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REVIEW ARTICLE

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

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ABSTRACT

Dill belongs to the family *Apiaceae*, genus *Anethum,* and species *Anethum graveolens.* The name dill is thought to have originated from a Norse or Anglo-Saxon word 'dylle' meaning to soothe or lull, the plant having the carminative property of relieving gas. In some English speaking countries, it is sometimes called Dillby. In some Asian local languages it is called as "Shepu" or "Sowa". Common names are dill, Indian dill. The name “dill” means to “calm or soothe,” and most likely originates from the plant’s known ability to calm troubled stomachs and colicky infants. The Latin name of a plant often tells us something about the plant’s characteristics, and dill is no exception. The name *Anethum* describes dill’s growth habits. The word is a combination of the words *ano* and *theo,* which when used together mean “upwards I run.” *Anethum* also originates from the Greek word *aneson* or *aneton*, which is most likely also the origin of the name anise. The Latin name *graveolens* comes from a combination of two words; *gravis*, meaning “heavy or weighty,” and *oleo*, which means “producing a smell or odor.” When combined into *graveolens* the meaning of these two words becomes “emitting a heavy odor or strong smelling.” Thus, the name *Anethum graveolens* means a tall plant with a vigorous growth habit that has a strong smell. Common names of dill in Gujarati: Suva, Hindi: Soya, Kannada: Sabbasige, Sabaseege, Sabbakkisoppu, Sabasi, Malayalam: chatakuppa, Manipuri: Pakhon, Marathi: Shepu, Balantshopa, Sanskrit: Shatapushpa, Misi, Shaaley, Sheetashiv, Chhatraa, Madhurikaa, Mishreyaa, Tamil: catakuppai, kattucata kuppai, Telugu: sompa.Dill is an important aromatic as well as medicinal annual herb from the Apiaceae family. Seeds and leaves of this plant are used as the main edible parts and it is a widely used spice due to its pleasant spicy aroma and plenty of nutritional and medicinal properties. Dill essential oil contains dill apiole, carvone, carvacrol, dihydrocarvone, limonene, p-cymenand α-phellandrene. It is used in the treatment of several ailments *viz*., gripe water to relieve colic pain in babies and flatulence in young children, while the seed is carminative, mildly diuretic, galactogogue stimulant and stomachic. It is also used in the cure of certain urinary complaints, piles and mental disorders. In India during 2019–2020, dill was cultivated in an area of 32.79 thousand ha with a production of 34.56 thousand tonnes seed and a productivity of 1054 kg/ha. These tiny flowers make small umbellate flower bunch which provides a right landing platform for pollinators. The relative significance of insect pollinators for reproductive success of any cross pollinated plant species depends on availability of pollen and nectar, visitation frequency and ability to deposit pollen on the stigma in single visit. Earlier studies reported honeybees, solitary bees, syrphids, muscids, some beetles and butterflies species as floral visitors of seed spices. This annual plant with aromatic foliage and seeds, *Anethum graveolens*, is the sole species in that genus of the parsley family (Apiaceae or Umbelliferae). It is thought to have originated in Eastern Europe, southern Russia, central and southern Asia. It has naturalized in many other parts of the world, and can be seen as a roadside weed in July and August in many parts of the United States. Although we know it primarily as a culinary herb, it was used historically for medicinal and magical purposes. In this review article on Origin, Taxonomy, Botanical Description, Genetic Diversity, Breeding and Cultivation of Dill are discussed

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INTRODUCTION

Dill belongs to the family *Apiaceae*, genus *Anethum,* and species *Anethum graveolens* **(**Schlosser, 2007; Datiles and Acevedo-Rodriguez, 2015; Masoody et al., 2023; Pawbakea et al., 2023; Bionity, 2024; USDA, 2024; Wikipedia. 2024; Wikipedia, 2024a). The name dill is thought to have originated from a Norse or Anglo-Saxon word 'dylle' meaning to soothe or lull, the plant having the carminative property of relieving gas. In some English speaking countries, it is sometimes called Dillby. In some Asian local languages it is called as "Shepu" or "Sowa" (Bionity, 2024). Common names are dill, Indian dill. The name “dill” means to “calm or soothe,” and most likely originates from the plant’s known ability to calm troubled stomachs and colicky infants. The Latin name of a plant often tells us something about the plant’s characteristics, and dill is no exception. The name *Anethum* describes dill’s growth

habits. The word is a combination of the words *ano* and *theo,* which when used together mean "upwards I run." *Anethum* also originates from the Greek word *aneson* or *aneton*, which is most likely also the origin of the name anise. The Latin name *graveolens* comes from a combination of two words; *gravis*, meaning "heavy or weighty," and *oleo*, which means "producing a smell or odor." When combined into *graveolens* the meaning of these two words becomes "emitting a heavy odor or strong smelling." Thus, the name *Anethum graveolens* means a tall plant with a vigorous growth habit that has a strong smell **(**Schlosser, 2007**).** Other names are American dill, aneth, aneth odorant, anethi fructu **(**LLC, 2024**).**

Common names of dill in Gujarati: Suva, Hindi: Soya, Kannada: Sabbasige, Sabaseege, Sabbakkisoppu, Sabasi, Malayalam: chatakuppa, Manipuri: Pakhon, Marathi: Shepu, Balantshopa, Sanskrit: Shatapushpa, Misi, Shaaley, Sheetashiv, Chhatraa, Madhurikaa, Mishreyaa, Tamil: catakuppai, kattucata kuppai, Telugu: sompa (Singh, 2024). Indian Names are in Hindi : Sowa, Bengali : Sowa, Gujarati : Surva, Kannada : Sabasige, Kashmiri : Sor, Malayalam : Sathakuppa, Marathi : Surva, Shepu, Punjabi : Sowa, Sanskrit : Satapushpi , Tamil : Sathakuppi Sompa, Telugu : Sabasiege, Urdu : Sowa (Wikipedia. 2024; SPI, 2025;).

International Common Names are In English garden dill; Spanish anis alemán, eneldo; French aneth, aneth odorant, fenouil batard, fenouil puant ; Chinese shi luo; Portuguese endro; Czech Republic kopor vonavý, kopr vonný; Dominican Republic Hinojo, inojo; Estonia aedtill; Germany Dill, Garten, Gurkenkraut; Greece anethon; India sowa; Indonesia adas manis, adas sowa, ender; Italy aneto odoroso, oneto; Laos phak s'I;Latvia smaržig; Lesser Antilles fenouil bâtard, lami dill; Lithuania paprastasis krapas; Malaysia adas china, adas pudus, ender; Myanmar European dill, Indian dill, sameik, samin; Netherlands dille; Panama anisillo dill; Portugal anetho, aneto, Endrâo, endro maior, endro ordinario; Puerto Rico dill-weed; Russian Federation ukrop; Spain abezón domestic, anega, anella, anet pudent; Thailand phakchi lao, thian-khaopluak, thian-tatakkataen (Datiles and Acevedo-Rodriguez, 2015).

Dill was believed to provide protection from witchcraft, most likely because of its strong smell. People thought that if a witch cast a spell on you, the cure could be found by drinking a cup of dill water. Conversely, dill was also thought to be used by magicians and witches when they were casting their spells. Charms were often made from sprigs of dill to provide protection from witchcraft; they were hung around the house or worn on the clothing. Dill was often added to love potions and aphrodisiacs to make them more effective. The herb was also believed to bring happiness and good fortune to marriages. In Germany and Belgium, brides would attach a sprig of dill to their wedding gowns or they would carry it in their bouquets in the hopes that happiness would bless their marriages. A bride who did not want her husband to be in charge of the marriage could secretly bring mustard and dill seeds to her wedding and repeat the words "I have you, mustard and dill, Husband, when I speak, you stay still!" Dill means "good spirit" or "to lull" in the language of flowers. European monks believed that dill could hinder fertility and that it had the power to chase off incubus or male demons that preyed sexually on sleeping women **(**Schlosser, 2007**).** There is little information available on the toxicity of dill or of its extracts, The National Academy of Science reported in 1967 that the safety margin between organoleptically acceptable levels and toxic levels is small. The presence of myristicin, which has been implicated in liver damage and which is a psychoactive agent, appears to have influenced this statement. Also influential is the fact that the apioles are, structurally, closely related to myristicin and safrole and that they are biologically active (Henry, 1982). The plant has a long and ancient history in many countries as a culinary and medicinal herb. The earliest known record of dill as a medicinal herb was found in Egypt 5,000 years ago, when the plant was referred to as a "soothing medicine." **(**Schlosser, 2007**).** Around 3,000 B.C.E. the Babylonians were known to have grown dill in their gardens. Dill was also a widely used and familiar plant in the Greek culture. Dill scented oil was burned in Greek homes, and the plant's essential oil was used to make some of their wine **(**Schlosser, 2007**).** Dioscorides, a Greek doctor and surgeon, wrote that scorched dill seeds were used to aid with healing wounded soldiers, a practice which was also shared by the Romans **(**Schlosser, 2007**).** Gladiators were fed meals covered with dill because it was hoped that the herb would grant them valor and courage **(**Schlosser, 2007**).** Pliny the Elder was the author of *Naturalis Historia* which was the precursor to the modern day Encyclopedia. He included information about dill in the sections that talked about exotic plants and spices **(**Schlosser, 2007**).** Dill seeds are often called "meeting house seeds" because they were chewed during long church services to keep members awake or kids quiet. The seeds were also chewed in order to freshen the breath and quiet noisy Stomachs **(**Schlosser, 2007**).** *A. graveolens* has long been a highly prized herb, and in many cultures it was taxed or tithed. One such case is that of Edward I of England, who did not have enough money to repair London Bridge. He imposed a tax on dill and other spices that ships brought into the harbor to help raise the needed funds **(**Schlosser, 2007**).** During the seventeenth century, dill became a popular herb in Englandand it could be found in many "hortus," or kitchen gardens **(**Schlosser, 2007**).** The plant most likely arrived in America by means of the early settlers. John Winthrop, who led a group of English Puritans to the New World, was known to have grown dill in his garden **(**Schlosser, 2007**).** Dill is one of the important seed spices crop, mainly grown for culinary purpose and medicinal uses. Seeds and oil of dill are used in preparation of various medicines (Sharma *et al.,* 2010). The chief producers of dill in the world are India, Pakistan, China, Western Russia, Hungary and Egypt. Major importing countries of dill seed, seed powder and dill oil are USA, Japan and Germany (Sharma *et al.,* 2010). In India dill is mainly cultivated in the states of Rajasthan, Gujarat, Punjab, Karnataka and West Bengal for its seeds (Sharma *et al*., 2010). Dill is primarily a summer crop of temperate regions, but it has also adopted to grow in warmer areas to produce herb (Sharma *et al*., 2010). The dry and cool climate is suitable for dill cultivation. In north Indian plains it is grown during rabi (winter) season. It requires cold weather for early vegetative growth and warm sunny days for seed formation and seed maturity. A temperature of above 30°C and below 7°C is not favourable for its growth and development (Sharma *et al*., 2010). The humid climate is not suited for the crop as it favours to the appearance of diseases and pests during flowering or early maturity. It can tolerate higher rainfall but water logging is not favourable for the growth (Sharma *et al*., 2010). Dill is a seed spice crop and an important aromatic herb which is used for flavouring tea, pickles, and confectionery (Gupta *et al.,* 2012). Dill leaves are rich in minerals, proteins and fibre. The seeds are mainly used for spice, culinary and medicinal uses. It is also used as a vegetable and an aromatic and as an inhibitor of sprouting in stored potatoes (Gupta *et al.,*

2012). The aroma volatiles of seed and herb of dill have been identified along with several therapeutic properties, and the antimicrobial activity of carvone isolated from the dill seed oil has been reported (Gupta *et al.,* 2012). Dill contains carotenoids, vitamin C and polyphenols, the contents of which vary during different stages of its growth (Gupta *et al.,* 2012). Dill is probably native to South West Asia or South East Europe, and has been cultivated since ancient times. Europe, Africa and Asia are considered as the centre of origin for dill crop. It is cultivated worldwide in countries like India, Germany, Hungary, the Netherlands, Pakistan and the USA (Gupta *et al*., 2012). Principal dill production areas are India and Pakistan; but Egypt, Mexico, the Netherlands, the USA, Hungary, Germany and Holland also have commercially productive areas. In India dill is grown with the name of sowa (A. *sowa*) in the states of Rajasthan, Gujarat, Maharashtra, Andhra Pradesh and Madhya Pradesh for its seeds (Gupta *et al*., 2012). The earliest reference to the use of dill seed in medicine goes back to 'Charak Samhita' (700 BC) (Gupta *et al.,* 2012). It is an ancient Egyptian remedy described in the Ebers papyrus (1500 BC), where it is an ingredient in a pain-killing mixture(Gupta *et al.,* 2012). The Romans chewed dill seeds to promote digestion, and they hung dill garlands in their dining halls, believing the herb would prevent stomach upset (Gupta *et al*., 2012). It was also spread on the floors of banquet halls so that its fragrance would counteract the heavy food smells. In the seventeenth century, Nicolas Culpeper listed dill as a 'tonic that strengthens the brain'(Gupta *et al.,* 2012). The Puritans were known to place dill seeds in their Bibles to discreetly chew so that their stomach would not rumble during the long church services (Gupta *et al*., 2012).

Dill is a medicinal herb that has been used for more than 2000 years. The fruits (seeds) are carminative, stomachic, digestive, and tranquilizing, and have been traditionally used for treating stomach ailments, colic, hiccups, bad breath, flatulence, and hemorrhoids (Najaran *et al*., 2016). Although in different parts of the world dill seeds are still being used for these purposes, because of the lack of scientific proof for this plant's medical effectiveness it has not been accepted in modern Western medicine (Najaran *et al.,* 2016). Dill seeds' volatile oil is an important part of gripe water, which is a mixture used to treat infants' hiccups and colic. It also has galactogogue properties and promotes milk flow in nursing mothers (Najaran *et al*., 2016). It has been reported that chewing dill seeds clears up bad breath or halitosis (Najaran *et al*., 2016). Dill seed oil is active against harmful intestinal bacteria including *Escherichia coli* and against paramecia and helminthes (Najaran *et al*., 2016). Dill seed preparations applied externally in poultices and compresses can also be used to treat bruises, blocked milk ducts and overloaded breasts in women who are breast feeding, and gum infections. The leaves can also be used for the same purposes (Najaran *et al*., 2016). Dill essential oil rubbed onto the skin can stop feelings of nausea (Najaran *et al*., 2016). Being rich in vitamin C can explains why dill was once used to treat scurvy, a disease caused by a lack of vitamin C (Najaran *et al*., 2016). It is an herb that has been used in Indian herbal and Ayurvedic medicine for its digestive properties. Specific uses are for fever, jaundice, and intestinal and genitourinary tract infections; it has also been used in rheumatic affections (Najaran *et al.,* 2016). Dill is used fresh or processed for food seasoning and preservation (Oivind and Flemming, 2018). Production is concentrated in temperate regions but can be grown as a cool season crop in India and Thailand (Oivind and Flemming, 2018). Several secondary metabolites, among them essential oils are present in the plant and with claimed health benefits (Oivind and Flemming, 2018). Despite the many potential benefits, dill is an underutilized crop (Oivind and Flemming, 2018). The evaluation showed that important agro-botanical traits correlated, such as plant height, umbel size and other size characters (Oivind and Flemming, 2018). Furthermore, essential oil composition was clearly influenced by high temperature stress (Oivind and Flemming, 2018). The observations were recorded on five randomly selected plants for fourteen characters viz., plant height, number of branches, number of umbels per plant, number of umbellate per umbel, seed yield per plant, number of seeds per umbel, number of seeds per umbellate, test weight, oil content, days to 1st flowering, days to 50% flowering, days to maturity, germination percentage and seed yield per plot (Raut, 2020). The data so obtained was subjected to analysis of variance, estimation of different variability parameters, genetic correlation coefficient analysis and path analysis (Raut, 2020). Analysis of variance revealed significant values of genotypic mean sum of square, for all the fourteen characters under study (Raut, 2020). The characters, number of seeds per umbel, number of umbels per plant, days to first flowering, plant height at maturity and days to 50% flowering exhibited higher magnitude for genotypic mean sum of square. High GCV coupled with high heritability and expected genetic advance of a character provides good selection advantage (Raut, 2020). Dill is a popular culinary herb in Scandinavia, Russia, Finland, Iran, China and India (Opara and Magali, 2021). Its leaves, seed and oil are added to baked goods, snacks, condiments, and meat products (Opara and Magali, 2021). Dill is also used in cosmetics, perfumes, creams and lotions, as well as detergents (Opara and Magali, 2021). Employed in witchcraft practices in Europe in the Middle Ages, it has been used in traditional medicine in Eastern and Western traditions, mostly for digestive and urinary complaints (Opara and Magali, 2021). Research, mainly from the Indian subcontinent and the Middle East, with a small number from Europe, provides evidence of dill possessing a range of bioactive properties although the body of research is not large for some (Opara and Magali, 2021). These properties include its antioxidant, anti-inflammatory, analgesic, glucose lowering, anti-diabetic, lipid lowering, hepato-protective, chemopreventive/anti-cancer, neuroprotective/ memory enhancing, anxiolytic (calming), anti-epileptic and antimicrobial properties (Opara and Magali, 2021). Dill is also reported to affect fertility, decrease labour during pregnancy, possibly due to its contractile properties, and may be of use in the management of dysmenorrhea due to its analgesic properties. There are also reports that it may affect the elasticity and pigmentation of skin (Opara and Magali, 2021). Dill is a seed spice crop and an important aromatic herb, that is used for flavoring, tea, pickles, and confectionery. Dill leaves are rich in minerals and fibre (Raut *et al.,* 2021). The seeds are mainly used for spice, culinary and medicinal purposes. It is also used as a vegetable and as aromatic herb (Raut *et al*., 2021). In addition to growing naturally, it also is grown in gardens in our country frequently (Raut *et al.,* 2021). In India, dill is grown with the name of Shepu or Shatapushpa or sowa also known as Indian dill, in the states of Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, and Madhya Pradesh for its seed (Raut *et al.,* 2021). Dill is primarily a summer crop of the temperate region, but it has also adapted to grow in warmer areas (Raut *et al*., 2021). In the northern Indian plains, it is grown during the rabi season (Raut *et al*., 2021). Dill is an important aromatic as well as medicinal

annual herb from the Apiaceae family. Seeds and leaves of this plant are used as the main edible parts and it is a widely used spice due to its pleasant spicy aroma and plenty of nutritional and medicinal properties (Meena *et al*., 2022). Dill essential oil contains dill apiole, carvone, carvacrol, dihydrocarvone, limonene, p-cymenand α-phellandrene. It is used in the treatment of several ailments *viz*., gripe water to relieve colic pain in babies and flatulence in young children, while the seed is carminative, mildly diuretic, galactogogue stimulant and stomachic (Meena *et al*., 2022). It is also used in the cure of certain urinary complaints, piles and mental disorders (Meena *et al*., 2022). In India during 2019–2020, dill was cultivated in an area of 32.79 thousand ha with a production of 34.56 thousand tonnes seed and a productivity of 1054 kg/ha (Meena *et al*., 2022). These tiny flowers make small umbellate flower bunch which provides a right landing platform for pollinators. The relative significance of insect pollinators for reproductive success of any cross pollinated plant species depends on availability of pollen and nectar, visitation frequency and ability to deposit pollen on the stigma in single visit (Meena *et al*., 2022). Earlier studies reported honeybees, solitary bees, syrphids, muscids, some beetles and butterflies species as floral visitors of seed spices (Meena *et al.,* 2022).

Dill belonging to Apiaceae or Umbelliferae family, is a sweet, crisp, fennel-like annual or biennial industrial herb with lovely ferny foliage and a sweet fresh aroma that is used to flavor tea, pickles, and sweets (Awasthi *et al*., 2022). The term *Anethum* is derived from the Greek word “aneeson or aneeton”, which means "strong odor." Dill plants have had many uses as a horticultural and aromatic crop since ancient (Awasthi *et al*., 2022). Mainly it was used as a flavoring agent in food species at that time, but its medicinal values are not known to humans due to a lack of scientific research (Awasthi *et al*., 2022). Different parts like leaves and seeds of dill, are used for both aromatic and medicinal purposes. In the spring and summer, before the plants grow up tall heads of small golden flowers, the leaves are at their best (Awasthi *et al*., 2022). Minerals, proteins, and fibers abound in dill leaves. The leaves are commonly used in fish and egg dishes, as well as dill pickles, and can also be minced into soups and salads (Awasthi *et al.,* 2022). Dill is considered the native spice of South West Asia or southeast Europe and has been growing since antiquity. The dill crop is thought to have a center of origin in Europe, Africa, and Asia (Awasthi *et al.,* 2022). It is grown in nations such as India, Germany, Hungary, the Netherlands, Pakistan, and the United States (Awasthi *et al*., 2022). Depending upon locality and growing regions, it has a diversity in its name as it is known as “dilly aneton and garden dill” in French, “indische dille, gurkenkraut” in German, “aneto” in Italian, “garden dill” in England, Germany, Hungary, and the United States of America, whereas it is known as “Shih lo, diru, shibith, and anithos” in China, Japan, Arab countries, and Greece, respectively but the most commonly grown and widely spread variety of *Anethum graveoeloens* L. is the Indian dill, commonly known as “Sowa” that prefers cold climate typically of japan, Indian sub-continent, and Malaysia (Awasthi *et al.,* 2022).

Dill which has been cultivated since ancient times is native to South West Asia or South East Europe and belongs to the Apiaceae (Umbelliferae) family. There are two cultivated species of dill in the world: European dill which grows in most parts of the World and Indian dill (*Anethum sowa*) which grows in and around India (Alan and Ilbi, 2023). In addition to its leaves being used as vegetable, both its leaves and seeds are consumed as medicinal and aromatic plants due to the essential oils it contains by 2.5-4% (Carvon, Apiol, Dihydrocarvon, Limonen) and it is also used as a sedative, antispasmodic, diuretic and carminative in babies (Alan and Ilbi, 2023). According to the recent statistics, the amount of dill production has increased in Turkey. The amount of production, which was 2.978 tons in 2010, reached to 8.267 tons with an increase of 194% in 2020. While 1.6% of this production is provided by greenhouse production, open field growing accounted for the remaining part of it. And organic production is carried out for approximately 50 tons of the specified production amount while conventional production is performed for the remaining amount (Alan and Ilbi, 2023). Single cut is performed when grown as a green vegetable but two cuts are recommended under good care conditions (Alan and Ilbi, 2023). For seed production, dill requires cool weather conditions in vegetative development periods and warm and dry weather conditions during seed formation and seed maturity. Thus, seeds can be planted in regions having temperate climatic conditions with relatively warm winters in early spring (February-March) or in autumn (September-October) seasons (Alan and Ilbi, 2023). It was stated that, various production factors such as soil, cultural practices, harvest time, and climate conditions affect seed quality. Especially climate conditions (maximum and minimum temperature, precipitation, humidity) in the period that starts with flower formation and continues with pollination, fertilization, and seed maturation affect seed quality and yield (Alan and Ilbi, 2023). It is an upright, aromatic herb with feathery, segmented leaves with sheathed petioles. Flowers are yellow and located in umbels, which contain several peduncles. There is one main umbel and several smaller lateral umbels on branches from the main stem. Seeds are oval and flat with three longitudinal grooves and two wings (Kadoglidou *et al*., 2023). Dill is a typical out-crossing species and it is diploid ($2n = 22$) (Kadoglidou *et al*., 2023). Leaves and seeds of dill are used for flavoring in culinary processes. As such, it is cultivated for the fresh or dried herb market, but high variability in morphological, aroma, and flavor characteristics are observed between cultivars (Kadoglidou *et al.,* 2023). The green tissues and the fruits (seeds) contain essential oils, fatty oils, moisture, proteins, carbohydrates, fiber, ash, and mineral elements such as calcium, potassium, magnesium, phosphorous, sodium, vitamin A and niacin (Kadoglidou *et al*., 2023). Dill also contains other important phytonutrients, including furanocoumarin, 5-(4″-hydroxy-3″methyl-2″-butenyloxy)-6, 7-furocoumarin, oxypeucedanin, oxypeucedanin hydrate, falcarindiol and flavonoids (Kadoglidou *et al*., 2023). Dill leaf essential oil is rich in volatile compounds with *α*-phellandrene being the major compound, followed by *α*-pinene, *β*-phellandrene, dill ether, myristicin, dill apiole and apiole (Kadoglidou *et al*., 2023). Leaf essential oil composition differs from that of seed essential oil which contains mainly carvone, but also dihydro-carvone and limonene (Kadoglidou *et al.,* 2023). The biological properties of dill essential oil include antibacterial, antifungal, insecticidal, analgesic, and antioxidant activities, many of which are useful in food preservation (Kadoglidou *et al.,* 2023). Several commercial dill cultivars for example, Ambrozja, Kronos, and Lukullus, are available with varying characteristics, such as, density and color of foliage, time of flowering, nutritional value, and intensity of aroma (Kadoglidou *et al.,* 2023). In Greece, traditional dill landraces are cultivated by local communities, being selected and

adapted to the prevailing climatic and environmental conditions in which they are grown. Many of these landraces are conserved in the Greek Gene Bank but these have not yet been fully evaluated (Kadoglidou *et al*., 2023).

Dill has been used in ayurvedic medicines since ancient times and it is a popular herb widely used as a spice and also yields essential oil (Verma *et al.,* 2023). Dill can be gown under irrigated condition and rainfed condition (Verma *et al.,* 2023). The trial was conducted under irrigated condition to test the performance of dill entries for seed yield. European type dill AD-01-43(E) showed higher plant height (134 cm) as compared to Indian type dill AD – 2 (90 cm). AD-2 recorded early (132 days) seed maturity as compared to European type dill (Verma *et al.,* 2023). The variety tested at ICAR-NRCSS Ajmer for yield performance. Ajmer Dill -2 recorded higher (1466 kg/ha) seed yield as compared to local variety (1207 kg/ha) which was 21% higher. Indian dill AD-2 recorded lowest percent disease incidence (PDI) 5.2% (Tolerant) as compared to other tested entries (Verma *et al.,* 2023). The proposed variety AD- 2 recorded higher (15.3 q/ha) seed yield as compared to check variety (9.64 q/ha) at farmers field (Verma *et al.,* 2023).

This annual plant with aromatic foliage and seeds, *Anethum graveolens*, is the sole species in that genus of the parsley family (Apiaceae or Umbelliferae). It is thought to have originated in Eastern Europe, southern Russia, central and southern Asia. It has naturalized in many other parts of the world, and can be seen as a roadside weed in July and August in many parts of the United States. Although we know it primarily as a culinary herb, it was used historically for medicinal and magical purposes (love potions, casting spells and for protection against witchcraft) (Wisconsin, 2024). Dill plants grow 18 inches to 4 feet tall and resemble fennel. The soft, alternate, blue-green leaves are finely divided, giving a fern-like appearance. The leaves can be cut anytime after the plant is a few inches high until the seed stalk begins to form. Continually cutting the foliage back will help delay flowering. The plant has a tap root like a carrot. When the weather gets hot or dry, one long flower stalk will be produced. The small yellow flowers are borne in small open umbels 1 to 3½ inches across, followed by light brown "seeds". (Technically a type of dry fruit called a schizocarp but they look like a seed and therefore are normally referred to as seeds.) (Wisconsin, 2024). Deadhead spent flowers to prevent prolific self-seeding. The flat, winged, oval seeds are about ¼ inch long, with lengthwise ridges in the surface. The seeds will shatter when ripe, so flower heads should be cut from the stalks when the seeds are fully developed but before they have turned brown. The seed heads can be dried on screens or placed in paper bags and left in a warm, dry place for a week before separating the seeds from the stems. Store the seed in an airtight container in a cool location. Seed is viable for several years if kept dry and cool. The flowers are attractive to small wasps, flies and other insects, including beneficial flower or hover flies (family Syrphidae), the larvae of which eat aphids (Wisconsin, 2024). Several cultivars are available in two broad classes: those intended mainly for seed production and "slow-bolt" types intended mainly for leaf production; there are also some short types intended especially for containers. Some common cultivars include (Wisconsin, 2024): 'Bouquet' is best for seed production. It grows 2-3 feet tall and 1½ -2 feet wide with blue-green foliage. 'Dukat' is similar to 'Bouquet' in size and color but with heavier foliage and later blooming. 'Super Dukat' is an improved form. Both have a strong flavor and high oil content. 'Fernleaf' is a short variety, good for containers. It has extra finely cut foliage, is slow to bolt, and only gets about 18" tall. 'Hercules' is a tall (up to 5 feet in ideal conditions), tetraploid variety bred for foliage production that is slow to bolt. 'Long Island Mammoth' has sparser, green foliage, produces large flower heads on multiple stalks, and is considered the best variety for pickling. 'Vierling' has blue-green foliage and strong stems, and the flower/seed heads are used commercially as a cut flower. Both the foliage and the seeds are used for flavoring foods. The leaves are often referred to as dill weed to distinguish this from dill seed. The aromatic leaves can be used fresh or dried, although flavor rapidly declines when dried. The leaves wilt quickly once picked but will keep in a plastic bag in the refrigerator for about a week. The leaves can also be frozen (preferably in water), but will turn dark and some flavor will be lost, but not as much as with dried leaves. Seeds can also be used fresh or dried. Dill oil can be extracted from all above-ground parts of the plant (Wisconsin, 2024).

Dill is an important seed spice crops, medicinal and aromatic plant belongs to Apiaceae family (Ravi Kumar *et al.,* 2024). In India all most all the states grown as rabi or winter season crop for commercial purpose. In the states of Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Madhya Pradesh and Rajasthan for seed purpose, dill crop was grown in the name of sowa and it is also named as Indian Dill (Ravi Kumar *et al.,* 2024). Mainly the leaves are used for vegetable purpose and seeds widely used for spice purpose because its pleasant spicy aroma and plenty of nutritional and medicinal properties (Ravi Kumar *et al*., 2024). It is also used for the purpose of flavoring of tea and pickles. The crop leaves are rich in minerals and fibers. The seeds are useful for spice and medicinal purpose and leaves used as a vegetable and aromatic herb (Ravi Kumar et al., 2024). The aroma volatiles of seed and leaves of dill have many therapeutic properties and the anti-microbial activities of carvone (terpenoid) isolated from dill seed oil (Ravi Kumar *et al*., 2024). It is also used for the curing of the many health issues like urinary infections, piles problems and mental health disorders (Ravi Kumar *et al*., 2024). Dill is a cross-pollinated crop with protandrous in nature bearing a small flowers in colour and diploid (2n = 22) chromosome number (Ravi Kumar *et al*., 2024). The inflorescence is a small small yellow flowers with compound umbel type. The umbel is on an average of 4-16 cm in diameter and flowers are blooming in a sequential order. The flower blooming was initiated first at main umbel and followed by the remaining umbels present in the plant (Ravi Kumar *et al*., 2024). Duration of the inflorescence is completed within 10–12 days and stigma receptivity is continued up to midday depending upon the ambient temperature and anthers dehiscence will take place during the morning hours (Ravi Kumar *et al*., 2024). Dill inflorescence are hermaphrodite and homogamous in nature. Hermaphrodite means both male and female reproductive parts are present in the same flower and these two are matured at a same time is called as homogamous flowering nature (Ravi Kumar *et al.,* 2024). In dill inflorescence type, the sometimes the umbels are having fully pistillate type of flowers or some staminate flower types and only few are hermaphrodite in nature (Ravi Kumar *et al*., 2024). In umbels the flower bearing type is the primary umbels bear hermaphrodite flowers. Hermaphrodite flowers bear once in the margin of the umbels and staminate flowers are in the centre in case of secondary and tertiary umbels. In dill flowers, pistillate flower contains

ovary of the two ovals (Ravi Kumar *et al.,* 2024). The insect attraction for the pollination work, specially for bees, flies and other pollinating insects, the staminate flowers contain sufficient quantity of nectar with strong odour. Mainly the honey bee species Apis florea as recorded as the main pollinating insects for dill crop (Ravi Kumar *et al*., 2024). For vegetable purpose dill grows up to the height of 40-60 cm and for seed purpose it will grows up to the height of 145 to 150 cm (Ravi Kumar *et al.,* 2024). The seeds are smaller in size, flattened shape and lighter in seed weight with a pleasant aromatic odour (Ravi Kumar *et al.,* 2024). Propagation is mainly through seeds and seed viability is present up to 3-10 years. The seeds are harvested by cutting the umbels when the seed is beginning to ripe (Ravi Kumar *et al*., 2024).

Dill is an annual herb belonging to the family, Apiaceae. The genus Anethum includes two species, *Anethum graveolens* L. (European type) and *Anethum sowa* Roxb. (Indian type), with a chromosome number of 2n=20 (Gote *et al*., 2024). Dill is believed to be native to the Mediterranean and West Asia, making it one of the oldest cultivated seed spices. Europe, Africa, and Asia are considered centers of origin for the dill crop (Gote *et al*., 2024). Dill is classified as a minor seed spice crop, primarily grown for its spices, medicinal uses and as a leafy vegetable in various regions. Leaves of dill are used for food, because of their typical aroma and taste. Fresh and dried dill leaves are widely used as herbs in Europe and Central Asia (Gote *et al*., 2024). Dill is cultivated worldwide, including in India, Pakistan, Germany, Hungary, the Netherlands, and the USA. In India, dill is known as Sowa and is grown in states such as Rajasthan, Gujarat, Punjab, Karnataka, West Bengal, Uttar Pradesh, Odisha, and Madhya Pradesh (Gote *et al.,* 2024). Medicinally, dill is known to help with stomach issues, loss of appetite, and intestinal gas, particularly for children and women (Gote *et al.,* 2024).

Dill is used fresh or processed for food seasoning and preservation (Solberg and Yndgaard, 2025). Production is concentrated in temperate regionsbut can be grown as a cool season crop in India and Thailand (Solberg and Yndgaard, 2025). Several secondary metabolites, among them essential oils are present in the plant and with claimed health benefits (Solberg and Yndgaard, 2025). Accessions from the Nordic germplasm collection were evaluated, aiming at tracing trait patterns.The survey showed both gaps and overlaps in available genebank holdings (Solberg and Yndgaard, 2025). Accessions from outside Europe were highly under-represented in the global collections, as were wild material and crop wild relatives (Solberg and Yndgaard, 2025). The evaluation showed that important agro-botanical traits correlated, such as plant height, umbel size and other size characters (Solberg and Yndgaard, 2025). Furthermore, essential oil composition was clearly influenced by high temperature stress (Solberg and Yndgaard, 2025). Dill is cultivated for its taste and flavour. Fresh, tender leaves and crowns (young umbels with flower buds) are consumed as vegetables (Solberg and Yndgaard, 2025). Dried fruits (hereafter termed seeds) are used as food seasoning and preservative or for oil extraction (Solberg and Yndgaard, 2025). Dill has an annual (some places biennial) growth pattern (Solberg and Yndgaard, 2025). The umbels are holding numerous of small yellowish flowers and brown fruits (Solberg and Yndgaard, 2025). Production is concentrated to the temperate region of the world and especially Europe and USA but the crop is grown all over the world, from the Arctic Circle in northern Norway to tropical and subtropical sites with a significant production in Thailand and India. A related species, Indian dill (*Anethum sowa* Roxb.) is grown in Asia in addition to the common dill. Dill has a long tradition in Ayurvedic medicine (Solberg and Yndgaard, 2025). One characteristic of dill plants is the odour, and the scientific nameAnethum is derived from theGreek word of strong smelling (Solberg and Yndgaard, 2025). Dill is part of the traditional flavours of the Scandinavian spirit Aquavit, a tradition that goes back to at least the 15th century (Solberg and Yndgaard, 2025). Several secondary metabolites, among them essential oils, are present in the plant (Solberg and Yndgaard, 2025). The oils can inhibit growth of bacteria and fungiandhave repellent effects on certain insects (Solberg and Yndgaard, 2025). Despite the wide spread use and many potential benefits, dill is a minor or underutilized crop (Solberg and Yndgaard, 2025). To be able to maintain or improve yield and quality, access to genetic resources is fundamental (Solberg and Yndgaard, 2025). In this review article on Origin, Taxonomy, Botanical Description, Genetic Diversity, Breeding and Cultivation of Dill are discussed

ORIGIN AND DISTRIBUTION

Anethum graveolens is believed to have its beginnings in the Mediterranean region **(**Schlosser, 2007**).** It belongs to the family *Apiaceae* and genus *Anethum*, which includes two species *A. graveolens* L. (European type) and *A. sowa* Roxb. (Indian type). Dill is one of the minor seed spices crop mainly grown for spices and medicinal uses. Probably dill is native to the Mediterranean West Asia and is one of the oldest cultivated seed spices from ancient times. Europe, Africa and Asia are considered as centre of origin for dill crop (Sharma et al., 2010). Dill is cultivated worldwide including India, Pakistan Germany, Hungary, Netherland, and USA. In India dill is grown with the name of sowa in the states of Rajasthan, Gujarat, Punjab, Karnataka, West Bengal, J & K, Uttar Pradesh, Orissa, and Madhya Pradesh for its seeds. In Rajasthan dill producing districts are Chittorgarh, Nagaur, Jhalawar, Udaipur, Kota and Bundi (Sharma *et al*., 2010). The earliest known use of *Anethum graveolens* was in ancient Egypt, and as a result of this long history its origin remains uncertain, although it is probably south Eurasia. It has been present in Europe since Roman times and it is assumed that monks brought dill to the rest of Europe. *A. graveolens* now grows spontaneously in both temperate and hot regions of the world where it is considered an alien species, including Puerto Rico, Brazil, Austria, Finland, Lithuania, many parts of the USA, Canada, Spain, and the Mediterranean. Dill is now cultivated in India, Germany, the Netherlands, Poland, England and the Americas **(**Datiles and Acevedo-Rodriguez, 2015**).** Dill is probably native to south-west Asia or south-east Europe and also has been cultivated since ancient times. India and Pakistani are the most producer countries of this plant. Moreover, USA, UK, Mexico, Germany, Hungary and Netherlands produce high amounts of dill (Raut *et al*., 2021).

It is native to the eastern Mediterranean region and western Asia. The word *dill* comes from the old Norse word *dylla*, meaning to soothe or lull. It dates back in writing to about 3000 B.C. when it earned a mention in Egyptian medical texts. In the 1st century Rome, dill weed was considered a good luck symbol. Ancient Egyptians used it to ward off witches and as an aphrodisiac. To the Greeks, dill signified wealth. Many cultures cultivated it for medicinal qualities, particularly its

ability to soothe an ailing stomach. It's even mentioned in the Bible. Puritans and Quakers gave their children dill seeds to chew on while at church as an appetite suppressant. Modern wisdom gives dill seed credit as a breath freshener and anti-bacterial, plus it's believed to stimulate milk production in breastfeeding women and alleviate colic (Filippone, 2019). The Netherlands, the United States, Hungary, Germany, and Pakistan are all countries where this plant is produced and cultivated. The plant is also grown in Punjab, Rajasthan, and Orissa cities in India (Masoody *et al.,* 2023).

Dill originated in central Asia. Zohary and Hopf remark that "wild and weedy types of dill are widespread in the Mediterranean basin and in West Asia." Although several twigs of dill were found in the tomb of Amenhotep II, they report that the earliest archeological evidence for its cultivation comes from late Neolithic lake shore settlements in Switzerland. Traces have been found in Roman ruins in Great Britain. In Semitic languages it is known by the name of Shubit. The Talmud requires that tithes shall be paid on the seeds, leaves, and stem of dill. The Bible states that the Pharisees were in the habit of paying dill as tithe (Bionity, 2024). A native of the Mediterranean countries and Southern Russia (Herbs, 2024). European Dill (Anetheum graveolens) is indigenous to Europe and is cultivated in England, Germany, Romania, Turkey, USA and Russia. The Indian dill (*Anetheum sowa*), a native of Northern India is bolder than the European dill. It is cultivated as a cold weather crop in many parts of India (SPI, 2025).

TAXONOMY

Anethum graveolens L. is a medicinal plant that is grown or sprouted wild. It is a short lived perennial herb, which includes 250 types of green crops. There are several varieties of dill in the world, which differ in content of active ingredients in quantity and quality. It is considered one of the spice and flavoring crops in a variety of foods and is used medicinally and still by herbalists (Masoody *et al.,* 2023). The genus name *Anethum* is the Latin form of Greek , which meant both "dill" and "anise". The form 'anīsum' came to be used for anise, and 'anēthum' for dill. The Latin word is the origin of dill's names in the Western Romance languages ('anet', 'aneldo'), and also of the obsolete English 'anet' (Wikipedia, 2024). There are two closely related cultivated species of dill*, i.e*. European dill (*A. graveolens*) and Indian dill (A. *sowa*) (Gupta *et al.,* 2012). Indian dill, which grows in India, has a lower carvone content and a slightly different flavour. The seeds are longer and narrower, with paler ridges. In India, dill is considered a minor seed spice crop and its cultivation is limited to a few parts of the country. Farmers cultivate the local varieties using their own seed. Mehasana local and Ruby local are those used by farmers in Gujarat and Pratapgarh local by farmers in Rajasthan (Gupta *et al*., 2012).

The species *Anethum graveolens*, or dill, is a common herb used throughout the world for culinary and healing purposes. The common name 'dill' may be derived from the Norse word 'dilla', meaning 'to lull or soothe' in reference to its medicinal usage. Indian dill, grown widely in northern India (formerly classified under the species *Anethum sowa*), is a distinct botanical variety (*Anethum graveolens* var. *sowa*) that has a high content of the toxic compound dillapiole compared with European dill, which is free of it (Datiles and Acevedo-Rodriguez, 2015).

Synonyms *(*Schlosser, 2007; Datiles and Acevedo-Rodriguez, 2015; *NCSU, 2024*)

Anethum arvense Salisb.
Anethum sowa Roxb. ex Fleming
Ferula graveolens (L.) Spreng.
Peucedanum anethum Jess.
Peucedanum graveolens (L.) Hiern
Peucedanum sowa (Roxb. ex Fleming) Kurz
Selinum anethum Roth
Selinum graveolens (L.) Vest

BOTANICAL DESCRIPTION

Depending upon the variety, the plant can grow anywhere from 30 cm (for dwarf varieties) up to 1.2 cm in ideal conditions. The branching stems have white to off-white, vertical striations that run down their length, and they are devoid of hair. Unlike fennel, which resembles dill in appearance, the stems of dill are hollow. They also end with a broad, expansive inflorescence is topped with yellow, scented, hermaphroditic flowers. Dill's inflorescences are arranged in umbels, in which the flower stalks develop from a common point. It is similar in appearance to an umbrella and it is this characteristic that gives the entire Umbelliferae family its name. The flowers develop into dry fruits called schizocarps that are split into two parts, each one holding seeds. The seeds are oval and progress from a bright green color when they first develop to dark brown later in the season. Like the stems, they have light colored lines or striations that run down their length. Dill's aromatic leaves are delicate in appearance and are often described as lacy, feathery, or needle-like. Dill produces a single taproot that can reach deeply into the ground in ideal conditions **(**Schlosser, 2007**).** Dill is an erect, hardy annual plant belonging to the family Apiaceae. The leaves are thin, wispy and fern like. The glossy stem is usually single, erect, dull-green cylindrical, subdichotomously branched and reaching up to 0.9–1.5 m in height. The umbels are large and contain small yellow flowers and yellowish brown, ridged, flattened, ovoid fruits. Unlike the flowers of most other umbelliferous crops, the small yellow dill flowers have a strong odour but contain little nectar. The flowers are homogamous and hermaphrodite. Some of them are entirely pistillate (female), some staminate (male), and a few are hermaphrodite. The primary umbels bear hermaphrodite flowers, the secondary and tertiary ones bear hermaphrodite ones on the margins and staminate ones in the centre, similar to coriander. The ovary of the pistillate flower normally contains two ovules. The yellow staminate flower has five stamens that arise between the petals. Nectar is visible on the staminate flowers, and very little or none on the pistillate flowers. The seed of dill is hard, light brown, winged and oval, with one side flat and the other convex. There are three ridges on the convex side with three vittae, or oil channels; the flat side bears two ridges. The ridges are more pronounced in Indian dill than in the European dill (Gupta *et al.,* 2012).

Erect, annual, blue-green, glabrous herb, up to 1.5 m tall, taproot up to 12 mm in diameter, all parts strongly smelling (herbaceous) especially after crushing. Stem subterete, up to 12 mm in diameter, much branched, sulcate, internodes often hollow. Leaves alternate, decompound, sheathed; sheath forming an open cone, embracing the stem at base, 1-3(-5) cm long, sulcate; petiole subterete, equally long or up to 13 cm longer than the sheath, lower leaves usually rather long petiolate, higher ones almost without petiole; blade triangular

to ovate in outline, up to 30 cm x 50 cm, usually much smaller, pinnately divided into 2-6 pairs or whorls of primary pinnae and one top-pinna; each pinna again pinnately divided 2-4 times into linear or filiform, acute lobes of 1-60 mm x 0.1-1 mm. Inflorescence a compound umbel, 4-16 cm in diameter; peduncle up to 30 cm long; bracts and bracteoles usually absent; primary rays 5-35 per umbel, 1-10 cm long, unequal in length, longest ones at the outside of the umbel; secondary rays 3-35 per umbellet, 1-15 mm long; flowers bisexual, actinomorphic, some central ones often remaining rudimentary, protandrous (usually the styles and stigmas becoming fully developed after shedding of the corolla and stamens); calyx vestigial, sometimes 5 small teeth present on top of ovary; petals 5, distinct, subovate in outline, up to 1.5 mm x 1 mm, top strongly inflexed and notched, yellow; stamens 5, filaments about 1.5 mm long, yellow; pistil with inferior, bilocular ovary and a fleshy, conical stylopodium bearing 2 spreading styles about 0.5 mm long. Fruit a lens-shaped schizocarp, 2.5-6 mm x 2-4 mm, light or dark brown with a whitish to pale brown margin, splitting at maturity into 2 one-seeded mericarps which are attached at their top to an erect thin carpophore; mericarp flat, usually with 3 longitudinal prominent ridges and 2 flat, wing-like commissural ridges; on the commissural side, usually 2 dark brown longitudinal vittae, and on the dorsal side, between each 2 ridges, one vitta; the fruits are crowned by the persistent stylopodium and styles. Seed with testa adnate to the mericarp. Seedling with epigeal germination; hypocotyl 5-25 mm long; cotyledons opposite, linear, 15-50 mm x 1-2 mm, entire **(**Datiles and Acevedo-Rodriguez, 2015**).**

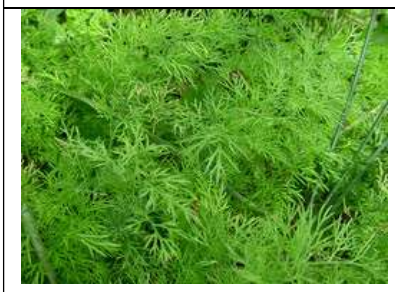
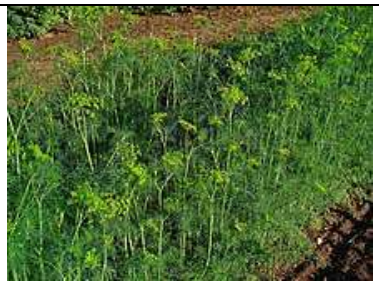
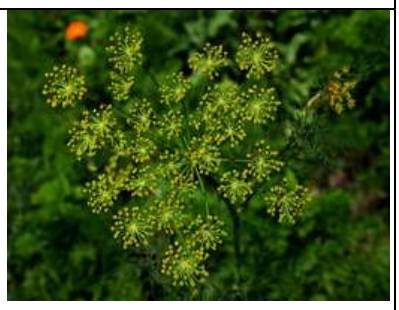
Dill is normally grown as a spice crop for seed purposes. Dill grows up to 40-60 cm as the leafy vegetable purpose and up to 145-155 cm, when grown for the seed production. Dill has slender hollow stems and alternate, finely divided, softly delicate leaves of 10-20 cm length. The ultimate leaf divisions are 1-2 mm broad, slightly broader than similar leaves of fennel, which are thread-like, less than 1 mm thick, and straight to slightly curved with a longitudinally ridged surface. Usually, there were two types of dill seeds exist in cultivation One is European dill and another is Indian dill (Raut *et al*., 2021). Dill is an upright, hardy annual or biennial plant in the Apiaceae family. Primarily it is grown as an annual crop but depending upon variety availability and location suitability, it can also be grown as a biennial crop. The stem is tender and glossy and normally develops from a single, tall, dull-green cylindrical stem that is subdichotomously branched and grows to a height of 0.9–1.5 m. The leaves are fern-like, slender, and wispy. In ideal conditions, leaves gain size of 7.5 – 17.5 cm. The leaves are fragrant, delicate, needle-like, and lacy. Dill's inflorescences are formed in umbels, with flower stalks branching out from a central point. Small yellow flowers and yellowish-brown, ridged, flattened, ovoid fruits adorn the huge umbels. The little yellow dill flowers, unlike those of most other umbelliferous crops, have a strong odor but little nectar. The flowers are hermaphrodite and homogamous. Some are fully pistillate (female), while others are staminate (male) or hermaphrodite. Similar to coriander, primary umbels have hermaphrodite flowers on the margins and staminate flowers in the center. Secondary and tertiary umbels have hermaphrodite flowers on the margins and staminate flowers in the center. Two ovules are generally found in the ovary of the pistillate flower. Five stamens emerge between the petals of the yellow staminate flower. Dill seeds are found in the schizocarp, which is the dried fruit of the plant. The seeds are firm, light brown, winged, and oval, with one side convex and the other flat. On the convex side, there are three ridges with three vittae or oil channels; on the flat side, there are two ridges (Awasthi *et al*., 2022).

The inflorescence of dill is a compound umbel, 4–16 cm in diameter and flowers bloom in a strict sequence. The main umbel is the first to bloom followed by different range umbels in order of their range. Flowering is normally completed in 9–12 days and anthers dehisce in the morning and remain receptive until midday depending upon ambient temperature. Flowers are homogamous and hermaphrodite. In the umbel, some flowers are entirely pistillate and some staminate, and a few are hermaphrodite. Primary umbels bear hermaphrodite flowers, whereas, the secondary and tertiary umbels bear hermaphrodite ones on the margins and staminate types in the centre. The ovary of the pistillate flower contains two ovals. Yellow staminate flowers have five stamens which arise between the petals. The staminate flowers contain noticeable quantity of nectar and have a strong odour, attracting mainly bees, flies, and other pollinators. Honeybees, particularly *Apis florea* have been documented as the most dominant floral visitors of dill flowers (Meena *et al*., 2022).

The cultivated plant has stalks with finely divided leaves composed of many linear segments. The leaves are borne alternately along the stalks and are sheathed at the base. The small yellow flowers are arranged in umbels (flat-topped clusters of flowers). The small dry fruits, often mistaken for the seeds, are broadly oval in shape, about 3.5 mm long, with three longitudinal dorsal ridges and two winglike lateral ridges. They are light brown in colour (EEB, 2024). Dill grows up to 0.46–1.52 m from a taproot like a carrot. Its stems are slender and hollow with finely divided, softly delicate leaves; the leaves are alternately arranged, 10–20 cm long with ultimate leaf divisions are 1–2 mm broad, slightly broader than the similar leaves of fennel, which are threadlike, less than 1 mm broad, but harder in texture. In hot or dry weather, small white to yellow scented flowers form in small umbels 2.5–8.9 cm diameter from one long stalk. The seeds come from dried up fruit 4–5 mm long and 1 mm thick, and straight to slightly curved with a longitudinally ridged surface (Wikipedia, 2024). Dill is an annual herb of parsley family, 45-75 cm in height, with finely feathered blue-green fern-like leaves and hollow stems. It produces small open umbels of creamy-yellow flowers in summer followed by dark brown seeds. The fruit, or seed, is broadly oval in shape, about 3.5 mm long, with three longitudinal dorsal ridges and two wing-like lateral ridges (KSSDB, 2024). It grows to 40-60 cm tall, with slender stems and alternate, finely divided, softly delicate leaves 10-20 cm long. The ultimate leaf divisions are 1-2 mm broad, slightly broader than the similar leaves of fennel, which are threadlike, less than 1 mm broad, but harder in texture. The flowers are white to yellow, in small umbels 2-9 cm diameter. The seeds are 4-5 mm long and 1 mm thick, and straight to slightly curved with a longitudinally ridged surface. Its seeds, dill seed are used as a spice, and its fresh leaves, dill, and its dried leaves, dill weed, are used as herbs (Bionity, 2024). Dill is an herbaceous annual in the family Apiaceae grown for its leaves which are used as a herb. Dill is a very aromatic plant with an erect growth habit. It possess branching stems and fine, soft, fibre-like leaves which are arranged into an open cone and are blue-green in color. The plant produces yellow flowers on umbels which can be up to 16 cm in diameter. Dill can grow up to 1.5 m in height and is

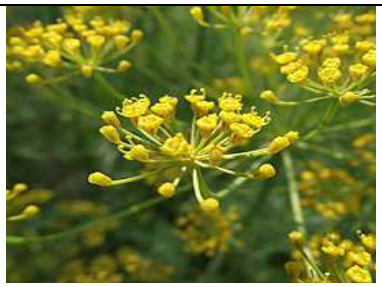
an annual plant, surviving only one growing season. Dill may also be referred to as garden dill and its origin is no known, although it is believed to be native to the Mediterranean (Plantvillage, 2024). Dill is an erect, freely branching annual herb with finely dissected, lacy, blue-green leaves. Dill is used in cooking in India as *soya*. The leaves are about 1 ft long and divided pinnately three or four times into threadlike segments each about 1 in long. The dill plant grows about 3-5 ft tall. Occasionally it becomes top-heavy and falls down. The flowers are yellow and borne in large, rounded, compound umbels, like all carrot family flowers. The umbels are borne on stiff, hollow stems. The whole inflorescence can be 25 cm across. The fruit is a flattened pod about 3 mm long. All parts of the dill plant are strongly aromatic (Singh, 2024). Dill is an aromatic, upright annual with feathery, blue-green leaves. By mid-summer it has produced flattened umbels of tiny yellow flowers about 10cm across on tall, hollow, ridged stems. At first it is easy to mistake it for Fennel, but although they have similarly shaped leaves those of Fennel are a yellow-green and Fennel has a pungent aniseed scent. *Anethum graveolens* is the smaller variety of Dill and is also known as Dill Bouquet. It is sometimes called Dill Weed (Herbs, 2024). Botanical description is given in Fig. 1.

GENETICS AND CYTOGENETICS: The green parts and the fruits of dill have been used since ancient times both as a culinary and as a medicinal herb. It has a pleasant aromatic odour but a slightly bitter and pungent taste. The chromosome count is 2n = 22 (CABI, 2015). An experiment conducted during rabi 2018-2019 for evaluation of Yield and Quality Characteristics of Dill. Among the sixteen genotypes *viz.,* AKDIL-01, AKDIL-02, AKDIL-03, AKDIL-04, AKDIL-05, AKDIL-06, AKDIL-07, AKDIL-08, AKDIL-09, AKDIL-10, AKDIL-11, AKDIL-12, AKDIL-13, AKDIL-14, AKDIL-15, AKDIL-16 and one check-Shiva. Among the genotypes plant height was ranged from 107.33 cm (AKDIL-07) to 153.33 cm (AKDIL-10) over check. Variation in yield and yield contributing characteristics were found among the sixteen dill genotypes. The genotype AKDIL-4 produced the maximum branches (6.40) followed by AKDIL-13 (6.33). A similar trend was also noticed in number of umbellets per umbel among the genotypes. The highest seed yield per plant was recorded in the genotype AKDIL-13 (14.7 g) while, it was the lowest in AKDIL-7 (3.67 g). For seed production potentiality, the genotype AKDIL-13 produced the highest amount of seed yield per plot (362.00 g) since it produced the maximum number of seeds per umbel (344.33). Seed yield per plot varied from 40.00 g to 362.00 (Raut *et al.,* 2021).

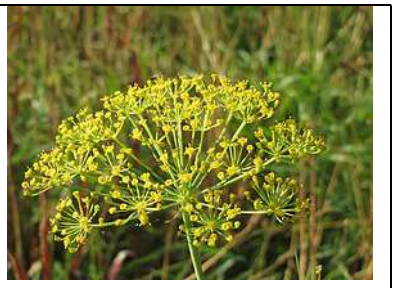
		
Seedlings	**Leaves**	**Leaves**
		
Foliage	**Plants**	**Cultivation**
		
Flower umbels	**Flower umbels**	**Flower umbels**

Continue ….

Stem and flower head



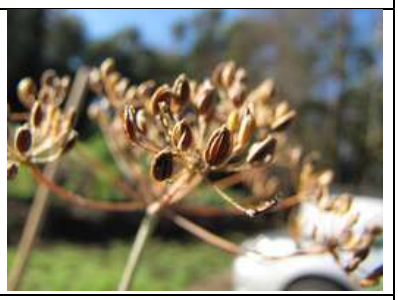
Closeup of a umbel



Yellow umbels

Seed head

Seed head



Seed head

Seed head

Seeds

Seeds

Fig. 1: Botanical Description

GENETIC DIVERSITY

In order to evaluate the genetic diversity in different landraces of dill based on morphological traits and molecular markers, the seeds of 37 accessions collected from different areas of Iran in addition to one European accession were cultured. Based on morphological traits assessment, the highest correlation coefficients were observed among the days to primary and secondary flowers which were 0.98. Cluster analysis classified the accessions of *A. graveolens* into four main groups. Cluster analysis framed by morphological traits was performed using Ward's cluster analysis and upon molecular markers the UPGMA and Jaccard's similarity coefficients was carried out in cluster analysis appeared by amplified fragement length polymorphism (AFLP) markers. Twenty 5-mer primers were used and 355 bands were detected with138 loci (39.8%) polymorphic. Principal coordinates analysis showed that 13 factors justified 69% of data variations. Mantel statistics revealed that the dendrogram was in conformity with similarity matrices (r=0.8). Results of cluster analysis showed that genetic diversity expressed by morphological traits and molecular markers did not completely correlate with geographical region (Solouki *et al.,* 2012). This investigation was undertaken to assess the genetic diversity of 16 *A. graveolens* accessions based on random amplified polymorphic DNAmarkers. Of the 60 random primers used, 12 primers gave reproducible amplification banding patternsfor 109 polymorphic bands out of 119 bands scored, accounting for 91.6% of the polymorphism acrossall the accessions. Seven primers (OPB07, OPB12, OPB13, OPB15, OPB18, OPB20, and OPC01) gener-ated 100% polymorphic patterns. Nei's genetic diversity and Shannon's information index had theirhighest value for primer OPB15 and their lowest value for primer OPC04. Jaccard's coefficient of simi-larity varied from 0.00 to 0.64, indicative of a high level of genetic variation among all the studied acces-sions. UPGMA cluster analysis indicated three clusters denoted as group-1, group-2, and group-3, andone outgroup. Despite the identification of several groups, these dendrograms showed no strong relation-ship with respect to geographical distribution. The result provides valid guidelines for the collection and conservation of dill genetic resources (Cho *et al.,* 2012). Dill is one of the neglected and minor spice crop, with low genetic variability. The genetic improvement of dill is being limited due to lack of genetic resources. Dill is mainly grown for seed as well as foliage leaf, the leaf yields are varied with the genetic background of genotypes. Therefore, the selection of genotypes with high leaf yield is highly desired, along with magnitude of heritability and genetic advance for wider adaptation and cultivation. In this view, the local genotypes were collected and their genetic variables were assessed, and results of analysis of variance revealed the significant differences among the genotypes. High heritability coupled with high genetic advance as per cent over mean was observed for economical trait (85.5 and 34.7% for leaf yield, respectively) indicated that, the traits were highly heritable in nature, hence selection breeding is most effective. The phenotypic coefficient of variation was noted low (3.29–8.66), medium (10.6–18.2) and high (26.9), and genotypic coefficient of variation witnessed low (1.71–8.1), medium (10.3–17.5) and high (24.0) variation among genotypes and

lines. The leaf yield was highly significant, positively correlated with growth and other yield traits. The genotypic correlation was greater than the phenotypic correlation among the genotypes. Hence, either simple selection, or mass selection of desirable traits and their associated traits would be effective for improvement of leaf yield of dill genotypes. Furthermore, significantly high leaf yielding genotypes (ACKD-6, ACKD-8, ACKD-11, ACKD-14, ACKD-16, ACKD-23, ACKD-28, ACKD-29 and ACKD-30) can be directly recommended for cultivation (Sinhasane *et al.,* 2022). In order to evaluate the genetic diversity in different landraces of dill based on morphological traits and molecular markers, the seeds of 37 accessions collected from different areas of Iran in addition to one European accession were cultured. Based on morphological traits assessment, the highest correlation coefficients were observed among the days to primary and secondary flowers which were 0.98. Cluster analysis classified the accessions of *A. graveolens* into four main groups. Cluster analysis framed by morphological traits was performed using Ward's cluster analysis and upon molecular markers the UPGMA and Jaccard's similarity coefficients was carried out in cluster analysis appeared by amplified fragement length polymorphism (AFLP) markers. Twenty 5-mer primers were used and 355 bands were detected with138 loci (39.8%) polymorphic. Principal coordinates analysis showed that 13 factors justified 69% of data variations. Mantel statistics revealed that the dendrogram was in conformity with similarity matrices (r=0.8). Results of cluster analysis showed that genetic diversity expressed by morphological traits and molecular markers did not completely correlate with geographical region (Solouki *et al*., 2012).

Within and between genetic diversity of 17 dill landraces from different areas of Iran was evaluated using five ISSR markers. In total, 29 polymorphic bands were generated. The average of polymorphism was 54.7%. The highest and the lowest values of Polymorphic Information Contents were 0.46 for $((CA)_8G$ primer) and 0.40 for $((AG)_8T$ primer), respectively, and with an average of 0.43. Based on the highest and the lowest indices of Polymorphic Loci (0.392 and 0.248), expected heterozygosity (93.10 and 62.07) and shannon's Information Index (0.567 and 0.360) between all populations, the highest and lowest genetic diversity was detected among Ardebil and Azarshahr genotypes, respectively. The genetic dissimilarity matrix showed that Sari and Kerman populations had the highest genetic distance and Ardabil and Borazjan populations had the lowest ones. Partitioning variations within and between populations, using an analysis of molecular variance (AMOVA), showed that 12% of the total genetic variation existed between growing regions. Cluster analysis based on UPGMA method showed a poor relationship between genetic distance and the geographical grouping of dills (Bahari *et al.*2015).

33 Greek dill landraces collected from diverse areas were evaluated using traits based on UPOV descriptor list. Phenotypic diversity was assessed using Shannon-Weaver diversity index (H′) and non-linear principal component analysis. Grouping of landraces was further performed through hierarchical cluster analysis. The H' index ranged from 0.32 (stem waxiness) to 0.98 (density of foliage) with a mean value of 0.68 indicating a high level of phenotypic diversity. High H' values were recorded for the foliage width, stem color and anthocyanin coloration. Multivariate analysis revealed three common genetic groups: 1) North mainland Greece, 2) Aegean islands and 3) Central mainland Greece. The landraces' heterogeneity was attributed to various traits linked to specific geographic origin, such as early time of flowering and high stem waxiness allied with the landraces originated from the Aegean islands. Greek dill landraces revealed useful variation on yield component traits related to fresh herb weight and to seed production, such as high number of leaves/plant and large diameter of main umbel that can be promptly exploited in breeding programs (Ninou *et al.,* 2017). An attempt was made to develop and design *in-silico* and computationally derived highly informative microsatellite markers. Current investigation was the first attempt to develop and design microsatellite markers from Dill EST and genomic sequences. A total of 1556 SSRs were found with a density of 1SSR/0.38 kb in 589.390 kb sequence searched. Of the total, 1265, 81.30% were perfect and 291, 18.70% were identified as compound SSRs in nature. Mononucleotides (1089, 69.98%) were most frequent followed by trinucleotides (254, 16.32%), dinucleotides (183, 11.76%), tetranucleotides (22, 1.41%), hexanucleotides (6, 0.38%) and the least frequent were pentanucleotides (2, 0.13%) (*Jethra et al., 2018)*.

Among the different genotypes of the dill viz., DDC-1, DDC-2, DDC-3, DDC-4, DDC-5 & two varieties namely AD-1, AD-2 (check varieties) for both the years differed significantly. The pooled data for evaluation of different genotypes of dill, the genotype DDC-5 recorded significantly the highest plant height (139.65 cm) at harvest stage, primary branches (6.70 No./plant), secondary branch (15.15 No./plant), umbels (46.85 No./plant), number of umbellets (49.30 No./umbel), No. of seeds (31.80/umbel), seed yield (16.85 g/plant) & seed yield (14.55 q/ha) at harvest stage followed by the variety AD-1 plant height (137.65 cm), primary branches (5.55 No./plant), secondary branch (14.35 No./plant), umbels (42.85 No./plant), number of umbellets (46.70 No./umbel), No. of seeds (28.05/umbel), seed yield (15.55 g/plant) and seed yield (13.18 q/ha) at harvest stage. While, the lowest plant height (124.20 cm), number of primary and secondary branches (4.50 & 12.05 No./plant), umbels (31.15/plant), umbellets (25.70/umbel), No. of seeds (20.50/umbel), seed yield per plant (10.50 g/plant) & seed yield per ha (8.11 q/ha) was recorded by DDC-2 **(**Ravi Kumar *et al.,* 2024**).** About seventeen genotypes and one check (AD-2) dill genotypes were used for this study and were evaluated during Rabi season 2023-24. The experiment was laid out in randomized block design (RBD) and replicated thrice. Data on growth, yield and quality parameters such as plant height (cm), leaf area (cm2), stem diameter (cm), number of branches per plant, number of leaves per plant, internodal distance (cm), plant weight (g), leaf yield (kg/plot), leaf yield (q/ha), quality parameters viz., chlorophyll content (mg/100 g) and iron content (mg/100 g) were also estimated and analyzed statistically. The results revealed that, AKDIL-17 recorded the maximum values of growth, yield and quality parameters among the eighteen genotypes evaluated. AKDIL-17 recorded the highest values for total leaf yield per plot (8.09 kg/plot) and estimated yield (89.92 q/ha), followed by AKDIL-01 and AKDIL-08 recorded which higher values then rest of the genotypes (Gote *et al*., 2024).

BREEDING

Genetic Resources and Breeding: Institutional germplasm collections are rare (82 accessions at the North-Central Regional P.I. Station of the United States Department of

Agriculture) and breeding programmes of dill are not known to exist. Even officially released cultivars do not exist. Seed firms in Europe market their own, unofficial selections. Some examples of selections for herb production are Dukat, Superdukat, Mammut and Pikant (Scandinavia), Mammoth (USA), Sari, Herkules, Goldkrone, Prager and Tetra-dill (Germany) and Budakalaszi (Hungary). No special selections are known for dill seed production, although some of the herb selections are recommended for that purpose (Datiles and Acevedo-Rodriguez, 2015).

No work has been done about the breeding aspects of this important plant. In breeding studies aimed at producing new kinds with desired features, a larger genetic basis takes precedence. Native landraces, local selections, exceptional cultivars, promising exotic arrivals, and wild relatives of crops with specific features make up this diversity. Germplasm traits must be known based on 2 to 3 years of evaluation at one or more locations for a set of heritable characteristics to make better use of germplasm in crop improvement initiatives. Genotypes with the appropriate features are then used as donor parents in the development of new kinds. As a result, promoting the usage of this crop as a means of conserving its genetic variety is essential (Awasthi *et al*., 2022).

Major Cultivars

Indian dill, grown widely in North India (formerly classified under the species *Anethum sowa*), is a distinct botanical variety (*Anethum graveolens* var. *sowa*). This variety (var. *sowa*) has inflorescences with fewer primary rays; its fruits are less flat but longer with more prominent ridges and the essential oil from the fruits is chemically different (less carvone but containing the toxic compound dillapiole, which is absent in European dill). The National Research Centre on Seed Spices in India has developed and recommended two improved varieties of dill: Ajmer dill 1 (NRCSS-AD-1) and Ajmer dill 2 (NRCSS-AD-2) for general cultivation (Gupta et al., 2012). Ajmer dill 1 is a European-type dill variety which is suitable for cultivation under irrigated conditions. The leaves are dark green in colour with good content of herbal constituents. The seeds are dillapiole-free and contain about 3.5 % essential oil. The average plant height of Ajmer dill 1 is 134 cm. It takes about 142 days to reach maturity and yields 14.7 q/ha of seed under irrigated conditions (Gupta et al., 2012). Ajmer dill 2 is an Indian-type dill variety, with bold, compact and dark brown seeds. It is suitable for the cultivation under irrigated and rain-fed conditions. The average plant height is 90 cm and it takes about 135 days to reach maturity. The average seed yield is 14.6 q/ha under irrigated conditions and 5.8 q/ha under rain-fed conditions. Seed of this variety contains about 3.2 % essential oil (Gupta *et al*., 2012).

13 Varieties are described by Schlosser, 2007; Lofgren, 2020; Grant, 2022; HF, 2024; *NCSU, 2024*

1. Bouquet: This variety gets its name because it's often used in cut flower bouquets, thanks to its tall stems and big, showy umbels of bright yellow flowers. It features beautiful dark-= green foliage, which makes it ideal if you want an ornamental plant for your garden that is also edible. In other words, this dill does it all. Perhaps that's why it's one of the most commonly grown types. If you want to make pickles, this is an exceptional option thanks to its abundant seeds. It's also frequently used for making a soothing tea. 'Bouquet' grows up to the feet tall at maturity, and the leaves are ready for harvest in 40-60 days. It's quick to flower – in only 85-100 days, which is good or bad depending on your goals, since flowering means the leaves will start to die back and lose their appealing flavor.

2. Compatto: 'Compatto' is a compact variety with blue-green foliage and a bold, aromatic taste. It grows to a diminutive 12-18 inches tall at maturity, and is slow to bolt. Plants are somewhat drought and heat tolerant. Leaves are ready to harvest in just 40-50 days. It's the perfect size if you're looking for a container herb.

3. Delikat: 'Delikat' has abundant, thick, dense foliage. It's a reliable producer, and has a heavy leaf and seed yields compared to other dill varieties. It grows about 10-24 inches tall at maturity and foliage is ready to harvest in about 40 days, with seeds maturing in 90 days.

4. Dukat: 'Dukat' dill, also known as 'Tetra,' is a Danish variety that is slower to bolt than other types. With an intense flavor, it's a good option if your primary goal is to harvest the leaves for cooking. 'Dukat' has a high oil content, which makes it especially aromatic and flavorful. This variety tops out at about one to two feet tall at maturity, which makes it ideal for growing in a container. The leaves are ready for harvest in 40-50 days, and the seeds are good to go in about 90-100 days.

5. Elephant: 'Elephant' is a late-flowering cultivar that's slow to bolt – so you can get in a longer season of clipping the dark green leaves. Mild-flavored leaves mature in between 60-90 days, and seeds are ready at 110-140 days. With a mature height of four feet tall and a spread of two feet.

6. Fernleaf: A winner of the All-America Selections award in 1992, 'Fernleaf' matures to a petite 18 inches tall, with a compact growth habit. It's ideal for growing in a container or a small herb garden. The leaves, as you might have guessed, have a bushy fern-like appearance. I love to use them in flower bouquets as a filler because not only are they pretty, they have that incredible dill scent as well. 'Fernleaf' also makes a beautiful specimen plant in the ornamental garden, or it is suited to growing in a container indoors. After cutting, the leaves retain their flavor for longer than some other varieties. 'Fernleaf' is ready to harvest in 40-60 days for the leaves, and 90-100 days for the seeds.

7. Greensleeves: 'Greensleeves,' sometimes referred to with the alternate spelling 'Green Sleeves,' is resistant to bolting and produces an abundance of dark green leaves with a sweet, mild flavor. It grows to a relatively compact height of 30 inches tall, and has a long harvest window. Suitable for growing in containers, you can harvest the leaves in 45 days. Seeds mature in about 100 days.

8. Hera: 'Hera' is slow to bolt and has dark green, almost blue leaves. Considered a "bunching" variety, fragrant leaves mature in 40-60 days, and the seeds are ready 50 days later. Growing to a compact size of 12-18 inches at maturity, 'Hera' works well for container growing.

9. Herkules: 'Herkules,' also known as 'Hercules,' grows to an impressive three feet tall at maturity, with lots of long, arching leaves. It produces massive flower heads and is slow to

bolt. The downside is that the older leaves tend to lose some flavor, and you may need to stake it because of its height. This is a great option if you want to attract beneficial insects like bees and butterflies. Pluck the leaves after 40-60 days. The seeds are mature in between 90 and 100 days.

10. Mammoth Long Island: 'Mammoth Long Island,' aka 'Mammoth' or just 'Long Island' dill, is a large cultivar. It averages about three feet tall, but in the right conditions, it can grow up to six feet tall at maturity. It's popular for its large, flavorful leaves that are perfect for chopping up and sprinkling on fish. Because of its large size, this variety may require staking. The leaves are ready to harvest after just 65 days, and the seeds are ripe around 110 days after planting.

11. Superdukat: 'Superdukat' is a heavy producer that is slow to flower. I've harvested this variety for three straight months, with no need for succession sowing. Its abundant foliage has a high oil content, for an intensely aromatic flavor. 'Superdukat' can grow up to five feet tall at maturity. Plants tend to grow uniformly and quite straight, and stems may need staking. It takes 40-50 days to reach leaf harvest, and 90-100 days for seed harvest.

12. Teddy: 'Teddy' grows fast, with dense foliage in an upright form. This cultivar has thicker leaves than the typically fine, delicate ones you see on other dill plants. A dwarf variety, 'Teddy' is a good candidate for container growing. The leaves are ready in 45-55 days and the seeds can be harvested in between 95 and 115 days.

13. Vierling: 'Vierling' is an heirloom variety with dark blue leaves and thick stems. It is slow to bolt. The seed heads are popular with commercial florists for use in cut flower arrangements. In the garden, it attracts beneficial insects and pollinators. 'Vierling' tops out at about 36-60 inches tall at maturity. This dill weed is ready to harvest in 45 days, and the seeds are good to go in 95 days. You can find seeds available in capsules, to store in the freezer prior to planting, from Frozen Seed Capsules via Amazon.

Nutritional Value: When considering the chemical composition of dill and its oils the situation is complicated by the availability of the two distinct species, Anethum graoeolens and Anethum sows, This topic has been the subject of a number of publications but all identify two major components—carvone and limonene. These investigations have been well summarised by Scheffer and coworkers. Dill seed oil from Anethum graoeolens is characterised by a high carvone and high limonene content, carvone imparting a distinct caraway-like aroma. Dill seed oil from Arnethum SOUXJcontains a much Iowercarvone content than tbe above, together with significant quantities of dillapiole. In fmt Betts repmtedt hatthe dillapiole content is usually twice that ofcarvone. Dill weed oiZ from Anethurn graueokns contains carvone, Iimonene, and significant amounts of a-phellandrene and an as yet unidentified compound of molecular weight 152 (possibly a cumarane). a The flavour is quite distinctly "greener" than that from the seed, though the identity of those compounds responsible for this note have not been fully identified. Table I indicates typical figures obtained by GLC analysis of various dill oils. Over thirty separate compounds have been reported as being present, of which about twelve have been consistently reported as being present at levels of O.1% and above. It is generally agreed that the presence of dillapiole or apiole in the oils signifies that the oil originates from *Anethurn sows*. However, two factors may contradict this assumption. Lichtenstein and coworkers have identified the presence of these two compounds in the roots of *Anethum graueolens* (Henry, 1982).

Per 100 g edible portion dry dill herb contains approximately: water 7 g, protein 20 g, fat 4 g, carbohydrates 44 g, fibre 12 g, ash 12 g, ascorbic acid 60 mg. The energy value is approximately 1060 kJ/100 g. The essential oil content is 0.1-1.5%. The approximate composition of dry dill fruits per 100 g edible portion is: water 8 g, protein 16 g, fat 14 g, carbohydrates 34 g, fibre 21 g, ash 7 g. The energy value is 1275 kJ/100 g. The essential oil content is 2-6% **(**Datiles and Acevedo-Rodriguez, 2015**).** Phytochemical analysis of dill plant revealed the presence of alkaloid, carbohydrate, resin, terpenoids, flavonosides, saponin, steroid, tannin, flavanoid and absence of reducing sugar, glycosides, anthraquinone, phlobatanins (Chahal *et al*., 2017). Dill is very rich in minerals, Vitamin C, and flavenoids. The seeds comprise of so much calcium that 1 tablespoon contains 100 milligrams; more than a third of a cup of milk. The essential oil, of which the seeds contain up to 4 per cent, has stimulant, carminative and stomachic properties, and promotes lactation (Herbs, 2024).

Distillatlon time: The relationship between carvone and limonene content is to some extent determined by distillation time. When distilling dill seed oil, the d-carvone distills over before the limonene, since carvone is much more water soluble than the hydrocarbon, Iimonene,ll Thus the carvone content is to some extent determined by the distillation time; a fact described by Koedam and coworkers.' After two hours distillation the limonene:carvone ratio was found to be 20:80; aRer sixteen hours the ratio was 42:58. Solvent extraction of seed oil yielded a limonene:carvone ratio of46:54, thus indicating that some limonene is still retained in the seed after prolonged steam distillation. This fact may be a possible means of producing high carvone content seed oil from Anethwn sows by simply reducing the distillation time, Obviously, the particle size of the crushed seed will also influence distillation time; the finer the grind the more rapid the distillation, although fine grinding will lead to volatile oil loss due to the heat produced in the mill. This can, however, be obviated by the use of liquefied nitrogen or carbon dioxide (Henry, 1982).

Distillation conditions: Dihydrocarvone is present in both its cis and trans form and it is interesting to note that each has a characteristic aroma.x Trans-dihydrocarvone is caraway-like, whereas cis-dihydrocarvone is cineole/woody in character. The ratio between the cis and tram form varies with the pH of the distillation water and length of distillation, It has been repatedt hat solvent extracted oils have a cis:trans ratio of 84:16, whereas in steam distilled oils the ratio varies throughout the pH range being (for exampie) 70:30 at pH7.' This then indicates that the conditions of distillation would contribute to a flavour change, It is also very likely, as reported by Koedam and coworkers, that this change from cis to trans is catalysed by metal ions either present in the seed or dissolved from the process apparatus.1 It is interesting to note that a number of metal ions including copper, iron and manganese have been found to represent in dill seeds in sufficient levels to effect this change. The as yet unidentified compounds of MW152 (either a cyclic ether or epoxide) have also been shown to be pH

dependent. f The amount present increased with increasing pH to a maximum at pH 8 (Henry, 1982).

Essential Oils Chemical Composition: However, the amount of essential oil that may be extracted from different sections of a plant depends on the type of plant it comes from, such as leaves, flowers, and seeds. Dill essential oil yields were 2.0% (v/w), 0.3% (v/w), and 0.06 percent (v/w) from fruit, aerial part, and root cultures, compared to a mere 0.02 percent (v/w) from hairy root cultures. The dill plant contains many active compounds, from which volatile oils called dill oil are extracted In addition to the two substances, limonene, Carvone, it accounts for up to 3% of the weight of the fruits, and its most important components are carvone. Phellendrene and Limonene, the place of cultivation, the plant portion used, and the time of growth all influence the oil's composition and active components. It also consists of, triterpenes, eugenol, phenolic acids, flavonoids, coumarins, α phellandrene, anethole,and umbelliferones. The chemical composition of dill essential oil and the amount varies depending on the plant parts and the developing stage of the plant at harvest time. *A. graveolens* seeds contain 4% volatile oil, which includes limonene (33%), carvone (30-60%), phellandrene (20.61%), dihydrocarvone, diterpene, pinene, cineole, myrcene, paramyrcene, dillapiole, isomyristicin, myristicin, myristin, apiol and dillapiol, furan. Dill oil contains Terpinene and Linalool and Limonene, as well as phellandrene, Carvone, Eugenol (Masoody *et al.,* 2023).

Uses: A number of historical references can be found to the use of dill; the following are two typical examples. Pliny states that inhalation of the vapour is recommended to cure hiccups and administration of the seed alleviates indigestion, though he warns that dill may also weaken the eyesight and the generative powers. In the Middle. Ages in England, it was reportedly used by magicians in their spells against witchcraft (Henry, 1982). The fresh herb is widely used in Scandinavia, Germany, and Eastern European countries as a flavoring for many foods, including pickled cucumber, vinegar, salads, pickled and fermented cabbage, sauces and marinades particularly for fish (gravlax being a classic example), and as a garnish on vegetables. In Balkan and Middle Eastern countries yoghurt, sour cream, chicken, stuffed vine leaves, and soups may be flavoured with dill. Generally the uses of dill are similar to those of parsley and mint in tbe United Kingdom, and it is quite common for afl three herbs to be included in the same recipe, as for example lamb casserole or savoury yoghurt soups. When used in this way dill tends to be the predominant flavour in Scandinavian dishes, whereas in the Middle East it is often the mint which is the more important herb. It is thus somewhat surprising that in the United Kingdom the “se of dill is very limited. Perhaps there exists an opportunity for the development of new retail products incorporating dill as part of a mixed herb seasoning. Dill fruits (seeds) are often used as an alternative to caraway seeds in breads and flour confectionery (Henry, 1982). The seed and herb oils and, to a more limited extent, the oleo-resins find many applications as a part of compounded seasonings and flavouring for use in food products such as meat products, desserts, pickles, alcoholic beverages, and in the perfumery and soap industries. The primary use of the herb oil, especially in Germany and the United States, is in the production of pickled cucumber. In addition to those applications listed above, the fresh or dried herb has uses in cheese (Henry, 1982). The seed oil, particularly that of *Anethum graoeolens*, possesses carminative, stomachic, and stimulant properties and is excellent for digestive problems in children. Two preparations in the British Pharmaceutical Codex include dill oil (Henry, 1982): 1, Dill Water Concentrated B. P,C., which contains 2% v/v of “European” dill seed oil (minimum 43% carvone), 2. Sodium Bicarbonate Mixture, Pediatric B, P,C., which again contains 2% v/v of the same seed oil. Both are primarily recommended as a remedy for flatulence in children (Henry, 1982). There are diverse uses of dill plant. The young tender leaves are used for culinary purposes and seeds are used as spices. Apart from these, it is also used for medicinal purposes (Sharma *et al*., 2010). Dill seeds are used both whole and ground as a condiment in soups, salads, processed meats, sausages, spicy table sauces and in dill pickling. Dill stems and blossom heads are used for dill pickling and for flavouring soups. The green herb is used as a flavouring agent (Sharma *et al*., 2010). Both seeds and oil are used in the preparation of various indigenous medicines. It has a prominent place for stomach problems, especially in the ailments of children and women. The essential oil, dill oil or its emulsion in water commonly known as dill water is considered to be an aromatic, carminative specially useful in control of flatulence, colic pain, hyperacidity, vomiting, diarrhoea and hiccups due to indigestion in infants. Its application with turmeric powder prevents formation of ulcers and heals them quickly. Leaves boiled in sesame oil makes an excellent liniment for reducing swelling and pain of the joints. Seeds are effective in respiratory disorders like cold, influenza and bronchitis. It is useful in inflammatory and painful conditions of piles for which it is used with vacha as fumigation therapy. It is very useful for women during delivery for expulsion of placenta and promotes milk secretion (Sharma *et al*., 2010).

The green parts and the fruits of dill have been used since ancient times both as a culinary and as a medicinal herb. It has a pleasant aromatic odour but a slightly bitter and pungent taste. Finely chopped fresh or dry leaves and young inflorescences are used as a culinary herb in soups, salads and sauces. Inflorescences and ripe fruits are used to flavour pickled cucumbers, onions, vinegar, sauces, pastries and bread; in India the fruits are an ingredient of curry powder. Dill oleoresin is a concentrated aromatic powder, obtained by extracting the fruits with alcohol and then drying the extract; it is especially recommended for low-salt or salt-free diets. Essential oils can be steam-distilled from the green parts (dill herb oil, dill weed oil) and from the fruits (dill seed oil). In the USA the regulatory status 'generally recognized as safe' has been accorded to dill (GRAS 2382), dill herb oil (GRAS 2383) and dill seed oil (GRAS 2384). Dill herb oil is mainly used for flavouring and seasoning in the food industry and has largely replaced the whole herb. Dill herb oil is frequently adulterated with d-limonene, which is obtained in the preparation of sweet-orange oil concentrate, and with synthetic carvone **(**Datiles and Acevedo-Rodriguez, 2015**).** Dill essential oil is colourless or pale yellow when freshly distilled. The chief components of dill herb oil are phellandrene (35%) and 3,9-epoxy-p-menth-1-ene (25%), and of dill fruit oil are limonene (up to 70%) and carvone (up to 60%) (limonene and carvone are closely related; together they represent about 95% of the oil). Carvone can be applied as a germination suppressor, *e.g*. in potatoes. The essential oil composition of dill varies strongly with geographical origin, cultivar and maturity of the extracted part; for example, carvone content in fruit oil ranges from 50-60% in the USA and 35-60% in Europe. Wide differences in data on the composition of the essential oil can also partly be explained by different extraction and distillation methods. After oil

extraction, the fruits contain approximately 15% protein and 16% fat, and are used as cattle fodder. Monographs on the physiological properties of the dill oils have been published by the Research Institute for Fragrance Materials (RIFM) **(**Datiles and Acevedo-Rodriguez, 2015**).** Dill seed oil, usually in the form of dill water (distilling one part of fruits with 20 parts of water), is used medicinally to alleviate digestion problems, especially of children. Dill oil is said to be strongly antiseptic; it inhibits the activity of several fungi and in mice it shows anticarcinogenic properties. Dill fruits have been shown to be spasmolytic and bacteriostatic for dyspeptic disorders. Bruised and boiled in water and mixed with dill roots, dill fruits are applied externally against swellings of the joints. In general dill is said to have carminative, stomachic, stimulant, diuretic, resolvent, emmenagogue and galactogogue activity. Fresh and dried inflorescences and infructescences are increasingly being used in the ornamental flower industry **(**Datiles and Acevedo-Rodriguez, 2015**).** The flavor of dill weed resembles the licorice-like flavor mild caraway or fennel. The plant is, in fact, often mistaken for fennel fronds. Add fresh dill weed at the end of cooking to preserve its flavor and color. Dill seeds can be crushed or ground or incorporated whole at an earlier stage as heat actually brings out the flavor. The flavor of fresh dill weed does not carry over to the dried herb, though it is available in supermarket spice sections. Beyond its use as a pickling spice, dill weed has a natural affinity for zucchini and summer squash, asparagus, and spinach. It complements cold-water fish such as herring and salmon and makes a notable appearance in recipes for *borscht*. It adds an unmistakable taste to herb salad blends, and often shows up in *tzatziki*, among other classic Greek dishes (Filippone, 2019).

Dill has a warm, slightly sharp flavour somewhat reminiscent of caraway. The entire plant is aromatic, and the leaves, small stems, and immature flower umbels are used fresh or dried for flavouring soups, salads, sauces, fish, sandwich fillings, and particularly pickles. It is especially popular in the cuisine of eastern Europe and Scandinavia. The whole seeds and the seed oil have carminative properties and have been used in treating flatulent colic (EEB, 2024). Herb that is used in food; flowers in crafts. Used since ancient Egyptian times as a culinary and medicinal herb to aid in digestion and gastronic health. The essential oils are believed to have antimicrobial, antifungal and antioxidant properties often used in soaps. It has been historically been used for magical purposes (love potions, spells). This plant is also popular for ornamental displays and gardens (*NCSU, 2024*). Leaves (dill weed), seeds, and flowers are edible (used in teas, pickling, and as culinary seasoning). Dill herb and dill seed oils are steam-distilled and used by the food industry as seasonings. Add to pickles, mince in butter, and cook with salmon, borscht, fish, and soups. Dill can be used in teas and as seasoning for butter, cakes, bread, vinegars, soups, fish, pickles, salads (*NCSU, 2024*). Fresh and dried dill leaves (sometimes called "dill weed" to distinguish it from dill seed) are used as herbs. Like caraway, its fernlike leaves are aromatic, and are used to flavor many foods, such as gravlax (cured salmon), borscht and other soups, and pickles (where sometimes the dill flower is used). Dill is said to be best when used fresh, as it loses its flavor rapidly if dried; however, freeze-dried dill leaves preserve their flavor relatively well for a few months. In the Middle Ages, dill was thought to protect against witchcraft. Dill oil can be extracted from the leaves, stems and seeds of the plant (Bionity, 2024). Fresh and dried dill leaves (sometimes called "dill weed" to distinguish it from dill seed) are used as herbs. Like caraway, its fernlike leaves are aromatic, and are used to flavor many foods, such as gravlax (pickled salmon), borscht and other soups, cream cheese and pickles. Dill is said to be best when used fresh, as it lose its flavor rapidly if dried; however, freeze-dried dill leaves preserve their flavor relatively well for a few months. Dill seed is used as a spice, with a flavor similar to caraway. Dill oil can be extracted from the leaves, stems and seeds of the plant (Wikipedia, 2024a). Like caraway, the fern-like leaves of dill are aromatic and are used to flavour many foods such as gravlax (cured salmon) and other fish dishes, borscht, and other soups, as well as pickles (where the dill flower is sometimes used). Dill is best when used fresh, as it loses its flavor rapidly if dried. However, freeze-dried dill leaves retain their flavour relatively well for a few months. Dill oil is extracted from the leaves, stems, and seeds of the plant. The oil from the seeds is distilled and used in the manufacturing of soaps. Dill is the eponymous ingredient in dill pickles (Wikipedia, 2024). Dill seed is used both whole and ground as a condiment in soups, salads, processed meats, sausages and pickling. Dill stems and blossom heads are used for dill pickles. The essential oil is used in the manufacture of soaps. Both seeds and oil are used in indigenous medicinal preparations. The emulsion of dill oil in water is an aromatic carminative (SPI, 2025).

Food Safety: Dill is classified as generally safe (GRAS), but the hazards and/or side effects are not known for proper therapeutic dosages. Contact photodermatosis is possible, as in most *Apiaceae* members. Fresh juice may cause photodermatosis. The dill crop grown in India (formerly included under the species *Anethum sowa*), contains dillapiole in varying levels; some cultivars have up to 25-30%. Apiole is toxic and causes nausea, menstrual changes, abortion and damage to the liver and kidney. It is a very potent inhibitor of CYP3A4, a member of the cytochrome P450 family of mixed oxidases, found largely in the liver and involved in the detoxification process. This in turn can lead to liver damage. The National Institute of Health reports indicated that in test animals apiole causes: spastic paralysis with or without sensory change, affects lungs, thorax, or respiration and behavioural changes such as altered sleep time (including change in writhing reflex). The use of dill oil should therefore be regulated and pregnant women and those having liver and kidney problems should avoid overdoses of Indian dill oil (Datiles and Acevedo-Rodriguez, 2015).

Health Benefits: Dill used to treat intestinal disorders such as colic, flatulence and indigestion. Its boiled seeds were used to get rid of gases, such as a drink for newborns, to relieve stomach pain and an ointment to relieve muscle spasms, treat fatigue and remove headaches. This herb has numerous medical applications: it is antibiotic, antispasmodic, tumor-fighting, sedative/disinfecting and antibacterial, as well as diuretic and carminative. It also has hypolipidemic activity and could be utilized to protect the heart from heart disease. Test bacteria that were found to be inhibited by Dill seed oil included E. faecalis, P. mirabilis, P. aeruginosa, K pneumonia, and E. coli; the biggest inhibition zone diameter was seen on S aureus (70-72mm). These diverse activities are all owing to the chemical structures of different active components including dillapiole and anethol in the aqueous dill extract. Dill also demonstrated antibacterial and antihyperlipidemic effects as well as being an antioxidant and diuretic. Foods that contain dill seed powder are also added in order to lower blood pressure, soothe the nervous system, induce a peaceful night's

sleep, and eliminate chronic headaches. Balances insulin production, strengthens heart and spleen, treats asthma, and lowers blood sugar. The blood sugar levels are raised as well as A high amount of caroline in the ash from burning seeds aids in wound healing and the treatment of hematomas, kidney stones, and conjunctivitis, as well as snake bites; it also has anti-inflammatory properties and can be used to treat a variety of skin conditions (Masoody *et al.,* 2023) Side Effects (LLC, 2024).

When taken by mouth: Dill is likely safe when consumed as a food. Dill is possibly safe for most people when taken by mouth as a medicine. Some people are allergic to dill.

When applied to the skin: There isn't enough reliable information to know if dill is safe. Dill can cause skin irritation in people with dill allergies. Also, fresh dill juice can also cause the skin to become extra sensitive to the sun. This might put you at greater risk for sunburns and skin cancer. Avoid sunlight. Wear sunblock and protective clothing outside, especially if you are light-skinned.

CULTIVATION

Propagation: Dill is easily propagated from seed. Seeds remain viable for 2-3 years without special storage measures and the germination rate is about 75% (Datiles and Acevedo-Rodriguez, 2015). Dill is an annual which grows to about 90cms in height. It is best sown where it is to flower in late spring and at in monthly intervals after that and the plants thinned to approximately 20 cm apart. Grow apart from Fennel otherwise Dill's flavour becomes less intense. Dill is spindly and appreciates some support with twiggy sticks when small. A sheltered spot is best as the hollow stalks are top heavy once it flowers. It likes to grow in the sun. Work the soil until fine and water it. Place the seeds on the soil, press in firmly and only just cover them. Water well during the germination period of one to two weeks. The plants mature in about six weeks so small sowings at fortnightly intervals throughout the summer are recommended to produce a continuous supply of fresh leaves. Dill likes a lime soil and some fertilisation once a month; without the latter it begins to turn yellow (Herbs, 2024).

Soil: Dill can be grown on a wide range of soils. In heavy black soils with high moisture retention capacity, it is grown as a rainfed crop, while in light soils it is cultivated as an irrigated crop. Lower to medium fertility is appropriate for good seed yield and for leaves high fertility is advisable. It can be grown successfully in saline sodic soils, however very high salinity and sodicity hampers the growth and yield of crop. Deep and frequent irrigations are not advisable for higher growth and yield including insect-pest and disease infestation (Sharma *et al.*, 2010; DASP, 2016).

Recommended varieties: Dill is considered a minor seed spices crop and not much attention has been paid to its breeding. There are two closely related cultivated species of dill *i.e.* European type dill (*Anethurn graveolens*) and Indian type dill (*A. sowa*). Farmers cultivate the local varieties using their own seed. Mehasana local and Ruby local are grown in Gujarat and Pratapgarh localin Rajasthan. National Research Centre on Seed Spices has developed and recommended two improved varieties of dill for general cultivation. The name and general characteristics of the varieties are given as under (Sharma *et al*., 2010; DASP, 2016).

Name of the variety	Characteristics
Ajmer Sowa 1 (NRCSS-AD-1)	• It is a European type dill variety which is suitable for cultivation under irrigated conditions. • The leaves are dark green in colour. • It is suitable for export as seeds of the variety are dillapiole less and contain about 3.5% essential oil. • The average plant height is 134 cm. • It takes about 142 days to maturity. • Average seed yield is 14.7 q/ha under irrigated conditions.
Ajmer Sowa 2 (NRCSS-AD-2)	• It is of Indian type dill variety suitable for cultivation both under irrigated and rainfed conditions. • The seeds are bold, compact and dark brown in colour, which require pressure to split. • The average plant height is 90 cm. • It takes about 135 days to reach maturity. • The average seed yield is 14.6 q/ ha under irrigated conditions and 5.8 q/ ha under rainfed conditions. • The seed contain about 3.2% essential oil.

Field preparation: The soil should be prepared well into good tilth before sowing by one deep ploughing with soil turning disc plough followed by two ploughings with harrow. For rainfed/unirrigated crop production moisture is conserved by ploughing and planking after rains. The field should be well leveled before sowing for better germination (Sharma *et al*., 2010; DASP, 2016).

Sowing time: The dill crop is cultivated as annual crop sown generally during rabi and early rabi season. Time of sowing has a significant effect on plant growth and seed yield. However, it may vary with the climatic conditions of the area. The rainfed crop is sown early in the season in the month of August-September. The irrigated main rabi season crop is sown in the month of October preferably during 15-30th October. Delayed sowing after 30th October reduced seed yield as well as volatile oil content (Sharma *et al*., 2010; DASP, 2016).

Sowing method: The general practice of sowing of dill is by broadcasting of the seeds in the field. But line sowing is better to facilitate intercultural operations effectively in the field. The seed should be sown 1.5 to 2.0 cm deep. The row spacing should be 50-60 cm for European type dill and 40-50 cm for Indian type dill. Plant to plant distance should kept 20 cm in both the cases. A light irrigation is required just after sowing if initial moisture in soil is not sufficient. The seeds take 10 to 12 days to germinate. The soil temperature should be around 30°C with sufficient moisture content for better germination of dill seeds (Sharma *et al*., 2010; DASP, 2016).

Seed rate: Cleaned, bold and healthy seeds should be selected for easy and even germination. Preferably seeds less than 2 years old should be used. Soaking seeds in water for a day before sowing accelerates the germination. The seed rate depends on the sowing method used and irrigation conditions. A higher seed rate is required for broad casting method under rainfed cultivation as Advance Production Technology of Dill compared to line sowing and irrigated conditions. The seed requirement is 3 kg/ ha for irrigated and 5 kg/ ha for rainfed conditions (Sharma *et al*., 2010; DASP, 2016).

Seed treatment: The seed should be treated with seed dresser fungicides like thiram or captan or carbendazim @ 2.5-3.0 g/kg seed before sowing to get rid of soil borne and seed borne pathogens. There should be uniform and sufficient coating of

the fungicide on the seed surface (Sharma *et al*., 2010; DASP, 2016).

Manure and fertilizers: Dill crop requires good fertility status providing all nutrients as it responds well to fertilizer application. The application of fertilizers can effect seed yield and seed oil composition, hence it isneeded to apply the balanced dose of nutrients in the form of fertilizers at right time. The soil should be tested before sowing for nutrient status of the field and nutrients should be applied as required in the form of manures and fertilizers after soil testing report. The general manures and fertilizers application should be given as under (Sharma *et al*., 2010;, DASP, 2016).

Irrigated conditions: Well decomposed FYM or compost @ 10 t/ ha should be applied at time of field preparation. Additional nutrients should be applied through fertilizers. The application of 90 kg nitrogen, 40 kg phosphorus and 20 kg potash has been recommended for higher seed, straw and biological yield under semi arid conditions. The 1/3rddose of nitrogen is to be applied as basal dose at the time of sowing with phosphorus and potassium. Remaining quantity of nitrogen should be applied in two split doses first at 30 days after sowing and second at flowering stage as top dressing (Sharma *et al*., 2010; DASP, 2016).

Rainfed conditions: Under rainfed conditions the manure should be applied in form of well decomposed FYM or compost (10 t/ ha) once in two years. The fertilizer requirement is 40 kg N, 30 kg P,O, and 20 kg K2O per hectare. The fertilizers should be applied at the time of sowing (Sharma *et al*., 2010; DASP, 2016).

Inter-cultural operations

Thinning: Thinning should be done 3 weeks after sowing and plant to plant distance should be maintained 15-20 cm (Sharma *et al*., 2010; DASP, 2016).

Hoeing and Weeding: The initial growth of dill crop is slow, therefore it is necessary to keep the field clean and weed free by proper weeding and hoeing. In general, two or three manual or mechanical weeding is required. First weeding and hoeing should be done in about 3-4 weeks after sowing. Next weeding should be done whenever required at 30 days interval. Weed can also be controlled by pre-emergence application of oxadiargyl @ 0.075 kg/ha or spraying pendimethalin @ 0.75 to 1.0 kg /ha after sowing or oxadiargyl @ 0.075 kg/ha + one hand weeding at45 days after sowing. There should be sufficient moisture in the soil at the time of weedicide application to ensure better weed control by the chemicals (Sharma *et al*., 2010; DASP, 2016).

Intercropping and crop rotation: Little is known about intercropping and crop rotation with dill. In general dill should be grown as sole crop to get the good results of seed yield. However, it can be intercropped with onion and carrot during rabi season. The crop should be grown by following 3-4 years crop rotation for healthy crop cultivation (Sharma *et al*., 2010; DASP, 2016).

Irrigation: Dill crop plants should be irrigated as required for its better growth during cropping period. The crop is sown under irrigated conditions in the light soil as well as unirrigated condition as a rainfed crop in black cotton soils. Under irrigated conditions a pre planting irrigation is required to wet the seed bed. If soil moisture is not sufficient at the time of sowing a light irrigation can be given just after sowing for proper germination. At the time of flower initiation and seed development stage sufficient soil moisture should be available to the crop. In all, 3-4 irrigations are sufficient to raise the crop. Irrigation interval of 15 days proved better in terms of seed, straw and biological yield (Sharma et al., 2010; DASP, 2016).

Diseases: Dill is susceptible to a number of plant pathogenic fungi, but the damage is extensive in respect of root rot and foliar diseases like powdery mildew and blight. The disease incidence and damage on dill crop depends on the climate and soil conditions. Humid and moist conditions generally favour the appearance and spread of diseases. The important diseases of dill are described as under (Sharma et al., 2010;, DASP, 2016).

Powdery mildew: Powdery mildew in dill is caused by fungus Erysiphepolygoni. The symptoms of the disease appear on all green plant parts including leaves, stem, and inflorescence as white powdery mass. The symptoms, later on extended to other parts of plants including seeds, which affect yield as wellas quality of seeds. The disease can be effectively controlled by sulphur dusting @ 20-25 kg/ha at the initial stage. Spraying with dinocap (0.1%) or wettableSulphar (0.2 %) is also effective for the management of disease. First spray should be given on the appearances of disease and repeated at an interval of 10-15 days if required depending on the spread of disease (Sharma *et al*., 2010; DASP, 2016).

Root rot: Root rot is cause by fungus Fusarium spp. The disease symptoms can appear in all growth stages, but early vegetative growth stage is more affected with the disease. The leaves showing chlorosis initially become yellow and ultimately the plant dries and dies prematurely. The affected plant roots show browning and rotting. The disease can cause severe yield losses if it appears early in the season. Phytosanitary measures and seed treatment are important for controlling the disease. Seed treatment with carbendazim (2g/kg seed) or biofungicideTrichoderma @ 4 g/kg seed are effective to control the disease (Sharma *et al*., 2010; DASP, 2016).

Other diseases

Dill crop is also affected by several other diseases of minor importance at regional levels. The list of diseases and their causal organism are given below (Sharma *et al.,* 2010; DASP, 2016):

- Damping off- Pythium spp., Rhizoctonia spp.
- Seedling blight - Alternaria radicina
- Leaf spot - Ascochytaanethicola
- Head rot - Botrytis spp., Alternaria spp.
- Scab - Fusicladium spp.
- Rust -Pucciniapetroselini
- Celery mosaic virus

Insect pests: Dill is frequently attacked with insect pests of the locally important vegetable crops and other umbelliferae crops, but the damage is comparatively less. The crop is generally attacked by insects like aphid, cutworm and leaf eating caterpillars (Sharma *et al.,* 2010; DASP, 2016).

Aphid: It sucks tender part of the plant and flowers resulting in yellowing of crop and shrivelled grains. It can be controlled by spraying of endosulfan (35 EC) 0.07% @ 500-600 litres/ha solution, which is considered a relatively safer insecticide and should be used in evening when insect population is least (Sharma *et al.,* 2010; DASP, 2016).

Leaf eating caterpillar: The caterpillar generally damages the leaves of the plant. It can be controlled by spraying of endosulfan 0.05% once or twice depending on caterpillar population (Sharma et al., 2010; DASP, 2016).

Harvesting: The carvone content of the seeds gradually increases during their development. This is ccompanied by a decrease in the limonene content whereas the aphellandrene levels appear to remain fairly constant. Thus the chemical composition and flavour of dill and its extract will depend on the maturity of the plant at the time of harvest (Henry, 1982). The harvesting time of dilldepends upon the purpose for which it is grown. When it is grown for vegetable purpose it can be harvested at 4-5 leaves stage. When it is grown for seed purpose the crop is harvested at maturity. The crop matures in 130-150 days and can be harvested in April. Harvesting is done by cutting the plants with sickle 40 cm above ground level when seeds of main umbel turn brown. Delay in harvesting results in shattering of grains into the field. The harvested dill plant bundles should be dried under shade and threshed either manually by beating with stick or mechanically in a seed spices thresher. Threshed seeds should be cleaned, dried and stored in ventilated bins to minimize the losses during storage (Sharma *et al.,* 2010). The moment of harvesting depends on the required product. For dill herb (foliage), harvesting usually takes place before flowering, about 40-50 days after sowing. For the production of herb oil, dill is cut immediately after flowering, when the seed has just started to ripen but is not yet fully developed. As this period is very short, planting should be staggered to enable the harvesting of larger areas at the proper stage of maturity. Fruits are harvested at a stage when they are fully developed but still green, *i.e.* 7-9 days after petal drop (oil content 2.6-3.7%). When the colour changes from green to dark grey, the oil content decreases to about 1.7%, *i.e.* 22-24 days after petal drop. At this stage profuse shedding takes place resulting in substantial yield losses **(**Datiles and Acevedo-Rodriguez, 2015**).**

Foliage: Harvest the dill weed as soon as the foliage begins to grow. Cut the foliage at the stem. You can keep harvesting the dill weed up until the plant flowers (HF, 2024).

Seed Heads: When the seeds start to turn brown or golden, harvest them. Some suggest cutting the dill plant down, putting it in a paper bag upside down and shaking the plant to harvest the seeds. The paper bag catches all the seeds that fall from the plant (HF, 2024).

Flowering: Let your dill flower before cutting it all the way down. The yellow umbel blooms attract beneficial insects to your garden. You definitely want to allow your dill to flower and go to seed (HF, 2024).

When to Harvest : Dill plants can survive a light frost, and you can even plant dill in midsummer to harvest late fall. Cut the stems down almost to the ground. The tough stalky stem of the dill plant can be thrown out. But you can use the foliage and seeds (HF, 2024).

Yield: On an average the yield is 10-15 q/ha under irrigated conditions and 6-7 q/ha under rainfed conditions. This seed yield of dill can be obtained under better management of crop production (Sharma et al., 2010). The yield of fresh dill herb varies from 3-20 t/ha, while dill seed yields range from 0.7-1.2 t/ha. Essential-oil yields of dill herb and dill seed are estimated at 56 kg/ha and 30 kg/ha, respectively. The yield of dry dill herb is about 10% of the fresh product **(**Datiles and Acevedo-Rodriguez, 2015**).**

Handling After Harvest: Dill herb is marketed fresh for culinary use. To maintain its keeping quality, the fresh herb can be put in sealed, polythene bags in cartons and kept at low temperatures (6-12°C). Fresh dill may be chopped and frozen with water in ice cube trays. When it is to be marketed in dried form, the drying temperature should be 80°C initially, lowered to 40°C halfway through the drying process. The dried product should have a minimum essential-oil content of 0.15% and maximum contents of water and ash should be 8 and 6%, respectively **(**Datiles and Acevedo-Rodriguez, 2015**).** For herb-oil production, it is advisable to harvest only as much fresh plant material as can be distilled during one day. Prolonged drying in the field results in considerable loss of oil by evaporation, especially of the more volatile terpenes. Moreover, fruits still attached to the harvested plant material continue to ripen, and the oil thus obtained approaches the composition of dill seed oil, which is undesirable in dill herb oil. Therefore, plant material should be distilled as fresh as possible or dried for a very short period **(**Datiles and Acevedo-Rodriguez, 2015**).** For seed production harvested plants are dried under shade and fruits are threshed out in regular threshers. Threshed fruits should be spread out in a thin layer and turned over frequently until thoroughly dry. When dill seed oil is desired, the fruits are crushed between heavy cylinders, mixed with water and then distilled **(**Datiles and Acevedo-Rodriguez, 2015**).**

Processing: The oil of dill can be extracted from both herbs and seeds. For the production of dill herb oil, fresh plants are chopped into 2-3 pieces and distilled immediately. Oil is extracted from dried fresh seeds through steam distillation. The quality of oil received from seeds is superior. An essential oil yield of 0.9 to 1.5% and 2.5 to 4% can be achieved from herbs and seeds respectively. The volatile oiland oleoresins extracted from dill seed has its demand in pharmaceutical, cosmetics and food industry (Sharma *et al*., 2010).

Processed products (Sharma *et al*., 2010).

- Herb essential oil
- The dried fruit or spice dill seed
- Seed essential oil
- Oleoresin

Preserving: Dill retains its flavor well when dried, dehydrated, frozen, or preserved in salt. You can preserve the foliage or the seeds to use all year long. If you want your dill to last for 20 years, you can freeze-dry your dill. We love the flavor of dried dill seed or dill weed, so we prefer dehydrated dill (HF, 2024).

Freezing Dill: You can wash the dill fronds, pat them dry, chop them into small pieces, fill an ice cube tray with the chopped dill, fill up the ice cube tray with water, and put it in the freezer. Or, simply wash the dill, dry it, and seal it into a freezer bag. All of these methods for freezing work well (HF, 2024).

Dehydrating Dill: Learn how to dry fresh herbs in the oven, dehydrator or air-drying. To preserve the color and flavor of the dill, begin dehydrating the same day as harvesting. Keep moisture and sunlight away from the dill, and dehydrate on the lowest possible setting until completely dry. Once dry, you can crumble and store it in an airtight container (HF, 2024).

Preserving Dill in Salt: The foliage remains in large sections and can be stored on the counter in one method. The other method blends dill with salt and stores it in the refrigerator. Both methods perfectly preserve the flavor of the dill while making a delicious seasoning salt that you can use to sprinkle on food (HF, 2024).

Production and Trade: Worldwide the cultivation of dill for its fruit is most important; the largest producers are India, Pakistan, China, western Russia and surrounding republics, Hungary and Egypt. Major users are the USA (about 600 t annually), Japan (50 t) and Germany (30 t). Worldwide annual production of dill seed oil is estimated at 50 t with a value of US$ 0.3 million. Dill herb production (mostly fresh, sometimes dried or freeze-dried) is predominantly small-scale in gardens all over the world, but no statistics are available. Larger scale production in Europe is known from Scandinavia and Germany (200 ha). Worldwide annual production of dill herb oil is estimated at 100-150 t with a value of about US$ 1 million. The largest producers are the USA (1000 ha), China and Australia (Datiles and Acevedo-Rodriguez, 2015).

Diseases, Insects, and Other Plant Problems: No serious insect or disease problems. Blight and aster yellows can cause significant damage. Dill is susceptible to aphids, tomato horn worms, and powdery mildew. If planted too close to a carrot crop, it can reduce yield; however, it is a good companion plant for cucumber and broccoli (*NCSU, 2024*).

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