The Cultivation of Chamomile (*Matricaria chamomilla* L.) in India: Insights into Origin, Distribution, and Germplasm Availability for Effective Farming Practices

Abstract

German Chamomile (*Matricaria chamomilla* L.), often referred to as the "star of medicinal plants," is a highly regarded member of the Asteraceae family. Renowned for its extensive use in folk and traditional medicine, chamomile offers diverse therapeutic, cosmetic, and nutritional benefits, supported by both traditional knowledge and scientific research. Its demand is steadily growing in domestic and international markets, though the plant is often adulterated or substituted with closely related species. The blue oil extracted from dry capitula holds significant value in international trade. Initially introduced as a crop in India, chamomile is predominantly cultivated in Jammu and Kashmir, Uttar Pradesh and Assam. This is 4-6-month crop is mainly propagated by seeds, either through transplanting or direct sowing. This study aims to provide a comprehensive review of chamomile, covering its origin and distribution, germplasm availability, cultivation practices, and post-harvest techniques. By doing so, it seeks to promote the expansion of chamomile cultivation in the South Indian region and enhance its effective and safe utilization as a "potential medicinal herb," raising awareness of the benefits of plant-based medicine.

Key words: Chamomile, Botany, Distribution, Cultivation, Asteraceae, Distillation

1. Introduction

The well-known old time drug chamomile is ascribed to three species belonging to family Asteraceae: compositae. The three species are *Matricaria chamomilla* Linn. (2n=18) (German or Hungarian chamomile or persian chamomile), *Anthemis nobilis* Linn. (English or Roman chamomile or Double chamomile) and *Ormenis multicaulis* Braun - Blanquet and Marie (Moraccan chamomile). The German or Hungarian or small chamomile, having a variety of uses also yields an essential oil, commonly known as `Blue oil', on account of its deep blue colour, is of great medicinal and aromatic importance and being in great demand throughout the world. Its demand is increasing due to its use in natural health products, aromatherapy, and modern medicines, making it a widely grown and used herb worldwide (Farooqi and Sreeramu., 2004; Jimayu, 2017).

1.1 Application

According to Global Information Research, the market size of chamomile oil is expected to increase to $ 934 million by 2030 at an annual rate of 5.1%. (Globenewswire.com, 2024). The increasing demand for chamomile may be due it multiple benefits to mankind. Chamomile is known for its wide range of uses, produces an essential oil called 'Blue oil' due to its deep blue color, which is highly valued for its medicinal and aromatic properties and being in great demand throughout the world (Farooqi and Sreeramu., 2004; Praveen *et al*. 2023). Chamomile is a multi-therapeutic, cosmetic, and nutritional benefits which enhance extensive traditional use and scientific research. It is used to treat flatulence, colic, hysteria, and intermittent fever. The flowers of *M. chamomilla* contain blue essential oil (0.2 to 1.9%), which has multiple applications. In Europe, chamomile infusion is used as a mild sedative and digestive aid. Moreover, chamomile is primarily used as an anti-inflammatory and antiseptic, as well as an antispasmodic and mild sudorific. Internally, it is taken as a tisane (infuse one tablespoon of the drug in one liter of cold water without heating) for stomach pain, sluggish digestion, diarrhea, nausea, urinary tract inflammation, and painful menstruation. Externally, chamomile powder is applied to slow-healing wounds, skin eruptions, infections like shingles and boils, hemorrhoids, and inflammations of the mouth, throat, and eyes. Chamomile flower extracts are marketed in Europe for various ailments. However, chamomile tea eye washing can induce allergic conjunctivitis, with the pollen of *M. chamomilla* being the allergen responsible for these reactions (Singh *et al.* 2011). A review by Dai *et al*. (2023) indicated that this plant improves appetite, nourishes the nerves and the stomach. Additionally, it relieves painful swellings and sweating, and as well as using to treat chronic headaches, constipation, poor sweating, joint swelling, and urinary system disorders.

It is also included in medicinal preparations like 'chamomile tea' and toiletries such as baths and shampoos. The essential oil is used in beverages, ice cream, baked goods, chewing gums, and as a flavoring agent. It is also utilized in high-class perfumes in small quantities. The oil has numerous therapeutic properties, acting as an antispasmodic, expectorant, carminative, anthelmintic, anti-inflammatory, sedative, and diuretic. It is used to treat infant ailments such as teething troubles and stomach disorders and possesses antibacterial and fungicidal activities (Farooqi and Sreeramu., 2004; Jimayu, 2017; Chauhan *et al.* 2021and Sah *et al.* 2022).

1.2 Distribution

Matricaria chamomilla L. (German chamomile) is a significant medicinal herb native to southern and eastern Europe. Hungary is a major producer of chamomile biomass, especially in poor soils, providing income to local inhabitants. Flowers are exported to Germany for oil distillation. It is also cultivated in France, Russia, Yugoslavia, and Brazil. The plant is found in North Africa, Asia, North and South America, Australia, and New Zealand. It was introduced to India during the Mughal period, now it is grown in Punjab, Uttar Pradesh, Maharashtra, and Jammu and Kashmir by Chandra *et al*. (1968). Historically, chamomile has been used in herbal remedies for thousands of years, known in ancient Egypt, Greece, and Rome. Anglo-Saxons considered it one of the nine sacred herbs given by the lord. Chamomile is included in the pharmacopoeia of 26 countries and is an ingredient in various traditional, Unani, and homeopathic medicinal preparations (Balak ram *et al*. 1999 and Chauhan *et al.* 2021).

1.3 Description of the plant

Chamomile is an annual herbaceous plant, either spreading or erect, that can reach a height of 60-90 cm. It has leafy, hollow stems and doubly pinnate leaves with narrow, flat or channeled linear segments that are convex underneath, all acute, often bristle-pointed, and slightly hairy. The plant produces terminal, solitary flower heads with a diameter of 1.3-2.5 cm, which are slightly longer than a daisy and feature a convex yellow disk tilted to one side. The involucre consists of 2-3 rows of shining membranous bordered scales that are somewhat downy. The receptacle is obtusely conical. The ray florets are incomplete, zygomorphic, female, epigynous, and ligulate with white, 3-lobed, reflexed ligules, numbering about 12-30 and small. The disc florets are numerous, yellow, and tubular. Peduncles are 2.5 cm long, dark brown or dusky greenish yellow. The gynoecium is bicarpellary and syncarpous with a long tubular style and penicillate stigmas; the ovary is inferior and unilocular with a single ovule. The stamens are five in number, syngenesious, and epipetalous with anthers longer than the filaments and basifixed, dehiscing longitudinally. The fruit is a small achene with 3-5 ridges, and each flower head produces 40-50 seeds. The seeds are less than 1.0 mm in size and yellow or light brownish in color (Galambosi *et al*. 1988, Farooqi and Sreeramu., 2004, Peter and Babu, 2012 and Stark *et al*. 2023).

1.4 Varieties

The two most common varieties used for thousands of years in Egypt, Rome, and Greece and are still in use are *Matricaria chamomilla* (L.) and *Chamaemelum nobile* (L.), (Dai *et al.,* 2023). In India, Recently a *M.chamomilla* variety `Vallary and Prashant has been released by the Central Institute of Medicinal and Aromatic Plants, Lucknow. The cultivar ‘Prashant’ is superior to ‘Vallary’ in all respects like plant height (85 cm), diameter of the capitulum (1.5 cm), and gross oil production (22 %) (Sushil *et al.* 1999).

1.5 Phytochemistry

The essential oil extracted from the flowers contains azulene (1-15%, average 6%) which determines its quality. Besides, the oil contains pro-chamazulene or matricin, terpene hydrocarbons, sesquiterpene alcohols including bisabolol, an unsaturated ketonic alcohol, bisabolol oxide, methoxy coumarin (Umbelliferone methyl ether), furfural and paraffins. The active constituents of the flower as such are the viscous oil, a bitter principle (3%), apigenin and its glycosides apiin, quercimetritrin, 7-methoxy coumarin, 7-hydroxy coumarin, a dioxy coumarin, salicylic acid, a resin, phytosterol, fatty acids, vitamin C and nicotinic acid. (Farooqi and Sreeramu., 2004, Albrecht and Otto, 2020 Chauhan *et al.* 2021 and Kazemi *et al.* 2024).

1.5.1 Phytohormone in roots and flowers

Vijendra Kumar *et al*. (2011) reported that there are many qualitative phytochemicals present in the flowers of chamomile. They established that by using hydroalcoholic extract method. Flavonoids, polyphenols, glycosides, carbohydrates, proteins, amino acids and triglycerides were found to be present in chamomile flowers. The quality and authenticity of these phytochemicals were determined using high performance thin-layer chromatography (HPTLC) fingerprint profiling. As they assessed the quantitative rate of the phytohormone, total polyphenol was 11.24% w/w and the estimated flavonoid content was 4.16 %w/w. The crude extract of apigenin-7-O-glucoside was observed to contain 0.81% w/w of apigenin-7-O-glucoside in reference to the standard using HPLC.

Volatile compounds such as chamomillol and polynes were identified in chamomile roots using GC-MS and HPLC-MS analysis. This analysis also revealed the presence of four coumarin glycosides, more than ten phenolic acid esters, and five glyceroglycolipids. Polar extracts exhibited IC50 values ranging from 13 to 57 µg/mL in the DPPH radical scavenging assay, aligning with values reported for chamomile flower extracts (Mailander *et al*., 2022).

The level of apigenin in chamomile flower depends on the post-handling processes that lead to degradation of apigenin 7-glycoside (Schreiber *et al*., 1990). Moreover, inoculation of chamomile before planting with Arbuscular mycorrhizal fungi Increases apigenin-7-*O*-glucoside in chamomile flowers (Baczek *et al*., 2019 and Aglawe *et al*. 2020).

1.6 Soil, Climate and Season

Chamomile can be grown on any type of soil. Moist, moderately heavy soils, rich in humus are best suited for this crop. The optimum soil pH is 7 but soils having pH as high as 9.0 also support good growth (Mishra and Kapoor., 1978). For example, In Yugoslavia, it is grown with success on saline soil. In Hungary also it is cultivated in sub-standard clayey-alkaline soils, which are considered poor for other crops. Temperature and light conditions have a greater effect on essential oil and azulene content. The optimum temperature for seed germination is between 10 to 20^{O} C. Season plays a very important role in this crop. In India chamomile can be grown as a winter crop in plains and as a summer crop on hills up to an altitude of 2000 m. Since this is a Rabi crop, it is sown on the second fortnight of December in North Indian hills, whereas in plains it is sown in late September or early October. Kanjilal and Singh (2000), report indicated that transplanting the crop in the first week of December optimizes yield. Furthermore, chamomile is a winter season crop, and its duration is about 5 months (December-April). Hence it fits well in rotation with paddy for waterlogged lowlands. It also forms a good combination with crops like maize and early potato and on sub-marginal lands following a green manure crop, it gives better results (Peter and Babu, 2012).

Southern India can support chamomile growing because of subtropical climatic condition especially in places such as Bangalore, Ooty and Kodaikanal regions which features a cool and dry winter. Successful nursery management depends on optimal germination, which takes place between 10 and 25°C. Therefore, establishing the nursery around mid-November, coinciding with the onset of the cooler winter months, ensures timely transplantation by early to mid-December for maximum yield.

Chamomile start blooming from the second week of March and three flower pickings (between March 25 and April 19) can be done manually at an interval of 7–10 days. Also, chamomile has been found to be a suitable intercrop with aromatic grasses, such as lemon grass and palmarosa, which remain dormant in winter by Mishra *et al*. 1999.

2. Cultivation

2.1 Propagation

It is a crop of 4-6 months mainly propagated by seeds either by transplanting or by direct sowing. Chamomile is propagated through seeds and about 1 kg of seeds are required to raise seedlings sufficient to plant one hectare of land. One-month-old seedlings are transplanted into the main field. Sometimes the crop is also grown by direct sowing, for which 3 kg seeds are required per hectare. A thousand seeds weigh 0.088 to 0.153 g.

2.2 Nursery raising

The nursery area is well prepared by repeated ploughing and brought to a fine tilth. A well decomposed farmyard manure is applied into the soil and convenient size of nursery beds are prepared. As the seeds are small, the seeds are mixed with sand or fine soil in the ratio of 1:4 and sown in the nursery beds. The seeds sown are covered with a very thin layer of powdered compost and the nursery should be watered frequently. The seeds germinate in 15-20 days of sowing and the seedlings are ready for transplanting in the main field when they are 4 to 5 weeks old (Farooqi and Sreeramu., 2004; Peter and Babu, 2012).

2.3 In Vitro Propagation

Tissue culture involves the in vitro cultivation of plant cells or organs under sterile and controlled conditions. In commercial settings, it's often referred to as micropropagation, where whole plants are grown from explants. For *Matricaria chamomilla*, two tissue culture types (E40 from leaf and BK2 from stem) were grown in modified Murashige and Skoog medium, both producing essential oils with similar chromatographic profiles. Studies by Szoke *et al*. (1981) revealed that callus tissues from root, stem, and flower responded best to growth regulators like kinetin and 2,4-D, with coconut milk also enhancing growth. Cellarova *et al*. (1982) demonstrated successful shoot induction in chamomile callus cultures using kinetin and NAA.

2.4 Land preparation

Chamomile is a shallow rooted plant hence deep ploughing is not necessary. The land is ploughed once followed by four cross harrowing and levelled properly and flat beds of convenient size are made. At the time of the final harrowing farm-yard manure or compost 20-25 tonnes per hectare is applied and cultivated well into the soil (Peter and Babu, 2012).

2.5 Transplanting

To obtain maximum flower and essential oil yield the crop has to be planted ata spacing of 30 cm x 30 cm. For varieties with a spreading habit 40 cm x 40 cm spacing is ideal. The studies conducted by Farooqi and Sreeramu (2004) revealed that 30 × 30 cm spacing was found to be better. It gave higher flower and essential oil yield. Many scientists worked in this aspect with different spacings like 15 × 15 cm, 20 × 20 cm, 30 × 30 cm, and 45 × 45 cm, but the best spacing found was 30 × 30 cm (Nidagundi and Hegde., 2007).

2.6 Manures and fertilizer

The crop responds well to the application of fertilizers. Many reports have indicated that applying a balanced dose of fertilizer maximizes flower and essential oil yield. Hadi *et al*. (2011) found that 15-20 t/ha of vermicompost and amino acids improves growth, flowering and 27% more of the essential oils' levels. They indicated that the vermicompost contained N (4.12%), P (0.61%), K (3.19%), Zn (27-40 ppm), Fe (36-50 ppm) and Mn (15-20 ppm) with organic matter of 65% and pH of 7. Application of 100:60:40 kg NPK ha^{-1} improved plant height (28%), flower yield (47.7%) and oil yield (23%) according to Upadhyay *et al*. (2016). Application of 60 kg N and 60 kg P_2O_5 per hectare is recommended for red sandy soils. However, a fertilizer dose of 80 kg N, 40 kg P_2O_5 and 20 kg K_2O per hectare is considered optimum for a good crop (Farooqi and Sreeramu., 2004).

According to Bączek *et al*. (2019), inoculation of chamomile seeds with arbuscular mycorrhizal fungi increases the mass of herb, roots and flower heads of chamomile. Salehi *et al.* (2018) studied the effects of zeolite, vermicompost, and plant growth-promoting rhizobacteria (PGPRs) on the flower yield, essential oil content, and composition of German chamomile (*Matricaria recutita* L.) in a semi-arid region of Iran. Results showed that organic fertilizers led to the highest flower yield and enhanced essential oil quality, with more oil components and higher concentrations of key constituents compared to chemical fertilizers. The findings suggest that vermicompost, zeolite, and PGPRs are beneficial for improving chamomile cultivation in arid regions.

(Monjezi, 2018) reported that applying 10 tons/ha of cow manure significantly improved yield, zinc concentration, and uptake in German chamomile. Organic fertilizers, particularly cow manure, increased zinc levels in roots, stems, leaves, and flowers, enhancing overall plant growth. The findings suggest that cow manure is an effective alternative to chemical fertilizers, offering environmental benefits while improving plant performance.

The Isfahan ecotype of plants showed maximum height and essence yield during spring planting at the 50% flowering stage. Both manure and chemical fertilizers had similar effects on flower dry weight, with mixed fertilizers increasing flower dry weight by 325%, 189%, and 104.6% compared to the control. In both fall and spring plantings, mixed fertilizers produced the highest biological yield, while no fertilizers resulted in the lowest yield, with no significant difference between chemical and manure fertilizers. In spring planting, mixed fertilizers, manure, and chemical fertilizers improved the harvest index by 18.99%, 18.20%, and 10.35%, respectively, compared to control, while in fall planting, the increases were 25.85%, 18.26%, and 13.47% (Shams, 2012).

Nitrogen deficiency in *Matricaria chamomilla* triggers various physiological changes, particularly in antioxidant enzyme activities. Under N deficiency, the activities of catalase (CAT) and guaiacol peroxidase (GPX), crucial for managing reactive oxygen species (ROS), decrease in leaves but increase in roots. This suggests that the roots have enhanced oxidative stress protection, while the leaves are more vulnerable. Additionally, nitrogen-starved plants show increased phenolic content and phenylalanine ammonia-lyase (PAL) activity, which play a role in ROS detoxification. Root growth is promoted, while shoot growth is inhibited, indicating a stress adaptation response (Sanchez *et al*. 2000, Kovacik *et al.* 2007 and Kovacik and Backor, 2007).

2.7 Irrigation Management

Chamomile has shallow roots and needs irrigation about once a week for optimal growth. Heavier soil needs less water than lighter soils. For sandy loam, irrigation should occur every 4 to 5 days, depending on the weather conditions.

Chamomile performs well with frequent irrigation since it is a shallow rooted crop. Frequent irrigation at the blooming or rosette period increases flower yield. They added that on alkaline soils, regular irrigation of about 6–8 times is required throughout the crop cycle, Singh *et al*. (2011).

Effect of different Irrigation treatments (25-, 50-, 75-, and 100-mm pan evaporation) and plant spacing (5, 10, 15, 20, and 25 cm intra-row with 30 cm inter-row) were tested. The best results were observed with irrigation at 50 mm evaporation and a 10 cm intra-row spacing, producing the highest yields of dried flowers, essential oil, seeds, and biomass (Pirzada *et al.* 2011).

A field experiment in 2008 at Zabol University, Iran, studied the effects of water stress and fertilizer type on chamomile (*Matricaria chamomilla*). Three water stress levels (90%, 70%, and 50% of field capacity) and four fertilizer types (no fertilizer, chemical, manure, and compost) were tested. Results showed a 50% field capacity reduced flower yield by 18.1%. The highest yields and growth components were observed with 90% field capacity and chemical fertilizer. However, under severe water stress, manure performed best. The highest essential oil content was found at 70% field capacity. Both carbohydrate and proline levels increased with stress (Arazmjo *et al*. 2010).

2.8 Weeding and Interculture Operation

About 3-4 weedings and hoeings are required for raising a good crop. In case of crop grown in saline alkaline soils only one thorough weeding and hoeing, one month after planting is sufficient.

In the organic cultivation of chamomile, Kwiatkowski *et al.* (2020). from Poland reported approximately a 20% reduction in annual weed density with the application of bioproducts Bio-algeen and Herbagreen Basic compared to the control. Furthermore, it was found that crop geometry has a considerable impact on weed infestation, with broader row spacing (40 cm) producing more weed biomass than narrower row spacing (30 cm). Frabboni *et al*. (2019) reported that essential oils of rosemary (*Rosmarinus officinalis* L.) and oregano (*Origanum vulgare* L.) at two concentrations undiluted and 50% diluted treated three times during the chamomile crop cycle. They observed greater weed control efficiency with the undiluted essential oil treatment. Another study found that application of sodium salt of 2,4-D (2,4-dichlorophenoxyacetic acid) at 1.0–1.5 kg/ha after four weeks of transplanting resulted in a good control of weeds (Singh *et al*. 2011).

2.9 Cropping sequence

Patra *et al*. (2005) reported Chamomile, a winter (Rabi) season crop, is well-suited for rotation with major summer (Kharif) crops like paddy and maize. It can follow pulses such as green gram and pigeon pea, as well as summer vegetables like okra and cucumber. Additionally, chamomile can be cultivated after early maturing Brassicas and can thrive in residual soil fertility before green manuring or heavily fertilized crops. It is also viable as an intercrop with various arable crops.

Mishra *et al*. (1999) reported successful intercropping of chamomile with celery, ajwain, fennel, and Dill in a 1:1 ratio. The main crop was sown on November 2, and 8-week-old chamomile seedlings were transplanted in early January, with a spacing of 45 × 20 cm. Dried biogas slurry was applied during land preparation, and the crops received three irrigations. Chamomile began blooming in mid-March, allowing for three manual flower pickings between March 25 and April 19. Additionally, chamomile was found to be a suitable intercrop with aromatic grasses like lemongrass and palmarosa, which remain dormant in winter.

2.10 Harvesting and Yield

To maintain the essential oil in the drug for a longer time, the chamomile flower should be harvested at the medium flower ripening stage (Letchamo, 2010). Flowering starts from the second fortnight of February, and it continues till the middle of April. Fully opened flowers should be picked immediately, as delay in harvest may result in shedding of seeds. Picking of individual flowers may be done by hand or by means of flower scoops or skippers. About 4-5 harvests could be taken at 10-15 days interval. The harvest of flowers will be maximum in the 3rd or 4th flush of flowering. The last flush of flowers (5th) will be allowed to set seeds on the plant itself. The crop gives fresh flower yield of 60 q/ha and 10-15 q/ha dry flower yield. The crop under Bangalore conditions also performed well. It gave fresh and dry flower yields of 6.09

tonnes/ha and 1.64 tonnes/ha, respectively, with the closer spacing of 30 × 20 cm. It gave essential oil yield of 6.36 kg/ha (Nidagundi and Hegde., 2007).

3 Plant protection

Chamomile (*Matricaria chamomilla* and related species) is a valuable medicinal and aromatic plant, but its cultivation and storage face challenges from various pests, diseases, and storage issues. Effective management of these problems requires an integrated pest disease approach.

3.1 Fungal Diseases

Chamomile is susceptible to a range of fungal infections, including *Albugo tragopogonis* (white rust), *Erysiphe cichoracearum and Sphaerotheca macularis* (powdery mildew), *Peronospora leptosperma and P. radii* (downy mildew) *and Alternaria species., Septoria chamomillae,* and *Puccinia anthemedis* (Singh *et al.,* 2011).

Management

Use disease-free seeds and resistant varieties, implement crop rotation with non-host crops. Apply neem oil or bio-fungicides like Trichoderma viride, maintain proper spacing for airflow to reduce humidity. Use fungicides like Carbendazim or Benomyl (e.g., 0.1% Benlate for *Alternaria* leaf blight) and Copper-based fungicides (e.g., Copper oxychloride) for downy mildew (Singh *et al.,* 2011).

.

3.2 Viruses and insects

The yellow virus (*Chlorogenus callistephi var. californicus Holmes, Callistephus virus 1A*) can cause severe damage to chamomile crops. From 1960 to 1964, no diseases were reported in chamomile grown at the Regional Research Laboratory in Jammu. However, 20 years later, in February, plants showing virus-like symptoms were found, and these were destroyed by burning to stop the disease from spreading. In early March, leaf blight caused by *Alternaria* species appeared but was controlled using a 0.1% Benlate spray. Other pests were also observed, including black bean aphids (*Aphis fabae*), which fed on the plants, *Nysius minor*, which caused flowers to drop, and *Autographa chryson*, which led to leaf loss (Bottcher and Gunther, 2005).

Management

Remove and burn infected plants immediately to prevent spread, encourage natural predators of vector insects like aphids (e.g., ladybugs). Release beneficial insects like parasitoid wasps to control aphids, use neem oil, garlic extracts, or chili sprays as repellents. Apply pheromone traps to monitor and control moth populations in storage. Use systemic insecticides such as Fosfothion (0.2%) for aphids. Fumigate storage areas with Methyl Bromide or Phosphine to control stored product insects.Apply synthetic pyrethroids for pests like *Autographa chryson*. Use reflective mulches to deter aphid populations. Spray insecticides such as Imidacloprid or Dimethoate to control vector insects. Aphid infestations (*Doralis fabae Scop*.) were effectively controlled with a 0.2% fosfothion spray. Methyl bromide (3 kg/100 m³) was also effective as a fumigant against *Ephestia elutella* in dried chamomile. Furthermore, *Metalydacolus longistriatus* was found to infest chamomile roots in Egypt's Giza region (Mathur *et al.* 1967).

3.3 Storage pest and disease

In addition to damaging cultivated chamomile crops, fungi and insects cause significant harm to dried flowers during storage, reducing the quality of the dried raw product. This is because dried chamomile, especially flowers, contains a high amount of hydrophilic compounds (sugars, flavonoids, mucilages, phenyl carbonic acids, amino acids, choline, and salts), and chamomile herbs are also hygroscopic. Fungal deterioration occurs rapidly, and in marginal conditions, the most xerophilic species, such as *Aspergillus* and *Penicillium* molds, appear first. The metabolism of bacteria and fungi releases increasing moisture, supporting the growth of other organisms like *Fusarium* and *Rhizopus*, creating a cascade effect. The metabolic by-products from these microbes also make the stored product smell musty or damp, significantly reducing its quality. Furthermore, there is a risk of mycotoxin contamination, which poses health hazards (Singh *et al.* 2011).

The dried product is also a common habitat for certain insects. The larvae and beetles damage the stored product by feeding on it and contaminating it with excreta and webs, significantly reducing quality and leading to complete deterioration within a short period. The main storage pests affecting chamomile include *Plodia interpunct Ella* Hb. (copper red-Indian meal moth), *Ptinus latro* F. (dark brown thief beetle), *P. testaceus* Oliv. (yellow brown thief beetle), *Gibbium psylloides* Gzemp. (smooth spider beetle*), Lasioderma servicorne,* and *Stegobium paniceum* (Sharifan *et al*. 2017).

Management

Store dried flowers in airtight containers at low humidity (<10%). Use natural repellents like dried neem leaves or cedarwood in storage areas. Periodically expose stored material to sunlight for sterilization. Apply food-safe desiccants (e.g., silica gel) to reduce moisture. Treat storage areas with antifungal agents or fumigants (e.g., Sodium Metabisulfite) (Sharifan *et al*. 2017).

4. Drying and storage

Since freshly harvested flowers have 60-85% moisture, it is essential to dry to as low as 10% moisture. Different research groups assessed different drying methods and had the best drying method enhancing the essential oils or the chemical profiles (Boettcher and Günther., 2005 Abbas *et al*., 2021; Benkovic-Lacic *et al*., 2023). Abbas *et al*. (2021) evaluated how different types of drying conditions influence the level of the essential oil and the number of compounds to be identified in the chamomile flower head. They confirmed this assertion with 72 hours of drying using solar, sunlight and oven (42^{o}C) in addition to shade drying for a week and 5 minutes of microwave. They found that solar drying had the highest levels of essential oils (0.35–0.50%) and identified compounds (21) whereas microwave had the least levels. Furthermore, Benkovic-Lacic *et al*. (2023) assessed another four different drying methods. They used sun drying (temperature at 30 °C) for 4 days, shade drying at 20–25 °C for 7 days, in a dryer at 105 °C for 24 h, and in a climate chamber at 60 °C for 48 h. The color, aroma, dry biomass, and chemical profile of chamomile flowers were all affected by the drying methods. The climate chamber had the highest color change. The least color change was observed under the sun drying method and had the highest contents of polyphenolic compounds and antioxidant activity. Drying at 105 °C decreased the total phenols and total flavonoids compared to in the sun and shade drying. Moreover, Yee *et al.* (2022) assessed various drying techniques to estimate powder production and physicochemical characteristics. The drying techniques included spray-drying at 140°C (10.5 and 12 ml/min), freeze-drying at -50°C, and convection oven-drying at 45°C. The lowest powder yield (16.67%) was obtained by spray-drying at 140°C and 12 ml/min; however, oven-drying (90.17%) and freeze-drying (83.24%) produced significantly higher powder yields. The total polyphenol content of oven-drying and freeze-drying was higher than that of spray-drying.

Moreover, different drying methods were evaluated by Yee *et al*., (2022) to estimate powder yield and physicochemical properties. The drying methods were convection oven-drying at 45 °C, freeze-drying at −50°C, and spray-drying at 140°C (10.5 and 12 ml/min). Spray-drying conducted at 140°C, 12 ml/min resulted in the lowest yield of powder (16.67%) but oven-drying (90.17%) and freeze-drying (83.24%) had significantly reasonable powder yield. Oven-drying and freeze-drying had higher total polyphenol content compared to those of spray-dried.

Quality is usually maintained during storage. For example, higher storage temperatures and advance ripening of flowers are the major cause of essential oil loss in chamomile drug. For instance, essential oil quality or level reduces by 40% by storing the big flower heads at 16°C at 60% relative humidity (RH) whereas the same size of flowers when stored at 2°C and 85% RH maintain the essential oil status at 84%. Letchamo (2010) suggested that to maintain the essential oil levels, it is optimal to harvest chamomile at the medium-ripe stage and store it at low temperatures. Altogether, drying chamomile flowers at low temperatures with a reasonable time improve or sustain the quality of chamomile flowers and the essential oils or physio-chemicals.

5 Distillation of oil and yield

The essential oil from the air-dried flowers is extracted through steam distillation. Steam of high pressure viz., 7 atmospheres per sq.cm. in the steam generator, is used for distillation. The oil deposits on the inner walls of the condenser, the flow of the cooling water is frequently stopped until the temperature of the condenser rises sufficiently. The distillation process takes 5 hours. The yield of oil varies from 0.3 to 1.3 per cent and is influenced by the location, strain, environmental conditions and the fertility status of the soil. The day temperature during the flowering period also influences the oil content of flowers, and the best results are obtained when the temperature ranges from 22°C to 25°C. The chamomile oil possesses a deep blue colour when freshly distilled, and changes into brown Colour under the influence of light and air during storage (Farooqi and Sreeramu., 2004).

Conclusion

Chamomile is in high demand globally due to its extensive medicinal and pharmacological benefits. With a growing preference for natural over synthetic substances, many herbal medicines, like chamomile, are valued for being free from side effects, readily available, and health-promoting, while also offering income potential. However, chamomile diversity is increasingly threatened by unregulated wild harvesting and urban expansion. Therefore, cultivating chamomile is recommended to ensure quality control of key bioactive components, producing uniform plant material at planned intervals and in desired quantities. In India, there is significant potential to cultivate chamomile as a commercial medicinal and industrial crop. Given its high international market value, promoting chamomile cultivation for the export of chamomile oil would be a worthwhile commercial endeavor.

Chamomile can be successfully grown in Southern India, particularly under Bangalore's conditions, during the colder winter months. Nursery management is crucial, as germination rates are highly dependent on temperature, which should range from 10–25°C for optimal germination. Therefore, the ideal time to start the nursery is around mid-November, with seedlings ready for transplantation by mid-December to ensure good productivity.

References

1. Abbas, A. M., Seddik, M. A., Gahory, A. A., Salaheldin, S., & Soliman, W. S. (2021). Differences in the aroma profile of chamomile (*Matricaria chamomilla* L.) after different drying conditions. *Sustainability*, 13(9), 5083-5086.
2. Aglawe,S., Gayke,A., Sharma,K., Jadhav,S., Gore,S., Pandit,B., Valate,S. and Wagh, M. (2020)..Chamomile: A Review. Res. J. Pharmacology and Pharmacodynamics, 12(1),12-14.
3. Albrecht, S., & Otto, L. G. (2020). *Matricaria recutita* L.: true chamomile. Medicinal, aromatic and stimulant plants, 313-331.
4. Arazmjo, E., Heidari, M., & Ghanbari, A. (2010). Effect of water stress and type of fertilizer on yield and quality of chamomile (*Matricaria chamomilla* L.). *Iranian Journal of Crop Sciences*, 12, (2), 100-111.

5. Bączek, K. B., Wiśniewska, M., Przybył, J. L. *et al*., (2019). Arbuscular mycorrhizal fungi in chamomile (*Matricaria recutita* L.) organic cultivation. *Industrial Crops and Products*, 140(15),111-156.
6. Balak Ram, B. R., Misra, P. N., Sharma, N. L., & Katiyar, R. S. (1999). Effect of different levels of sodicity and fertility on the performance of German chamomile (*Chamomilla recutita*) under subtropical conditions. I. Growth and yield. 21(3),692-694.
7. Benković-Lacic, T., Orehovec, I., Mirosavljevic, K., Benkovic, R., Cavar Zeljkovic, S., Stefelova, N., and Salopek-Sondi, B. (2023). Effect of Drying Methods on Chemical Profile of Chamomile (*Matricaria chamomilla* L.) Flowers. *Sustainability*, 15(21), 153-173.
8. Boettcher, H., & Günther, I. (2005). *Storage of the dry drug.* Boca Raton: CRC Press, 211-220.
9. Cellarova, E., Grelakova, K., Repcak, M., & Honcariv, R. (1982). Morphogenesis in callus tissue cultures of some *Matricaria* and *Achillea* species. *Biologia plantarum*, 24(7), 430-433.
10. Chandra, V., Singh, A., & Kapoor, L. D. (1968). Experimental cultivation of some essential oil-bearing plants in saline soils (*Matricaria chamomilla* L.) *Perfumer and Essential Oil Record*, 59:87.
11. Chauhan, R., Singh, S., Kumar, V., Kumar, A., Kumari, A., Rathore, S., & Singh, S. (2021). A comprehensive review on biology, genetic improvement, agro and process technology of German chamomile (*Matricaria chamomilla* L.). Plants, 11(1), 1-29.
12. Dai, Y. L., Li, Y., Wang, Q., Niu, F. J., Li, K. W., Wang, Y. Y., and Gao, L. N. (2022). Chamomile: a review of its traditional uses, chemical constituents, pharmacological activities and quality control studies. *Molecules*, 28(1), 133-185.
13. Farooqi, A. A., & Sreeramu, B. S. (2004). Cultivation of medicinal and aromatic crops. Universities Press.
14. Frabboni, L., Tarantino, A., Petruzzi, F., & Disciglio, G. (2019). Bio-herbicidal effects of oregano and rosemary essential oils on chamomile (*Matricaria chamomilla* L.) crop in organic farming system. *Agronomy*, 9(9), 475-488.
15. Galambosi, B., Marczal, G., Litkey, K., Svab, J., & Petri, G. (1988). Comparative examination of chamomile varieties grown in Finland and Hungary. *Herba Hungarica*, 27(8),45-55.
16. Globenewswire.com/news-release/2024/11/27/2988071/0/en/Chamomile-Flower-Oil-Industry-Report-2025-2030-Global-Market-Revenue-Forecast-to-Reach-6-09-Billion-by-2030.html
17. Hadi, M. R. H. S., Darz, M. T., Ghandehari, Z., & Riazi, G. (2011). Effects of vermicompost and amino acids on the flower yield and essential oil production from *Matricaria chamomile* L. *Journal of Medicinal Plants Research*, *5*(23), 5611-5617.
18. Jimayu, G. (2017). Review on Effects of Organic and Chemical Fertilizer on Chamomile (*Matricaria Chamomilla* L) Production. *Academic Research Journal of Agricultural Science and Research*, 5(6), 453-460.
19. Kanjilal, P. B., & Singh, R. S. (2000). Effect of spacing and planting time on chamomile performance. *journal of agricultural science*, 70(4), 631-637.
20. Kazemi,A., Shojaei-Zarghani, S., Eskandarzadeh,P., and Hashempur, M.H. (2024). Effects of chamomile (*Matricaria chamomilla* L.) on sleep: A systematic review and meta-analysis of clinical trials. Complementary Therapies in Medicine,84,1-8.
21. Kováčik, J., & Bačkor, M. (2007). Changes of phenolic metabolism and oxidative status in nitrogen-deficient *Matricaria chamomilla* plants. *Plant and soil*, 29(7), 255-265.
22. Kováčik, J., Klejdus, B., Bačkor, M., and Repčák, M. (2007). Phenylalanine ammonia-lyase activity and phenolic compounds accumulation in nitrogen-deficient *Matricaria chamomilla* leaf rosettes. *Plant Science*, 172(2), 393-399.
23. Kwiatkowski, C. A., Haliniarz, M., & Harasim, E. (2020). Weed infestation and health of organically grown Chamomile (*Chamomilla recutita* (L.) Rausch.) depending on selected foliar sprays and row spacing. *Agriculture*, 10(5), 168-186.
24. Lee, S. Y., Ferdinand, V., & Siow, L. F. (2022). Effect of drying methods on yield, physicochemical properties, and total polyphenol content of chamomile extract powder. *Frontiers in Pharmacology*, 13, (08),100-3209.

25. Letchamo, W., Gosselin, A., & Hölzl, J. (1995). Growth and essential oil content of Angelica archangelica as influenced by light intensity and growing media. *Journal of Essential Oil Research*, 7(5), 497-504.
26. Mailänder, L. K., Lorenz, P., Bitterling, H., Stintzing, F. C., Daniels, R., & Kammerer, D. R. (2022). Phytochemical characterization of chamomile (*Matricaria recutita* L.) roots and evaluation of their antioxidant and antibacterial potential. *Molecules*, 27(23), 850-888.
27. Mathur, A. C., & Sharma, M. L. (1962). Nysius minor Dist. (Lygaeidae, Hemiptera) a pest of *Matricaria chamomilla* Linn. *Indian Journal of Entomology*, 24(7),64–66.
28. Mishra, D. K., Naik, S. N., Srivastava, V. K., & Prasad, R. (1999). Effect of drying *Matricaria chamomilla* flowers on chemical composition of essential oil. *Journal of Medicinal and Aromatic Plant Sciences*, 21(8), 1020-1025.
29. Mishra, P. N., and Kapoor, L.D. (1978). *Matricaria chamomilla* Linn. –A remunerative crop for saline alkali-soils. *Indian Forester*, 104(9), 631-637.
30. Monjezi, S., Norouzi Masir, M., Moezzi, A. and Mahmoudisourestani, M., (2018). Effect of some organic and chemical fertilizers on zinc uptake and growth indices of German chamomile (*Matricaria chamomilla L*.). *Journal of Soil Management and Sustainable Production*, 8(2),63-69.
31. Nidagundi, R., & Hegde, L. (2007). Cultivation prospects of German chamomile in South India. *Natural Product Radiance,* 6(2), 135-137.
32. Parveen, A., Perveen, S., Naz, F., Ahmad, M., & Khalid, M. (2023). Chamomile. In Essentials of Medicinal and Aromatic Crops (pp. 1009-1040). Cham: Springer International Publishing.
33. Patra, D. D., Misra, H. O., Lal, R. K., Agarwal, K. K., Prasad, A., & Anwar, M. (2005*). Matricaria recutita cultivation. Farm Bulletin CIMAP, Lucknow.*
34. Peter, K. V., & Babu, K. N. (2012). Introduction to herbs and spices: medicinal uses and sustainable production. In *Handbook of herbs and spices* (pp. 1-16). Woodhead Publishing.
35. Pirzada, A., Shakiba, M. R., Zehtab-Salmasi, S., Mohammadi, S. A., Hadi, H., & Darvishzadeh, R. (2011). Effects of irrigation regime and plant density on harvest index of German chamomile (*'Matricaria chamomilla'L.*). *Australian Journal of Agricultural Engineering,* 2(5), *120-126.*
36. Sah, A., Punnoth, N. and Kuruniyan, N.P., (2022). A Comprehensive Study of Therapeutic Applications of Chamomile. Pharmaceuticals,15, 1284.
37. Salehi, A., Gholamhoseini, M., Ataei, R., Sefikon, F., & Ghalavand, A. (2018). Effects of zeolite, bio-and organic fertilizers application on german chamomile yield and essential oil composition. *Journal of Essential Oil-Bearing Plants*, 21(1), 116-130.
38. Sánchez, E., Soto, J. M., García, P. C., López-Lefebre, L. R., Rivero, R. M., Ruiz, J. M., & Romero, L. (2000). Phenolic compounds and oxidative metabolism in green bean plants under nitrogen toxicity. *Functional Plant Biology*, 27(10), 973-978.
39. Schreiber, A., Carle, R., & Reinhard, E. (1990). On the accumulation of apigenin in chamomile flowers. *Planta medica*, 56(02), 179-181.
40. Shams, A., Abadian, H., Akbari, G., Koliai, A., & Zeinali, H. (2012). Effect of organic and chemical fertilizers on Amount of Essence, biological yield and harvest index of *Matricaria chamomile*. *Annals of Biological Research*, 3(8), 3856-3860.
41. Sharifan, A., Hajhoseini, A., & Bakhtiari, M. (2017). Clinical trial and in vitro study investigating topical application of *Zataria multiflora* Boiss. and *Matricaria chamomilla* extracts for androgenetic alopecia. *Cogent Medicine*, 4(1), 142-1405.
42. Singh, O., Khanam, Z., Misra, N., & Srivastava, M. K. (2011). Chamomile (*Matricaria chamomilla* L.): an overview. *Pharmacognosy reviews*, 5(9), 82-95.
43. Singh, O., Khanam, Z., Misra, N., & Srivastava, M. K. (2011). Chamomile (*Matricaria chamomilla* L.): an overview. *Pharmacognosy reviews*, *5*(9), 82-97.
44. Stark, T., Ştefan, V., Wurm, M., Spanier, R., Taubenböck, H., & Knight, T. M. (2023). YOLO object detection models can locate and classify broad groups of flower-visiting arthropods in images. *Scientific Reports*, 13(1), 16-364.

45. Sushil Kumar, S. K., Rao, M. G., Khanuja, S. P. S., Gupta, S. K., Moumita Das, M. D., Shasany, A. K., and Govind Ram, G. R. (1999). The chamazulene-rich chamomile variety-Prashant (a new genotype). *Journal of Medicinal and Aromatic Plant Sciences*, 21(8), 1096-1098
46. Szoke, E., Verzar-Petri, G., Shavarda, A. L., Kuzovkina, I. N., & Smirnov, A. M. (1981). Differences in the essential oil composition in isolated roots, root callus tissues and cell suspensions of *Matricaria chamomilla*. *Izvestiya Akademii Nauk SSSR, Biologicheskaya,* 6(4), 943-949
47. Upadhyay, R. K., Singh, V. R., & Tewari, S. K. (2016). New agro-technology to increase productivity of chamomile (*Matricaria chamomilla* L.). *Industrial Crops and Products*, 89(12), 10-13.
48. Vijendra Kumar K B, Hemanth Kumar C M, V. C Barangi, S. Aluri, Devaraj K N, Chandrashekara B. M., Prakruthi, H. R., Prakasha, K. C., (2011). Characterization of the Phytochemicals n chamomile and evaluation of their biological activity. *Journal of Pharmacy and Biological Sciences,* 4(1), 26-33.

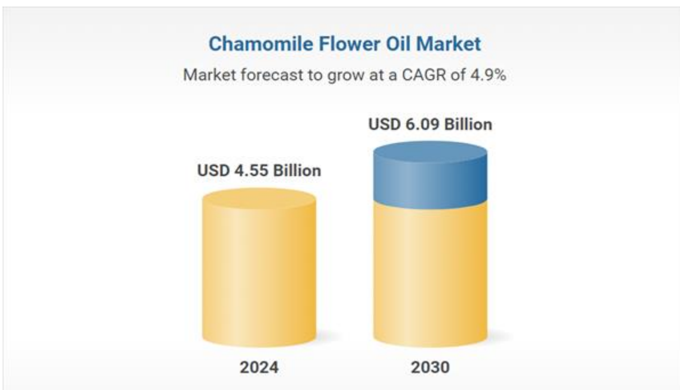

Fig.1: Chamomile Flower Oil Industry market 2025-2030

Fig. 4: General view of Chamomile

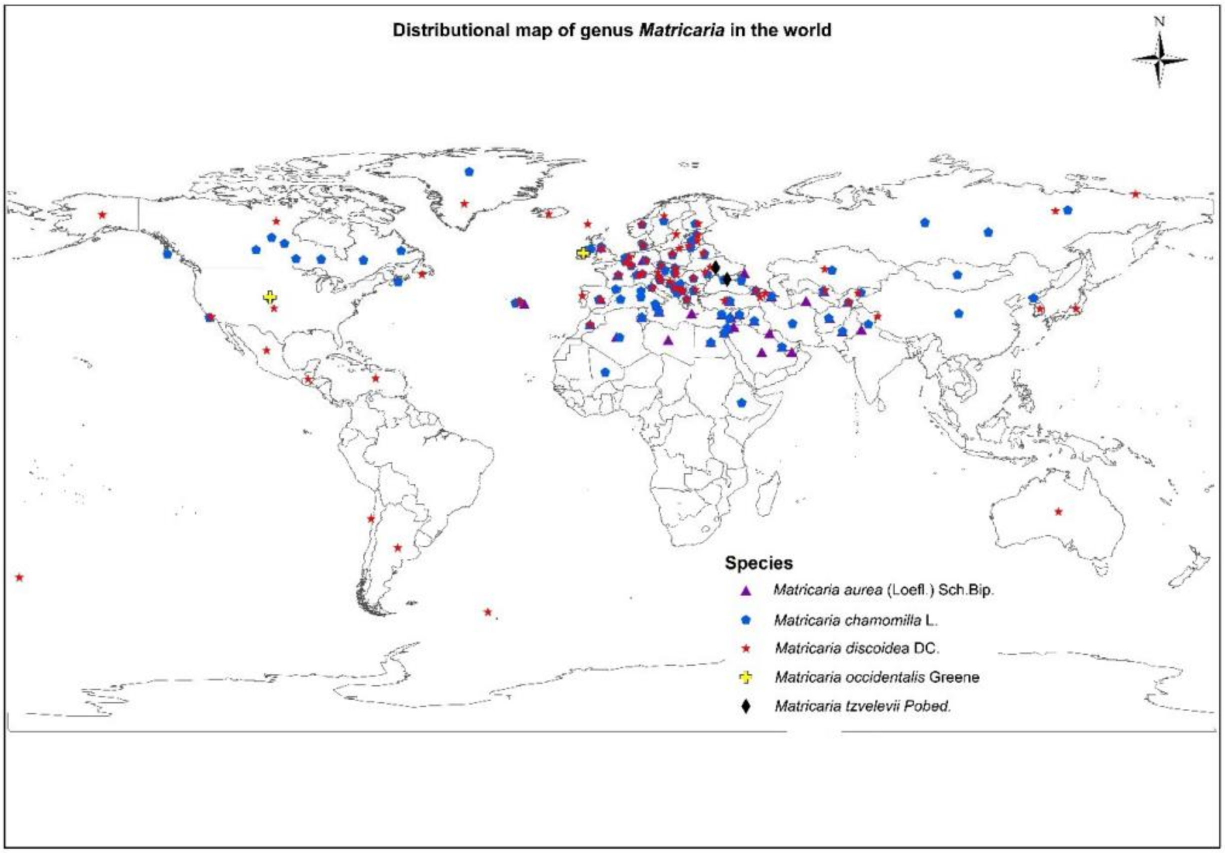

Fig. 2: Globally accepted species of the genus *Matricaria* and their geographical distribution

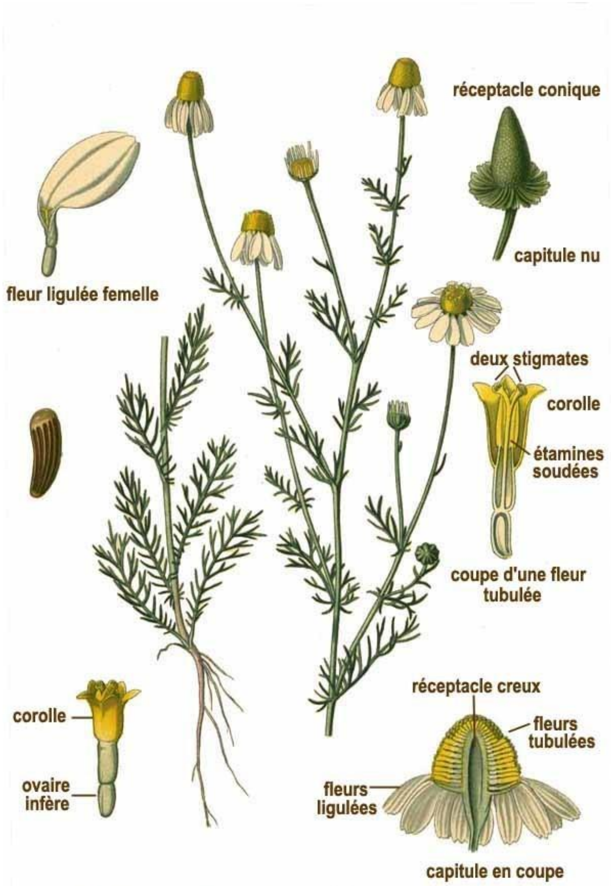

Fig. 3: Plant Anatomy of Chamomile (Stark *et al*. 2023)

Table 1. Taxonomy Classification of Chamomile (Chauhan *et al.* 2021)

Category	**Details**
Kingdom	Plantae - Plants
Super Division	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Asteridae
Order	Asterales
Family	Asteraceae
Genus	*Matricaria*

Table 2. Properties and their applications of German chamomile**.** (Chauhan *et al.* 2021)

Sl. No.	Properties	Utilizations
1	Organoleptic	Flavor, taste, and color of food
2	Anti-allergic	Effective against allergic reactions
3	Anti-spasmodic	Abdominal pain, to relax intestinal muscles and irritation
4	Anxiolytic	Effective against anxiety
5	Anti-inflammatory	Penetrate deep in skin and reduce redness, swelling, pain, and eye irritation
6	Anti-microbial	To inhibit growth of bacteria (Gram-positive and Gram-negative) and fungi
7	Neuroprotective	Helpful in recovery of neuro disorders
8	Sedative	Induce sleep, sedation, and calming effects
9	Anti-oxidant	Rich source of antioxidants
10	Anti-depressive	Stimulant to relax the muscles and effective against depression
11	Anti-cancer	Control over cancerous cells
12	Hepatoprotective	To recover liver damage
13	Anti-diarrheal	In treatment of children's colic and diarrhea
14	Gastrointestinal cure	To soothe bowel movement and flatulence
15	Healing	Wound healing
16	Anti-viral	Relief in common cold and inhibit Poliovirus
17	Anti-ulcer	Mouth ulcers, intestinal irritations, and ulcers

Table 3. Major chemical components and their composition in essential oil of German chamomile (Chauhan *et al.* 2021)

Sl. No.	Major Components	Composition (%)	Population /plant Origin
1	Chamazulene	11.0–21.0	Finland
		15.8–19.2	Germany
		0.7–15.3	European
		15.1	Iran
		8.4	Italy

		4.8–8.0	Iran
		1.0–6.6	Iran
		6.4	Bosnia and Herzegovina
		5.6	India
		4.7	Estonia
		4.2	Khorasan-Razavi, Iran
		2.6–3.3	Iran
		2.4	Iran
2	β-bisabolol	0.1–44.2	European
		23.9–44.2	Moldova, Russia, and Czech Republic
		16.0	India
		5.6	Estonia
		5.0	Khorasan-Razavi, Iran
		2.4	Bosnia and Herzegovina
		1.7	Iran
3	β-bisabolol oxide A	57.81	Egypt
		3.1–56.0	European
		33.8–55.4	Iran
		7.3–55.3	Iran
		46.5	Egypt
		37.2–44.5	Iran
		43.8	Iran
		20.2–43.2	Moldova, Russia, and Czech Republic
		39.4	Estonia
		36.5	India
		17.4–35.3	Germany
		21.5	Khorasan-Razavi, Iran
		17.14	Iran
		11.6–16.5	Brazil
		11.2	Italy

		7	Bosnia and Herzegovina
4	β-bisabolol oxide B	3.1–35.7	Iran
		15.5–35.6	Germany
		3.9–27.2	European
		9.9	Estonia
		8.6	India
		4.6–8.1	Iran
		3.7–7.1	Iran
		7	Khorasan-Razavi, Iran
		6.3	Bosnia and Herzegovina
		5.17	Iran
		3.8	Iran
5	β-bisabolone oxide A	8.3–39.9	Iran
		0.5–24.8	European
		11.7–16.5	Iran
		13.9	Estonia
		13.6	Iran
		10	Khorasan-Razavi, Iran
		4.9–9.1	Germany
		6.15	Iran
		3	Bosnia and Herzegovina
6	β-bisabolene	19.6	Iran
7	β-farnesene	29.8	Bosnia and Herzegovina
		2.0–19.7	Iran
		10.8–18.1	Iran
		13.3–15.4	Iran
		14	India
		2.3–6.6	European
		5.2	Khorasan-Razavi, Iran
		2.7–3.9	Germany

8	β-farnesene	9.3	Bosnia and Herzegovina
		3.1	Iran
9	cis-en-yn-dicycloether	8.8–26.1	European
		9.7–24.2	Iran
		11.5	Estonia
		6.2	Iran
10	Spathulenol	9.4	Khorasan-Razavi, Iran
		3.4	Iran
11	Germacrene D	6.2	Bosnia and Herzegovina
		3.0	Iran
12	Occidol acetate	7.2–13.4	Iran
13	Isobornyl isobutyrate	11.1–14.0	Germany
14	Z-spiroether	5.6–9.9	Iran
		5.1	Bosnia and Herzegovina
15	n-Octanal	6.0	Iran

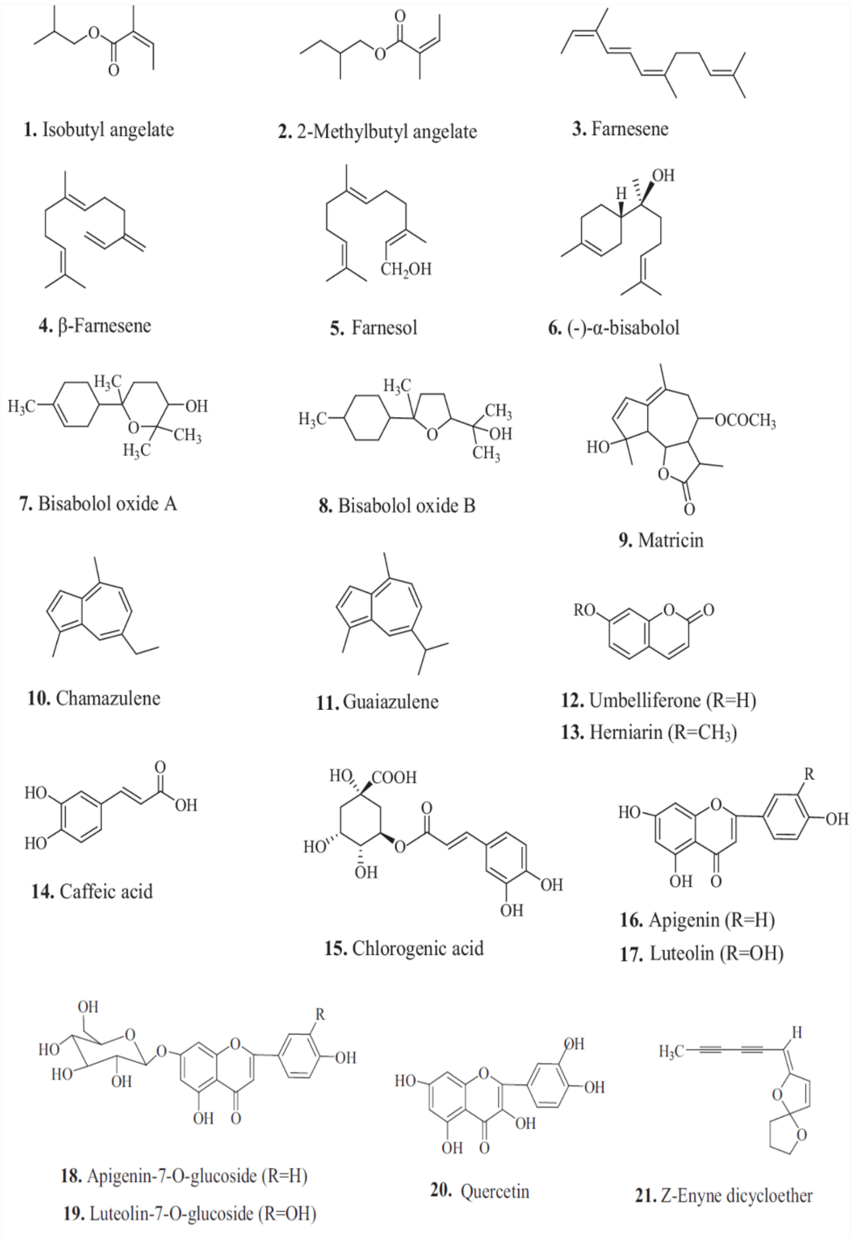

Fig. 5: Structural Diversity of Secondary Metabolites in German Chamomile