size of harvested stigmas, the flowers of between 50,000 and 75,000 individual plants are required to produce about 1 pound of saffron; each corm produces only one or two flowers, and each flower produces only three stigmas. Stigmas should be harvested mid-morning when the flowers are fully opened. Saffron crocus can be used as an ornamental (Wikipedia, 2024c).

CULTIVATION

The triploidy of saffron crocus results in a disturbed meiosis leading to at least partial sterility. As result of erroneous chromosome pairing, meiosis progresses only incompletely and yields abnormal pollen. In consequence, cross-fertilization between *C. sativus* and other species is limited. Nevertheless, as the *C. sativus* pollen tube is incapable to penetrate the *C. sativus* ovule, a self-incompatible species was suggested as the most likely progenitor. Although pollen infertility is higher than the ovule sterility, irregular chromosome arrays also occur in megaspores, making them genetically unbalanced and infertile. Along the same lines, haploid gametes with a whole set of chromosomes only infrequently form in triploids; another cause of saffron's sterility. Similarly, there have been no reports of hexaploid saffron that may have emerged from triploid saffron as it was occasionally observed for other triploid plant species that used hexaploidization as a route to regain fertility. Therefore, the vegetative propagation by daughter corms is considered as the only way of saffron reproduction. Nevertheless, the multiplication rate of daughter corms reduces saffron productivity, rendering high-quality propagation material crucially important (Kazemi-Shahandashti *et al.,* 2022).

The saffron crocus, unknown in the wild, probably descends from *Crocus cartwrightianus*. It is a triploid that is "self-incompatible" and male sterile; it undergoes aberrant meiosis and is hence incapable of independent sexual reproduction—all propagation is by vegetative multiplication via manual "divide-and-set" of a starter clone or by interspecific hybridisation. *Crocus sativus* thrives in the Mediterranean maquis, an ecotype superficially resembling the North American chaparral, and similar climates where hot and dry summer breezes sweep semi-arid lands. It can nonetheless survive cold winters, tolerating frosts as low as −10 °C and short periods of snow cover. Some reports suggest saffron can tolerate an air temperature range from −22 to 40 °C. Irrigation is required if grown outside of moist environments such as Kashmir, where annual rainfall averages 1,000–1,500 mm; saffron-growing regions in Greece (500 mm annually) and Spain (400 mm) are far drier than the main cultivating Iranian regions. What makes this possible is the timing of the local wet seasons; generous spring rains and drier summers are optimal. Rain immediately preceding flowering boosts saffron yields; rainy or cold weather during flowering promotes disease and reduces yields. Persistently damp and hot conditions harm the crops, and rabbits, rats, and birds cause damage by digging up corms. Nematodes, leaf rusts, and corm rot pose other threats. Yet *Bacillus subtilis* inoculation may provide some benefit to growers by speeding corm growth and increasing stigma

biomass yield (Wikipedia, 2024). The plants fare poorly in shady conditions; they grow best in full sunlight. Fields that slope towards the sunlight are optimal (*i.e.,* south-sloping in the Northern Hemisphere). Planting is mostly done in June in the Northern Hemisphere, where corms are lodged 7–15 cm deep; its roots, stems, and leaves can develop between October and February. Planting depth and corm spacing, in concert with climate, are critical factors in determining yields. Mother corms planted deeper yield higher-quality saffron, though they form fewer flower buds and daughter corms. Italian growers optimise thread yield by planting 15 cm deep and in rows 2–3 cm; depths of 8–10 cm optimise flower and corm production. Greek, Moroccan, and Spanish growers employ distinct depths and spacings that suit their locales (Wikipedia, 2024). *C. sativus* prefers friable, loose, low-density, well-watered, and well-drained clay-calcareous soils with high organic content. Traditional raised beds promote good drainage. Soil organic content was historically boosted via application of some 20–30 tonnes per hectare (9–13 short tons per acre) of manure. Afterwards, and with no further manure application, corms were planted. After a period of dormancy through the summer, the corms send up their narrow leaves and begin to bud in early autumn. Only in mid-autumn do they flower. Harvests are by necessity a speedy affair: after blossoming at dawn, flowers quickly wilt as the day passes. All plants bloom within a window of one or two weeks. Stigmas are dried quickly upon extraction and (preferably) sealed in airtight containers (Wikipedia, 2024). The high retail value of saffron is maintained on world markets because of labour-intensive harvesting methods, which require some 440,000 hand-picked saffron stigmas per kilogram– equivalently, 150,000 crocus flowers per kilogram. Forty hours of labour are needed to pick 150,000 flowers. One freshly picked crocus flower yields on average 30 mg of fresh saffron or 7 mg dried; roughly 150 flowers yield 1 g of dry saffron threads; to produce 12 g of dried saffron, 450 g of flowers are needed; the yield of dried spice from fresh saffron is only 13 g/kg. When saffron is dried after its harvest, the heat, combined with enzymatic action, splits picrocrocin to yield D–glucose and a free safranal molecule. Safranal, a volatile oil, gives saffron much of its distinctive aroma. Safranal is less bitter than picrocrocin and may comprise up to 70% of dry saffron's volatile fraction in some samples (Wikipedia, 2024).

As a sterile triploid, *C. sativus* is unknown in the wild and relies upon manual vegetative multiplication for its continued propagation. Because all cultured individuals of this plant are clonal, there is minimal genetic diversity from the single domestication event, making it quite hard to find cultivars with new, potentially beneficial properties, l*et al*one combine them by breeding. Cultivars of saffron are nevertheless produced by a number of means: 1) Clonal selection. Any plant with a desirable mutation is kept and further grown. This is the traditional approach. 2) Mutation breeding. Mutagenesis can be used to cause a wide range of mutations to select from. The traditional clonal process follows. 3) Sexual reproduction (Wikipedia, 2024c).

Crocus sativus is a triploid sterile plant, propagated through rhizomes. The rate of natural propagation is very low and is widely being cultivated in different parts of the world. At the flowering stage, the flowers are being hand-picked and allowed to dry under shade conditions. This method is very traditional and is reported as poor method, because it leads to reduction of saffron production, which is considered as responsible for its high economic value. In India, cultivation of *C. sativus* is restricted to Jammu and Kashmir State only and is reported from its both Provinces. The glittering saffron of Pampore is very famous in Kashmir Province but the saffron cultivated in Kishtwar vale also maintained its charm in Jammu Province. Overall the Jammu and Kashmir based saffron is world famous due to its quality. The annual consumption of saffron in India from all sources is reported to be 5 to 6 tons. But due to receding cultivating land of the saffron and utilizing conventional cultivation practices, the production of the world famous saffron is in danger. At *in vivo* level the efficiency of daughter corms generation was reported very low. So, it is believed that to propagate the saffron bulbs is not an easy job that is why, its propagation rate is receding. Some people suggested *in vitro* techniques to generate the propagating material at large scale, but at practical level no efficient protocol is available to achieve this target. Utilizing various tissues of the saffron as an ex-plant, shoot generation of saffron plant was also reported but with very low frequency. To enhance the potential capabilities to cultivate saffron to get the maximum yield, various biotechnological approaches (considered as most feasible techniques) were employed (Dar *et al*., 2017).

Saffron crocus bulbs, known as corms, are typically planted in June in the Northern Hemisphere. Corms are lodged 7-15 cm deep in well-drained, friable clay soils rich in organic content. Proper spacing and depth are crucial for optimal yields. The saffron crocus thrives in Mediterranean climates, tolerating temperatures from -10 °C to 40 °C. During the growth period, irrigation is necessary if natural moisture is insufficient. By October, the crocus flowers bloom, displaying hues from light pastel lilac to dark mauve. Each flower produces three vibrant crimson stigmas—the precious threads harvested for saffron (Zar, 2024). Traditional methods of harvesting saffron are labor-intensive and require precision: Timing: Farmers hand-pick each flower at dawn when blooms are fresh and open. Technique: Delicate stigmas are carefully separated from the flower using meticulous hand-picking techniques. Volume: Approximately 150,000 flowers are required to produce just one kilogram of dried saffron, underscoring the intensive labor involved. Farmers have honed these traditional methods over centuries, ensuring that the delicate stigmas retain their quality and potency from field to table (Zar, 2024).

The saffron harvest: Between mid and late October, the largest *Crocus sativus* bulbs will begin to flower. Depending on the weather conditions, the period in which new flowers emerge from the ground lasts about three weeks. The saffron harvest can begin during this period, with the entire flower usually picked when it has just opened. It is often said that the flowers are best picked early in the morning before the flowers open, but we think that is a bit nonsense. Besides the fact that it is difficult to pick unopened flowers properly and undamaged, the pistils in the flower will be slightly longer when the flower is open, so that they are easier to remove later (Cardone *et al.*, 2020).

Each corm of saffron produces one flower. Each flower produces three red stigmas. These stigmas are what you'll harvest to receive the saffron. The reason saffron is so sought after is because it takes around 60 bulbs to produce a single tablespoon of the spice. Every two to three years, you must divide each corm you plant. This is important because each corm produces more of itself beneath the soil. This cycle will

continue over the years, and you could have plenty of saffron at your disposal. You should harvest saffron when the bloom of the plant has opened completely. It's best to harvest in the morning on a dry day. Use a pair of tweezers to pluck the stigmas from each open flower. You may dry the stigmas and store them in a warm location within a sealed container until you're ready for use (Poindexter, 2024).

The stripping of the saffron flowers: After the opened flowers have been picked, they are often spread out on a table, after which the pistils can be manually removed from the flower. Each flower has three stigmas that are attached to each other with their white ends. Because the best saffron consists only of the red part of the pistils, also called the stigmas, it is best to throw away the part where the pistil changes from red to light yellow and white. In the end, you will only have the beautiful red parts that you then collect in a container or on a dish (Cardone *et al*., 2020).

The drying of the saffron pistils: When enough stigmas have been collected, we can start drying. Make sure that the stigmas that are harvested are dried on the same day to avoid loss of quality. Saffron flowers that have not yet been stripped can be kept refrigerated for several days, although this is not preferred. Drying saffron stigmas can be done in different ways. The most traditional way is to roast the stigmas over hot coals or a wood fire. You can do this by spreading them out on a very fine mesh grid and roasting them over the heat source until the saffron threads are sufficiently dry. Fortunately, nowadays there are more modern ways of drying herbs that are easier to control. For example, you can spread the fresh threads on an oven grid lined with baking paper and let them dry in the middle of a (convection) oven. At a temperature of about 50 to 60 degrees Celsius, drying takes between 15 and 30 minutes, depending on the type of oven and the amount you are drying at a time. The saffron is dry when it feels slightly crispy and no longer sticks together. The threads then have a vibrant dark red color with dark orange edged ends. There are also special spice dryers on the market that are very suitable for drying saffron threads (Cardone *et al.,* 2020).

The conservation and storage of the saffron threads: After the saffron threads have dried, they should be packed airtight, for example in a glass jar or a tightly closed tin. Store the saffron in a cool, dry and dark place and it will be ready to use after about a month. Saffron can be kept for one and a half to two years without loss of quality (Cardone *et al*., 2020). Saffron will not spoil, but will lose flavour within six months if not stored in an airtight, cool and dark place. Freezer storage can maintain flavour for up to two years (Wikipedia, 2024).

Major Regions of Production: Today, saffron is produced in several key regions: Iran: Known for its high-quality saffron with deep red stigmas and strong aroma. Spain: Producers like La Mancha are famous for their aromatic and slightly milder saffron. India: Particularly Kashmir, where the saffron is prized for its dark maroon-purple hue and robust flavor. Each region's specific climate and soil conditions contribute to subtle variations in flavor and color, making regional saffron unique (Zar, 2024).

Exploring Regional Variations in Saffron Production: Saffron's unique qualities vary significantly depending on its region of production. Here's a closer look at some of the most notable varieties: Iran dominates the global saffron market, producing around 88% of the world's supply. Known for its deep red color and potent fragrance, Iranian saffron is often considered the gold standard. The stigma threads are long and thick, offering a robust flavor profile. Spanish saffron, particularly from the La Mancha region, is renowned for its mellow aroma and flavor. Spanish varieties are usually graded by government standards into categories like Coupe and Mancha, ensuring consistent quality. This saffron is used extensively in dishes like paella. Kashmiri saffron stands out with its dark maroon-purple hue and earthy notes. It's one of the rarest and most expensive types, prized for its high crocin content, which imparts a vibrant color to dishes. Kashmiri saffron is a staple in Indian cuisine. Afghan saffron has gained recognition for its quality, rivalling even the best Iranian saffrons. Grown primarily in Herat province, it features slender threads with an intense aroma and taste. Afghan saffron has become a significant player in the global market due to its excellent quality (Zar, 2024).

Saffron market in Mashad, Iran: Almost all saffron grows in a belt from Spain in the west to India in the east. Iran is responsible for around 88% of global production. In 2018, Iran cultivated an area of 43,408 ha producing 174 tonnes from a productivity of 4 kg/ha. Afghanistan comes second, which produced over 67 tons in 2023. Spain is the third largest producer, while the United Arab Emirates, Greece, the Indian subcontinent and Morocco are among minor producers. According to the statistics for saffron trade in 2019, Iran was ranked as the world's largest producer of saffron, supplying 430 tons of the total 450 tons of saffron produced worldwide and is expected to reach 500 tons in 2020. India, producing only 22 tons of saffron annually, ranked second. Other countries reported based on their share in global saffron production included Greece (7.2 tons), Afghanistan (6 tons), Morocco (2.6 tons), Spain (2.3 tons), Italy (1 ton), China (1 ton), and Azerbaijan (0.23 ton) (Wikipedia, 2024).

Production and price of saffron: Saffron consisting of the stamen of the blue-purple crocus flower, is often described as the world's most expensive spice, as well as the most adulterated spice in history. The majority of saffron (c. 80–94%) is grown in Iran. Iran is the main global producer contributing more than 160 tons a year. India contributes 5% of the world production (in Pulwama and Budgam districts), with lesser contributions from Afghanistan, Greece, Morocco, Spain, and Italy. The only way to harvest saffron is by hand with between 70,000 and 200,000 flowers needed in order to produce 1 kg of dried saffron threads. Each stigmata of saffron weighs approximately 2 mg and each flower contains three stigmata. As such, 150,000 flowers must be carefully picked by hand, in order to produce 1 kg of the spice. Harvesting the flowers and separating the stigmas is very time consuming. 45–55 min are typically needed to pick 1000 flowers, while another 100–130 min are required to remove the stigmas for drying. This equates to a total of around 370–470 h of work per kg of dried saffron (Spence, 2023).

Appearance: High quality saffron is intensely red in color. The major components responsible for the coloring strength of saffron are compounds called "crocins" which are highly water soluble (Resources, 2024).

Flavor Characteristics: Astringent, bitter, cardboard, earthy/dirty, musty, plastic, tea, and woody (5). Some sources

also describe saffron as having an "iodine-like" quality. Tasting Notes. Saffron contains between 0.3-0.8% volatile oils. A compound called "safranal" is the principal substance responsible for the aromatic profile. Up to 150 other volatile components round out the complex aroma and flavor of saffron (Resources, 2024).

Grades: Saffron is not all of the same quality and strength. Strength is related to several factors including the amount of style picked along with the red stigma. Age of the saffron is also a factor. More style included means the saffron is less strong gram for gram because the colour and flavour are concentrated in the red stigmas. Saffron from Iran, Spain and Kashmir is classified into various grades according to the relative amounts of red stigma and yellow styles it contains. Grades of Iranian saffron are: *sargol* (Persian : red stigma tips only, strongest grade), *pushal* or *pushali* (red stigmas plus some yellow style, lower strength), "bunch" saffron (red stigmas plus large amount of yellow style, presented in a tiny bundle like a miniature wheatsheaf) and *konge* (yellow style only, claimed to have aroma but with very little, if any, colouring potential). Grades of Spanish saffron are *coupé* (the strongest grade, like Iranian sargol), *mancha* (like Iranian pushal), and in order of further decreasing strength *rio*, *standard* and *sierra* saffron. The word *mancha* in the Spanish classification can have two meanings: a general grade of saffron or a very high quality Spanish-grown saffron from a specific geographical origin. Real Spanish-grown La Mancha saffron has PDO protected status and this is displayed on the product packaging. Spanish growers fought hard for Protected Status because they felt that imports of Iranian saffron re-packaged in Spain and sold as "Spanish Mancha saffron" were undermining the genuine La Mancha brand. Similar was the case in Kashmir where imported Iranian saffron is mixed with local saffron and sold as "Kashmir brand" at a higher price. In Kashmir, saffron is mostly classified into two main categories called *mongra* (stigma alone) and *lachha* (stigmas attached with parts of the style). Countries producing less saffron do not have specialised words for different grades and may only produce one grade. Artisan producers in Europe and New Zealand have offset their higher labour charges for saffron harvesting by targeting quality, only offering extremely high-grade saffron. Under ISO 3632, determination of non-stigma content ("floral waste content") and other extraneous matter such as inorganic material ("ash") are also key. Grading standards are set by the International Organization for Standardization, a federation of national standards bodies. ISO 3632 deals exclusively with saffron and establishes three categories: III (poorest quality), II, and I (finest quality). Formerly there was also category IV, which was below category III. Samples are assigned categories by gauging the spice's crocin and picrocrocin content, revealed by measurements of specific spectrophotometric absorbance. Safranal is treated slightly differently and rather than there being threshold levels for each category, samples must give a reading of 20–50 for all categories. However, many growers, traders, and consumers reject such lab test numbers. Some people prefer a more holistic method of sampling batches of threads for taste, aroma, pliability, and other traits in a fashion similar to that practised by experienced wine tasters (Wikipedia, 2024).

Major Saffron Production states in India: Jammu & Kashmir and Himachal Pradesh are the two most important producing states. Kesar in Hindi, Kong in Kashmiri, Jafran in Bengali, Zafran in Punjabi, Keshar in Gujarati, Zafran in Urdu, Asra, Aruna, Asrika, Kunkuma in Sanskrit are some of the native names (Staff , 2021).

Adulteration: Despite attempts at quality control and standardisation, an extensive history of saffron adulteration, particularly among the cheapest grades, continues into modern times. Adulteration was first documented in Europe's Middle Ages, when those found selling adulterated saffron were executed under the *Safranschou* code. Typical methods include mixing in extraneous substances like beetroot, pomegranate fibres, red-dyed silk fibres, or the saffron crocus's tasteless and odourless yellow stamens. Other methods included dousing saffron fibres with viscid substances like honey or vegetable oil to increase their weight. Powdered saffron is more prone to adulteration, with turmeric, paprika, and other powders used as diluting fillers. Adulteration can also consist of selling mislabelled mixes of different saffron grades. Thus, high-grade Kashmiri saffron is often sold and mixed with cheaper Iranian imports; these mixes are then marketed as pure Kashmiri saffron, a development that has cost Kashmiri growers much of their income. Safflower is a common substitute sometimes sold as saffron. The spice is reportedly counterfeited with horse hair, corn silk, or shredded paper. Tartrazine or sunset yellow have been used to colour counterfeit powdered saffron. In recent years, saffron adulterated with the colouring extract of gardenia fruits has been detected in the European market. This form of fraud is difficult to detect due to the presence of flavonoids and crocines in the gardenia-extracts similar to those naturally occurring in saffron. Detection methods have been developed by using HPLC and mass spectrometry to determine the presence of geniposide, a compound present in the fruits of gardenia, but not in saffron (Wikipedia, 2024).

Toxicity: Ingesting less than 1.5 g of saffron is not toxic for humans, but doses greater than 5 g can become increasingly toxic. Mild toxicity includes dizziness, nausea, vomiting, and diarrhea, whereas at higher doses there can be reduced platelet count and spontaneous bleeding (Wikipedia, 2024).

REFERENCES

Alonso, G.L., Zalacain, A. and Carmona, M. 2012. Saffron. In: Handbook of Herbs and Spices (Second Edition), Volume 1, Editor K.V. Peter.

Azafran. 2011. About The Saffron Plant. https://www.azafran.com/saffron.html

Babaei, S., *et al*., 2014. Analysis of genetic diversity among saffron (Crocus sativus) accessions from different regions of Iran as revealed by SRAP markers. Scientia Horticulturae, 171:27–31

Baraghani, A. 2018. What Is Saffron, the World's Most Legendary Spice?. https://www.bonappetit.com/story/what-is-saffron

Bayat, M., *et al*., 2016. Determining the most effective traits to improve saffron (*Crocus sativus* L.) yield. Physiol Mol Biol Plants, 22(1): 153–161.

Caiola, M.G. 2004. Saffron Reproductive Biology. Acta Hortic. 650: 25-37

Cardone, L., *et al*., 2020. Saffron (Crocus sativus L.), the king of spices: An overview. Scientia Horticulturae, 272(3):109560

Cardone, L., *et al*., 2020. Saffron (*Crocus sativus* L.), the king of spices: An overview. Scientia Horticulturae, 272: 109560. https://doi.org/10.1016/j.scienta.2020.109560Get rights and content

Crampton, L. 2023. Crocuses: Beautiful Flowers, Saffron Spice, and Colchicine. Gardening Channel. *https:// owlcation.com/stem/ Crocus-Beautiful-Flowers-Saffron-Spic…*

Dar, R.A., *et al*., 2017. Cultivation, distribution, taxonomy, chemical composition and medical importance of *Crocus sativus.* The Journal of Phytopharmacology, 6(6): 356-358

Fazil, S., *et al*., 2024. Estimation of Genetic Variability in Saffron (*Crocus sativus* L.) Germplasm for Morphological and Quality Traits. Journal of Scientific Research and Reports 30 (6):745-63.

Field, L. 2023. Most Of The World's Saffron Comes From One Country (And It's Not India). https://www.foodrepublic.com/1424218/origin-history-saffron-iran/

Gedik, A., *et al*., 2017. Genetic diversity of crocus sativus and its close relative species analyzed by iPBS-retrotransposons. Turkish J Field Crops, 22(2): 243-252 Ghaffari, S.M. 2022. Cytogenetics of saffron (Crocus sativus), a natural autotriploid species; an investigation on the reasons for its sterility. Iranian Journal of Botany, 28 (1): 57-63

GIAHS. 2012. Saffron heritage site of kashmir in india. GIAHS Saffron Site Report (Part-1). https://openknowledge.fao.org/server/api/core/bitstreams/faca1326-c8be-4a9b-ac83-abad5130673e/content

Hanief, M. 2022. Saffron- the "Red Gold' of Kashmir. https://www.greaterkashmir.com/opinion/saffron-the-red-gold-of-kashmir/

Husaini, A.M. 2020. A Value Chain of Saffron in New Areas of NW Himalayas by Engaging Youth and Women for Strengthening a Bio-Based Green Economy. https://nmhs.org.in/pdf/Progress_Reports/Annual_Report_2020/Project/118.DR.AMJAD%20M.HUSAINI/Saffron%20Tissue%20Culture%20Manual_F

Husaini, A.M., Kamili, A.N., Wani, M.H., Silva, J.A.T. and Bhat, G.N. 2010. Sustainable Saffron (*Crocussativus*Kashmirianus)Production: Technological and Policy Interventions for Kashmir. Functional Plant Science and Biotechnology. ©2010GlobalScienceBooks

Husaini, A.M., Haq, S.A. and Jiménez, A.J.L. 2022. Understanding saffron biology using omics- and bioinformatics tools: stepping towards a better *Crocus* phenome. Mol Biol Rep., 49: 5325–5340

Iqbal, A.M., *et al*., 2023. Genetic variability assessment of indigenous and exotic saffron germplasm through morpho-agronomic characterization at Jammu and Kashmir, India. In: Plant Genetic Resources, 21(5): 389-398.

Irfan, M., *et al*., 2022. Corm size determination and genetic variability studies in Saffron (*Crocus sativus* L.). Emer Life Sci Res., 8(2): 186-191

Javan, I.Y. and Gharari, F. 2018. Genetic Diversity in Saffron (Crocus sativus L.) Cultivars Grown in Iran Using SSR and SNP Markers. J. Agr. Sci. Tech., 20: 1213-1226

Kazemi-Shahandashti, S.S., Mann, L., El-nagish, A., Harpke, D., Nemati, Z., Usadel, B. and Heitkam, T. 2022. Ancient Artworks and Crocus Genetics Both Support Saffron's Origin in Early Greece. Front. Plant Sci. 13:834416.*doi: 10.3389/fpls.2022.834416*

Khan, I.A. 2007. Development of high yielding saffron mutant. Acta Hortic. 739: 255-257 DOI: 10.17660/ActaHortic.2007.739.31

Krishnaswami, S. 1986. Mulberry Cultivation in South India. Central Sericultural Research & Training lnstitute, Mysore.

Kumar,A., *et al*., 2022. Introduction of high-value *Crocus sativus* (saffron) cultivation in non-traditional regions of India through ecological modelling. Scientific Reports 12(1): 11925

Lachheb, M., *et al*., 2021. Genetic diversity analysis of Moroccan saffron (*Crocus sativus* L.) of different origins based on intermicrosatellite markers. Journal of Applied Horticulture, 23(3): 242-248.

Machii, H., Koyama, A. and Yamanouchi, H. 2024. Mulberry breeding, cultivation and utilization in Japan. https://www.fao.org/4/X9895E/x9895e05.htm

Manjunath, K.K., Harshitha, B.S., Anusha, N.M. and Bhargavi, H.A. 2023. Breeding for mulberry improvement: A review. The Pharma Innovation Journal 2023; 12(2): 477-481

Mir, J.I., Ahmed, N., Singh, D.B.. Khan, M.H., Zaffer, S. and Shafi, W. 2015. Breeding and biotechnological opportunities in saffron crop improvement. African Journal of Agricultural Research, 10(9): 970-974

Mir, M.A., *et al*., 2021. Deciphering genetic diversity analysis of saffron (*Crocus sativus* L.) using RAPD and ISSR markers. Saudi J Biol Sci., 28(2): 1308–1317.

Mogili, T., Sarkar, T., Gnanesh, B.N. 2023. Mulberry Breeding for Higher Leaf Productivity. In: Gnanesh, B.N., Vijayan, K. (eds) The Mulberry Genome. Compendium of Plant Genomes. Springer, Cham. https://doi.org/10.1007/978-3-031-28478-6_3

NLM. 2021. Crocus sativus (saffron crocus). https://pubchem.ncbi.nlm.nih.gov/taxonomy/Crocus-sativus#section=Consolidated-References

Pandit, U. 2021. Kashmiri Saffron: The Story of the World's Sweetest, Most Expensive Spice.

Poindexter, J. 2024. How to Grow Saffron Crocus Flowers (*Crocus sativus*). Gardening Channel.

PRP. 2019. Saffron comes from Attica -- origin of the saffron crocus traced back to Greece. Molecular Phylogenetics and Evolution. *10.1016/j.ympev.2019.03.022*

Qadri, H., *et al*., 2013. Genetic diversity in saffron (*Crocus sativus* L.). Journal of Spices and Aromatic Crops, 22 (2) : 228–232

Resources. 2024. Saffron. https://www.mccormick scienceinstitute.com/resources/culinary-spices/herbs-spices/saffron

Rogers, K. 2024. Saffron. The Editors of Encyclopaedia Britannica. https://www.britannica.com/topic/saffron

Saxena, R.B. 2010. Botany, Taxonomy and Cytology of *Crocus sativus* series. Ayu, 31(3): 374–381

Shafat, A.M. 2021. Chapter 7 - Cytogenetic and bioactive attributes of *Crocus sativus* (Saffron): a tool to unfold its medicinal mystery. Pp 145-167. In: Medicinal and Aromatic Plants

Shahandashti, S.S.K., *et al*., 2022. Ancient Artworks and *Crocus* Genetics Both Support Saffron's Origin in Early Greece. Front Plant Sci., 13: 834416

Shokrpour, M. 2019. Saffron (*Crocus sativus* L.) Breeding: Opportunities and Challenges. In: Al-Khayri, J., Jain, S., Johnson, D. (eds) Advances in Plant Breeding Strategies: Industrial and Food Crops. Springer, Cham. https://doi.org/10.1007/978-3-030-23265-8_17

Staff , K.J. 2021. Saffron Cultivation: A Complete Information. Krishi Jagran. Saffron Cultivation: A Complete Information - Search (bing.com)

Soukrat, S., *et al*., 2017. Boosting saffron (*Crocus sativus* L.) micro-propagation through in vitro corm production. Acta Horticulturae, 1184: 87-96

Spence, C. 2023. Saffron: The colourful spice. International Journal of Gastronomy and Food Science, 34: 100821. https://www.sciencedirect.com/science/article/pii/S1878450X23001634

Srivastava, R., *et al*., 2010. *Crocus sativus* L.: A comprehensive review. Pharmacogn Rev., 4(8): 200–208.

Sunder, K. 2020. Red gold: The rich tradition of Kashmiri saffron. https://asia.nikkei.com/Life-Arts/Life/Red-gold-The-rich-tradition-of-Kashmiri-saffron

Verma, M.K., , Mir, J.I. and Yasmeen, S. 2024. Floral Biology and Breeding Approaches in Saffron (Crocus sativus L.) Improvement. In:Souvenir and Abstract for conference on seed spices and allied crops, Ajmer, Rajastan

Wikipedia. 2024. Saffron. From Wikipedia, the free encyclopedia. https://en.wikipedia.org/wiki/Saffron

Wikipedia. 2024a. History of saffron. From Wikipedia, the free encyclopedia. https://en.wikipedia.org/ wiki/ History_of_saffron

Wikipedia. 2024b. The history of saffron. https://en.wikipedia.org/wiki/History_of_saffron. https://www.sativus.com/en/saffron/history/?srsltid=AfmBOopjR6QruK9XER6CSmgd49ghtArJD8IDSIFeRDn

Wikipedia. 2024c. *Crocus sativus.*From Wikipedia, the free encyclopedia. https://en.wikipedia.org/wiki/Crocus_sativus

Zar, A. 2024. Where Does Saffron Come From? The Ultimate Guide. https://saffronice.com/blogs/saffron-value-heritage/where-does-saffron-come-from

****