Cultivation of ZUFA HERB (*Hyssopus officinalis* L.)

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Kingdom: *Plantae* (plants)

Phylum: *Tracheophyta* (vascular plants)

Class: *Angiosperms* (flowering plants)

Clade: *Eudicots* (dicotyledons)

Order: *Lamiales* (Lamiidler)

Family: *Lamiaceae* (mint family)

Cenus: Hyssopus

Species: *Hyssopus officinalis L.* (Stan et al., 2019)

INTRODUCTION

Zufa herb (*Hyssopus officinalis* L.) is a perennial, semi-woody shrub species belonging to the Lamiaceae family. Due to its distinct aromatic properties, high ornamental value during the flowering period, and ability to remain green throughout the year, it is also used as a landscape plant (Mchoy, 2009; Pamay, 1994). This species generally reaches a height of 30-60 cm and has a woody base, producing numerous upright stems and shoots (Mchoy, 2009; Pamay, 1994). Among medicinal and aromatic plants, zufa otu (çördük) is noteworthy for both its traditional uses and its potential for value creation based on essential oils; therefore, cultivation practices should be addressed within an integrated framework that targets quality as well as yield (Sharifi-Rad et al., 2022).

Zufa herb is suitable for long-term plantations due to its shrub-like growth habit and perennial structure. Basal lignification supports its perennial life strategy, while its shoot structure and branching pattern contribute to both ornamental and aromatic value during the flowering

period (Mchoy, 2009; Pamay, 1994). These morphological characteristics enable the species to form a dual value chain linking its landscape use with medicinal-aromatic production.

The natural distribution of zufa herb extends across a wide geographical area from Southern Europe to India, and its main distribution belt is reported to stretch from the Eastern Mediterranean to Central Asia and Mongolia (Güner et al., 2012). In addition to its native range, Zufa herb (çördük) has become widespread as a cultivated plant and landscape plant in various regions, which can be interpreted as an indication of its adaptability and suitability for cultivation under various ecological conditions (Güner et al., 2012).

Zufa herb grows naturally in Turkey, and there have been reports of increased domestication efforts focused on cultivation (Kürkçüoğlu et al., 2016). Considering Turkey's national goals of increasing value creation in plant diversity and the medicinal and aromatic plants sector, çördük offers strong potential both for field-scale cultivation and for strengthening the processing-marketing chain (Temel et al., 2018).

The economic value of Zufa herb is closely linked to its essential oil yield and the chemical profile of the essential oil. Recent studies indicate that Zufa herb essential oil is rich in monoterpenes and oxygenated monoterpenes, and that various phenolic compounds may also be associated with biological activity (Sharifi-Rad et al., 2022).

Quality in medicinal and aromatic plants is shaped not only by genetic potential but also by important management and processing variables such as harvest time, water management, drying conditions, and processing parameters. For Zufa herb, it has been reported that agricultural practices affect the volatile oil profile and that the harvest stage and crop management can alter the ratios of the main components (Moro et al., 2011). Similarly, harvest timing and drying practices have

been shown to be decisive for essential oil content and bioactivity (Zheljazkov et al., 2012). Studies conducted under Turkish conditions also highlight changes in composition throughout the flowering stages and differences in yield/oil ratio as a function of drying time (Kızıl et al., 2008; Katar et al., 2021). Collectively, these findings support the view that Zufa herb cultivation protocols should be designed around the dual objective of "yield + standardized quality."

The purpose of this book chapter is to present the botanical and ecological framework of the zufa herb, discuss its production potential in terms of Turkey's medicinal and aromatic plants sector, and serve as a guide for growers/practitioners by relating cultivation practices to the key factors that determine product quality.

ECONOMIC IMPORTANCE / POTENTIAL

Zufa herb, which has a long history of use in traditional medicine, is known for its antiseptic, cough-suppressing, and expectorant properties. For centuries, its leaves and flowers have been used in folk medicine to alleviate and treat various ailments (Fathiazad et al., 2011). In kitchens, its fresh or dried leaves are used as a spice to add a distinctive aroma to dishes (Ağaç and Çalışkan, 2017). It also contributes to the preservation of biodiversity due to its ability to attract bees and butterflies. Its nectar-rich flowers are a valuable food source for these important pollinating insects (Mchoy, 2009; Pamay, 1994).

The fact that Zufa herb has such a wide range of uses and a long historical background clearly demonstrates the importance of the plant in terms of both agricultural production and scientific research. The plant's traditional medicinal uses indicate the presence of bioactive compounds, which in turn provides a basis for pharmaceutical research (Mchoy, 2009; Pamay, 1994). Its potential for use in the kitchen offers new opportunities for the food industry, while its role in attracting

pollinators highlights its ecological value. Due to this multifaceted role, comprehensive studies should be conducted to increase the cultivation and use of Zufa herb.

BOTANICAL CHARACTERISTICS

Morphological Structure (root, stem, leaf, flower, fruit)

The morphological structure and various parts of Zufa herb are quite remarkable:

Root: The plant has numerous thin, fibrous roots emerging from a woody root stem (rhizome). This developed fibrous root system allows the plant to firmly anchor itself in the soil and effectively absorb nutrients (Hegazy et al., 2016).

Stem: Zufa herb has a woody base and an upright, highly branched structure, typically reaching a height of 30 to 60 cm (Mete, 2017). Some sources indicate that this height can reach up to 80 cm (Mete, 2017). The plant is shrubby or semi-shrubby in form. Young shoots are characteristically four-sided and finely hairy (Mete, 2017). Stems may also be striate (longitudinally striated) and puberulent (very finely hairy) in appearance (Alpina, 2015).

Leaf: The leaves are narrow and lanceolate or elliptical in shape, typically 1 to 3 cm long and less than 1 cm wide (Alpina, 2015) The leaves are sessile (without a stalk) and may have slightly serrated or completely smooth (entire) margins (Alpina, 2015). The leaves are a glossy dark green color and emit a distinctive aromatic scent (Alpina, 2015). Glandular-punctate hairs are present on their undersides (Mete, 2017). The leaves are arranged oppositely on the stem (Alpina, 2015). Some sources also indicate that the leaf margins may be entire (toothless or lobeless) (Mete, 2009).

Flower: Zufa herb blooms from midsummer until early autumn. These small, two-lipped, tubular flowers are arranged in long, dense spikes or racemes (Mchoy, 2009). The flowers are usually purple-blue in color, but can sometimes be pink (Pamay, 1994; Moghtader, 2014) or, rarely, white (Pamay, 1994; Moghtader, 2014). These flowers have a pleasant scent and are rich in nectar (Mchoy, 2009). The flowers are hermaphroditic, meaning they contain both male and female reproductive organs, and are pollinated by bees (Pamay, 1994; Moghtader, 2014).



Figure 1. Zufa Herb (*Hyssopus officinalis* L.) flower. (Collection-Eskişehir)

Fruit: The fruits of Zufa herb are small, oblong (long oval) in shape and consist of four single-seeded nuts (tetra-achenes) (Moghtader, 2014). The fruits are approximately 2.5 mm long and contain four locules (compartments) (Moghtader, 2014).

CLIMATE and SOIL REQUIREMENTS

Zufa herb is known as an important medicinal and aromatic plant with high resistance to cold. Zufa herb prefers areas with full sunlight or partial shade that receives at least 6 hours of direct sunlight for optimal growth (Cătălina et al., 2019). Full sunlight helps the plant develop a more intense aroma and produce more abundant flowers (Cătălina et al., 2019). In hot summer climates, it can tolerate some shade during the excessive heat of the afternoon (Cătălina et al., 2019). It can grow in hardiness zones 3 to 10, as determined by the United States Department of Agriculture (USDA) (Chiej, 1984; Eric, 2016). This wide range of zones clearly demonstrates its ability to adapt to different climatic conditions (Chiej, 1984; Eric, 2016). It is quite tolerant to drought and generally does not require regular watering after the plant is transplanted into the soil (Chiej, 1984). This characteristic provides a significant advantage for cultivation in regions with water scarcity. It has a self-pollinating (hermaphroditic) structure and is also effectively pollinated by bees (Chiej, 1984). This increases the plant's reproductive success in terms of cultivation. It prefers warm and hot climates (Eric, 2016). It thrives best under full sunlight (Chiej, 1984).

Zufa herb prefers well-drained and dry to moderately moist soils (Zawislak, 2013; Moghtader, 2014). Its growth may be negatively affected in moist soils. It can tolerate poor to moderately fertile, sandy, clayey, or gravelly soils, but performs best in fertile and loamy soils (Zawislak, 2013; Moghtader, 2014). It also prefers light, dry, and calcareous soils (Zawislak, 2013; Moghtader, 2014). In terms of soil pH, it prefers the alkaline (pH > 8.0) to neutral (pH 6.0-8.0) range (Zawislak,

2013; Moghtader, 2014). It can also tolerate soils with a pH range of 5.0 to 7.5 (Zawislak, 2013; Moghtader, 2014). For soil preparation, adding organic matter such as compost or manure to the soil before planting is beneficial for plant development (Sourestani et al., 2014). Sand can be mixed into the soil to improve the drainage of heavy clay soils (Sourestani et al., 2014). The ideal soil pH for Zufa herb is around neutral (Ghorbanpour, 2017; Shahhoseini, 2017). Although Zufa herb is not very selective about soil, one of its most important requirements is good drainage. Loamy soils enriched with organic matter and having an alkaline or neutral pH provide ideal conditions for the plant's optimal growth. Very heavy and water-retaining soils should be avoided at all costs (Ghorbanpour, 2017; Shahhoseini, 2017).

REPRODUCTIVE BIOLOGY of *H. officinalis*

Zufa herb can be propagated using four different methods. The plant can be propagated generatively using seeds, as well as vegetatively using both rooted side shoots and claws with apical/terminal and lateral buds taken from the root collar. The suitability of Zufa herb for different propagation methods offers growers flexibility in production at different scales and under various conditions. Seed propagation is a cost-effective method for large areas and large-scale production, while vegetative propagation methods (cuttings and root division) may be preferred to obtain genetically identical plants and ensure a faster start. These methods are particularly important for the preservation and propagation of specific varieties.

Seed: Zufa herb seeds can be sown directly outdoors in spring after the last frost danger has passed (Stan et al., 2019; Minter, 1995). The sowing depth of the seeds should be approximately 0.5 to 1 cm (Mete, 2017). Seeds can be sown in rows 8 to 10 cm apart (Güner et al., 2012). For an earlier start, seeds can also be grown indoors approximately 8 to 10 weeks before the last frost date (Minter, 1995). The germination

process generally takes 14 to 21 days. Seeds germinate better at temperatures between 18 and 21°C and with sufficient light (Mete, 2009). For rapid germination, seeds must be kept constantly moist (Mete, 2009).

Seedlings: Zuffa seedlings grown indoors are planted outdoors after the last frost danger has completely passed, typically at 30 to 45 cm intervals (Mete, 2017). In some cases, a planting interval of 50 x 50 cm may also be used (Mete, 2009).

Propagation by Cuttings: Zephyr grass can be easily rooted using semi-ripe cuttings taken in the summer (Cătălina et al., 2019). Propagation by cuttings is also possible in spring or autumn (Chittendon, 1956). The ideal length of cuttings is generally between 5 and 7 cm, and heel cuttings are preferred (Chittendon, 1956).

Root Division: Mature Zufa herb plants can be propagated by dividing their roots in spring or autumn (Cătălina et al., 2019). Root division can generally be performed at intervals of 3 to 5 years (Bean, 1981).



Figure 2. Zufa herb (*Hyssopus officinalis* L.) in a vial (Collection-Eskişehir).

SOIL PREPARATION

Soil preparation in agricultural production is carried out to aerate the soil, reduce water loss, increase water infiltration into the soil, control weeds, and prepare a suitable seed/seedling/sapling bed. Qualitative soil cultivation, performed at the right time (at the right stage) and with the appropriate tools, is of great importance in ensuring the germination and emergence of a sufficient number of seeds and in maintaining healthy plant growth and development until harvest (Altuntaş et al., 2007).

One of the key practices effective in increasing profitability in crop production is reducing the amount of energy consumed during the production process. A significant portion of the energy used in agricultural production is expended in soil tillage activities. Therefore, significant energy savings can be achieved by avoiding unnecessary soil tillage. Another critical issue to consider in soil cultivation is the destructive effect that excessive and untimely soil cultivation has on the soil structure/aggregate structure. Similarly, incorrect and untimely soil cultivation increases the risk of erosion and can lead to agricultural soil loss. In this context, particular care should be taken to minimize the number of tillage operations, especially in erosion-prone areas, and to prioritize tillage methods that minimize erosion-related soil loss through the use of appropriate tools and equipment.

Especially during soil cultivation in the fall, it is important to use plows that tear the soil from below and leave part of the stubble on the soil surface, rather than plows that turn the soil upside down. Soil erosion can be minimized in areas tilled with this type of plow, and the loss of water through surface runoff during rainfall will also be reduced. This is because the stubble partially remaining on the surface prevents water from flowing over the surface, thereby increasing infiltration into the soil (Altuntaş et al., 2018).

Zufa herb is typically sown indoors throughout the year and outdoors in the spring after the last frost danger has passed. The germination period can vary between 5 and 21 days (Katar et al., 2014; Moghtader, 2014). The ideal temperature for germination is approximately 20°C. The flowering period usually begins in the summer months (starting in June) and continues until autumn (Katar et al., 2014; Moghtader, 2014).

PLANTING DENSITY and TIMING

Zufa herb seeds can be sown directly outdoors in spring after the last frost danger has passed (Minter, 1995). The sowing depth should be approximately 0.5 to 1 cm. Seeds can be sown in rows spaced 8 to 10 cm apart. For an earlier start, seeds can also be grown indoors approximately 8 to 10 weeks before the last frost date (Minter, 1995). The germination process usually takes 14 to 21 days. Seeds germinate better at temperatures between 18 and 21°C and with sufficient light (Mete, 2009; Minter, 1995). For rapid germination, seeds must be kept constantly moist (Cătălina et al., 2019).

In plantings for seed production, both row spacing and intra-row spacing are kept wider. Especially in commercial production on large areas, seedlings produced using certified seeds are planted in previously prepared fields using seedling planting machines when they reach planting size (Gabr et al., 2021).

FERTILIZATION

Zufa herb generally does not require large amounts of fertilizer, especially when grown in moderately fertile soils. In fact, it prefers nutrient-poor soils (Kerolla et al., 1994). However, if the plant's growth is slow, applying a balanced, slow-release fertilizer or compost in the spring can be beneficial (Rohloff et al., 2005). Fertilization with organic compost can be done every year in early spring (Rohloff et al., 2005).

For Zufa herb plants grown in pots, it is appropriate to apply liquid fertilizer regularly due to the faster depletion of nutrients in the soil (Kerolla et al., 1994). Applying diluted liquid fertilizer approximately 10 days after seed germination is also beneficial (Kerolla et al., 1994). The use of organic fertilizers is recommended in Zufa herb cultivation (Mazzanti et al., 1998; Garg et al., 1999). Over-fertilization should be avoided (Mazzanti et al., 1998; Garg et al., 1999).

Zufa herb is a plant with relatively low nutrient requirements. However, especially when grown in poor soils or pots, light fertilization can promote plant growth and flowering. The use of organic fertilizers is important for the healthy development of the plant and product quality. (Mazzanti et al., 1998; Garg et al., 1999).

IRRIGATION

Newly planted Zufa herb plants should be watered regularly, especially during the first four weeks. In some cases, watering once a week may be sufficient (Khazaie et al., 2008). After planting, the plants become drought-tolerant, but regular watering still promotes healthier growth and development (Bilalis et al., 2014). Zufa herb is a highly drought-tolerant plant. Watering should be done thoroughly after the topsoil has dried out. However, overwatering should be avoided at all costs (Khazaie et al., 2008), as this can lead to root rot (Khazaie et al., 2008). Zufa herb plants grown in pots may require more frequent watering due to faster moisture loss in the soil (Khazaie et al., 2008). Regular watering is essential in pot cultivation. The drip irrigation method is recommended as it allows water to reach the root zone directly, providing more efficient irrigation (Khazaie et al., 2008). Although Zufa herb is drought-tolerant after maturity, it is important to water it regularly, especially until the root systems of young plants are fully developed. Good soil drainage should be ensured to avoid overwatering and prevent the plant's roots from remaining constantly wet.

In Zufa cultivation, optimizing nitrogen management, water stress, and harvest together is as important for quality as it is for yield. Nitrogen applications in Lamiaceae species (including Zufa) can increase biomass as well as affect the volatile oil content and component balance; therefore, instead of a "single dose–single recommendation" approach, a feeding approach based on local soil analysis and tailored to the target product yields more accurate results (Zheljazkov et al., 2009; Zheljazkov et al., 2012). The most practical approach in terms of application is to consider the "volatile oil yield (kg/da) + basic component stability" target together with factorial trials of 2–3 doses of nitrogen × 2 irrigation regimes × 2 harvest periods in the same ecology. Determining the harvest time often has a greater impact on quality than fertilization. Since the essential oil ratio and composition can change during the budding–flowering initiation–full flowering period, if the production target is the drug, "aroma/color preservation" and low moisture should be prioritized; if the target is essential oil, "basic component balance" should be prioritized (Zawiślak, 2013). Another practical way to improve quality is to protect the plant from sudden water stress fluctuations, as far as the ecology allows. The goal is not "more water at all times"; rather, it is to support the plant's regular growth during phenological critical periods (especially shoot emergence–flowering onset) to reduce negative effects on volatile oil biosynthesis.

WEED MANAGEMENT

Weed management in Zufa herb cultivation is of great importance, especially for protecting young plants from competition. Weeds can be effectively controlled using methods such as hand weeding or mulching (Yurtseven et al., 2001; Ekmekçi et al., 2005). Mulching prevents weed growth by covering the soil with a layer of organic or inorganic material (Yurtseven et al., 2001; Ekmekçi et al., 2005). Zufa herb itself can also be used as a companion plant that repels certain harmful insects. It is

known to repel cabbage butterflies and flea beetles in particular (Yurtseven et al., 2001; Ekmekçi et al., 2005).

Weed management also contributes to the healthy growth of zufa plants by ensuring they receive sufficient sunlight, water, and nutrients. The natural ability of zufa plants to repel certain pests reduces the need for chemical control, supporting a more sustainable approach to cultivation.

Conditions that keep leaf surfaces moist for extended periods (close planting, poor air circulation, late-day watering) may increase the likelihood of fungal problems such as powdery mildew in Lamiaceae; mint has also been reported among the hosts of powdery mildew pathogens (Braun et al., 2024). Therefore, a practical approach involves planting density that enhances air circulation between rows, morning watering and drip irrigation where possible, removal of infected plant debris, weed control, and selection of tolerant material in high-risk areas.

During the seed/seedling stage, the germination–seedling development phase is the most sensitive period. Since seed-related problems such as "seed rot/seedling decay" caused by Fusarium proliferatum may occur in Zufa herb, it is necessary to pay special attention to certified/clean seeds, proper storage, and pre-sowing hygiene practices (Ignjatov et al., 2020).

HARVESTING

Harvest Time and Ripeness Criteria:

The leaves of Zufa herb can be harvested at any time after the plant is planted and matured (Ekren et al., 2003). To obtain the best flavor, the leaves are usually harvested after the morning dew has dried (Ekren et al., 2003). The plant can be harvested throughout the season (Ekren et al., 2003). The flowers are harvested when they are fully open or when

about two-thirds of them are open (Güler, 2007). The flowering period generally lasts from mid-summer to early autumn (Güler, 2007). According to some sources, the flowering period can continue from July to early autumn (Güler, 2007). If harvesting is to be done to obtain essential oil, the most suitable time is the beginning of flowering (Güler, 2007). Harvesting before the flowers are fully open may result in a higher concentration of active compounds in the plant (Güler, 2007). To obtain seeds, the seed capsules should be allowed to dry completely and turn brown (Ekren et al., 2003). The harvest time varies depending on the intended use of the zufa herb. While the leaves can be harvested continuously, the flowers and seeds are collected at specific stages of maturity. The flowering harvest time is critical in terms of essential oil yield.

Harvesting Methods (by hand, mechanically):

For harvesting small quantities of Zufa herb, cutting the stems or leaves by hand is usually sufficient (Tansı, 1999). Stems should be cut just above the point where the leaves emerge (leaf node) (Tansı, 1999). At any one time, no more than one-third of the plant's total mass should be harvested. In large-scale Zufa herb production, mechanical harvesting equipment can be used (Tansı, 1999). For seed harvesting, the drying flower heads are cut to separate the seeds. Dried seeds can be easily separated from their capsules (Ceylan, 1995). The harvesting method varies depending on the scale of Zufa herb production and the available labor force. Manual harvesting may be suitable for smaller-scale production and selective harvesting, while mechanical harvesting is a more efficient option for large areas (Tansı, 1999).

Post-Harvest Drying Methods and Conditions:

Harvested zufa herb plant parts are usually stored by drying (Güler, 2007). The drying process is necessary for optimal storage of the plant.

Drying should be done in a cool, dry, and well-ventilated place, away from direct sunlight (Güler, 2007). The shade drying method is generally preferred. Plants can be hung in bundles or spread out on suitable shelves (Güler, 2007). The drying time can take approximately 6 days (Güler, 2007). The plant should be allowed to dry completely. Different methods such as oven drying (35-60°C), microwave drying, or freeze drying can also be used. It is stated that methods such as low-power microwave drying (100 W) and oven drying at 40°C can better preserve the active components of the plant. Applying the correct drying methods is vital for preserving the quality of zufa herb products (such as color, aroma, and essential oil content) and extending their shelf life. The drying temperature and method used can significantly affect the characteristics of the final product (Güler, 2007).

This study demonstrates that *Hyssopus officinalis* has high cultivation potential and usage potential. Its evaluation as an alternative species in the production of medicinal and aromatic plants in Turkey is important both for increasing agricultural diversity and for rural development. It is recommended that future experimental studies quantitatively determine yield and quality factors.

CONCLUSION AND RECOMMENDATIONS

Zufa herb cultivation, when combined with appropriate ecological requirements and sound agricultural management, offers a sustainable production pathway under low to moderate input conditions while creating added value through two main product streams: crude drug (dried plant) and essential oil. The practices outlined in this section—site selection, propagation, planting, nutrient management, irrigation, and crop care—enable growers to achieve consistent biomass yields and establish a stable production system within a perennial plantation framework. However, commercial success is determined not only by yield increases but also by the capacity to preserve and standardize

quality in post-harvest processing; therefore, the harvest period, drying conditions, and distillation protocol when targeting essential oil should be considered integral components of the production chain.

From a cultivation perspective, the appropriate strategy is to set the production target at the outset. In raw drug production, priority is given to a drying-storage workflow that preserves color and aroma, provides low moisture content, and guarantees hygienic quality. In essential oil production, however, importance is placed on selecting the harvest time that preserves the balance of the main components and applying processing standardization at the batch level. When both objectives are pursued in the same area, higher and more consistent yields can be achieved by planning the number and timing of harvests based on a coordinated triad consisting of "product target-quality criterion-processing capacity."

Finally, the fastest gains in scaling up Zufa herb (çördük) production can be achieved by developing locally validated, replicable "best practice protocols." Multi-year trials conducted in different ecosystems, jointly monitoring yield, essential oil productivity, and chemical profile, will establish practical, transferable thresholds (e.g., harvest timing, drying upper limits, critical periods for irrigation, and nutrient management approaches) that can be directly communicated to producers. As such evidence-based thresholds and a culture of record-keeping/traceability strengthen, Zufa herb will increasingly emerge as a medicinal-aromatic alternative crop that enhances both producer income and the reliability of the final product.

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