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REVIEW ARTICLE

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

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

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

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Corresponding author:
K.R.M. Swamy

ABSTRACT

Cumin belongs to the family Apiaceae (Carrot family), genus *Cuminum* and species *Cuminum cyminum.* The English name of cumin is derived from the old English Cymene, from Latin 'Cuminum' which is the Romanization of the Greek 'Kuminon', cognate with Hebrew kammon, Arabic Kammun. Forms of this word are attested in several ancient semitic languages, including Kamunu in Akkadian. The ultimate source is the Sumerian word Gamun. The earliest attested form of the word Kuminon is the Mycenaean Greek Ku-mi-on, written in Linear B syllabic script. The term comes via Middle English *comyn*, from Old English *cymen* (which is cognate with Old High German *kumin*) and Old French cummin, both from the Latin term *cuminum*. This in turn comes from the Ancient Greek κύμινον (*kúminon*), a Semitic borrowing related to Hebrew כמון (*kammōn*) and Arabic (*kammūn*). All of these ultimately derive from Akkadian (*kamūnu*). Common names for Cumin in • Assamese: Jira • Bengali: Jira • Gujarati: Jirum • Hindi: Jeera • Kannada: Jeera, Jeerige • Manipuri: Jira • Marathi: Jire • Tamil: Jeerakam • Urdu: Zeera. Cumin (Cuminum cyminum), commonly known as 'Jeera' or 'Zeera' is an important spice used in Indian kitchens for flavouring various food preparations. It is the second most popular spice in the world after black pepper. It is very pungent and aromatic, and is used whole and/or ground. Though Cumin is a native of Egypt, it is mostly produced in India. India is the largest producer of cumin in the world. Cumin's aromatic, nutty-flavoured seeds come in three colours: amber (the most widely available), white and black (both found in Asian markets). White cumin seed is interchangeable with amber, but the black seed has a more complex, peppery flavour. Cumin is one of the main ingredients in curry powders, and the combination of cumin and coriander leaves gives a characteristic smell to most Indian food. India produces 70% of the world supply and consumes 90% of that (which means that India consumes 63% of the world's cumin). Other producers are Syria (7%), Iran (6%), and Turkey (6%). The remaining 11% comes from other countries. In total, around 300,000 tons of cumin per year is produced worldwide. USA, European Union, Middle East, South East Asia are the major export markets for Indian Cumin Seed. The cumin prices are also sensitive to the international demand and supply. Thus the production in the other countries like Turkey and Syria affects the export prices and volume of Zeera. In India, cumin seed is almost exclusively cultivated in Rajasthan and Gujarat. It grows abundantly in the mild, equable climate of Gujarat and Rajasthan where rich, well drained, sandy, loamy soil and the sunny conducive environment are available. Thus Gujarat and Rajasthan are the two main production centres in India. They contribute more than 90% of total cumin production in the country. Rajasthan is the largest producer of cumin seeds contributing about 50-55% of the total production of India. Cumin is a spice made from the dried seed of a plant known as *Cuminum cyminum*, which is a member of the parsley family**.** It's an ancient spice grown in Egypt and the Middle East. In fact, it has been found in 4,000-year-old excavations in Syria and ancient Egypt used as both a cooking spice and for mummification purposes. Cumin also appears in both the Old Testament and the New Testament. Since ancient times, cumin has been used in India and by the Greeks and Romans, making its way into various cuisines all around the world. Both whole and ground cumin are used in cooking. Whole seeds are often featured in Indian dishes, often added to hot oil at the beginning of cooking to infuse the oil and add flavor to the rest of the ingredients. Lightly roasted whole seeds over a pan will bring out the full cumin flavor. Whole seeds can be kept in the freezer over a long period to maintain their flavour. Ground cumin does not need heat or time for the flavor to be released. However, once the seeds are ground, the cumin will gradually lose its flavor over time and should be replaced regularly. Ground cumin should be stored in a cool, dark place and will last up to 6 months. In this review article on Origin, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding and Cultivation of Cumin are discussed.

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INTRODUCTION

Cumin belongs to the family Apiaceae (Carrot family), genus *Cuminum* and species *Cuminum cyminum* (Agarwal *et al*., 2017; Bansal *et al*., 2014; NWE, 2024; Wikidoc, 2024; Wikipedia, 2024). The English name of cumin is derived from the old English Cymene, from Latin 'Cuminum' which is the Romanization of the Greek 'Kuminon', cognate with Hebrew kammon, Arabic Kammun. Forms of this word are attested in several ancient semitic languages, including Kamunu in Akkadian. The ultimate source is the Sumerian word Gamun. The earliest attested form of the word Kuminon is the Mycenaean Greek Ku-mi-on, written in Linear B syllabic script (Gh. Amin, 2012). The term comes via Middle English *comyn*, from Old English *cymen* (which is cognate with Old High German *kumin*) and Old French cummin, both from the Latin term *cuminum*. This in turn comes from the Ancient Greek κύμινον (*kúminon*), a Semitic borrowing related to Hebrew כמון (*kammōn*) and Arabic (*kammūn*). All of these ultimately derive from Akkadian (*kamūnu*). The English word is traditionally pronounced *KUM-in*, like "coming" with an □n□ instead of ⟨ng⟩ (/ŋ/). American lexicographer Grant Barrett notes that this pronunciation now is rarely used, replaced in the late 20th century by hyperforeignized *KYOO-min* and *KOO-min* (Wikipedia, 2024). The English "cumin" came from the the French "cumin" that was borrowed indirectly from Arabic "Kammon " through Spanish "comino" during the Arab rule in Spain in the fifteenth century. This makes sense because this spice is native to Syria (an Arabic speaking country) where cumin thrives in its hot and arid lands. Cumin seeds have been found in some ancient Syrian archaeological sites. The word found its way from Syria to neighboring Turkey and nearby Greece most likely before it found its way to Spain, but like many other Arabic words in the English language, cumin was acquired through Western Europe rather than the Greece route. Some theories suggest that the word is derived from the Latin *cuminum* and Greek κύμινον, however, this is unlikely. The Greek term itself has been borrowed from Arabic. Forms of this word are attested in several ancient Semitic languages, including *kamūnu* in Akkadian. The ultimate source is a native Syrian language that could be the Sumerian word *gamun.* A folk etymology connects the word with the Persian city Kerman, where, the story goes, most of ancient Persia's cumin was produced. For the Persians, the expression "carrying cumin to Kerman" has the same meaning as the English language phrase "carrying coals to Newcastle." Kerman, locally called "Kermun," would have become "Kumun" and finally "cumin" in the European languages. In India and Pakistan, cumin is known as *jeera* or *jira* or sometimes *zira*; in Iran and Central Asia, cumin is known as *zira*; in Turkey, cumin is known as *kimyon*; in northwestern China, cumin is known as *ziran*. In Arabic, it is known as *al-kamuwn*. Cumin is called *kemun* in Ethiopian (NWE, 2024). The English form is derived from the Latin *cuminum* and Greek κύμινον. The Greek term itself seems to have been borrowed from a Semitic source; forms of this word are attested in several ancient Semitic languages, including Akkadian. The ultimate source seems to be the Sumerian word *gamun*. A folk etymology connects the word with the Persian city Kerman, where, the story goes, most of ancient Persia's cumin was produced. For the Persians the expression "carrying cumin to Kerman" has the same meaning as the English language phrase "carrying coals to Newcastle". Kerman, locally called *Kermun*, would have became *Kumun* and then cumin in the European languages. In India and Pakistan, cumin is known as *jeera* or *jira*; in Iran and Central Asia, cumin is known as *zira*; in northwestern mainland China, cumin is known as *ziran*. In Arabic, it is known as *kamuwn* (Wikidoc, 2024). The English "cumin" is derived from the Old English via Latin *cuminum*[3] from the Greek κύμινον (*kyminon*), which is related to Hebrew (*kammon*) and Arabic (*kammūn*) (Wiki, 2024). Superstition during the Middle Ages cited that cumin kept chickens and lovers from wandering. It was also believed that a happy life awaited the bride and groom who carried cumin seed throughout the wedding ceremony. Cumin is also said to help in treatment of the common cold, when added to hot milk and consumed (Wikidoc, 2024).

Table 1. International Names (Agarwal *et al.,* 2017)

Names	Language	Country/Region
Comino, Comin hortense	Spanish	Spain
Cumin, Cumin blanc	French	France
Romischer Kummel	German	Germany
Spiskummin	Swedish	Sweden
Kamoun, Kamun	Arabic	Northwestern Arabia
Komijn, Djinten	Dutch	West Germanic
Comino	Italian	Italy
Cominho	Portuguese	Portugal
Jira	Nepali	Nepal
Kumin, Umazeri	Japanese	Japan
Zi ran	Chinese	China
Zirch, Zirch Sabz	Farsi	Western Iranian
Kmin, Kumin	Russian	Russia
Jira, Safaid Jeera, Zeera	Hindi	India
Green cumin, White cumin	English	England, USA, New Zealand

Table 2. Indian Names (Bansal *et al.*, 2014).

Language	Name
Hindi	Jira, Safaid Jeera, Zeera
Punjabi	Jira, Safaid Jeera
Bengali	Jeere
Gujarati	Jeeru
Kannada	Jeerige
Kashmiri	Zyur
Malayalam	Jeerakam
Marathi	Jeregire
Oriya	Jeera
Sanskrit	Jiraka, Jeera
Sindhi	Zero
Tamil	Ziragum
Telugu	Jidakara, Jikaka

Common names for Cumin in • Assamese: Jira • Bengali: Jira • Gujarati: Jirum • Hindi: Jeera • Kannada: Jeera, Jeerige • Manipuri: Jira • Marathi: Jire • Tamil: Jeerakam • Urdu: Zeera (Prajapati, 2024).

Cumin a herbaceous, annual and medicinal which is one of the most important export crops for countries such as India , Iran and some other Asian countries (Bahraminejad *et al.,* 2011). Economic value of cumin is the numerous uses of the seeds as a drug and spicy for about a thousand years ago. It is regarded as part of food culture in West Asia, a predominant habitat of this plant. Therefore, trade and consumption of the crop is almost limited to natural areas that produce it (Bahraminejad *et al.,* 2011). The areas of production create numerous business opportunities because the planting operations of cumin require many human resources, thus create employment prospects in those regions (Bahraminejad *et al*., 2011). Cumin yield components include number of umbel per plant, number of seeds per umbel and 1000-seed weight. The number of umbel per plant explained alone about 96% of yield variation (Bahraminejad *et al.,* 2011). Different regions of cumin adaptation can vary in terms of yield and genetic components due to variation in genetic characteristics and ecological influence. Therefore, geographical and genetic diversity play a related role in cumin characteristics (Bahraminejad *et al.,* 2011). Cumin is allogam due to its protandery nature. One significant advantage of cumin which was compared to other crops is its high harvest index; an increase in this index in terms of agronomy can increase production of other parameters in cumin (Bahraminejad *et al.,* 2011). Cumin aldehyde is a major merger in the composition of cumin essence with chemical formula C10H12O (Para Iso Propel Benzaldehyde, molecular weight of 148.13 g) and it constitutes 63% of the total essence. Cumin aldehyde has a powerful dour and is used only in traces in compounding synthetic floral perfumes such as cassie (Bahraminejad *et al.,* 2011). Plant genetic diversity is created over thousands of years in nature to remain stable. Masses of native plants are germplasem for appropriate eugenics programs (Bahraminejad *et al.,* 2011). It is imperative that researchers tirelessly work and provide information on Gene banks collection, identification, and evaluation for the protection of gene pool and plant masses. Agriculture and food production also depends on the use of plant genotypes (Bahraminejad *et al.,* 2011).

With prevalence to synthetic drugs, traditional medicine was forgotten but in recent decades because of the appearance of some problems and introduced side effects about chemical material, utilization of vegetable drugs in all over the world is lionized (Baghizadeh *et al*., 2013). Traditional medicine has an ancient root in Iran. Achaemenian age; Tasmanian dynasty age and especially after currency of Islam till Mogul age are of luminary ages for traditional medicine in Iran (Baghizadeh *et al.,* 2013). Nowadays, the tributary of traditional medicine to cure patients by plants is lionized is most of its other tributaries (Baghizadeh *et al.,* 2013). In our villages, utilization of this plants whether in pharmaceutical or additive form as aromatic spice is common yet.Apiaceae family because of having pharmaceutical and food plants are considered as very important (Baghizadeh *et al*., 2013). In a division, three kinds of known green cumin in the world, they are: Iranian cumin, Indian cumin. and Middle east cumin. In another division, the kinds of green cumin are: *Cuminum cyminum* : In some references it is mentioned as "caraway", It is an annual plant with a red petal and fruits having tiny downs; *Bunium persicum* : In some references and in public, it is mentioned as black cumin, it is a perennial plant and has corm; *Carum carvi* : In some references, it is mentioned as European cumin and in some other references as black cumin. This species has annual, biennial and perennial plants; *Pesamigyton setifolium* : In some references,it is mentioned as a subspecies of *Cuminum cyminum*.It is an annual plant that has been lionized recently and has a white petal with fruits having long downs (Baghizadeh *et al.,* 2013). English name of this plant is cumin, that its source is Greek word "kymynon".The origin of this plant is Egypt, but it has been cultivated in Arabian countries, India, China, Iran and Mediterranean area since olden times (Baghizadeh *et al.,* 2013). Based on numerous reports, chromosomal set of *Cuminum cyminum* is : 2n=14 in somatic cells and n=7 in gametic cells (Baghizadeh *et al.,* 2013). The utilizable part of this plant is its fruit

that includes resin 13%, oil 7%, essence 2.5-4% and aleurone.Essence is obtained by the distillation of crushed fruits and is colorless or yellowish and adhesive. Special smell of essence and fruit is because of having cuminol (CH10H12O), but there is another material as in cymene, phellandrene, carvone in it (Baghizadeh *et al.,* 2013). Also the meal of green cumin is rich and includes carbohydrate 26%, protein 18.7%, oil 10%, a little of calcium, phosphorus and amin (Baghizadeh *et al*., 2013).

Cumin with chromosome number of 2n= 2x= 14 is an economically and pharmaceutically important small herb of family Apiaceae (Kumar *et al.,* 2015). It is mainly cultivated in India, Iran, Syria, Pakistan and Turkey (Kumar *et al.,* 2015). It is widely used in foods, beverages, liquors, medicines, toiletries and perfume industries (Kumar *et al.,* 2015). The mature dried fruit contains 2–5% essential oil (Kumar *et al.,* 2015). Though it is an important plant among seed spices, it suffers with various inherent problems. Low germination rate and poor seedling establishment are one of the major problems in cumin (Kumar *et al*., 2015). Similarly, being a monotypic species, phenotypic and genetic variability in cumin is also low. Because of which there is no source of resistance available against biotic (Alternaria blight and Fusarium wilt) and abiotic (frost and salinity) stresses. The flowers being small and slender restricts possibilities of artificial pollination creating hinders in following recombination breeding for genetic improvement. Consequently, most of the varieties available today are developed by selections (Kumar *et al.,* 2015). The genu Cuminum is derived from the Greek word *kuminon ,* itself probably derived from the Babylonian ku-mu-na (Kumar *et al.,* 2015). Cumin or jeera with medicinal, pharmaceutical and nutraceutical properparties (Kumar *et al.,* 2015). Origin of cumin is still in dispute but it is native to northern Africa and has spread via West Asia to Central Asia (Kumar *et al.,* 2015). It is one of the old cultivated food herbs in Asia, Africa and Europe (Kumar *et al.,* 2015). The crop is mostly grown in Morocco, Turkey, Greece, Egypt, Iran and the southern part of the Mashad province (Kumar *et al.,* 2015). The chief cumin exporters are India, Syria, Pakistan, and Turkey while India and the USA are main oil producers (Kumar *et al*., 2015). Cumin is extensively used in foods, beverages, liquors, medicines, toiletries and perfumes (Kumar *et al.,* 2015). It is grown in the mild climate of Gujarat, Rajathan, Hayana, Madhya Pradesh, and Uttar Pradesh (Kumar *et al*., 2015). Its seeds have been commonly used forv culinary and flavour (Kumar *et al*., 2015). Globally India is largest producer (70%) as well as cosumer of cumin (Kumar *et al.,* 2015). Bangladesh, Brazil, Japan, Malaysia, Nepal, Singapore, the UAE, the UK, the USA are chief importer of Indian cumin (Kumar *et al.,* 2015).

Cumin is an annual herbaceous flowering plant belonging to family Apiaceae, also known as the Umbelliferae family. Cumin is native from the East Mediterranean to South Asia and today, grown all over the world for its pleasantly aromatic seeds (Agarwal *et al*., 2017). Cumin has been found to possess various pharmacological activities such as immunomodulator, anti-diabetic, anti-microbial, anti-fungal, analgesic, hepatoprotective, anti-osteoporotic, anti-oxidant, anti-inflammatory, anti-asthamatic, anti-stress, anti-infertility, dietary fibre, anti-cancer, blood platelet aggregation, anti-tussive activities and also has ophthalmic effects due to the presence of various chemical constituents (Agarwal *et al.,* 2017). It contains 2.5 to 4.5% volatile oil, 10% fixed oil and proteins. Volatile oil mainly consists of 30 to 50% cuminaldehyde, small quantities of α-pinene, β-pinene, phellandrene, cuminic alcohol, hydrated cuminaldehyde and hydro cuminine which make it suitable for medicinal purpose (Agarwal *et al.,* 2017). Cumin (*Cuminum cyminum*) is an annual herbaceous flowering plant belonging to family Apiaceae, also known as the Umbelliferae family. Cumin is native from the East Mediterranean to South Asia and today, grown all over the world for its pleasantly aromatic seeds (Agarwal *et al*., 2017). The only species in its genus, cumin depend on the seed source. Its seeds are used in the cuisines of many different cultures. The aromatic substances present in these herbs have attracted the enormous attention of researchers worldwide to experimentally validate the therapeutic uses of cumin seeds, which are documented in several indigenous healing systems (Agarwal *et al*., 2017). Seed spices are known as gold in arid and semi arid areas of India. In India seed spices are mostly grown in Rajasthan, Gujarat, besides these two states, seed spices are also grown in Uttar Pradesh, Madhya Pradesh, Punjab, Haryana and some parts of South India. India is the largest producer, consumer and exporter of seed spices in the world. The states, Rajasthan and Gujarat have together contributed more than 80 % of the total seed spices production of the country (Verma *et al*., 2017). The total area under cumin is around 701560 ha with the production of 372290 tonnes. The chief cumin exporters are India, Syria, Pakistan and Turkey, while India and the USA are main cumin oil producers. The total export of seed spices is worth of more than Rs 2800 crore annually out of which cumin alone contributed more than Rs 1500 crore (Verma *et al*., 2017). Cumin is an annual herbaceous spice cum medicinal plant. It belongs to family apiaceae and has basic chromosome number 2n=14 (Verma *et al*., 2017). Cumin is mentioned as an essential ingredient of many traditional dishes. In Ayurvedic system of medicine, dried cumin seeds are used for therapeutic purposes. It is known for its activities like enhancing appetite, taste perception, digestion, vision, strength and lactation. It is used to treat diseases like fever, loss of appetite, diarrhea, vomiting, abdominal distension, edema and puerperal disorders. It is one of the oldest cultivated medicinal food herbs in Asia, Africa and Europe. Apart from India cumin is mostly grown in Morocco, Turkey, Syria, Greece, Egypt and the southern part of the Mashhad province, Iran. Progress in breeding programme of any crops depends on the extent and nature of variability existing in the base population (Verma *et al.,* 2017). Conventional methods based on selection of desirable genotypes have modified crops during the past decades and this has created awareness of the diversity of population and the first prerequisite step in improve plants. The plant breeding aspect of cumin is quite new due to limited research work conducted in that area (Verma *et al.,* 2017). Crop also suffer from lack of usable variation for important yield traits and disease resistance in the germplasm collection and even if present may not be used with ease on account of very small size of their flower, thus restricting the crop improvement programs. The chromosomes of the different varieties have morphological similarities and there is no distinct variation in length and volume (Verma *et al.,* 2017). Genetic enhancement of cumin is possible only by the methods of hybridization or induced mutation. Since, the variability naturally present in this crop is very low, so, induced mutation can be an option for improvement of this crop. Gamma rays have been used for induced variation for different traits like days to flowering, days to maturity and individual plant weight in cumin. Mutagenic efficacy and efficiency varied between crops, species and mutagens used. Gamma rays were relatively more potent mutagen on cumin as compared to other mutagens. Efficient mutagens more often yielded superior progenies in cumin *i.e.* progenies having significantly higher yield than their parent (Verma *et al*., 2017).

Due to their rich chemical composition in volatile and non-volatile constituents, spices are used for improve the taste and aroma of foods but also for medicinal and pharmaceutical purposes with a possible influence on human health. In countries like Malaysia, India, Sri Lanka, Indonesia spices are used mainly for food flavoring while in the West countries, 80-90% are used in the industrial sector with the main objective to protect food for oxidative deterioration and therefore, expanding the food shelf life (Simona *et al.,* 2018). Cumin is an aromatic plant from the *Apicaceae* family and its seeds has been used as a spice from ancient times, being mentioned also in the Bible. The seeds are used in cooking, while volatile oil it is useful in flavouring foods but also in cosmetics and perfume industries (Simona *et al*., 2018). Cumin , known as zeera, is an aromatic plant from the *Apicaceae* family and its seeds has been used as a spice from ancient times, being mentioned also in the Bible (Simona *et al*., 2018). It could be cultivated in the plains areas, semi-arid regions, but also in the hills, being resistant to water deficit and having a seeds production of about 12 000 tons per year (Simona *et al.,* 2018). Cumin has been originally cultivated in Iran, but it was also well known in Greece and ancient Rome, being introduced by Spanish and Portuguese colonists also in America. It was also found in the pyramids, indicating that is was known 5000 years ago by the Egyptians. Nowadays, India is the biggest consumer and the largest producer of cumin reaching 90% of the world's production (Simona *et al.,* 2018). The main components of cumin essential oil and seeds are cumin aldehyde, γ-terpinene, β-pinene, and ρ-Cymene, carvacrol, spathulenol, longifolene, but also phytochemicals like alkaloid, anthraquinone, coumarin, flavonoid, and glycoside (Simona *et al.,* 2018). The total phenolic content of cumin has been reported to reached the value of 53.6 mg/g dry weight with over 19 identified compounds which include flavonoids and phenolic acids. Flavonoids could reduce the lipid peroxidation and may have anticancer-effects (Simona *et al*., 2018). *Cuminum cyminum* may have positive effects on metabolic disorders like hyperglycemia, dyslipidemia, on weight reduction and could ameliorate insulin function, preventing the progression of diabetes described that cumin could have beneficial effect on digestion, flatulence, diarrhea and possess antioxidant and antispasmodic properties (Simona *et al.,* 2018). Cumin seeds and its oil are recognized by the literature as having antispasmodic, carminative, diuretic, antiseptic, antiinflammatory, antioxidant and stimulant properties (on digestive and secretory system) on the human body. Cumin oil could have antifungal activity against *Candida albicans*, which is responsible for the appearance of dental caries. Cumin oil is also involved in the increment of glutathione in human tissue up to 700%. Glutathione is a key for preventing body oxidative damage which may lead to diseases like cancer, dementia, cardiovascular disease (Simona *et al.,* 2018). Cumin have more than 100 different chemicals, including volatile oils and essential fatty acids. It contains also minerals like potassium, sodium, iron, calcium, phosphorus, sodium, vitamins like riboflavin, niacin, ascorbic acid and vitamin A (Simona *et al.,* 2018). In the past, in order to cover the lack of meat, cumin seeds have been used in food processing for flavoring bread and other dishes at ceremonial fasting thanks to its strong aromatic odor with a mild and bitter taste. Nowadays, cumin seeds are used in barbecue sauces, snack food, beverages, liquors and for flavoring cheese (Simona *et al*., 2018). Cumin powder it is used mainly in countries such as India, Iran, North Africa, Mexico where food is generally highly spiced. In Morocco it is used in association with lamb meat, in Mexico it is used as an ingredient for chili con carne, in Germany it is used in traditional German food like sausages, sauerkraut, pickles and Munster cheese, or can be added as a raw material for lime or lemon based marinades for pork, lamb, turkey, chicken meat (Simona *et al.,* 2018). Cumin seeds could be also added to coffee, tea, canned food, extracted for wine or vinegar and mixed with different types of honey in order to create new food items (Simona *et al.,* 2018). Cumin oil prevents the deterioration of butter being even more efficient than butylated hydroxytoluene a toxic and carcinogenic organic compound. Blends of cumin oil with coriander oil could lead to obtain oxidative-resistant oils, which are needed on deep fried and baked foods industry. In bakery industry, cumin oil showed antifungal activity leading to prolong the self-life of the final baked products (Simona *et al.,* 2018).

Cumin, commonly known as 'Jeera' or 'Zeera' is an important spice used in Indian kitchens for flavouring various food preparations. It is the second most popular spice in the world after black pepper (Dar *et al*., 2019). It is very pungent and aromatic, and is used whole and/or ground. Though Cumin is a native of Egypt, it is mostly produced in India. India is the largest producer of cumin in the world (Dar *et al.,* 2019). Cumin's aromatic, nutty-flavoured seeds come in three colours: amber (the most widely available), white and black (both found in Asian markets). White cumin seed is interchangeable with amber, but the black seed has a more complex, peppery flavour (Dar *et al.,* 2019). Cumin is one of the main ingredients in curry powders, and the combination of cumin and coriander leaves gives a characteristic smell to most Indian food (Dar *et al.,* 2019). India produces 70% of the world supply and consumes 90% of that (which means that India consumes 63% of the world's cumin). Other producers are Syria (7%), Iran (6%), and Turkey (6%). The remaining 11% comes from other countries (Dar *et al.,* 2019). In total, around 300,000 tons of cumin per year is produced worldwide. In 2007, India produced around 175,000 tons of cumin on an area of about 410,000 ha i.e. the average yield was 0.43 tons per hectare (Dar *et al.,* 2019). USA, European Union, Middle East, South East Asia are the major export markets for Indian Cumin Seed. In the international market, Nepal and Sri Lanka are the major importer preferring Cumin Seed of 95%-96% purity, whereas the European market has a strong preference for 100% purity for machine clean stocks (Dar *et al*., 2019). The main competitors in the international market are Turkey and Iran offering at cheaper rate. Though India is the largest producer of cumin seed, the country consumes most part of its produce and the rest is exported. Its produce commands premium prices in the global markets due to its quality and flavour (Dar *et al.,* 2019). The cumin prices are also sensitive to the international demand and supply. Thus the production in the other countries like Turkey and Syria affects the export prices and volume of Zeera (Dar *et al.,* 2019). India exports cumin seed to Bangladesh, Japan, Malaysia, Nepal, Pakistan, Singapore, South Africa, UAE, UK, USA and many other countries and cumin seed powder to Canada, UK, USA (Dar *et al.,* 2019). India also exports oleoresins of cumin seed and cumin seed oil to USA, UK, Germany, etc. Nepal was the largest importer of cumin seed from India in 2003 with 28.87% share of total exports, followed by USA (14.44%), UK (11.35%), Malaysia (9.76%), Singapore (6.51%) and Japan (6.24%) (Dar *et al*., 2019). In India, cumin seed is almost exclusively cultivated in Rajasthan and Gujarat. It grows abundantly in the mild, equable climate of Gujarat and Rajasthan where rich, well drained, sandy, loamy soil and the sunny conducive environment are available. Thus Gujarat and Rajasthan are the two main production centres in India. They contribute more than 90% of total cumin production in the country. Rajasthan is the largest producer of cumin seeds contributing about 50-55% of the total production of India (Dar *et al*., 2019). Gujarat is the second largest producer of cumin seeds. As per some of the

traders view, both the states produce almost equally. Due to cash payment, weight of commodity in front of farmers, lower market cess, high prices, availability of processors, exporters and brokers and better infrastructure facilities, a fairly large amount of Cumin arrives in Gujarat mandis for trading purpose (Dar *et al.,* 2019). In Gujarat, Banaskantha, Sabarkantha, Mehsana, Patan, Surendranagar and Rajkot are the major districts producing cumin seed, whereas in Rajasthan Badmer, Jalore, Nagaur, Pali, and Jodhpur are the main producing districts (Dar *et al.,* 2019). As per the trade, the annual demand for the Zeera is about 2000000 bags *i.e.* about 110000 tonnes. As India is the largest consumer of cumin seeds in the world, the remaining stock after consumption is meant for the export purposes. Zeera is an environmental sensitive crop (Dar *et al.,* 2019).

Cumin is often described as boasting a robust flavor profile that is warm and earthy with a spicy bittersweet aroma and light citrus overtones. Cumin is commonly compared to caraway seeds as a slightly spicier, and bitter alternative. Also possessing flavor similarities to its more expensive counterpart, Black Pepper, Cumin was often used (and bartered for) as a household spice and Black Pepper substitute in ancient Rome (Pacificspice, 2020). Cumin seeds are a pale, tan-green color with an oblong shape (like a tapered cucumber). They have nine raised ridges and oil canals around the perimeter that mark the seed length-wise. Seeds measure between ⅛ – ¼ inches long (Pacificspice, 2020). Unsurprisingly, cumin seeds are often mistaken for caraway seeds due to their strong resemblance and similar aroma. The most noticeable difference between the two is that cumin seeds are lighter in color and are covered in very fine, barely-visible, bristles (Pacificspice, 2020). Cumin is an ancient spice that was first made popular by the Greeks and Romans. In early times, it was tied to superstitions, utilized in home remedies, and was employed in religious and political ceremonies (Pacificspice, 2020). Peaking in popularity in Europe and Britain in the Middle Ages, cumin slowly lost prevalence in that market. However, it maintained stability in the Middle East, North Africa, and India as an essential spice in national dishes such as couscous, bhārta, chutney, and curry (Pacificspice, 2020). In recent times, the popularity of cumin has grown in the United States through the influence of Latin American cuisine. It is a staple seasoning south-of-the-border as a key ingredient in chili powder which is used generously in traditional dishes. In the United States, the most common use of it is in Mexican and Indian food (Pacificspice, 2020). Although color and flavor vary between regions, cumin flavor is *less* impacted by origin and *more* impacted by oil content (Pacificspice, 2020). Cumin seed ranges from 2-5% essential oil content, we source prime-quality seed that ranges from 3-5% to secure intense flavor. It's important to note that volatile oils dissipate over time and cause it to lose flavor. To guarantee our product stays fresher for longer, we import whole cumin and grind the seeds in-house (Pacificspice, 2020). Because we hold ourselves to the highest standard of quality and safety, we process and clean our product locally. Under our control, we ensure that our strict manufacturing methods far exceed the quality standards of U.S. food manufacturers. This results in product that is pure, free of contaminants and adulterants (Pacificspice, 2020). Cumin is a small annual herbaceous plant that is a member of the aromatic plant family (Apiaceae), also known as the Umbelliferae family. This plant was named the "best of condiments" in ancient Greece and well known due to its significant uses and has vast pharmaceutical significance (Chaudhry *et al*., 2020. Cumin is an essential spice, and the seeds of this plant are well used to add flavor to spicy dishes in almost all the culinary preparations (Chaudhry *et al*., 2020. The seeds of this plant and essential oil extracted from them are used in the food, perfumery, beverage, and drug sectors of industries (Chaudhry *et al*., 2020. Due to its essential oil components, cumin has a strong warm aroma and unique flavor. Its main constituent aroma compounds are cumin aldehyde and cumin alcohol. The extent of each of these chemical constituents varies depending on the type of species (Chaudhry *et al*., 2020. Furthermore, cumin seeds contain several phytochemicals that have several industrial applications that range from food to traditional value to pharmaceutical products (Chaudhry *et al.,* 2020.

Cumin is a seed spice which finds its place in variety of global cuisines, especially in Indian context. India leads in the world in production of cumin with 70% of world's production and consumes 90% of this produce (Brar *et al.,* 2022). It is a high potential crop with great demand around the world due to changing food consumption behavior, and increasing demand for value-added products such as oil and powder (Brar *et al.,* 2022). Cumin has a distinct flavor and aroma owing to presence of essential oils (Brar *et al.,* 2022). Cumin has different biological and biomedical properties and finds use in various ayurvedic preparations in different forms (Brar *et al.*, 2022). Cumin has been found in three types of colours: amber, white, and black. Among this amber is widely accepted and black also have unique flavour (Brar *et al.,* 2022). Cumin is a crop of tropical and subtropical regions and suitable for cultivation on wide variety of soils (Brar *et al.,* 2022). Cumin production can be easily done with very few hindrances such as frost injury, wilt and powdery mildew (Brar *et al.,* 2022). The cumin commonly known as Jeera is an important seed spice crop belonging to family Apiaceae of the order Apiales. It holds more than 22% share of area under spice crops, and is the most widely grown seed spice in India with an area share of more than 48% among seed spices (Brar *et al.,* 2022). In India cultivation of this spice is very popular in states of Rajasthan and Gujarat, along with some parts of Madhya Pradesh and Uttar Pradesh during Rabi season (Brar *et al.,* 2022). During 2019–20, cumin was cultivated on 8.42 lakh hectares in India with total production amounting to 5.47 lakh tonnes. Rajasthan and Gujarat are the leading producers and contribute to nearly 99% of the total production of India. India as a leading producer has a world market share of 70%, followed by Syria (13%), Turkey (5%), and UAE (3%) (Brar *et al.,* 2022). These four countries produce about 91% of cumin of the world, while the remaining production comes from other tropical or sub-tropical Asian and African countries (Brar *et al.,* 2022). Cumin as a condiment is vital in composition of mixed spices, curry powders, and it also imparts good flavour to soups, sausages, pickles (Brar *et al.,* 2022). Some of the bakery products such as breads and cakes are also seasoned with these seeds in Germany, while in some of the European countries it is used for flavouring cheese (Brar *et al*., 2022). This seed spice is an essential component of varied cuisines such as Iranian, Mexican, Turkish, Cuban, Indian, South East Asian and Egyptian (Brar *et al.,* 2022). Cumin is a regular feature in confectionary, beverages, medicines, liquors, sausages, meat, perfumery and bread manufacturing. In food processing industries cumin is used as a preservative (Brar *et al.,* 2022). Cumin oil has a characteristic flavour and odour due to the presence of falvour component called cuminaldehyde (Brar *et al.,* 2022). This seed spice possesses several medicinal properties such as stomachic, carminative, antimicrobial, stimulant, and astringent properties (Brar *et al.,* 2022).

Cumin according to some survey is the most popularly used spice in the world. A member of the family Apiaceae, it is a small herb with chromosome number of 2n = 2x = 14, and it is economically very important and its cultivation is a means of livelihood of millions in Gujarat and Rajasthan (Meena *et al*., 2023). Cumin is mainly cultivated in India, Iran, Syria, Pakistan, and Turkey. India is the largest producer and exporter. It is widely used in foods, beverages, liquors, medicines, toiletries, and perfume industries (Meena *et al*., 2023). The mature dried fruit contains 2–5% essential oil. Though it is an important plant among seed spices, it suffers from various inherent problems. Low germination rate and poor seedling establishment are one of the major problems in cumin. Similarly, being a monotypic species, phenotypic and genetic variability in cumin is also low, because of which there is no source of resistance available against biotic (*Alternaria* blight and *Fusarium* wilt) and abiotic (frost and salinity) stresses (Meena *et al.,* 2023). The flowers being small and slender restricts possibilities of artificial pollination, which hinders recombination breeding for genetic improvement. Consequently, most of the varieties available today are developed through selective breeding. Large number of efforts have been made in identification of bioactive constituents and verification of their pharmacological effects in animal systems. Cumin is one of the most widely used raw drug in the Indian system of medicine (Ayurveda) (Meena *et al.,* 2023). But as compared to cumin's classical breeding including mutagenesis, very less efforts have been made on molecular breeding. Therefore, practically no molecular tools are available and no genomics-based breeding programs for improvement of cumin have been initiated yet (Meena *et al*., 2023).

As I was making my Sunday rounds at the markets, I spotted a beautiful bunch of baby carrots and immediately I just wanted them to roll around in a warm bath of salted butter, cumin, and a titch of honey. So that's just what I did (Lee, 2023). Cumin is not only my favourite spice, but also a historically important one that has been used for thousands of years. Despite some articles you may have read, cumin, the brown little wormy-looking seeds, which are readily available in markets and supermarkets, is not the same spice used in the mummification process of ancient Egypt. This type of cumin is known as *Nigella sativa* or black cumin and has nothing to do with the brown cumin that is common in Latin, Indian, and Middle Eastern cuisines (Lee, 2023). From feasts in northern Iraq around the 9th Century to Ancient Greece and the Roman Empire, cumin has been documented to be used widely as a flavouring and natural medicine to cure or ease a variety of ailments such as digestive problems. From its origins in Mesopotamia, cumin moved through Europe as a spice, a medicine, and even as a currency in Medieval England where it was used to pay rent (Lee, 2023). The Colombian Exchange**, i**nstigated by Italian Explorer Christopher Columbus began in the late 15th Century and initiated the transference of many food products from the old world to the new and vice versa. Animals, plants, cotton, sugar, and spices were some of the products that were traded along this route, cumin was one of them that made the voyage and embedded itself into a variety of cuisines in the Americas (Lee, 2023). Despite being known as a spice, the cumin seed is actually a fruit derived from a small flowering plant technically known as *Cuminum cyminum* and is from the same family of dill, parsley, and carrot (no wonder they go so well together!) (Lee, 2023). The 'roasty' flavour of cumin has a slightly citrus tang on the tongue combined with warmth like cinnamon and invites complimentary spices like coriander, chilli, and turmeric. It is commonly used in savoury dishes but adds a wonderful layer of flavour to sweet dishes as well (Lee, 2023). It is a small but powerful seed that helps stimulate digestive enzymes, aids the body in absorbing minerals, and is also known as an anti-inflammatory. Hot cumin water with a dash of honey is a wonderful way to start the day. It is also an element of modern-day pharmaceuticals and is used in aromatherapy (Lee, 2023). From Mexico to India, Greece, and Turkey, cumin is one of the most widely used spices in cuisines around the world and adds a unique profile to any dish whether it be a soup, tagine, salad, or even tea! (Lee, 2023). Cumin is predominately grown in India, providing 70% of the seed to the world, however, it is also cultivated in North Africa, Turkey, the Mediterranean, Mexico, and the Middle East (Lee, 2023). Cumin was and still is an extremely important commodity that can be grown in arid to semi-arid terrain, which allows it to be subject to sustainable agricultural practices. It is, however, an extremely labour-intensive crop that is usually hand harvested 120 days from when the seed is planted (Lee, 2023). As with all ingredients put down before us, we should celebrate the history and the people who made it possible for us to be exposed to such diverse ingredients wherever we are in the world. Cumin, one of the first written recorded spices in the world is a special one and I encourage you to experiment with incorporating it in a recipe or two, enabling you to understand its wonderful flavour, warmth, and diversity (Lee, 2023).

This herb may be a heat loving annual, but it turns out that with a few simple considerations in mind, growing it is very doable – even at my home in Vermont! (Buckner, 2023). Cumin is a tender flowering annual in the parsley family, Apiaceae**,** that is grown for its seed. It is used in many different cuisines, and is one of the most popular spices in the world (Buckner, 2023). The seed has a warm, earthy, slightly bitter flavor that can enhance many different types of dishes. It is especially popular in Indian, Mediterranean, Middle Eastern, north African, and Mexican cuisines (Buckner, 2023). The plant grows 1 to 2 feet tall and produces umbels of fragrant pink or white flowers that appear in midsummer, amidst feathery foliage similar to dill – which can be added to salads (Buckner, 2023). The flowers are followed by the characteristic fragrant seeds, which mature in about 120 days after planting (Buckner, 2023). In addition to its flavorful seeds, the flowers attract beneficial insects such as lacewings, predatory wasps, and ladybugs. Planting it in your garden near crops that tend to suffer from pest infestations can help keep pesky insects under control (Buckner, 2023). Native to the eastern Mediterranean, parts of the Middle East, and India, cumin is a very popular aromatic herb with a long history of use as a culinary spice and as a medicine (Buckner, 2023). Seeds were used in ancient Egypt as both a spice and a preservative in mummification. Ancient Greeks kept it in shakers on the table, similar to the way black pepper is commonly used today (Buckner, 2023). Also noted for its medicinal properties, in ancient Rome and Greece, it was commonly prescribed to aid women's reproductive health (Buckner, 2023). It contains the active ingredient cuminaldehyde, a volatile oil with anti-inflammatory, antioxidant, and carminative properties (Buckner, 2023). Today, it is still used medicinally, particularly among practitioners of the Ayurvedic tradition. It is often taken as a tea, to help improve digestion, relieve bloating, and assist in the assimilation of fats into the body (Buckner, 2023). Since this herb is adaptable to a wide variety of climates, it is now grown in many different places, with the majority of the world's supply produced in India (Buckner, 2023).

Cumin is a flowering plant in the family Apiaceae. Cumin seeds impart distinctive strong flavor, and warm perception on taste buds. This comes from certain group of essential oils in them. It is used in the cuisines of many different cultures, in both whole and ground form. It also has many uses as a traditional medicinal plant (Indiacuminseed, 2024). Cumin seed or 'Jeera' in Hindi is an oblong shaped, sharp flavored and dark colored aromatic spice. It is actually the dried fruit of an annual, thin-stemmed cumin plant, which belongs to parsley family. The plant has a short height of 25-30 centimeters and has white to red colored flowers. These flowers produce the fruits for the plant that are consumed all over the world as a flavoring agent in whole or grounded form. Cumin seed is also known for its curing characteristics and hence it is used in many herbal and Ayurvedic medicines (Indiacuminseed, 2024). Cumin is a drought-tolerant, tropical, or subtropical crop. It has a growth season of 100 – 120 days. The optimum growth temperature ranges are between 25 and 30° C. The Mediterranean climate is most suitable for its growth. Cultivation of cumin requires a long, hot summer of three to four months. At low temperatures, leaf colour changes from green to purple. High temperature might reduce growth period and induce early ripening. In India, cumin is sown from October until the beginning of December, and harvesting starts in February. In Syria and Iran, cumin is sown from mid-November until mid-December (extensions up to mid-January are possible) and harvested in June/July (Indiacuminseed, 2024). Although the small cumin seed looks rather unassuming, it packs a punch when it comes to flavor, which can be described as penetrating and peppery with slight citrus overtones. Cumin's unique flavor complexity has made it an integral spice in the cuisines of Mexico, India and the Middle East. Cumin seeds resemble caraway seeds, being oblong in shape, longitudinally ridged, and yellow-brown in color. This is not surprising as both cumin and caraway, as well as parsley and dill, belong to the same plant family (Umbelliferae). Cumin is available both in its whole seed form and ground into a powder (Indiacuminseed, 2024). Traditionally, it has also been used in natural remedies and herbal medicine. Traditional texts describe its use as a diuretic and to settle the stomach and stop flatulence. Like many herbs, it can be made into a poultice, especially for swelling or sore throat. Cumin seeds are used in cooking and the oil is used to flavor food and scent cosmetics. Components may have antioxidant, anticancer, antibacterial, and larvicidal effects. Cumin may lower blood sugar, reduce seizures, strengthen bones, and treat the eye (Indiacuminseed, 2024). India's production sums up to 1 to 2 lakh tons of cumin seeds per year that makes it the leading producer in the world. The country also has the largest area allotted towards cumin seeds production i.e. around 5.25 lakh hectares. The level of production and the total area under cumin seeds cultivation has increased significantly during the last few years. India exports around 8000 tons of cumin seed every year (Indiacuminseed, 2024). The main producer and consumer of cumin is India. It produces 70% of the world supply and consumes 90% of that (which means that India consumes 63% of the world's cumin). Other producers are Syria (7%), Iran (6%), and Turkey (6%). The remaining 11% comes from other countries. In total, around 300,000 tons of cumin per year is produced worldwide (Indiacuminseed, 2024). Cumin Seed is extensively used in culinary practices of the Indian Subcontinent and some other Asian, African and Latin American countries as a condiment or spice. Most of the cumin seeds are exported to the countries that do not produce cumin seed themselves and make huge markets for this spice. The major Cumin Seed consuming countries are India, USA, Mexico, Portugal, Spain, Turkey, China, Japan, Netherlands, Singapore, France and Morocco (Indiacuminseed, 2024).

Cumin seeds are used as a spice for their distinctive aroma. They are available in whole seed and ground forms. Cumin's distinctive flavor and strong, warm aroma is due to its essential oil content. Its main constituent and important aroma compound is cuminaldehyde (4-isopropylbenzaldehyde). Important aroma compounds of toasted cumin are the substituted pyrazines, 2-ethoxy-3-isopropylpyrazine, 2-methoxy-3-*sec*-butylpyrazine, and 2-methoxy-3-methylpyrazine (NWE, 2024). This spice is popular in North African, Middle Eastern, Western Chinese, Indian, Cuban, and Mexican cuisine. The flavor of cumin also plays a major role in Thai and Vietnamese cuisines. Historically, cumin was used heavily in ancient Roman cuisine (NWE, 2024). Cumin is well known as an ingredient of curry powder, and also is a critical ingredient of chili powder. It is found in achiote blends, adobos, sofrito, garam masala, and bahaarat. Cumin can be found in some Dutch cheeses like Leyden cheese, and in some traditional breads from France. It is also commonly used in traditional Brazilian cuisine. Cumin is one of the ingredients in the spice mix berbere (NWE, 2024). Cumin can be used to season many dishes, as it draws out their natural sweetnesses. It is traditionally added to curries, enchiladas, tacos, and other Middle-eastern, Indian, Cuban, and Mexican-style foods. It can also be added to salsa to give it extra flavor. Cumin has also been used on meat in addition to other common seasonings. The spice is a familiar taste in Tex-Mex dishes (NWE, 2024). Cumin seeds are often ground up before being added to dishes. Cumin seeds are also often toasted by being heated in an ungreased frying pan to help release their essential oils (NWE, 2024). In herbal medicine, cumin is classified as stimulant, carminative, and antimicrobial. It is believed to help induce labor in a woman who has gone post-dates with her pregnancy. In Sri Lanka, toasting cumin seeds and then boiling them in water makes a tea used to soothe acute stomach problems. Cumin is also said to help in treatment of the common cold, when added to hot milk and consumed. Rahman *et al*. (1999) found cumin to have significant antifungal activity (NWE, 2024). Superstition during the Middle Ages cited that cumin kept chickens and lovers from wandering. It was also believed that a happy life awaited the bride and groom who carried cumin seed throughout the wedding ceremony (NWE, 2024).

In this review article on Origin, Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding and Cultivation of Cumin are discussed.

ORIGIN AND DISTRIBUTION

Cumin seeds of two geographic origins, Tunisia (TCS) and India (ICS) (Bettaieb, 2011). Cumin, native of Egypt, is now grown in most hot regions like India, North Africa, China and America. The spice is especially associated with Morocco, where it is often smelt in the abundant street cookery of the *medinas.* Cumin was known to the Egyptians five million years ago. Its seeds have been found in the old kingdom pyramids. The Romans and Greeks used it medicinally and cosmetically to induce a pallid complexion (Lal *et al.,* 2014). Cumin is one of the most extensively used seed spices and is used by people all over the world. It is

the secondmost popular spice in the world after black pepper. Cumin seeds are used as a spice for their distinctive aroma,popular in Indian, Pakistani, North African, Middle Eastern, Sri Lankan, Cuban, Northern Mexican cuisines, and the Western Chinese cuisines of Sichuan and Xinjiang. In the Indian systems of medicine, cumin finds a very important role. Cumin has been cultivated since ancient times; it is difficult to determine its original home. It isprobably a native of the southern Mediterranean area, to the deserts of Egypt and other Arabian countries, and toCentral Asia (Turkestan). The plant is cultivated in many parts around the world. It is grown widely in China, India, Indonesia, Iran, Japan, Morocco, Southern Russia, Syria and Turkey. In Ethiopia, the fruits are offered forsale on almost every market and small-scale cultivation is widespread. Cumin is produced chiefly in India (Lal *et al*., 2014). In India Cumin is cultivated in Rajasthan and Gujarat and in some part of M.P. and U.P. as a *Rabi* crop. It contributed around 120.000 tonnes to the country's total production in the year 2003-04 and also has maximum area under cumin cultivation. Gujarat is the second largest cumin seed producer in India. Rajasthan and Gujarat together contribute approximately 90 per cent of the production of the country. India's production of cumin sums up to 100 to 200 thousand tonnes per year, which makes it the leading producer in the world. The country has the largest area under cumin production. The level of production and the total area under cumin cultivation have increased significantly during the last few years (Lal *et al.,* 2014).

Cumin has been in use since ancient times. Seeds excavated at the Syrian site Tell ed-Der have been dated to the second millennium BC. They have also been reported from several New Kingdom levels of ancient Egyptian archaeological sites. In the ancient Egyptian civilization, cumin was used as spice and as preservative in mummification. Cumin is believed to be a native of Egypt and Syria, Turkistan and eastern Mediterranean region. It is extensively cultivated in Iran, India, Syria, Turkey, Morocco, China, Southern Russia, Indonesia and Japan. Iran being major exporter of cumin seed is the India's major competitor in foreign trade (Dar *et al.,* 2019). Cumin has been in use since ancient times. Seeds excavated at the Syrian site Tell ed-Der have been dated to the second millennium BC. They have also been reported from several New Kingdom levels of ancient Egyptian archaeological sites. In the ancient Egyptian civilization, cumin was used as spice and as preservative in mummification. Cumin is believed to be a native of Egypt and Syria, Turkistan and eastern Mediterranean region. It is extensively cultivated in Iran, India, Syria, Turkey, Morocco, China, Southern Russia, Indonesia and Japan. Iran being major exporter of cumin seed is the India's major competitor in foreign trade (Dar *et al.,* 2019). Cumin seed is a tiny dried fruit that comes from a small Umbelliferae plant belonging to the same plant family as parsley, carrots, dill, and caraway. This plant is native to the Mediterranean region and Egypt, and is cultivated along the Western Mediterranean through the Middle East and India (Pacificspice, 2020). Cumin is an ancient spice grown in Egypt and the Middle East. It has been found in 4,000-year-old excavations in Syria and ancient Egypt, where it was used both as a spice and as an element in preserving mummies. It appears in the Bible in both the Old Testament and the New Testament. Since ancient times, cumin has been used extensively in India as well as by the Greeks and Romans. It made its way into Mexican and South American cuisine after European colonization, brought by the Spanish and Portuguese (Alfaro**,** 2024). Historically, Iran has been the principal supplier of cumin, but currently the major sources are India, Sri Lanka, Syria, Pakistan, and Turkey (Wikidoc, 2024).

TAXONOMY

Cumin belongs to the family Apiaceae (Carrot family), genus *Cuminum* and species *Cuminum cyminum* (Agarwal *et al*., 2017; Bansal *et al.,* 2014; NWE, 2024; Wikidoc, 2024; Wikipedia, 2024). The English name of cumin is derived from the old English Cymene, from Latin 'Cuminum' which is the Romanization of the Greek 'Kuminon', cognate with Hebrew kammon, Arabic Kammun.

Species

Although a number of potential species have been described based on morphological differences, merely four species names **(***Cuminus cyminum, C. borszczowii, C. setifolium, and C. sudanense*) are botanically acceptable. This aims at exploring the physiolocal and biochemical properties of cumin seed and the impact of genotype x environment interactions on the main biochemically active compounds available in the seed (Kumar *et al*., 2015).

Synonyms (Patel *et al*., 1966; Indiabiodiversity, 2024a).

Cuminia cyminum J. F. Gmel.
Cuminum aegyptiacum Merat ex DC.
Cuminum hispanicum Merat ex DC.
Cuminum odorum Salisb.
Cuminum officinale Garsault
Cuminum sativum J. Smith
Cuminum sudanense H. Wolff
Cyminon longeinvolucellatum St. Lag.
Ligusticum cuminum (L.) Crantz
Luerssenia cyminum (L.) Kuntze
Selinum cuminum (L.) E. H. L. Krause

BOTANICAL DESCRIPTION

Cumin is a herbaceous and annual plant that has 30-45 cm height with fruits having pharmaceutical properties. It's an aromatic plant with a white long slender root and a right branching stem having double and seldom triples divisions that these branches are

ended into composed umbel finally. The leaves are alternate and filamentous. There are involucres around the main umbel and involucel around the umbellules. Every flower includes some green separate sharp-pointed sepals and some pink separate unequal petals. Also it has five stamens and bicarpel ovary that produces schizocarp diackens fruit. Diackene fruits are connected at first, but finally they part with each other. They are 5-6 mm long and their diameter is 1.5-2 mm, and are elongated and fusiform. Green cumin is mostly autogamous and its outcross is specified about 2.35% , and wind has an important role in pollination of this plant (Baghizadeh *et al*., 2013). Cumin is an annual plant grown to aheight of 30-45 cm and produces many branches on stems with long divided deep green leaves. The flowers aresmall, white or rose in colour and are borne in umbels. The seed is elongated, approx. 6 mm long and light yellowish brown in colour. It is an herbaceous annual plant, with a slender branched stem 20-30 cm tall. The leaves are 5-10 cm long, pinnate or bipinnate, thread-like leaflets. The flowers are small, white or pink and bornein umbels. The fruit is a lateral fusiform or ovoid achene 4-5 mm long, containing a single seed. Cumin seeds resemble caraway seeds, being oblong in shape, longitudinally ridged, and yellow-brown in color, like other members of the Umbelliferae family such as caraway, parsley and dill (Lal *et al.,* 2014).

Cumin is the dried seed of the herb Cuminum cyminum, a member of the parsley family. The cumin plant grows to 30-50 cm tall and is harvested by hand. It is an herbaceous annual plant, with a slender branched stem 20-30 cm tall. The leaves are 5-10 cm long, pinnate or bipinnate, thread-like leaflets. The flowers are small, white or pink, and borne in umbels. The fruit is a lateral fusiform or ovoid achene 4-5 mm long, containing a single seed. Cumin seeds resemble caraway seeds, being oblong in shape, longitudinally ridged, and yellow-brown in color (Bansal *et al*., 2014). Cumin 'seeds' belong to family of small scented herbs known as Apiaceae. The cumin plant grows to 30-50 cm tall and is manually harvested. It is an herbaceous annual plant, with a slender branched stem 20-30 cm tall. The leaves are alternate, simple or compound and have a sheathing leaf base below. The flowers are small, pink and characteristically borne in umbels or umbrella-like clusters, where a large number of flowers with stalk of equal length spring from a common point so that all of them bloom at the same level. The flowers have both male and female structures together and an inferior ovary that develops into a very characteristic fruit called a cremocarp. This is dry, capsular and invariably breaks at maturity into two one-seeded bits, with a ribbed wall that has a number of longitudinal oil canals. It is these latter that give the characteristic odour, flavour and the very value to the fruit itself. Though these grain-like fruits are called the seeds, the true seeds are within them and come out only during germination through disintegration of the fruit wall (Parashar *et al*., 2014).

Cumin is an annual herbaceous plant which grows up to 15-50 cm height somewhat angular and tends to drop under its own weight. The leaves with bluish—green hue, 5-10 cm pinnate or bipinnate, are alternate, simle or compound and have a sheathing leaf base below. Flowers are on a compound umbel (arrangement of flowers looks like an umbrella) and umbel has 5-7 umbelletes. The umbellets of the first order show the maximum number of umbellets. Due to unequal sepal size in cumin, the flowers of the outerr whorl of umbellets are zygomophic (yoke shaped, bilateral) while those in inner are actinomophic (star shaped, radial). The flowers are bisexual with colors like pink and red growing on the inflorescence compound umbel up to 3-5 mm in diameter. Stamens are antisepalous with long filaments and dithecous anthers. The flowers have bicarpellary, syncarous and inferior ovary that develops into a very characteristics fruit called cremocarp. Ovary shows prominent ridges and furrows. In cumin along the ridges wall of the fertilized ovary shows 21-26 layers of cells of which 3-5 subepidermal layers are chlorophyllous (Kumar *et al.,* 2015).

Cumin is a flowering annual plant having 50 cm high with alternative, sparely hairy and dissected leaves. The leaves are bluish green regarding the color and have about 5 cm long. The flowers have a white or a pink color, each one containing 5-7 umbellets. The fruit have a brown, yellowish green color and a single seed contains ellipsoid to lateral fusiform non-dehiscent achene, as described (Simona *et al*., 2018). Cumin is a flowering plant in the family Apiaceae, native from the east Mediterranean to South Asia. Cumin is the dried seed of the herb *Cuminum cyminum*, a member of the parsley family. The cumin plant grows to 30–50 cm tall and is harvested by hand. It is an annual herbaceous plant, with a slender, glabrous, branched stem that is 20–30 cm tall and has a diameter of 3–5 cm. Each branch has two to three sub-branches. All the branches attain the same height; therefore the plant has a uniform canopy. The stem is coloured grey or dark green. The leaves are 5–10 cm long, pinnate or bipinnate, with thread-like leaflets, divided into long, narrow segments like Fennel, but much smaller and are of deep green colour, generally turned back at the ends. The upper leaves are nearly stalking less, but the lower ones have longer leaf stalks. The flowers are small, white or pink, and borne in umbels. Each umbel has five to seven umbellts. Anthesis starts from outer umbelets and proceeds towards inwards. Anthers dehiscence starts at 6-8 a.m.in the morning and continues till 2.00 p.m. Like other umbellifeorous plants, protoandrous condition is found in the crop. The flowers remain surrounded with stamens and experience self pollination. The fruit is a lateral fusiform or ovoid achene 4–5 mm long, containing two mericarps with a single seed. The seeds are elongated, approximately 6 mm long and light yellowish brown in colour. It has characteristic strong and heavy favour and is slightly bitter and somewhat disagreeable. On the external surface of the seeds, fine ridges are found, in between which four ridges are found. Along with these ridges, capillaries run parallel which serves as a strong organ of volatile oil in the seeds (Dar *et al.,* 2019). The cumin is a small bushy plant grown annually. It has thin stem having 3 to 5 cm diameter and height of 20 to 30 cm. It has a throne less branched stem of greenish colour at early stage and greyish colour at maturity. Cumin plant flourishes large number of small pink or white colour flowers at same level with equal length of stalk. The fruit of cumin is similar to cremocarp grows from lower ovary. The fruits are light brown or greyish in colour and ovate or fusiform in shape. The fruit of cumin is termed as seeds but the real seeds are come out by breaking the fruit wall at the time of germination. Cumin seeds are dry and capsuled shaped and split into two fragments with just one seed having a grooved wall at maturity stage. The seeds are curved lengthwise and brownish in colour similar to other members of *Apiaceae* family but more resemble to caraway seeds (Kumar *et al.,* 2021).

Cumin is an annual herb, growing up to 30-50 cm tall, with a slender, hairless, branched stem that is 20-30 cm tall and has a diameter of 3-5 cm. Each branch has two to three sub-branches. All the branches attain the same height, so the plant has a uniform canopy. The stem is colored grey or dark green. The leaves are 5-10 cm long, pinnate or double compound, with thread-like leaflets. The flowers are small, white or pink, and borne in umbels. Each umbel has five to seven umbellets. The fruit is a lateral spindle-shaped or ovoid achene 4-5 mm long, containing two mericarps with a single seed. Cumin seeds have eight ridges with oil canals. They resemble caraway seeds, being oblong in shape, longitudinally ridged, and yellow-brown in color (Prajapati, 2024). Cumin is the dried seed of the herb *Cuminum cyminum*, a member of the parsley family. The cumin plant grows to 30–50 cm tall and is harvested by hand. It is an annual herbaceous plant, with a slender, glabrous, branched stem that is 20–30 cm tall and has a diameter of 3–5 cm. Each branch has two to three sub-branches. All the branches attain the same height, so the plant has a uniform canopy. The stem is colored grey or dark green. The leaves are 5–10 cm long, pinnate or bipinnate, with thread-like leaflets. The flowers are small, white or pink, and borne in umbels. Each umbel has five to seven umbellets. The fruit is a lateral fusiform or ovoid achene 4–5 mm long, containing two mericarps with a single seed. Cumin seeds have eight ridges with oil canals (Wikipedia, 2024).

The cumin plant is small, slender, and herbaceous with finely dissected leaves. The flowers are borne in characteristic flat-topped umbel clusters and are white or rose-coloured. The cumin, or comino, “seeds” are actually dry fruits known as schizocarps. They are thin yellowish brown elongated ovals about 6 mm long. Each features five prominent longitudinal dorsal ridges interspersed with less-distinctive secondary ridges forming a tiny gridlike pattern. They contain between 2.5 and 4.5 percent essential oil, the principal component of which is cumaldehyde (Petruzzello, 2024). It is an herbaceous annual plant, with a slender branched stem 20–30 cm tall. The leaves are 5–10 cm long, pinnate or bipinnate, thread-like leaflets. The flowers are small, white or pink, and borne in umbels. The fruit is a lateral fusiform or ovoid achene 4–5 mm long, containing a single seed. Cumin seeds are similar to fennel and anise seeds in appearance, but are smaller and darker in color (Eagri, 2024). The earlier name *Umbelliferae* derives from the inflorescence being in the form of a compound "umbel." The small flowers are radially symmetrical with five small sepals, five petals, and five stamens. *Cuminum cyminum*, or cumin, is the only extant (living) species in its genus. It is a small annual herb with a slender branched stem 20 to 30 centimeters tall. The leaves are five to ten centimeters (two to four inches) long, pinnate or bipinnate, with thread-like leaflets. The flowers are small, white or pink, and borne in umbels. The fruit (commonly but imprecisely called seed) is a lateral fusiform or ovoid achene four to five millimeters (about three-sixteenths of an inch) long, containing a single seed. Cumin "seeds" are similar to fennel seeds in appearance, but are smaller and darker in color (NWE, 2024). Botanical description of cumin is given in Fig. 1.

		
Seeds	**Field**	**Plants**
		
Plants	**Umbels**	**Umbel with flowers**

Continue ….

		
Umbel with flowers	**Flower**	**Flower**
		
Umbels with seeds	**Umbels with seeds**	**Seeds**
		
Cumin Powder	**Cumin water**	**Cumin oil**
Fig. 1. Botanical Description		

Pollination

Pollination is the transfer of pollen from a male part of a plant to a female part of a plant, later enabling fertilization and the production of seeds, most often by an animal or wind. Pollination is the act of transferring pollen grains from the male anther of a flower to the female stigma. The goal of every living organism, including plants, is to create offspring for the next generation. Seeds can only be produced when pollen is transferred between flowers of the same species. Pollination being a process of sexual reproduction helps to maintain plant characters. Knowledge of pollination in tree spices is limited and is important with respect to crop improvement, production and biodiversity in tree spices. Most of the tree spices are cross pollinated thus increasing variability in population and provides chances for the evolution of new varieties and species and also pollinators in creating diversity among them (Patel *et al*., 1966). Pollination is critical for food production and human livelihoods, and directly links wild ecosystems with agricultural production systems. Pollination system started with the evolution of plants. It was around 125-115 million years ago that a new pollination strategy developed and angiosperms first appeared. Animal mediated pollination

contributed to the sexual reproduction of over 90% of the species of modern angiosperms. Knowledge of pollination system is thus broadly relevant with applications in the field of ecology, evolutionary biology, conservation, entomology and horticulture.
Cumin's dainty white flowers attract small butterflies from this low growing plant. Reaching a height around 15 inches, cumin's slender branches resemble many of the other herb. Cumin attracts blues, hairstreaks, sulphurs and many other small to medium-sized butterflies (Patel *et al*., 1966). Cumin is a cross pollinated spice and honey bees help in pollination. The ethereal color of the plant attractsinsects. Cross pollination is essential due towel marked protandry and the anthers dehisce even before the style and stigma are fully developed. The stylopodiums secrete nectar, attracting pollinators like flies, mosquitoes, gnats, beetles, moths, and bees (Kumar *et al.,* 2015).

Cumin flowers were visited by 20 species of insects belonging to 11 families from 6 orders. Apoidea (62.4%) and Diptera (27.5%) were the two major groups comprising 89.9% of the total visitors. *Apis florea* was the most dominant species (31.2%) followed by *A. mellifera* (16.9%), *A. dorsata* (13.4%), *Episyrphus balteatus* (13.0%) and *Musca* sp. 1 (9.6%). *A. mellifera* and *A. dorsata* started foraging early at 8.00 h and *A. florea* at 9.00, peaked from 12.00 to 14.00 hr and declined drastically thereafter. Non-*Apis* pollinators were visited cumin flowers early morning by 6.00 hr with meagre in population and present throughout the day with two peaks between 11.00 to 13.00 hr, while *E. balteatus* reached to its peak at 15.00 hr. Most of floral visitors ceased their population and few were negligible at 18.00 hr. Population dynamics of most abundant pollinators were recorded during fourth week of February. A minimum yield of 364.50 kg/ha was recorded in caged plots without insect pollinators (control). Yields in open and bee pollinated plots were 515.30 and 510.41 kg/ha, with an increase of 41.37 and 40.03% over without insect pollinated plots, respectively. Maximum yield was in plots treated with bee attractant -Jaggery solution 10% (520.83 kg/ha) which was 42.88% higher over control and 1.07 and 2.04% higher over open pollinated and bee pollinated plots. Bee pollination also increased quality of cumin seed over control (WIP) (Meena *et al*., 2018).

GENETICS AND CYTOGENETICS

Studies on cumin karyotype have shown that the chromosome number of cumin is 2n= 14. Cytological analysis of three cumin varieties also showed that the number of somatic chromosomes is 2n= 14. Most chromosomes had cavities at their end or central parts (Kafi, 2006). Cumin is a diploid species with 14 chromosomes (*i.e*. 2n = 14). The chromosomes of the different varieties have morphological similarities with no distinct variation in length and volume (Dar *et al*., 2019).

Polyploidization is a major trend in plant evolution that has many advantages over diploidization. Ploidy level manipulation is a powerful breeding tool for many plant species, including medicinal plants. To identify effective concentrations and target tissues for inducing polyploidy in cumin, three methods of seed treatment, root treatment and apical meristem treatment were tested on a cumin ecotype from South Khorasan under greenhouse conditions. Colchicine was used in varying concentrations (0.5, 0.2, 0.1, 0.05, 0.025% and 0%) for all assays. Different treatment times (12, 24, 36 and 48 hours) were considered for seed and root treatments, while the droplet method was used to treat the apical meristem. The ploidy level of the plantlets was verified by chromosome counts, flow cytometry, and cytology traits. The results showed that the seed and root treatments were not suitable for inducing polyploidy. The most effective method for inducing polyploidy in cumin was the application of colchicine (0.05%) on the apical meristem. However, applying 0.5% and 0.2% concentrations of colchicine on the apical meristem resulted in the wilting of the majority of seedlings. The tetraploid plants showed a significant difference in stomata size and pollen grain size and shape compared to the diploid mother plants.

GENETIC DIVERSITY

Genetic divergence estimated employing D2 technique among 30 genotypes of cumin based on 13 morphological traits. All the genotypes were grouped into five clusters, of which clusters I and II were closest. Evidence for and against the assumption that the genetic diversity is related to geographical origins were found. Grain yield contributed maximum to genetic diversity. Cumin is an important spice crop in India. It also has many medicinal properties. The improvement work done in this crop is limited. Initial evaluation of the germplasm has shown that the variability is limited in this crop (Avatar *et al.,* 1991). In order to assess the genetic diversity of cumin and determine the traits effective on seed yield and cumin- aldehyde, forty nine cumin ecotypes which they are sub-populations belonged to nine populations from different provinces of Iran were evaluated based on morphological and biochemical traits. Results indicated a significant variation for all the measured traits among and within populations derived from different provinces. Kerman and Esfahan populations showed the best performance based on the phenotypic data, while Yazd had almost the lowest levels of traits. Correlation analysis showed number of seed per umbel and umbel per plant had highest relationship with seed yield. Path analysis also demonstrated that number of umbel per plant and number of seed per umbel had the most direct effects on seed yield and were identified as the most effective factors on seed yield. Cumin aldehyde was mostly correlated by number of umbel per plant. The present study showed that different qualitative characteristics such as seeds with light color and without trichome and leaves without trichome, alternate and large pods of Petiole tend to produce high seed yield. Pattern analysis of different populations based on first two main principal components categorized the measured genotypes in to three groups: Pars, Northern_Khorasan, Golestan, Semnan and Yazd (Group1), Southern_Khorasan and Khorasan_Razavi (Group2) Kerman and Esfahan (Group3), which the third group are high yielding genotypes with different genetic background can be advised for cultivation and breeding programs. So the available genetic diversity among the Iranian cumin populations can be lead to produce high yielding population of cumin (Bahraminejad *et al*., 2011). Study of the genetic diversity in plant inherited stores in order to classify the genotypes regarding resistance to biotic and abiotic stress, preventing from genetic erosion is one of the basic and fundamental steps in the most breeding programs . Iran is one of the most important centers of genetic diversity because of having different climates, old civilization ,and Kerman province having ecological diversity

has unknown potential that must be considered plently. In this study, 32 genotypes of *Cuminum cyminum* containing 29 samples of different area from Kerman province and three samples from townships of Sabzvar, Tabas and Birjand were assessed by RAPD molecular markers.DNA extraction was done by modified CTAB method. After DNA extraction stages, complement gene locuses were amplified by 15 RAPD primers. These primers produced 154 bands, that 133 bands (about 86%) were polymorphic. Cluster analysis based on the resulting data was performed using UPGMA method and Dice's similarity coefficient in NTSYS software. The resulting dendogram categorized the accessions into six groups in 46% similarity. Principle Component Analysis was performed; 2 and 3 dimensions graphs using 15 primers were drawn (Baghizadeh *et al.,* 2013). Experiments were conducted to assess the genetic diversity among Indian cumin, accessions by using RAPD molecular markers. After DNA extraction, complement gene locuses were amplified by 20 RAPD primers, out of which only 15 primers showed amplification. These primers produced 1191 bands, of which 218 bands (about 18.30%) were polymorphic. This indicates very low level of genetic diversity among genotypes. Cluster analysis was performed using UPGMA method and Dice's similarity coefficient by NTSYS software. The resulting dendrogram categorized the accessions into three groups showing 53% similarity. Principle Component Analysis was performed and 3 dimensions graphs using 15 primers and 55 genotypes were drawn (Choudhary *et al*., 2015).

The present experiment on "Genetic diversity among cumin cultivars through PCR-DNA markers", was planned with objectives (1) to determine quality parameters from different cultivars of cumin, (2) to determine essential oil profile by GC-MS, (3) to observe the phylogenetic relationship among cumin cultivars using RAPD and SSR marker, and (4) to access genetic diversity among cumin cultivars using molecular markers. The seed quality analysis of fifteen cumin cultivars were analysed and the highest moisture content (10.4%) and total phenol (6.18 mg g-1) was found in RZ-223, total sugars (14.46 g%) in GC-4, free amino acid (162.2 mg%) and sodium (294 mg%) in RZ-209, total fiber (60.23%) in HAIRY CUMIN, phosphorus (1.35mg g-1) in RZ-341, potash (959 mg%) in JC-2000-54, iron (77.80%) in JC-94-262, total oil (14.46 g%) in GC-4, Essential oil (4.27%) and refractive index (1.79) in GC-3. The GC-3 showed maximum essential oil (4.27%) with highest fraction of cuminaldehyde (31.45%) as detected in GC-MS. Total 80 out of 120 component were identified in GC-3 cumin cultivars by GC-MS. Seventeen *viz*. compounds 1,2,3,4 Hexadecane tetrol, Artemiseole, Biocyclopentadiene dioxide, Camphenol, Caprylic alcohol, Cis-carvone oxide, Cis liminene oxide, Cis p-Menth-2,8-dien-1-ol, Cis-trans Farnesol, Cis-Verbrnol, Gamma-Thujaplicin, Isomenthol, Isopiperitenone, P-Menthan-2-one, Teresanyalol, Trans-2-Nonen-1-al and Trans linaloloxide were detected only in GC-3 and not found in GC-2, GC-4 and RZ-341 cumin cultivars. The RAPD analysis of 15 cumin cultivars was carried out with 18 OPA, OPB, OPC and OPG series primers which generated 135 DNA alleles out of which 115 were polymorphic with an average of 7.5 bands and 86.34% polymorphism per primer (Solanki, 2015). The best quality with respect to essential oil and refractive index was found in GC-3 cumin cultivars and it was identified by three unique markers 216bp (BAC-1), 379bp and 1947bp (BAC-9). Total 19 unique bands were produced by eleven RAPD primers to discriminate nine cumin cultivars. The 13 SSR primers produced 32 bands across fifteen cultivars, of which all were polymorphic. Total 11 unique bands were produced by eight SSR primers to discriminate six cumin cultivars. The collective study of all molecular markers revealed a dendrogram which consisted of two main cluster sharing 46% similarity and out grouped GC-1 from other 14 cultivars. Key words: Cumin cultivars, Molecular markers, RAPD markers, SSR markers (Solanki, 2015).

A set of 19 genotypes of cumin were tested for the diversity index using D2 technique over yield and nine morphological traits which were observed during 2009–10 and 2010–11. All the genotypes grouped into only two clusters, showing narrow genetic base. Primary branches contributed maximum to the genetic divergence, followed by yield/plot (Meena *et al*., 2017). Cumin is an important seed spice of India and having very narrow range of genetic variability. Induced mutagenesis by gamma rays has been found to be a very useful technique for crop improvement. Therefore, a study was undertaken to know the effect of gamma rays in cumin cv. RZ- 209 to create genetic variability for essential traits. Dry seeds were exposed to different doses of gamma radiations using 60Co as the radiation source at Bhabha Atomic Research Centre (BARC), Mumbai. The irradiated seeds along with control were kept for germination in petri dishes and also sown in the field. It was recorded that increased doses reduced the seed germination and survival of seedlings. The 48.4% survival of seedlings was recorded at the dose of 200Gy. This dose of gamma ray caused near about 50% reduction in root length, shoot length, seedling length and vigour index. The days to first flowering and days taken for fruiting to maturity was delayed as the doses were increased. The gamma rays dose 200Gy significantly increased the numbers of umbels per plant, 1000 seed weight (3.97g) and seed yield per plant (1.67g) over control (Verma *et al*., 2017).

It was studied in 49 landraces of cumin. The genetic bases of distinct traits were estimated to get an overview of the genetic variability for cumin breeding programs. Heritability, genetic advance, and genotypic and phenotypic correlation coefficients were determined for all the traits. The combined analysis of variance showed significant differences among all the sources of variation. The seed yield and EO content, as well as other traits, were affected by water stress. The GC–MS analysis of the elite landrace, Golestan (Jat), revealed that the main chemical compositions in both conditions were γ-terpinene, β-pinene, m-cymene and cuminic aldehyde. The landrace Golestan (Gonbad) was introduced as a good candidate for further breeding research on RWC. However, this landrace was clustered in medium-oil-yield group, while Semnan (Ivanakey), Yazd (Bafq) and Southern Khorasan (Ghaen) were grouped in the top-ranking landraces for EO. They were also suggested as suitable candidates for studying the physiological mechanisms and breeding involved in pigment and sugar accumulation. According to the results, we suggest carotenoid content, soluble sugars and RWC as drought-tolerance indices in cumin improvement programs (Kazemi *et al.,* 2018).

Genetic diversity was studied in fifty-four genotypes of cumin, at "Agricultural Research Station, Mandor, Jodhpur". The mean squares were found significantly different for all the characters under study, depicting the variability among the study materials. The high magnitude of phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) for seed yield, primary branches per plant and number of umbels per plant depicted the presence of vast amount of variation for the character along with high heritability (68-97%) combined with higher genetic advances as percentage of means for seed yield. The highest

intra-cluster distance was recorded in cluster VI (11.8) along with cluster VII (11.33) and cluster VIII (8.29) depicting large genetic variability among the genotypes of these three clusters. The highest inter-cluster distance was reported among cluster III and VIII (51.97) followed by cluster III and VII (40.07) and cluster IV and cluster VIII (34.77), suggesting wide range of diversity between genotypes of the clusters. Amongst the characters, seed yield contributed the highest towards genetic divergence (47.80%) followed by number of umbels plant-1 (25.65%), branches per plant (8.60%) and 1000 seed weight (6.64%) (Kumhar *et al.,* 2020).

BREEDING

Germplasm: Available literature indicates that variability in the germplasm particularly for yield, quality (volatile oil content) and reaction to different biotic and abiotic stresses is low in all the seed spices (Sharma, 1994). In the present germplasm collections variability for plant height, maturity duration is low even for these traits obviously there is an urgent need to enhance the germplasm base to successfully support the crop improvement programme. Genetic enhancement of seed spices is possible only through accumulation of variability in the form of germplasm. India is endowed with germplasm of different kind of seed spices crops and a number of indigenous and exotic origins are available at different centre's (Table 1) Germplasm collection activities were initiated from Rajasthan and Gujarat, the major areas for the cultivation of cumin. There is tremendous scope for collection of valuable land races of seed spices. The development of improved cultivars has improved the production and productivity of seed spices to some extent, which has endangered the accumulated diversity among the traditional cultivars of these crops species. Therefore, the conservation of germplasm of the seed spices is of profound importance for sustaining their production. If not collected and conserved these valuable genetic resources may be lost forever, hence prime importance is required to be given in collection and conservation of the biological diversity of seed spices from all over the country and abroad (Parashar *et al*., 2014).

Breeding Constraints: Most of the varieties available today are selections. The variability in yield and yield components is high. Varieties are developed by sib mating in enclosed chambers or by biotechnology. Cumin is a cross-pollinator, *i.e*. the breeds are already hybrids. Therefore, methods used for breeding are in vitro regenerations, DNA technologies, and gene transfers. The in vitro cultivation of cumin allows the production of genetically identical plants. The main sources for the explants used in vitro regenerations are embryos, hypocotyls, shoot internodes, leaves and cotyledons. One goal of cumin breeding is to improve its resistance to biotic (fungal diseases) and abiotic (cold, drought, salinity) stresses. The potential genetic variability for conventional breeding of cumin is limited and research about cumin genetics is scarce (Dar *et al.,* 2019). Cumin is a diploid species with 14 chromosomes (*i.e*. 2n = 14). The chromosomes of the different varieties have morphological similarities with no distinct variation in length and volume. Most of the varieties available today are selections. The variability in yield and yield components is high. Varieties are developed by sib mating in enclosed chambers or by biotechnology. Cumin is a cross-pollinator, i.e. the breeds are already hybrids. Therefore, methods used for breeding are in vitro regenerations, DNA technologies, and gene transfers. The in vitro cultivation of cumin allows the production of genetically identical plants. The main sources for the explants used in vitro regenerations are embryos, hypocotyls, shoot internodes, leaves and cotyledons. One goal of cumin breeding is to improve its resistance to biotic (fungal diseases) and abiotic (cold, drought, salinity) stresses. The potential genetic variability for conventional breeding of cumin is limited and research about cumin genetics is scarce (Dar *et al.,* 2019).

Breeding Strategies

In the following some important breeding strategies for development of sustainable cultivars with high yield, resistant to abiotic, biotic stresses and desired quality are described: Germplasm collection, evaluation and conservation, Population improvement and selection, Exploitation of Heterosis, Breeding for abiotic and biotic stresses, Improvement of quality, Mutation breeding, Breeding varieties for mixed cropping and Biotechnological approaches (Parashar *et al.,* 2014).

Breeding

Cumin is a cross-pollinator means the breeds are hybrids. Thus procedures used for breeding are in-vitro regenerations, DNA technologies, and gene transfer. The in-vitro cultivation of cumin allows the generation of genetically exact plants. One goal of cumin breeding is improved resistance to biotic (fungal diseases) and abiotic stresses (Agarwal *et al.,* 2017). Cumin is a diploid species with 14 chromosomes (*i.e*. 2n = 14). The chromosomes of the different varieties have morphological similarities with no distinct variation in length and volume. Most of the varieties available today are selections. The variability of yield and yield components are high. Varieties are developed by sib mating in enclosed chambers or by biotechnology. Cumin is a cross-pollinator, *i.e.* the breeds are already hybrids. Therefore, methods used for breeding are *in vitro* regenerations, DNA technologies, and gene transfers. The *in vitro* cultivation of cumin allows the production of genetically identical plants. The main sources for the explants used *in vitro* regenerations are embryos, hypocotyl, shoot internodes, leaves, and cotyledons. One goal of cumin breeding is to improve its resistance to biotic (fungal diseases) and abiotic (cold, drought, salinity) stresses. The potential genetic variability for conventional breeding of cumin is limited and research about cumin genetics is scarce (Wikipedia, 2024). Breeding for high yield, Volatile oil content, Resistance to powdery mildew, Resistance to blight, Resistance to wilt, Seed size, colour and lustre and Development of cultivars resistant to yellowing (Parashar *et al*., 2014). Population improvement is the process of pyramiding of the positive genes for desirable characters in a variable population through selection or recurrent selection. The appropriate strategy in Apiacee (cross-pollinated) spices would be to have short term and long term improvement programme. The short term programme would aim to improve the elite populations through recurrent selection based on the performance of individual plant progenies or even mass-selection. This approach has produced a number of good varieties cumin (Parashar *et al.,* 2014). Though recurrent selection, can be successfully employed in both intra as well as interpopulation improvement, the best approach to

exploit both the additive and non-additive gene effects would be the heterosis breeding. Search for cytoplasmic – genetic types of system of controlling male sterility should be taken up to make the heterosis breeding a reality (Parashar *et al*., 2014). The seed spices are affected by various diseases which reduce the yield level which is already low. Some of the diseases in cumin wilt and blight have so far evaded the effective control measures. Breeding programmes for resistance to these diseases need to be immediately initiated. Identification of pathogen and or its races causing the diseases, developing techniques to create uniform and artificial disease epiphytotics, use of tissue culture as an aid to accelerate the resistance screening programmes are some of the aspects on which research work need to be initiated to make the resistance breeding effective. Resistance breeding is also directly related to quality of the produce as it obviates the necessity of application of pesticides which often leaves undesirable residues. In addition to biotic stresses these crops are also affected by large number of abiotic stresses, therefore screening programmes on these stresses need to be initiated *eg:*- drought, salt and frost tolerant cultivars (Parashar *et al*., 2014). Quality of the produce needs special emphasis in seed spices as these are exported of foreign markets where the quality standards are very stringent. Volatile oil content, shape, size and luster of grains and their cleanliness constitute the important quality factors. Appropriate weightage has to be given to these quality attributes in the breeding programmes (Parashar *et al*., 2014).

Yield and salient features of cumin varieties developed in India are given in Table 2 (Dar *et al*., 2019).

Table 3. Yield and salient features of cumin varieties developed in India

S. No.	Variety	Dry seed yield (kg ha^{-1})	Essential oil (%)	Salient features
1	Mc. 43	580	2.7	Plant semi spreading, grains bold lustering withstand lodging and shattering, moderately tolerant resistant to *Fusarium* wilt, *Alternaria* blight & powdery mildew.
2	Guj. Cumin-1	550	3.6	Plants bushy and spreading, grains bold , linear oblong, withstands shattering and lodging, moderately tolerant to wilt, powdery mildew and blight.
3	RZ-19	560	-	Erect plant, pink flowers, bold, lustrous grain, gray pubescent, tolerant to wilt and blight suitable for late sowing season.
4	Guj. Cumin-2	620	4.0	Bushy plant, good branching habit, grains bold, medium sized, lustrous grain, tolerant to wilt and blight suitable for late sowing season
5	Guj. Cumin-3	620	4.4	Bushy dwarf plant, fruit medium sized, frost wilt resistant variety suitable for winter season in limited irrigation. Higher essential oil content, seed pungent with good aroma
7	RZ-209	650	-	A variety shows some resistance with blight and wilt disease
8	RZ-223	600	3-3.5	Wider adaptability, resistant to wilt, superior in yield and seed quality over RZ-19. Plants bushy, semi-erect, long bold attractive seeds, medium duration.
9	Ac-01-167	515	3.0	Bold seeds resistant to wilt.

Varieties in Rajastan and Gujarat: There are many varieties released for cultivation to different areas specially Rajasthan and Gujarat. The descriptions of some of the important cultivated varieties are given below (Lal *et al.,* 2014; Parashar *et al.,* 2014; Kumar *et al*., 2021; Brar *et al*., 2022; Eagri, 2024):

RZ-19: It was developed at, SKN College of Agriculture (RAU), Jobner through selection from a local collection. The plants are erect in growth behaviour bear pink coloured flowers and bold pubescent grains. It takes 120 –140 days to mature and gives an average yield of 5-6q/ha.

RZ-209: It was developed at SKN College of Agriculture (RAU), Jobner through selection. The variety has showntolerance to wilt. It takes 140-150 days to reach maturity and gives seed yield of 6.5q/ha.

RZ-223: This variety was developed at SKN College of Agriculture (RAU), Jobner through selection. The variety possesses resistant to wilt. The seeds yield an oil content of 3.23 per cent and gives seed yield of 6.0q/ha.

Gujarat Cumin-1: It was developed by Spice Research Centre (S.D.A.U), Jagudan from local germplasm. The plants are erect with pink flowers and bold, linear, oblong ash brown colour grains. The variety is tolerant to wiltdisease. It matures in 105-110 days and gives an average yield of 7.0q/ha.

Gujarat Cumin -2: It was developed by Spice Research Centre (S.D.A.U), Jagudan through pure line selection. The plants are bushy with good branching habit attractive grains. It matures in 100 days and gives an average yield of 7.0q/ha.

Gujarat Cumin -3: This variety also developed by Spice Research Centre (S.D.A.U), Jagudan through selection from exotic line. The variety is resistant to wilt. It matures in 100 days and gives an average yield of 7.0q/ha withessential oil content of 3.5%.

Gujarat Cumin -4: This variety was developed by Spice Research Centre (S.D.A.U), Jagudan through selection from GC-3. It gives an average yield of 8.75 q/ha and is resistant to Fusarium wilt.

New Varieties

India is the leader in the Cumin production and export. The short-duration Cumin Genotype "CZC-94" developed by the ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan shows earliness in the flowering (40 to 42 Days) and maturity (100 to 105 Days) and requires less irrigation. The shorter maturity duration favors timely sowing - early harvest and late sowing - timely harvest models. The CZC-94 is a win-win option for both the crop and growers. The shorter duration may also allow the Cumin spread in the non-conventional dry areas with short cold duration. In the Rabi 2021-22, the CZC-94 was commercially cultivated by 15 Cumin growers of the arid regions. The farmers response was encouraging and they are highly convinced by the under mentioned benefits of the CZC-94 shorter duration over the existing cultivars. It not only requires less irrigation / water and time in germination but, also requires only 3 irrigations after germination to harvest, thus, saving 1 to 2 irrigations. The landholdings are large in the arid regions, with limited water availability coupled with the limited hours of electricity supply. These constrains the limits cropping intensity, farmer can increase the area of Cumin cultivation with CZC-94 as it can be sown up to mid-December without reduction in the yield (ICAR, 2024).

Whole vs. Ground Cumin

Cumin is available as both whole seeds and ground powder and both are used in recipes. Whole cumin, for example, is featured in Indian dishes, where the whole seeds are added to the hot oil at the start of the dish so the flavor infuses the oil and therefore the rest of the ingredients. More flavor is brought out when the seed is lightly roasted, which is done easily using a dry pan over medium heat. Ground cumin is made by grinding dry roasted cumin seeds. It can be added at any time to a recipe as its flavor doesn't need heat or time to be released, as is the case with the seeds. More intense and nuanced flavor can be enjoyed by lightly roasting whole cumin seeds and then grinding the seeds in a spice grinder or with a mortar and pestle. You might want to consider that when using measurements for a recipe and grinding cumin from freshly roasted seed. Once ground, cumin will gradually lose its flavor over time and should be replaced regularly (Alfaro, 2024).

Uses

Cumin is a major ingredient of mixed spices powder and curry powder mixes. It is an ingredient of pickles andchutney mixes. Cumin seeds have an aromatic fragrance due to an alcohol, cuminol. The aromatic oil ofcumin seeds is also used for flavouring curries, liquor, cordials and has great use in perfumery industries. It has medicinal properties and is used in many Ayurvedic and veterinary medicines as carminative, stomachic, astringent and is useful against diarrhea and dyspepsia. Cumin seeds are very useful in digestive disorders like biliousness, morning sickness, indigestion, atonic dyspepsia, diarrhea, malabsorption syndrome and flatulent colic. Cumin is valuable in relieving sleeplessness. Dilute cumin water is an antiseptic beverage and very usefulin common cold and fevers, which is associated with sore throat (Lal *et al.,* 2014). Culinary uses: Seeds of cumin are generally added to dishes to bring out the perfect flavour of the seeds, they are usually toasted in a dry frying pan or with a little butter before adding. Below are the uses and how to use cumin (Agarwal *et al.,* 2017):

- Cumin is used in barbeque sauces and marinades.
- Sprinkle ground cumin inside a cheese omelette mixture.
- Fry along onions and use to flavour lentils.
- Blend with olive oil and pour over stir-fried vegetables.
- Used in hot and spicy soups or sauces.
- Added in curries and chillies.
- Cumin is mixed in pickles and chutneys.

Cumin seed is used as a spice for its distinctive flavour and aroma. Cumin can be found in some cheeses, such as Leyden cheese, and in some traditional bread from France. Cumin is an ingredient in chilli powder (often Tex-Mex or Mexican-style), and is found in achiote blends, adobos, sofrito, garam masala, curry powder, and bahaarat. In South Asian cooking, it is often combined with coriander seeds in a powdered mixture called dhana zeera. Cumin can be used ground or as whole seeds. It helps to add an earthy and warming feeling to food, making it a staple in certain stews and soups, as well as spiced gravies such as curry and chilli. In Sanskrit, cumin is known as Jiraka "that which helps digestion" and is called zira in Persian/Urdu. In the Ayurvedic system, dried cumin seeds are believed to have medicinal purposes. These seeds are powdered and used in different forms like kashaya (decoction), arishta (fermented decoction), vati (tablet/pills), and processed with ghee (a semifluid clarified butter). It is used internally and sometimes for external applications also. In southern Indian states, such as Kerala, Andhra Pradesh and Tamil Nadu, a popular drink called Jira water is made by boiling cumin seeds. Jeera is stimulant, antispasmodic and carminative. Because of its disagreeable flavour, its medicinal use at the present day is almost confined to veterinary practice, in which it is employed as a carminative. Formerly Cumin had considerable repute as a corrective for the flatulency of languid digestion and as a remedy for colic and dyspeptic headache. Bruised and applied externally in the form of a plaster, it was recommended as a cure for stitches and pains in the side caused by the sluggish congestion of indolent parts, and it has been compounded with other drugs to form a stimulating liniment (Dar *et al.,* 2019). Cumin seed is used as a spice for its distinctive flavour and aroma. Cumin can be found in some cheeses, such as Leyden cheese, and in some traditional bread from France. Cumin is an ingredient in chilli powder

(often Tex-Mex or Mexican-style), and is found in achiote blends, adobos, sofrito, garam masala, curry powder, and bahaarat. In South Asian cooking, it is often combined with coriander seeds in a powdered mixture called dhana zeera. Cumin can be used ground or as whole seeds. It helps to add an earthy and warming feeling to food (Dar *et al.,* 2019).

Cumin is a versatile spice that is typically used in savory dishes. Because of its strong flavor profile, it can easily season a dish on its own, but it also complements a variety of other spices. That's why you'll commonly find it in traditional spice blends. Cumin can also be added to soups, bean dishes, root vegetables, sauerkraut, meat marinades, cheeses, breads, and savory sauces. We encourage you to use your imagination and find your own favorite uses for this long-celebrated ancient spice (Pacificspice, 2020). Cooking with cumin will depend on whether the recipe calls for whole or ground cumin. As a rule of thumb, however, remember that whole cumin has a more potent flavor. So, if switching from whole to ground cumin and vice versa, be sure to portion correctly. Whole cumin seeds should be included early in the recipe in order for the spice to release its essence. Adding whole seeds to hot broth or oil will let the flavors disperse into the dish. Ground cumin is a more commonly used and is a staple in most curry powders and many spice blends (Colorado Spice, 2021). Cumin seed is used as a spice for its distinctive flavor and aroma. Cumin can be found in some cheeses, such as Leyden cheese, and in some traditional breads from France. Cumin can be an ingredient in chili powder (often Tex-Mex or Mexican-style) and is found in *achiote* blends, *adobos*, *sofrito*, *garam masala*, curry powder, and *bahaarat*, and is used to flavor numerous commercial food products. In Indian and other South Asian cuisine, it is often combined with coriander seeds in a powdered mixture called *dhana jeera*. Cumin can be used ground or as whole seeds. It imparts an earthy, warming and aromatic character to food, making it a staple in certain stews and soups, as well as spiced gravies such as curry and chili. It is also used as an ingredient in some pickles and pastries (Wikipedia, 2024).

In India, the seeds are powdered and used in different forms such as *kashaya* (decoction), *arishta* (fermented decoction), and *vati* (tablet/pills), and processed with *ghee* (a semifluid clarified butter). In traditional medicine practices of several countries, dried cumin seeds are believed to have medicinal purposes, although there is no scientific evidence for any use as a drug or medicine. Cuminaldehyde, cymene, and terpenoids are the major volatile components of cumin oil, which is used for a variety of flavors, perfumes, and essential oil. Cumin oil may be used as an ingredient in some cosmetics. Cumin's flavor and warm aroma are due to its essential oil content, primarily the aroma compound cuminaldehyde. Other aroma compounds of toasted cumin are the substituted pyrazines, 2-ethoxy-3-isopropylpyrazine, 2-methoxy-3-*sec*-butylpyrazine, and 2-methoxy-3-methylpyrazine. Other components include γ-terpinene, safranal, p-cymene, and β-pinene (Wikipedia, 2024). The odour and flavour of cumin is derived largely from the essential oil, which contains cumaldehyde or cuminic aldehyde as the main constituent. Other ingredients of the oil are dihydrocuminaldehyde, dl-pinene, d--pinene, para-cymene, dipentene, and cuminyl alcohol. Synthetic cuminaldehyde is an adulterant to cumin oil and is very difficult to detect chemically. The dried seed of cumin has 2.5 to 5 percent essential oil on a dry weight basis and is obtained by steam distillation (KSSDB, 2024). Cumin is used as a flavoring agent in many ethnic products such as cheeses, pickles, sausages, soups, stews, stuffings, rice and bean dishes, and liqueurs. It is an essential component of Mexican foods, along with chilli pepper and oregano. Its use is prevalent in many Latin American cuisines. Cumin is the key ingredient of Indian cooking like all types of curries and chilli powders (KSSDB, 2024). Oil of cumin is used in fragrances. As a medicinal plant, cumin has been utilized as an antispasmodic, carminative, sedative, and stimulant. Cumin oil has been reported to have antibacterial activity. Distinct phototoxic effects have been reported from undiluted cumin oil. It is also used in veterinary medicines and perfumes (KSSDB, 2024).

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Grading

There are three noteworthy sorts of cumin seed in the market which vary in seed shading, amount of oil and flavour (Wiki, 2024): Iranian, Indian and Middle Eastern (Wiki, 2024). The three noteworthy sorts of cumin seeds in the market vary in seed shading, amount of oil, and flavour (Wikipedia, 2024): 1) Iranian, 2) Indian, South Asian and 3) Middle Eastern.

Nutritional value

In a reference amount of 100 grams (3.5 oz), cumin seeds provide high amounts of the Daily Value for fat (especially monounsaturated fat), protein, and dietary fiber. B vitamins, vitamin E, and several dietary minerals, especially iron, magnesium, and manganese, are present in substantial Daily Value amounts (Wikipedia, 2024).

Health Benefits

It has tremendous health benefits: Iron for energy and immune function, seeds for good digestion, Cancer prevention, respiratory disorders, asthma, bronchitis, insomnia, piles, lactation and boils (Parashar *et al.,* 2014). Although the seeds of cumin are widely used as the spice for their distinctive aroma, they are also commonly used in traditional medicine to treat a variety of diseases, including chronic diarrhoea and dyspepsia, acute gastritis, diabetes, and cancer. The literature presents ample evidence for the biological and biomedical activities of cumin, which have generally been ascribed to its bioactive constituents such as terpenes,

phenols, and flavonoids. Those health effects of cumin seeds that are experimentally validated are discussed below (Srinivasan, 2018). Cumin is stomachic, diuretic, carminative, stimulant, astringent and antispasmodic. It is valuable in dyspepsia diarrhoea and hoarseness, and may relieve flatulence and colic. In the West, it is now used mainly in veterinary medicine, as a carminative, but it remains a traditional herbal remedy in the East.

It is supposed to increase lactation. and reduce nausea in pregnancy. Used in a poultice, it relieves swelling of the breast or the testicles. Smoke in a pipe with ghee, is taken to relieve the hiccups. Cumin also stimulates the appetite (Dar *et al*., 2019). In India, Cumin seeds are often chewed as a digestive aid, typically offered at the end of a meal for this purpose. Cumin is also high in iron and contains many phytonutrients and antioxidants, as well (Colorado Spice, 2021).

Health Benefits of Cumin Seed (Indiacuminseed, 2024)

- **Treatment of Boils -** Regular usage of cumin in your food helps in keeping your skin free from boils, rashes, pimples etc. This is because it has components such as Cuminaldehyde, Thymol and phosphorus which are good detoxifying agents. They help in facilitating regular removal of toxins from the body through the excretory system and not through boils.
- **Treatment of Skin Disorders -** Cumin has a high content of vitamin E which keeps your skin healthy and glowing. Besides, the essential oils, cumin have disinfectant and anti-fungal properties which protect your skin from fungal and microbial infections. Topical application of cumin paste on boils, pimples, eczema, psoriasis and other skin disorders facilitates quick healing.
- **Anti-Ageing Benefits -** Vitamin E present in cumin triggers the anti-ageing processes within the body, thus preventing pre mature ageing symptoms. It acts as an antioxidant to combat the free radicals that attack the skin and cause signs of ageing like wrinkles, age spots and sagging skin. This combination of antioxidant effect and antibacterial capacity of cumin provides you with a healthy, beautiful skin that lasts far into your old age.
- **Cures Itchiness and Body Heat -** If you are suffering from body heat and skin itchiness, you can put some cumin seeds in boiled water. Once it is cooled, take a bath with that water. It will help relive you body heat and itchiness.
- **Treatment of Burning Sensation -** Drinking cumin water can relieve the burning sensation of the palms and the soles.
- **Treatment of Dandruff -** Oil extract from cumin is a great stimulant, carminative, antioxidant and diuretic. It is often used for massage in aromatherapy and scalp treatments to get rid of dandruff.
- **Maintains Blood Levels -** Cumin helps to lower blood sugar levels and thus helps in maintaining proper blood content levels in the body. This is a great boon for people suffering from Diabetes.
- **Maintains Iron Deficiencies -** Cumin seeds are very rich in iron, which makes it an essential natural health ingredient. This iron content helps to treat anaemia, makes blood rich in haemoglobin content and also helps in acting as a carrier of oxygen to the cells in the body.
- **Fights Asthma -** Cumin seeds contain Thymoquinone, which reduces inflammatory processes and other mediators that cause asthma. They also act as a bronchodilator.
- **Immunity -** This is achieved by its anti-oxidant characteristics that fight against impurities and free radicals. This helps in making the body's immunity better in combating diseases.

CULTIVATION

Cumin grows well in tropical and subtropical areas of world ideally situated within the 20^{o} to 38^{o} north latitudes. Its cultivation is done best under moderately cold dry climate. Humidity during flowering and seed setting is deleterious as the crop is susceptible to fungal diseases. It is requires temperature range from 9^{o}C to 26^{o}C for proper growth and development. Frost at the time of flowering and early fruit sett has an adverse effect on the crop. Overall, locations having low atmospheric humidity and mild winters are most suited for cumin cultivation. Frequent rains at the time of flowering, fruit setting, and maturity leads to incidence of blight and powdery mildew in the crop (Brar *et al.,* 2022). Although cumin cultivation can be done on all type of soils, most suitable are sandy soils with low organic matter, and clay or clay loam with fair organic matter. Soil drainage is very crucial as water stagnation and excessive moisture are harmful for the crop. High soil pH also has adverse effect on the crop and preferred range of 6.8–8.3, while soil suspension EC of 14 dSm^{-1} is suitable for cumin cultivation. Saline soil or saline irrigation water results in better seed filling in cumin. Apart from deep, and shallow soil, gravely soils with good porosity and drainage are also suitable for this crop (Brar *et al.,* 2022). Soil analysis based fertilizer application is best for obtaining good growth of crop along with optimum use of fertilizers. For a good soil structure and soil properties, 10 t ha^{-1} FYM or 5 t ha^{-1} compost can be applied three weeks prior to sowing. Using the organic wastes such as FYM provides us with an option of climate resilient crop management module while reducing the chemical fertilizer load. Biofertilizers can also be used as they enhance biological activities of useful microbes in the soil along with improving the crop yield and quality. As the crop responds well to fertilizer, basal application of 15 kg N, 20 kg P, and 20 kg K_2O ha^{-1} can be done, and remaining 30 kg N can be applied as top dressing 60 days after sowing (Brar *et al.,* 2022). Well prepared land aids in good germination and growth of the plant. Bring the soil to a fine tilth through 2–3 harrow ploughings and then level the field with a plank. At the time of third ploughing, incorporate FYM/ compost in the soil. The beds of convenient size should be prepared with adequate placement of irrigation channels (Brar *et al.,* 2022).

Time of sowing while having no influence of cost of production, has immense influence on disease and pest incidence. Therefore, it is crucial to complete sowing at appropriate time so that flowering stage escapes the period of high atmospheric humidity. For better germination, optimum temperature required is 30^{o}C. In order to achieve good and healthy growth of the crop sowing can be

done between mid-November and first week of December (Brar *et al.,* 2022). Optimum seed rate is essential in order to ensure ideal plant population which allows proper growth of plants leading to higher yield. Seed rate is determined by the type of variety and sowing method. Optimal seed rate ranges from 10–20 kg per hectare, where bold seeded varieties need higher seed rate (Brar *et al.,* 2022). In order to control seed borne diseases, treat the seed with Trichoderma culture (10 g/kg seed) or alternatively with Thiram/carbendazim @ 2.5 g/kg. Inoculation with Azospirillum or Azotobactor and seed priming for 8 hours and drying of seed in shade is known to enhance the germination (Brar *et al*., 2022). Cumin can be sown by two methods, viz**.** in lines or by broadcasting the seed, where former requires a drill while latter can be done by manual labour. Conventionally farmers go for sowing through broadcasting as it is an easier and cheaper alternative. On the other hand sowing in lines facilitated intercultural operations at all the stages of the crop. For line sowing the spacing between lines should be 25 cm, with seed sown of 1.5 cm deep covered with thin layer of soil. In case of broadcasting, cover the seed with light layer of soil with the help of a teeth rake. Avoid sowing the seed too deep, to prevent germination problems (Brar *et al*., 2022).

Crop geometry is an important aspect which influences proper sunlight interception which leads to optimum physiological activities of plants. Optimal plant population aids in proper translocation of photosynthates in the plant. In case of higher than optimum plant population, competition for water, space, light, and nutrient increases which results in reduced accumulation of dry matter in plants. Therefore, optimum plant geometry is an important requirement to realise higher production of crops. Crop geometry in case of cumin within row spacing of 22.5–30 cm, within plant spacing of 15–30 cm (Brar *et al.,* 2022). Right amount of irrigation at appropriate time is essential for good germination and growth of the crop. For good germination of crop, a light irrigation should be given after sowing. Avoid heavy irrigation at this stage to avoid dislocation of the seed. After 10–12 days of sowing germination becomes visible, typically after second irrigation. In case of high temperature during day and dry weather another irrigation can also be given after an interval of 4–5 days. As per the prevailing weather and soil type irrigation is given at an interval of about 30 days. However, at the maturity stage avoid irrigation so as to prevent adverse effects on quality of seed. Sprinkler irrigation is also good in case the crop shows symptoms of wilting. Alternatively, drip may also be used but it is a very costly set up (Brar *et al.,* 2022). Weeds are an important problem in cumin cultivation as they compete with the crop for resources while contaminating the seed. So, in order to achieve a robust growth of the crop weed management should be done at appropriate times. First weeding and hoeing should be done when the crop has attained 4–5 cm height which happens at 30–40 days after sowing. To keep the crop free of weeds and to break the soil crust, another 2–3 weedings are needed (Brar *et al*., 2022).

Harvesting and Yield

Generally, cumin crop takes about 90-120 days to reach maturity. Physiological maturity (complete yellowing ofplant) is the best stage for harvest to get high yield of quality produce. Delayed harvesting (complete drying ofplants) showed negative results for all the quality parameters. It is also observed that sun drying of harvested material for long time before threshing is not advantageous for quality of cumin. The volatile oil content of cumin seeds is lost due to delayed harvesting and drying of crop in Sun. Further, crop should be harvested in early morning to avoid shattering of seeds and thereby losses of yield. There after the crop is beaten and trampled ona clean threshing floor. Threshing can also be done by threshers in large scale cultivation under the scientific cultivation practices the improved varieties of cumin give an average yield of 8-10 q/ha. Threshing is followed by winnowing, cleaning and grading through mechanical devices (Lal *et al*., 2014). The crop matures in 80-120 days depending upon variety and agro-climatic conditions. The harvesting is done when the crops turn yellow, leaves fall down and seeds turn light greyish brown. The crop is harvested by uprooting the individual plant or by cutting it close to the ground. The plant resembling zeera are rouged out from the field before harvesting to avoid admixture and contamination of seeds. Cumin seed is normally harvested from late May to late June in cold to moderate areas (*i.e.* Iran) and in January to February in subtropics and tropic areas (*i.e.* India). In the traditional system of harvesting, plants are cut with hand tools before shedding starts and seeds are separated from the straw by various means. However, in recent years attempts have been made to modify seed harvesters for this purpose. The yield is affected largely by diseases, however by following standard agronomic practices and controlling the diseases properly, healthy and disease free crop can yield 6-8 q seed ha-1. Generally cumin seeds are processed after drying in sun. The seeds should be dried to a moisture level of 8.5-9 % (Dar *et al*., 2019).

Cumin generally attains maturity in about 90–120 days. Physiological maturity as indicated by yellowing of plant is the most appropriate stage to obtain produce of high quality. Complete drying of plants has adverse effect on the crop quality. Apart from this prolonged sun drying of the crop prior to threshing is not advisable as it lowers the crop quality and has deleterious effect on oil content of seed. Harvest the crop early in morning to avoid grain shattering, followed by beating and trampling it on a clean threshing floor. In case of large scale cultivation threshing can also be with the help of a thresher which is very popular among the farmers now days. There have been attempts to design modified seed harvesters for cumin. After harvesting cumin is cleaned and graded with the help of mechanical devices. The thoroughly cleaned cumin seeds can be stored with 7–8% moisture level at 40% equilibrium relative humidity. Seeds can be stored in polythene film lined gunny bags in a well ventilated, dry and cool place till next sowing season (Brar *et al*., 2022).

On average, plants will produce seeds about 120 days after planting, but this can vary and range from 100 to 150 days. Keep a close eye on plants as the growing season progresses. If you miss the harvesting window, the seeds will dry out and scatter. Plants won't all necessarily ripen at the same time, so you may be harvesting a little bit every day over a period of time. The seed is ready to harvest when the flowers have finished blooming and the clusters turn brown and dry out. This generally happens in the fall. To harvest, cut the stems close to the ground and place the seed clusters in paper bags. Tie the stems together and hang the bags upside down in a warm, dry location to let the seeds dry out. After about a week, or when the pods are completely dry, rub them between your fingers to encourage the seeds to drop out of the pods. You can also thresh the bag against a hard surface to release

the seeds from the chaff. Once the seeds are removed from the pods, sift them through a sieve or mesh cloth to remove any debris (Buckner, 2023). Generally cumin crop takes about 110-115 days to reach maturity. Crop becomes ready to harvest, when plants turn yellowish brown. Harvesting should be done early in the morning by cutting/uprooting the whole plants. Harvested crop should be dried in the threshing yard thrashed to separate the seeds. Seeds should be cleaned by winnowing. Yield: 600 to 700 kg/h (Eagri, 2024).

Post Harvesting Management

Processing consists of drying, cleaning, sorting and grading. Sun drying is done on clean, cemented yard or tarpaulin. This will avoid the direct contact of seed with soil. Cleaning, sorting and grading is done with the help of different machines like spiral separator, Magnetic seed separator, Electronic colour sorter, Destoner, rotary knife etc. Commercially Vacuum or gravity separator is used for cleaning and grading cumin seeds. The properly cleaned cumin seeds are packed with an initial moisture level of 7-8% and at an equilibrium relative humidity of 40%. Well packed cumin seeds well packed are stored in ventilated dry and cool place under ordinary conditions till sowing of next season crop. Moisture proof package like gummy bags lined with polythene appropriate size poly bags, sealed steel containers should be used so that the produce can be saved from storage pests & fungal infections. CAP/MAP and vaccum packing is also becoming popular now days (Lal *et al*., 2014). After harvest cumin seeds are dried under partial shade in order to keep the moisture up to 9% for storage. Higher moisture content in seeds increases the chances of fungal contamination during storage. The cleaned, dried, and graded seed is packed in the standard size packaging with appropriate labelling. Storage of dried seeds is done in environment friendly plastic film lined gunny bags. While processing cumin, care should be taken to maintain the vitality of the organic ingredient. Selection of processing method should be in such a manner that number and quantity of additives as well as processing aids is kept to a minimum. Essential oil extraction is done by distillation of mature dried seeds, and generally it is done by hydro or steam distillation. For oil extraction, dried seeds can be crushed or steam distilled wholly to yield 2.5 to 4.5% oil content. In International market, there is a good demand for oleoresin obtained from cumin. After processing, various products are produced such as cumin powder, essential oil, cumin oleoresin and fixed oil. Volatile oil after extraction should be stored in well sealed containers (Brar *et al*., 2022).

Storage

I prefer to keep my spices in tightly lidded mason jars in a dark cupboard next to my oven for easy access when I'm cooking. You can also save a few to plant a new crop next year. The seeds will keep for about 2 years if stored properly. Seeds are commonly used whole or ground up, but wait to grind them until right before you are ready to use them. They will remain fresher and much more aromatic if you do! Dry roasted and ground cumin is one of my absolute favorite homegrown spices (Buckner, 2023). Cumin is a spice made from the dried seed of a plant known as Cuminum cyminum**,** a member of the parsley family**.** Cumin is one of the most popular spices and is commonly used in Latin American, Middle Eastern, North African, and Indian cuisines, among many others. It is available both as whole seeds as well as in ground form (Alfaro, 2024).

Cumin oil

The study revealed that the biochemical composition of cumin seeds is origin-dependent and that cumin seeds are rich in an unusual fatty acid, petroselinic acid. Besides, cumin essential oil is a rich source of many compounds, including cuminaldehyde and γ-terpinene. The overall results suggest the exploitation of cumin seeds as a low-cost renewable source for industrial processing in the fields of cosmetics, perfumes and pharmaceuticals (Bettaieb, 2011).

Production in India

India is the leading nation in the world under area, production, consumption and exporter of cumin since year 2010. In 2018-19 the area under cumin crop was 10.27 lakh ha. Its production and productivity were 6.08 lakh MT and 0.59 Mt/ha, respectively. Two states (Rajasthan and Gujarat) of India have played major role in cultivation and contribution of cumin crop production. Gujarat has been the leading state of cumin production in India from 2010 to 2019.

Gujarat was having highest productivity of 1.04 MT/ha in 2018. The production and area under cumin cultivation, in Gujarat has increased by 45.66% and 20.33% respectively, from year 2010 to 2019 (Kumar *et al.,* 2021).

Production Constraints (Dar *et al.,* 2019)

- Lack of suitable variety adapted to wide range of soil and climatic condition.
- Inherent poor production capacity.
- Shallow root system.
- Highly sensitive to soil and climate.
- Small seeds with low viability and vitality
- Unsolved chronic maladies of wilt and blight.

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