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Review

Intercropping Medicinal and Aromatic Plants with Other Crops: Insights from a Review of Sustainable Farming Practices

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Abstract

Intercropping medicinal and aromatic plants with other crops has demonstrated substantial potential for improving sustainable agricultural systems. Across a wide range of species, including yarrow, dill, wormwood, pot marigold, ajowan, coriander, saffron, cumin, lemongrass, Moldavian dragonhead, fennel, hyssop, dragons head, lavender, chamomile, lemon balm, mint, black cumin, basil, rose-scented geranium, aniseed, patchouli, rosemary, sage, summer savory, marigold, thyme, fenugreek, and vetiver, integration with cereals, legumes, vegetables, and perennial trees enhanced both land use efficiency and overall crop productivity. These systems often resulted in improved essential oil (EO) yield and composition, optimized plant growth, and increased economic returns, particularly when combined with organic inputs or biofertilizers. In addition to productivity gains, intercropping provides important ecological benefits. It can enhance soil fertility, stimulate microbial activity, and contribute to effective pest and weed management. Incorporating medicinal and aromatic plants into orchards, vineyards, or agroforestry systems further supported biodiversity. It influenced secondary metabolite production in companion crops, demonstrating the multifunctional role of these species in integrated farming systems. Overall, intercropping medicinal and aromatic plants represents a versatile and economically viable approach for sustainable crop production. The selection of compatible species, careful management of planting ratios, and appropriate agronomic practices are critical to maximizing both biological and economic benefits. Such strategies not only increase farm profitability but also promote environmental sustainability and resilience in diverse cropping systems. This review explores the effects of MAP integration on agroecological performance and identifies key mechanisms and practical outcomes.

Keywords: sustainable agriculture; crop diversification; soil fertility; soil health; integrated pest management; economic profitability

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1. Introduction

Agriculture constitutes not only the primary source of income for a significant proportion of the global population, but also represents an important aspect of cultural heritage in many countries. Traditional agricultural practices, such as the cultivation of crop mixtures (which are classified as forms of mixed cropping or intercropping), are widely observed across diverse agroecological regions [1]. Intercropping is a time-tested agricultural system that enhances crop diversity to strengthen agroecosystem functions, reduce the need for chemical inputs, and minimize the negative environmental impacts of crop production. This system, practiced globally for thousands of years [2], involves growing two or more crop species simultaneously, allowing them to coexist during a significant portion of the crop cycle while interacting with each other and with the surrounding agroecosystem [1].

Intercropping can be implemented in annual crops, perennial crops, or in the mixture of annual and perennial crops [3]. However, growing two or more crops together requires additional care and management for the creation of less competition among the crop species and to efficiently utilize natural resources. The choice of a proper intercropping system and appropriate management practices, like the choice of crops, planting geometry, intercultural operation and plant protection, are major concerns to obtain advantages from the intercropping system [1,4]. Different types of intercropping systems are adopted in various countries, and can be grouped as follows: (1) row intercropping; (2) mixed intercropping; (3) strip intercropping; (4) relay intercropping; (5) alternate intercropping [1,5–9].

Intercropping systems represent a promising agroecological strategy for enhancing biodiversity, improving resource use efficiency, and promoting sustainable agricultural practices [10]. Medicinal and aromatic plants (MAPs) produce bioactive compounds that serve protective functions for the plants themselves. Over time, humans have learned to utilize these compounds for therapeutic purposes and daily nutrition [11]. Furthermore, specific MAPs have been observed to influence the growth, survival, and reproduction of surrounding organisms, an effect that has been harnessed in agricultural contexts [12]. When intercropped with food, forage, orchard, or industrial crops, MAPs have the potential to enhance soil fertility, increase overall yield and profitability, and improve the quality of the primary crop [10,13,14].

This review critically examines the potential and challenges of integrating MAPs into diverse intercropping systems. It assesses the ecological, agronomic, and economic benefits associated with MAP-based intercropping, including improved soil health, pest and disease suppression, yield stability, and farm income diversification. This review draws attention to the potential influence of MAPs' physiological and biochemical properties on their performance and interactions in intercropping systems, while summarizing current empirical evidence. This aspect remains underexplored in the current scientific literature. In addition, the review presents case studies from various agroecological regions, analyzes constraints such as competition, allelopathy, and harvesting logistics, and offers practical guidelines for selecting suitable crop combinations. Finally, it identifies existing knowledge gaps and outlines future research directions. The overall aim is to support the strategic integration of medicinal plants into intercropping systems, to advance sustainable and resilient agriculture. In brief, this review addresses the central question of how the integration of MAPs into intercropping systems influences agroecological performance, particularly soil fertility, pest regulation, and crop productivity. By synthesizing evidence across different MAP species and cropping contexts, it clarifies the underlying ecological mechanisms and practical implications of MAP-based intercropping.

2. Parameters Used to Evaluate Intercropping Systems

A wide range of parameters can be measured in intercropping systems to evaluate their efficiency. According to the literature, the following parameters have been used to monitor the quality of MAPs during intercropping:

1. physiological and vegetative growth parameters: photosynthetic pigments (chlorophyll, carotenoids), leaf area (LA), Leaf Area Index (LAI), dry matter (DM), fresh weight (FW), dry weight (DW), number of daughter corms; daughter corm weight;
2. morphometric measures: plant height, leaf number per node, total leaf perimeter per node, total LA per node, internode length per node, internode thickness per node, total number of leaf peltate trichomes per node, number of inflorescences, number umbels per plant, number of seeds per plant;
3. yield component: biomass yield, seed yield, 1000 seed weight, harvest index (HI), dried stigma yield;
4. biological potential (polyphenol content, antioxidant activity);
5. weed interference indicators: weed species composition, weed density, weed biomass;
6. nutritive and nutraceutical parameters: crude protein (CP), water-soluble carbohydrates (WSC), detergent fiber (ADF), neutral detergent fiber (NDF), digestible dry matter (DDM), dry matter intake (DMI), total digestible nutrients (TDN), net energy for lactation (NEL), relative feed value (RFV), content of N, P, K, Ca, Na, Fe, Zn, Mn, essential oil (EO) content, yield and composition, fatty acid (FA) content, yield and composition;
7. pests control (insects and diseases), and rhizosphere community;
8. biophysical and economic parameters: Land Equivalent Ratio (LER), Area-Time Equivalent Ratio (ATER), Land Equivalent Coefficient (LEC), Relative Yield of Mixture (RYM), System Productivity Index (SPI), Percentage Yield Difference (PYD), and Percent Land Saved (% land saved), Aggressivity (A), Competitive Ratio (CR), Relative Crowding Coefficient (RCC), and Actual Yield Loss (AYL), Land Utilization Efficiency (LUE) and Intercropping Advantages (IA), Monetary Advantages Index (MAI), Net Return (NR), Additional Net Returns (ANR), Equivalent Yield (EY), Relative Net Returns (RNR), Relative Value Total (RVT), and Income (IER).

3. Examples of Intercropping Reported in the Literature

This review was compiled using relevant information from various databases, including ScienceDirect, Springer Nature, Web of Science, Scopus, and Google Scholar, as well as printed literature. The literature search was conducted using the keywords "intercropping" and "medicinal plant" in titles, abstracts, and keywords. Publications were screened to include studies that involved intercropping systems containing at least one MAP and presented experimental, field, or modeling results. Review papers were excluded. After screening, 152 relevant studies were selected and summarized in Supplementary Table S1.

To identify research trends in MAP intercropping, VOSviewer (ver. 1.6.20) software was used to analyze 152 abstracts from the studies listed in Supplementary Table S1. As depicted in Figure 1, the exploration of intercropping MAPs with other crops, based on the abstracts, revealed distribution across six distinct clusters. Within all clusters, there was an aggregation of the terms "soil," "fertilizer," "biofertilizer," "recommended dose of fertilizer," "farmyard manure," and "Azotobacter". All these terms are related to soil fertilization, suggesting that, in addition to intercropping, fertilization represents the second major factor influencing the observed clustering. A network visualization map illustrates keyword co-occurrence related to fertilization practices in intercropping systems (Figure 1). The six clusters are represented by distinct colors: soil (35 items, red), fertilizer (26 items, blue), biofertilizer (15 items, green), recommended dose of fertilizer

(8 items, yellow), farmyard manure (6 items, purple), and Azotobacter (3 items, orange). According to Pajek/VOSviewer output files, the size of each circle corresponds to the frequency of keyword occurrence, with larger circles indicating terms that appear in a higher number of articles. The approximate circle sizes correspond to small (≤5 articles), medium (6–15 articles), and large (≥16 articles) frequency categories.

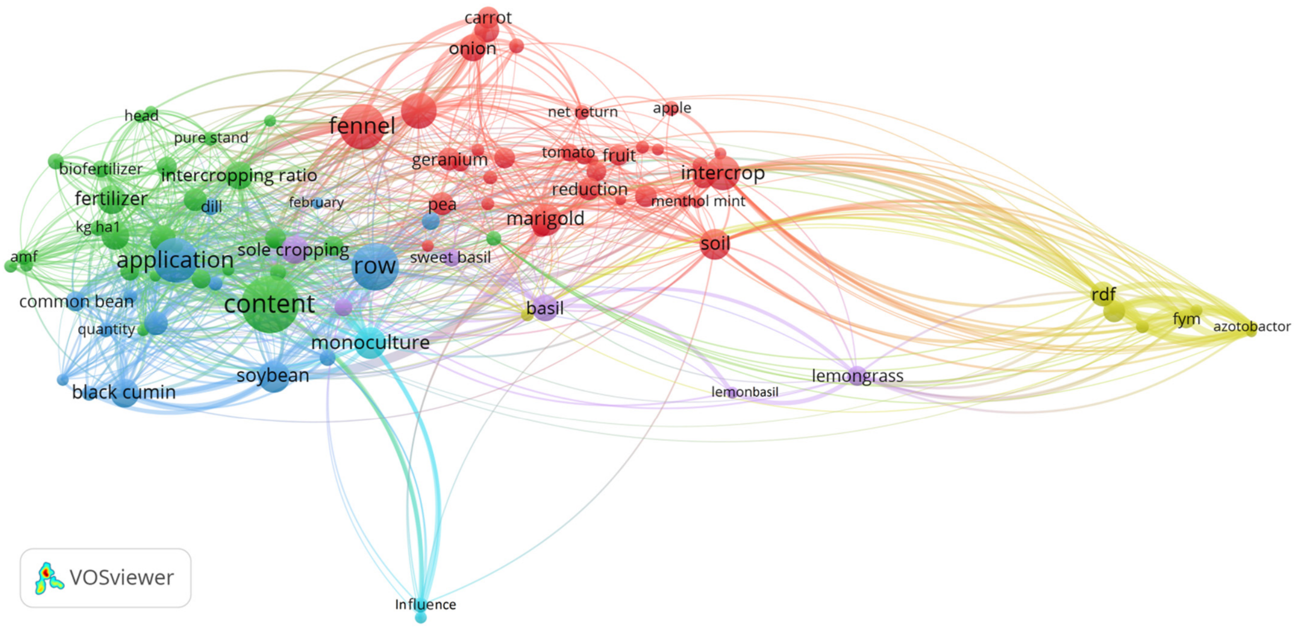

Figure 1. Co-occurrence analysis of terms related to "MAP intercropping" was performed based on the abstracts. The size of each circle indicates the frequency of term occurrence, while different colors represent distinct clusters of closely related keywords, enabling their classification. The term map was generated by using VOSviewer software, with data obtained from the Scopus database.

Supplementary Table S1 summarizes the collected data, with results organized alphabetically by plant species according to their Latin names. Research indicates that at least 42 species (29 genera) of MAPs have been studied in intercropping systems with other crops. Based on the available literature, MAPs used in intercropping include *Achillea millefolium* (yarrow), *Anethum graveolens* (dill), *Artemisia annua* (sweet wormwood), *A. scoparia* (redstem wormwood), *A. argyi* (mugwort), *Calendula officinalis* (pot marigold), *Carum copticum* (ajowan), *Coriandrum sativum* (coriander), *Crocus sativus* (saffron), *Cuminum cyminum* (cumin), *Cymbopogon citratus* (West Indian lemongrass), *C. flexuosus* (East Indian lemongrass), *C. winterianus* (Java citronella), *C. martinii* (palmarosa), *C. schoenanthus* (camel grass), *Dracocephalum moldavica* (Moldavian dragonhead), *Foeniculum vulgare* (fennel), *Hyssopus officinalis* (hyssop), *Lallemantia iberica* (dragon's head), *Lavandula × intermedia* (lavandin), *L. officinalis* (lavender), *Matricaria chamomilla* (chamomile), *Melissa officinalis* (lemon balm), *Mentha × piperita* (peppermint), *M. arvensis* (cornmint), *M. × gracilis* (spearmint), *Nigella sativa* (black cumin), *Ocimum africanum* (lemon basil), *O. basilicum* (sweet basil), *Pelargonium graveolens* (rose-scented geranium), *Pogostemon cablin* (patchouli), *Rosmarinus officinalis* (rosemary), *Salvia officinalis* (sage), *S. miltiorrhiza* (red sage), *S. sclarea* (clary sage), *Satureja hortensis* (summer savory), *Tagetes minuta* (wild marigold), *T. erecta* (African marigold), *T. patula* (French marigold), *Thymus vulgaris* (thyme), *Trigonella foenum-graecum* (fenugreek), and *Vetiveria zizanioides* (vetiver).

In addition to mutual intercropping among MAPs, they are also cultivated together with other herbs and spices, such as *Andrographis paniculata* (green chireta), *Coleus forskohlii* (medicinal coleus), *Curcuma longa* (turmeric), and *Zingiber officinale* (ginger), as well as with other food crops, including *Portulaca oleracea* (common purslane). MAPs are frequently intercropped with various vegetables, including *Abelmoschus esculentus* (okra), *Allium cepa* (onion), *A. porrum* (leek), *A. sativum* (garlic), *Brassica oleracea* var. *acephala* (kale), *B. oleracea* var. *capitata* (cabbage), *B. oleracea* var. *gemmifera* (Brussels sprouts), *Capsicum annuum* (pepper), *Citrullus lanatus* (watermelon), *Cucurbita pepo* (pumpkin), *Daucus carota* (carrot), *Fragaria* × *ananassa* (strawberry), *Lactuca sativa* (lettuce), *Raphanus sativus* (radish), *Solanum lycopersicum* (tomato), *S. melongena* (eggplant), *S. tuberosum* (potato), and *Spinacia oleracea* (spinach).

They are also intercropped with legumes, including *Cajanus cajan* (pigeon pea), *Cicer arietinum* (chickpea), *Cyamopsis psoraloides* (guar), *Dolichos lablab* (field bean), *Glycine max* (soybean), *Lens culinaris* (lentil), *Macrotyloma uniflorum* (horse gram), *Phaseolus vulgaris* (common bean), *Pisum sativum* (pea), *Trifolium alexandrinum* (Egyptian clover), *T. repens* (white clover), *T. resupinatum* (Persian clover), *Vicia faba* (faba bean), *Vigna mungo* (black gram), *V. radiata* (mung bean), and *V. unguiculata* (cowpea). MAPs are also cultivated alongside cereals, including *Avena sativa* (oat), *Eleusine coracana* (finger millet), *Hordeum vulgare* (barley), *Oryza sativa* (rice), *Pennisetum glaucum* (pearl millet), *Triticum aestivum* (wheat), and *Zea mays* (maize), as well as other industrial crops, such as *Brassica napus* (rapeseed), *B. nigra* (black mustard), *Gossypium hirsutum* (cotton), *Helianthus annuus* (sunflower), *Nicotiana tabacum* (tobacco), and *Saccharum officinarum* (sugarcane). Woody and bushy species commonly intercropped with MAPs include *Citrus sinensis* (sweet orange), *Cocos nucifera* (coconut), *Jatropha curcas* (physic nut), *Malpighia glabra* (Barbados cherry), *Malus domestica* (apple), *Morus nigra* (black mulberry), *Musa* sp. (banana), *Olea europea* (olive), *Pyrus communis* (pear), *P. pyrifolia* (Asian pear), *Quercus ilex* (holly oak), *Rosa canina* (dog rose), *Sesbania sesban* (sesban), *Vaccinium corymbosum* (blueberry), and *Vitis vinifera* (grape). A graphical representation of this information is provided in Figure 2.

3.1. Achillea millefolium (Yarrow)

Based on the available literature, yarrow has been successfully intercropped with several species, including lemon balm, winter wheat, and apple [15–17]. Intercropping yarrow with lemon balm did not significantly affect the growth or EO content of yarrow, but it increased chlorophyll b and total chlorophyll content [15]. Conversely, yarrow intercropped with winter wheat demonstrated strong nitrogen competition and grew to the same height as the wheat, which interfered with harvesting and rendered it unsuitable as a companion plant in cereal-based systems [16]. In contrast, when yarrow was planted in flower strips in apple orchards it successfully reduced the population of the pest *Hoplocampa testudinea* [17]. A significant decrease in adult insects was observed in areas adjacent to the yarrow strips. This effect is likely mediated by the repellent properties of yarrow EO, which was further supported by experiments in which apple trees were sprayed with the EO during the full bloom, resulting in reduced insect activity, oviposition, and flower damage.

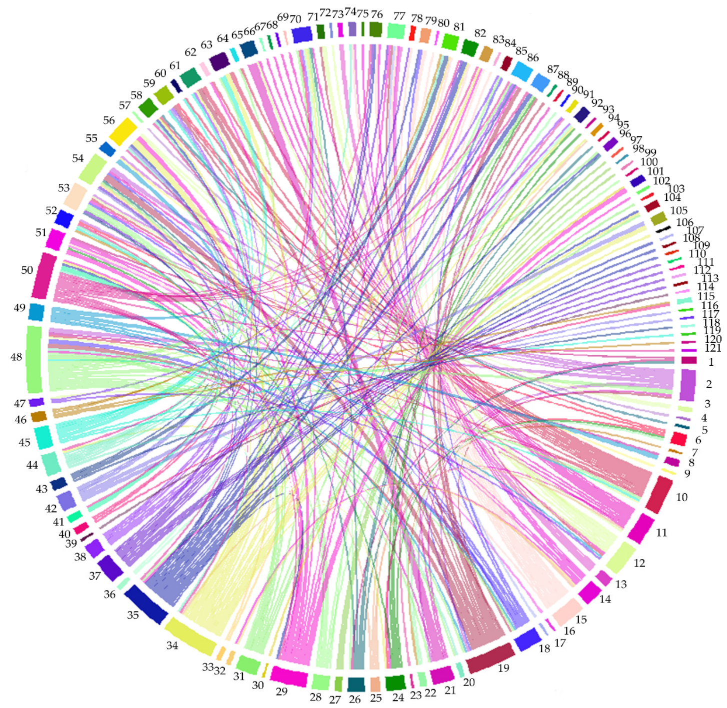

Figure 2. Graphical representation by Chord diagram illustrating the relationships among medicinal and aromatic plant species used in intercropping systems, as reported in the literature. The thickness of each block corresponds to the number of intercropping associations involving that plant. Each color represents a different plant species. Codes: 1—*Achillea millefolium*, 2—*Anethum graveolens*, 3—*Artemisia annua*, 4—*Artemisia argyi*, 5—*Artemisia scoparia*, 6—*Calendula officinalis*, 7—*Calendula officinalis*, 8—*Carum copticum*, 9—*Carum copticum*, 10—*Coriandrum sativum*, 11—*Crocus* sativus, 12—*Cuminum cyminum*, 13—*Cymbopogon citratus*, 14—*Cymbopogon flexuous*, 15—*Cymbopogon winterianus*, 16—*Cymbopogon martini*, 17—*Cymbopogon* schoenanthus, 18—*Dracocephalum* moldavica, 19—*Foeniculum vulgare*, 20—*Hyssopus* officinalis, 21—*Lallemantia iberica*, 22—*Lavandula angustifolia*, 23—*Lavandula Ã—intermedia*, 24—*Matricaria chamomilla*, 25—*Matricaria chamomilla*, 26—*Melissa officinalis*, 27—*Mentha Ã—gracilis*, 28—*Mentha Ã—piperita*, 29—*Mentha arvensis*, 30—*Mentha spicata*, 31—*Nigella sativa*, 32—*Ocimum africanum*, 33—*Ocimum bailicum*, 34—*Ocimum basilicum*, 35—*Pelargonium graveolens*, 36—*Pimpinella anisum*, 37—*Pogostemon cablin*, 38—*Rosmarinus officinalis*, 39—*Salvia miltiorrhiza*, 40—*Salvia officinalis*, 41—*Salvia sclarea*, 42—*Satureja* hortensis, 43—*Tagetes erecta*, 44—*Tagetes minuta*, 45—*Tagetes patula*, 46—*Thymus vulgaris*, 47—*Trigonela foenum-graecum*, 48—*Trigonella foenum-graecum*, 49—*Trigonella foenum-graecum*, 50—*Vetiveria zizanioides*, 51—*Triticum aestivum*, 52—*Brassica oleracea var capitata*, 53—*Glycine max*, 54—*Phaseolus vulgaris*, 55—*Pisum sativum*, 56—*Zea mays*, 57—*Oryza sativa*, 58—*Raphanus sativus*, 59—*Daucus carota*, 60—*Brassica oleracea var acephala*, 61—*Capsicum annuum*, 62—*Fragaria Ã—ananassa*, 63—*Malus domestica*, 64—*Pyrus communis*, 65—*Cicer arietinum*, 66—*Cucurbita pepo*, 67—*Citrullus lanatus*, 68—*Tanacetum parthenium*, 69—*Anthemis nobilis*, 70—*Vitis vinifera*, 71—*Gossypium hirsutum*, 72—*Lens culinaris*, 73—*Musa* sp., 74—*Solanum melongena*, 75—*Matricaria* chamomila, 76—*Vigna* mungo, 77—*Vigna unguiculata*, 78—*Cocos nucifera*, 79—*Vigna radiata*, 80—*Cyamopsis* psoraloides, 81—*Solanum lycopersicum*, 82—*Abelmoschus esculentus*, 83—*Cajanus cajan*, 84—*Macrotyloma* uniflorum, 85—*Vicia faba*, 86—*Allium cepa*, 87—*Allium sativum*, 88—*Sesbania sesban*, 89—*Portulaca* oleracea, 90—*Brassica* nigra, 91—*Quercus ilex*, 92—*Olea europea*, 93—*Rosa canina*, 94—*Jatropha curcas*, 95—*Lactuca sativa*, 96—*Mentha piperita*, 97—*Citrus sinensis*, 98—*Musa* sp., 99—*Malpighia glabra*, 100—*Vaccinium corymbosum*, 101—*Saccharum officinarum*, 102—*Brassica napus*, 103—*Hordeum vulgare*, 104—*Trifolium alexandrinum*, 105—*Pyrus pyrifolia*, 106—*Pennisetum glaucum*, 107—*Helianthus* annuus, 108—*Avena sativa*, 109—*Solanum tuberosum*, 110—*Curcuma longa*, 111—*Zingiber officinale*, 112—*Dolichos lablab*, 113—*Eleusine coracana*, 114—*Nicotiana tabacum*, 115—*Brassica oleracea var gemmifera*, 116—*Allium porrum*, 117—*Trifolium* resupinatum, 118—*Coleus forskohlii*, 119—*Spinacia oleracea*, 120—*Trifolium repens*, 121—*Andrographis paniculata*.

3.2. *Anethum graveolens* (Dill)

Dill is an annual species with a short growing season, making it highly suitable for intercropping with several species, including fennel, dragon's head, fenugreek, soybean, common bean, pea, and cabbage [18–26]. In dill–fennel systems, dill acts as the dominant species, achieving satisfactory grain and biomass yields while enhancing overall crop utilization efficiency, with optimal sowing ratios at 33:66 dill-to-fennel [18]. Intercropping dill with dragon's head reduced dill grain yield due to competition, though certain growth characteristics and EO content were enhanced at 50% optimal density [19]. Similarly, intercropping with fenugreek in various additive and replacement series improved EO content, plant biomass, seed yield, and harvest index, particularly when combined with organic or biofertilizers [20,21]. Legume intercrops, including soybean, common bean, and pea, enhance soil nitrogen availability through biological fixation, improving dill growth, yield, EO composition, and resource-use efficiency [27,28]. For example, a 2:1 soybean-to-dill pattern treated with organic manure optimized yield, land equivalent ratio, and antioxidant properties of dill EO [22]. Intercropping with common bean combined with arbuscular mycorrhizal colonization also positively influenced nutrient uptake, EO yield, and productivity indices [23,24]. Dill is particularly advantageous in organic systems, attracting pollinators and natural enemies that suppress pests, while improving soil health and the performance of companion plants [29,30]. Intercropping with pea reduces damping-off and downy mildew, enhancing survival, biomass, and seed weight [25], and intercropping with cabbage reduces populations of *Pieris rapae*, *Brevicoryne brassicae*, and *Plutella xylostella* without compromising yield [26].

3.3. *Artemisia* sp. (Wormwood)

Sweet wormwood (*A. annua*) has been successfully integrated into intercropping systems with crops such as soybean and maize, providing both agronomic and ecological advantages [31,32]. Other *Artemisia* species, including redstem wormwood (*A. scoparia*) and mugwort (*A. argyi*), have been utilized in phytoremediation-focused intercrops, growing with radish in lead-contaminated soils and with rice in cadmium-contaminated paddy fields, respectively, demonstrating their potential to improve soil health in contaminated environments [33,34]. Sweet wormwood can serve as a companion crop or grow at variable densities, enhancing biodiversity and suppressing arthropod pests without negatively affecting soybean yield [31]. When intercropped with maize, it supports multifunctional systems by improving resource use efficiency, diversifying production, and enhancing food security. Optimal spacing for smallholder systems includes 0.75×0.75 m or 0.9×0.9 m for wormwood alongside maize at 0.9×0.75 m, balancing intensification with positive crop interactions [32]. Studies on redstem wormwood and radish under Pb-contaminated conditions revealed strong allelopathic effects and high heavy metal accumulation capacity. While radish showed reduced root biomass and mineral content, redstem wormwood increased root biomass and iron accumulation and proved highly Pb-tolerant, significantly accumulating more Pb than radish [33]. Intercropping reduced radish Pb content and root biomass, while antioxidant changes were only observed under Pb stress. In Cd-contaminated rice paddies, intercropping with mugwort enhanced biomass and increased Cd uptake in both rice and mugwort, particularly in rice grains, mediated by higher rhizospheric organic acid concentrations [34]. While intercropping improved soil Cd extraction, it did not guarantee safe rice production because grain Cd levels remained elevated. These findings highlight both the potential and limitations of *Artemisia* species in multifunctional cropping systems, combining pest management, biodiversity promotion, and phytoremediation.

3.4. *Calendula officinalis* (Pot Marigold)

Pot marigold is a sustainable and multifunctional crop in intercropping systems, providing ecological services, such as pest control and pollinator attraction, while also offering economic value through its medicinal properties [35,36]. The species supports agroecological intensification, particularly in smallholder and organic farming systems, and aligns with the sustainable development goals in agriculture [37]. Intercropping studies have reported pot marigold grown alongside lavender [38], chamomile [39], white cabbage [40], and carrot [41]; however, these studies primarily focused on the companion crops rather than on the pot marigold itself.

3.5. *Carum copticum* (Ajowan)

Ajowan is an annual plant native to Egypt, India, and Iran, cultivated primarily for its aromatic seeds. Intercropping ajowan with fenugreek and pea, combined with chemical and organic fertilization, represents a more sustainable and environmentally friendly strategy for enhancing secondary metabolites and fatty acid profiles in ajowan compared to monocropping [42]. Moreover, cultivating these three species in a 2:2:2 ratio under both chemical and organic fertilization resulted in the highest forage quality, as indicated by elevated levels of nitrogen, phosphorus, and potassium, increased water-soluble carbohydrates, and reduced contents of crude fiber, acid detergent fiber, and neutral detergent fiber, thereby improving the feed value of the forage [43].

3.6. *Coriandrum sativum* (Coriander)

Intercropping is widely employed in vegetable and orchard production due to its economic benefits and potential to reduce pest infestations, suppress weeds, and decrease fertilizer requirements. Coriander has been intercropped with numerous species, including carrot, cumin, peppers, radish, kale, strawberries, pear, apple, fenugreek, and soybean [44–55]. In vegetable systems, coriander enhances agroecological functions by supporting beneficial insects. For example, intercropping with carrot increases populations of *Coccinellidae* and *Syrphidae*, natural enemies of pests [44], while in pepper production, coriander reduces the presence and damage of the pepper weevil (*Anthonomus eugenii*) without affecting marketable yield [46,47]. In strawberry cultivation, coriander boosts oviposition of aphidophagous lacewings, providing effective biological pest control [50]. In orchards, coriander yields are variable. Intercropping with pear and apple often has limited impact on soil nutrients, microbial biomass, or overall productivity [51,52], but can enhance biological control, as demonstrated by increased abundance and lifespan of parasitoids targeting leafrollers [53]. Coriander-legume intercropping provides both agronomic and ecological advantages. Fenugreek reduces weed pressure and increases coriander seed yield, supporting organic cultivation [54], while soybean, especially with arbuscular mycorrhizal fungi (AMF) inoculation, enhances coriander biomass, EO yield, and composition, providing additional advantages that further support its role in sustainable commercial production [55].

3.7. *Crocus sativus* (Saffron)

Saffron is a perennial crop that flowers in autumn and remains dormant for much of the year, which can lead to soil erosion and inefficient land use. Intercropping saffron with other crops provides a sustainable strategy to enhance productivity and optimize land use. According to the literature, saffron has been intercropped with pumpkin and watermelon, cumin, chamomile, chickpea, beans, wheat, and grape [56–62]. Intercropping saffron with pumpkin and watermelon improves flower number, dried stigma yield, corm growth, and nutrient content, particularly under limited irrigation [56]. Similarly, saffron intercropped with cumin at optimal planting densities enhances flower yield and land use efficiency, with a 50:50 saffron-to-cumin ratio recommended for maximum productivity [57]. Mixed cultivation with chamomile species shows no competition and improves soil conditions, with autumn-sown chamomile providing the highest combined yield and LER [58]. Saffron intercropped with chickpea under different irrigation regimes maintained high saffron yields, improved soil fertility, and achieved a total LER of 1.86, indicating a strong IA [59]. Likewise, saffron intercropped with white bean, coupled with glycine betaine application, mitigated heat stress, improved flower number and corm growth, and enhanced nutrient concentrations, increasing LUE in arid regions [60]. A four-year study showed that saffron intercropped with winter wheat under optimized irrigation and nitrogen management, enhances saffron EY and LER; therefore, this practice can increase income and land productivity while promoting clean and sustainable production [61]. Recently, intercropping saffron with grape significantly enhanced flower yield, improved soil pH, enriched beneficial microbial communities, and reduced pathogens, demonstrating benefits for both yield and soil health [62]. Overall, these studies highlight that saffron intercropping with diverse companion crops, along with optimized management practices, enhances yield, soil fertility, and LUE, offering practical approaches for sustainable saffron production in water-limited and arid environments.

3.8. Cuminum cyminum (Cumin)

Cumin has demonstrated significant agronomic, ecological, and economic potential when intercropped with diverse species under varying conditions. Reported intercropping partners include saffron, fenugreek, lentil, chickpea, cotton, and maize [45,57,63–68]. Intercropping cumin with saffron did not significantly affect cumin growth, yield, or EO content [57]. However, integration with fenugreek, combined with adjusted planting time and rhizobacteria application, reduced disease incidence without chemical inputs [63], and a 2:1 cumin-to-fenugreek paired row arrangement under combined organic and mineral fertilization maximized seed yield, cumin EY, and profitability [45]. Cumin–lentil intercropping improved cumin yields and LER despite lentil performing better in monoculture [64]. In arid cotton-growing regions of China, cumin intercropping improved soil quality, water use efficiency, and overall yield. Moderate seeding rates and drip irrigation improved cotton growth, yield, and economic return [66,67]. Similarly, cumin–maize intercropping in semi-arid areas improved resource use efficiency, as indicated by LER and water equivalent ratio, even though cumin was the less dominant species [68]. Delayed sowing in cumin–chickpea systems also highlighted intercropping advantages, with all treatments outperforming sole cropping in terms of LUE [65]. Overall, cumin-based intercropping systems are highly adaptable and economically viable, improving land use, resource efficiency, and crop profitability, particularly in semi-arid regions or under delayed sowing conditions. Challenges with mechanized harvesting remain a constraint, emphasizing the need for crop-specific equipment [69].

3.9. Cymbopogon sp. (Lemongrass)

Several *Cymbopogon* species, including lemongrass (*C. citratus*, *C. flexuosus*), Java citronella (*C. winterianus*), palmarosa (*C. martinii*), and camel grass (*C. schoenanthus*), have been successfully intercropped with a wide variety of crops, offering both agronomic and economic benefits. Reported intercropping partners include banana and coconut plantations, herbs such as lemon-scented basil and chamomile, legumes including mung bean, cowpea, soybean, guar, pigeon pea, and horse gram, vegetables such as tomato, okra, and eggplant, and cereals [70–80]. In Brazil, intercropping lemongrass with banana maintained banana yields while significantly increasing lemongrass biomass and EO content, with

LUE consistently exceeding 1.0 [70,71]. Intercropping during the lag phase of lemongrass or citronella improved land productivity and profitability, particularly when paired with legumes or short-duration vegetables [75–77]. Integrated nutrient management, including farmyard manure and biofertilizers, further enhanced yields and economic returns in *Cymbopogon* and wheat systems [78]. Moreover, intercropping *Cymbopogon* species helped reduce pest pressure in cowpea and eggplant, decreasing the need for chemical pesticides [79,80]. While citronella yield decreased slightly under coconut intercropping [72], and some legumes, such as horsegram, were highly competitive [76], overall evidence indicates that *Cymbopogon*-based intercropping systems enhance LUE, economic returns, and ecological sustainability.

3.10. Dracocephalum moldavica (Moldavian Dragonhead)

Intercropping *Moldavian dragonhead* with various legumes, including faba bean, soybean, common bean, mung bean, and fenugreek, has been shown to improve yield, EO quality, LUE, and overall sustainability [81–86]. For instance, a 2:2 intercropping ratio with faba bean, combined with biofertilizers and vermicompost, produced the highest dry herbage and EO yield, along with the greatest LER [81]. Similarly, soybean intercropping at 1:1 and 1:2 ratios under organic manure achieved LER values > 1, confirming its efficiency [82]. Intercropping with common bean or fenugreek, particularly with humic acid application, enhanced EO composition, increasing geranial, neral, and neryl acetate content [83]. Although a 3:2 ratio of *Moldavian dragonhead* and mung bean with combined bacterial and chemical fertilizers produced the highest LER, a 2:2 ratio was recommended for more sustainable management [84]. Moreover, intercropping with fenugreek at a 2:1 ratio, alongside inoculation with AMF and nitrogen-fixing bacteria, was identified as a practical approach for sustainable production [85,86]. Overall, these studies highlight *Moldavian dragonhead*'s compatibility with legumes, supporting both agronomic performance and ecological benefits.

3.11. Foeniculum vulgare (Fennel)

Fennel has been successfully intercropped with a wide range of species, including garlic, carrot, onion, common bean, cowpea, *Moldavian dragonhead*, dill, fenugreek, pepper, cotton, and leguminous trees such as *Sesbania* [18,83,87–96]. Intercropping systems have improved LUE, crop productivity, and EO quality. For example, fennel–onion at 2:1 and 2:2 ratios under 24 kg K_2O fertilizer optimized LER and ATER [88], while fennel–carrot (1:1) was the most productive and economically viable [87]. Fennel–dill intercropping stabilized seed yield over time [18]. Intercropping with common bean or Moldavian dragonhead enhanced EO components (*trans*-anethole, fenchone, limonene) despite slightly lower seed yields [83,89]. Ratios of 3:2 or 2:2 in fennel–bean systems yielded optimal LER values. Under semi-arid and organic conditions, intercropping with cowpea or beans improved yields, EO content, and LER [90]. Fennel–fenugreek systems, particularly with biofertilizers or humic acid, increased EO and FO, phenolics, and economic returns, with a 1:1 ratio plus 40 kg S/ha delivering the best results (LER 1.45) [91,92]. Alley cropping with *Sesbania* trees improved growth, nutrient uptake, and EO yield, especially when combined with nitrogen fertilization and endophytic fungi [96]. Fennel also contributes to pest suppression. Intercropping with pepper reduced *Phytophthora capsici* via root terpenes (limonene, estragole, anethole) that impaired zoospore motility and triggered pathogen cell rupture [94]. Chili–fennel systems, despite slight chili yield reductions, achieved high LER and economic returns, with optimal combinations depending on location [93].

3.12. *Hyssopus officinalis* (Hyssop)

Hyssop is a perennial aromatic plant that has rarely been studied in intercropping systems. Available data indicate that intercropping hyssop with fenugreek can enhance EO yield, improve its chemical composition, and increase antioxidant activity [97]. These results suggest that intercropping with fenugreek may be a promising strategy for sustainable hyssop cultivation.

3.13. *Lallemantia iberica* (Dragon's Head)

Dragon's head has been intercropped with fenugreek, dill, purslane, and chickpea [19,98–103]. Intercropping with fenugreek, combined with bacterial, mycorrhizal, and organic fertilizers, improved soil fertility, nutrient uptake, and the quantity and quality of FAs and EOs, with a 3:1 ratio showing optimal results [98]. Intercropping with dill or purslane primarily affected the companion crop, though it may indirectly support Dragon's head performance [19,99]. Intercropping with chickpea under specific irrigation and sowing conditions enhanced water use efficiency, nutrient uptake, drought tolerance, and EO quality [100,101]. In particular, a 2:1 row ratio combined with bacterial biofertilizer increased photosynthetic pigments, seed yield, and overall plant health [102], while monocultures with biofertilizers produced the highest individual seed yields. Complementary studies under rainfed conditions confirmed that this system improves LUE, EO yield and quality, beneficial FAs, and phenolic content [103]. Overall, these findings highlight chickpea–Dragon's head intercropping with biofertilization as a sustainable and climate-resilient approach for enhancing both productivity and crop quality.

3.14. *Lavandula* sp. (Lavender)

Lavender, a widely cultivated perennial aromatic plant, is infrequently intercropped. Reported systems include combinations lavender (*Lavandula officinalis*) with black mustard [104], marigold [38], and combination of lavandin (*L.* × *intermedia*) with oak [105]. Intercropping with black mustard, particularly when supplemented with humic acids, vermicompost, or other biological fertilizers, enhances EO yield and quality while being cost-effective and environmentally sustainable [104]. Similarly, lavender–marigold systems, supported by putrescine and AMF, promote flowering and improve EO content [38]. In oak–lavandin systems, lavandin initial growth and yield may be reduced near truffle-colonized oak trees, although truffle fruiting potential remains unaffected [105].

3.15. *Matricaria chamomilla* (Chamomile)

Chamomile has been intercropped with various species to improve productivity and EO quality, and LUE, including pot marigold, saffron, garlic, lemongrass, wheat, rosehip, jatropha, and olive [16,39,58,74,106–109]. Chamomile's EO composition, particularly chamazulene content, was influenced by seeding ratios in pot marigold intercrops, with 50:50 and 25:75 ratios being most favorable [39]. Intercropping with saffron yielded high flower yields without competition and achieved a LER of 1.69, while also improving soil conditions [58]. In chamomile-garlic systems, intercropping generally reduced flower yields compared to chamomile monocropping, but foliar application of amino acids enhancing key EO components, indicating that their combined use can reduce chemical fertilizer requirements and improve chamomile EO quality [106]. Chamomile intercropped with lemongrass under sodic soil benefited from gypsum application, improving EO yield and soil health [74]. Some systems, like chamomile with wheat, were unsuitable due to management conflicts [16]. Intercropping chamomile with rosehip seedlings or in basil–chamomile–jatropha sequences optimized land use, income, and soil quality [107,108]. In olive agroforestry, chamomile under shading and fertilization increased plant height, delayed flowering, and altered EO composition, producing commercially acceptable EOs [109].

3.16. *Melissa officinalis* (Lemon Balm)

Lemon balm has been intercropped with several species, including yarrow, peppermint, lettuce, kidney bean, and grapevine [15,110–113]. Intercropping with yarrow reduced lemon balm growth but enhanced chlorophyll a, b, total chlorophyll, carotenoids, and EO production [15]. In lettuce systems, lemon balm showed similar yield and EO content compared to monocropping; however, the economic analysis index exceeded 1.0, indicating potential benefits through improved land use and reduced weeding labor [111]. When intercropped with kidney bean and inoculated with AMF, lemon balm yield, EO content, and quality were significantly improved [112]. In peppermint systems, various intercropping ratios (25:75, 50:50, 75:25) influenced lemon balm growth and yield components, with the highest aerial biomass and maximum LER (0.98) observed in the 25% lemon balm + 75% peppermint treatment, though LER values < 1 indicate no clear LUE [110]. Additionally, intercropping lemon balm with basil and sage in vineyards affected grapevine 'Sangiovese' by delaying ripening and modifying volatile organic compound (VOC) accumulation, ultimately altering berry aroma profiles [113].

3.17. *Mentha* sp. (Mint)

Various *Mentha* species have been successfully intercropped with legumes (fenugreek, soybean, faba bean, pigeon pea, cowpea), other aromatic plants (rose-scented geranium, vetiver, lemon balm), berries (strawberry, blueberry, blackberry), oilseed crops, cereals (wheat, maize), sugarcane, and fruit trees (citrus, banana, Barbados cherry) [50,114–127]. Intercropping peppermint (*M. piperita*) with fenugreek, geranium, soybean, faba bean, or lemon balm enhanced EO yield and quality, LUE, and economic returns, with optimal results depending on planting dates, crop ratios, and spacing [110,114–116,119,128]. Peppermint's aromatic volatiles also contributed to pest suppression, as seen in strawberry systems [121]. Cornmint (*M. arvensis*) intercropped with geranium, strawberries, vetiver, pigeon pea, cereals, or cowpea improved resource-use efficiency, biomass, and EO yield, although sole cropping sometimes produced higher individual yields [50,117,118,120,122–124]. Sugarcane–cornmint intercropping showed variable outcomes depending on cultivar and spacing, affecting mint yield and LUE [125,126]. Hybrid mint (*M.* × *gracilis*) intercropped with fruit species in agroforestry systems achieved the highest biomass and EO yields with citrus and Barbados cherry, while banana and blackberry were less effective. EO composition (linalool, carvone) was influenced by the type of fruit species, highlighting the importance of selective intercropping for sustainable mint production [127].

3.18. *Nigella sativa* (Black Cumin)

Black cumin has been intercropped with legumes (soybean, common bean, fenugreek), vegetables (pepper, garlic), field crops (barley, berseem clover), and grapes to enhance yield, EO quality, and sustainability [129–136]. Although monoculture maximizes seed yield, intercropping improves FA content, composition, and LUE. A 50:50 black cumin–common bean ratio with bio-fertilizer increased EO content, chlorophyll, and LER (1.50) [130]. Intercropping with fenugreek in various ratios enhanced EO yield, thymol and *p*-cymene content, and linoleic acid levels, while legumes generally acted as complementary crops [131,132]. *Black cumin*–garlic intercrops improved growth, seed and FO yield, and nutrient accumulation under adjusted nitrogen levels [133]. In saline soils, living mulches with berseem clover and barley reduced weeds by up to 74%, enhanced FO yield (up to +45.7% vs. control), and improved FA profiles [134]. Intercropping with grapevine or pepper also boosted vine growth, berry quality, resilience, and farm profitability, supporting sustainable and climate-resilient production [135,136].

3.19. *Ocimum sp.* (Basil)

Basil species, especially *O. basilicum* and *O. africanum*, are highly compatible with intercropping across diverse crops, including woody perennials (jatropha, apple, pear, grapevine, olive), legumes (barseem clover, common bean, pigeon pea), cereals (maize, pearl millet), vegetables (pepper, tomato, okra), and other aromatic herbs (lemongrass, *Tagetes minuta*, lemon balm) [73,108,113,137–141]. Intercropping basil with jatropha or chamomile improved soil properties and profitability [108]. While monoculture typically maximized EO content, intercropping with legumes or cereals could sustain EO yields, improve nutrient uptake, and enhance LUE [142–145]. Multi-crop systems including maize, millet, pigeon pea, and okra maintained EO levels comparable to sole cropping while improving economic returns, with basil–pigeon pea at 50% population being most profitable [141]. Basil–lemongrass intercropping enhanced EO composition (citral, camphor) without affecting aroma [73]. Basil also provided pest management benefits, reducing pepper weevil incidence in jalapeño [47], though some combinations, such as basil–tomato, negatively affected tomato yield and biocontrol [146]. Ecologically, basil intercropped with apple or pear improved biological control of pests and enriched soil microbial communities, particularly enhancing nitrogen cycling and organic matter mineralization [137–139,147]. In vineyards, basil delayed grape ripening and modulated berry volatile compounds [113], while under olive trees, basil grew well without affecting tree productivity [140]. Overall, basil demonstrates high adaptability and potential to enhance yield, EO quality, ecological sustainability, and economic resilience in diverse intercropping and agroforestry systems.

3.20. *Pelargonium graveolens* (Rose-Scented Geranium)

Rose-scented geranium can be intercropped with a wide range of crops, including legumes (berseem, mung bean, urad bean), food crops (maize, oat, sunflower), vegetables (garlic, okra, onion, potato, radish), and herbs (cornmint, peppermint, vetiver) [117,119,120,148–152]. *Rose-scented geranium* is a slow-growing perennial cultivated in subtropical climates. Intercropping, particularly during the early stages, helps control weeds and provides additional yields. Intercropping with fodder crops such as oat or berseem may reduce geranium growth at the first harvest but has no significant effect by the second harvest [148]. A 2:2 ratio with garlic maximizes LUE and economic returns [149]. Fertilization with phosphorus (40 kg P_2O_5 ha^{-1}) and zinc (30 kg $ZnSO_4$ ha^{-1}) further enhances herb yield and EO content [150]. Intercropping with seasonal crops like maize, sunflower, mung bean, okra, onion, urad bean, or potato improves yield, resource utilization, and EO quality, while also increasing economic returns and supporting soil health [151,152]. Intercropping with cornmint or peppermint does not negatively affect geranium growth, biomass, or EO quality and effectively controlled weed growth and reduces weed biomass [119,120]. Geranium can also be intercropped with vetiver, okra, and radish, although detailed performance data are limited [117].

3.21. *Pimpinella anisum* (Aniseed)

Aniseed has demonstrated strong potential as an intercrop in grapevine and olive cultivation [109,135]. Although intercropping grapevine with aniseed reduced anise plant height, the number of branches and leaves per plant, plant fresh and dry weight, and seed yield, this combination still increased net profitability compared to monocropped grapevine [135]. In Mediterranean olive-based systems, aniseed intercropping improved EO composition, particularly *trans*-anethole content, while fertilization increased plant height. Although shading reduced growth, EO quality remained commercially acceptable. These findings indicate that aniseed can be successfully integrated into traditional silvoarable systems, supporting sustainable production of MAPs [109].

3.22. *Pogostemon cablin (Patchouli)*

Intercropping patchouli with compatible crops offers a sustainable approach to improve land use, soil fertility, pest suppression, and farm profitability. Studies have shown that patchouli can be successfully intercropped with legumes (finger millet, cowpea, field bean, blackgram, soybean, common bean), vegetables (okra), and spice crops such as turmeric and ginger, as well as perennial crops like coconut [72,153–155]. A 1:2 patchouli–field bean ratio yielded optimal biological and economic outcomes [154]. Intercropping with legumes and vegetables maintained patchouli biomass and EO quality while providing additional yields, with French bean and okra combinations proving most profitable [153]. Turmeric and ginger intercrops enhanced patchouli's active compounds and improved soil microbial activity, enzyme function, pH, and nutrient availability [155]. Although intercropping with coconut significantly reduced patchouli dry herbage yield and essential oil content compared to the sole crop, it maximized net income and benefit–cost ratio, demonstrating economic advantages [72].

3.23. *Rosmarinus officinalis (Rosemary)*

Rosemary can be intercropped with a variety of crops, including carrot, onion, sweet pepper, grapevine, truffle-inoculated oak, and olive [105,140,156–159]. Intercropping rosemary with carrot at full density improved LUE, although monoculture yielded the highest EO [156]. Similarly, onion–rosemary intercropping under irrigation achieved strong LER and competitive indices despite monoculture producing the highest yields [157]. In greenhouse conditions, rosemary reduced populations of key pests on sweet pepper without harming natural enemies, supporting integrated pest management [158]. Field and agroforestry trials showed compatibility with grapevine, truffle oak, and olive, with minimal negative effects on the main crops while maintaining rosemary growth and EO production [105,140,159]. Under artificial shading, rosemary displayed high adaptability, with only moderate herbage reduction and increased EO concentrations, outperforming sage and oregano [160].

3.24. *Salvia sp. (Sage)*

Various *Salvia* species have been successfully intercropped with crops such as Brussels sprouts, white cabbage, vetiver and black gram, grapevine, and tobacco [40,113,117,161,162]. Intercropping Brussels sprouts with sage reduced egg deposition by *Plutella xylostella*, highlighting pest management potential [161]. Studies with cabbage, vetiver, and black gram focused mainly on companion crop performance rather than sage outcomes [40,117]. In vineyards, intercropping sage with basil and lemon balm delayed grape ripening and enhanced berry VOC profiles, suggesting modulation of secondary metabolites [113]. Sage–tobacco systems improved soil microbial diversity, nutrient availability, and enzymatic activities, resulting in better tobacco growth and quality [162]. Under artificial shading (40–75%), sage showed moderate yield reductions, but EO content increased. However, α-thujone concentration declined with increased shade, indicating light-dependent changes in biochemical composition [160]. Overall, sage demonstrates adaptability to intercropping and shaded environments, offering ecological, agronomic, and biochemical benefits, though further field evaluation in tree-based systems is needed.

3.25. *Satureja hortensis (Summer Savory)*

Summer savory has demonstrated intercropping potential with crops, such as common bean, maize, Persian clover, leek, carrot, and in pear orchards [44,137,138,163–166].

Intercropping with common bean in a 2:2 row arrangement, combined with bacterial fertilization, enhanced EO and phenolic content [163]. While intercropping with sweet maize suppressed savory yield, it reduced weeds and improved maize productivity, indicating its suitability when maize is the primary crop [164]. Intercropping with Persian clover showed that plant density is critical: sole cropping produced the highest EO yield, but higher-density intercrops increased biomass and EO output [165]. Savory also contributes to pest management. When intercropped with leek or carrot, it reduced damage from onion thrips, carrot root fly, aphids, and nematodes, often outperforming other intercrops in pest suppression [44,166]. In pear orchards, savory improved soil organic matter, nitrogen availability, and water content, while favorably altering microbial communities involved in nitrogen cycling and organic matter mineralization [137]. Intercropping summer savory and other aromatic plants in a pear orchard also significantly reduced pest populations, increased beneficial insect ratios, and improved arthropod diversity and evenness, enhancing orchard health and productivity [138].

3.26. *Tagetes sp. (Marigold)*

Wild marigold (*T. minuta*), African marigold (*T. erecta*), and French marigold (*T. patula*) are commonly used in intercropping systems with vegetables, such as cabbage, carrot, cauliflower, eggplant, pepper, tomato, and leafy crops including coriander, spinach, and fenugreek, and they are also intercropped with maize, soybean, medicinal herbs like coleus, and co-cultivated with vetiver, radish, and sweet basil, as well as in apple orchards [40,47,117,139,147,167–174]. Monocropping of wild marigold resulted in the highest biomass yield, but intercropping with maize (75:25 ratio) produced superior biomass, EO yield, and quality [167]. Wild marigold has also shown compatibility with vetiver, radish, sweet basil [117], and effectively suppressed root-knot nematodes and other plant-parasitic species when intercropped with tomato, eggplant, cabbage, and cauliflower [40,168]. Intercropping African marigold with tomato reduced early blight (*Alternaria solani*) and protected against root-knot nematodes and insect pests, thereby improving tomato yield [172,173]. In combination with *Pseudomonas fluorescens* and neem cake, African marigold intercropped with coleus (*Coleus forskohlii*) reduced nematode populations and increased tuber yield, improving economic returns [174]. A 75:25 soybean-to-African marigold ratio was also most effective for weed suppression, soybean yield, and ecological efficiency [169]. When intercropped with carrot and cauliflower, French marigold maintained its flower yield and carotenoid content while reducing forked carrots and increasing cauliflower yield and profitability [170]. Under varied nitrogen levels, intercropping French marigold with spinach enhanced growth and flower yield, while combinations with fenugreek and coriander improved flower diameter [171]. In systems with jalapeño pepper, French marigold reduced pepper weevil infestation without affecting yield [47], and in apple orchards, it modified arthropod populations, reducing codling moths and rosy apple aphids presence [139,147].

3.27. *Thymus vulgaris (Thyme)*

Research shows that thyme can be successfully intercropped with several vegetables, including cabbage, tomato, and Brussels sprouts [40,146,161]. Although one study primarily focused on white cabbage and did not assess thyme parameters in detail, it confirmed the compatibility of thyme in intercropping with cabbage [40]. Intercropping tomato with thyme under organic cultivation enhanced root development, increased flower and fruit production, and improved overall tomato growth and yield [146]. Furthermore, intercropping Brussels sprouts with thyme significantly reduced the egg load of the pest *Plutella xylostella* on the crop [161].

3.28. *Trigonella foenum-graecum* (Fenugreek)

Fenugreek has been successfully intercropped with a wide range of Fabaceae (faba bean, pea), Lamiaceae (peppermint, dragon's head, Moldavian dragonhead, hyssop), Apiaceae (dill, coriander, fennel, cumin, ajowan, black cumin), and other economically important crops, such as onion, grapevine, pear, and apple [51,92]. Intercropping with faba bean reduces broomrape infestation and increases shoot dry weight and seed yield [175]. Fenugreek–peppermint systems may slightly reduce biological yield but are advantageous when evaluated using intercropping indices [114]. Intercropping with dragon's head, Moldavian dragonhead, and hyssop, particularly when combined with biofertilizers, AMF, or plant growth-promoting bacteria, enhances seed yield, FO content, and unsaturated FA composition [85,86,97,98]. Fenugreek also improves yield and growth of dill, suppresses weeds in coriander cultivation, and increases FA and phenolic content in fennel and cumin [20,54,63,91]. Multi-species intercrops with ajowan, fenugreek, and pea enhance forage quality, nutrient content, and secondary metabolites [42,43]. Intercropping with onion and black cumin improves yield, nutritional quality, and seed nutrient content [132,176]. In perennial systems, intercropping fenugreek with grapevine or fruit orchards improves vine growth, berry quality, soil fertility, microbial activity, enzymatic function, and overall system productivity and economic returns [51,52,135]. These findings underscore fenugreek's versatility and ecological, agronomic, and economic benefits in diverse intercropping systems.

3.29. *Vetiveria zizanioides* (Vetiver)

Due to its very slow initial growth, vetiver leaves unused space between rows that can be efficiently utilized through intercropping. Six combinations have been explored: sweet basil–radish–wild marigold, black gram–clary sage, kalmegh–garlic, okra–radish–geranium, pigeon pea–menthol mint, and maize–radish–onion [117]. Among these, the sweet basil–radish–wild marigold combination was the most productive in terms of LER, LUE, and relative net return, although it slightly reduced vetiver's EO content.

4. Insights from Large-Scale Implementation

In addition to numerous examples reported in the literature, practical applications of intercropping have been documented in large-scale production in Serbia, Spain, and Albania. These include intercropping clary sage with dill and coriander; lavender with peas and holm oak; sage with peas, wild cherry and bay laurel; and wormwood with holm oak (Figure 3).

Current Serbian literature generally recommends intercropping biennial or perennial MAPs with annual species to ensure a harvest even in the first year of cultivation. For example, intercropping biennial caraway (*Carum carvi*), which forms only a leaf rosette in its first year, with barley, or combining clary sage with dill (*Anethum graveolens*) or coriander (*Coriandrum sativum*), is advised [177]. Intercropping MAPs with trees is an emerging practice in agroforestry systems that enhances land productivity, improves soil health, and supports biodiversity. Shade-tolerant MAPs, such as anise, lemongrass, or tulsi, can thrive under canopies of grapevine, olive, and poplar, contributing to sustainable yields, enriched soil microbial activity, and increased overall system profitability [109,135,158]. Additionally, intercropping medicinal plants with legumes has emerged as a promising trend in organic and regenerative agriculture. Legumes naturally fix atmospheric nitrogen, improving soil fertility and reducing reliance on synthetic fertilizers, while also enhancing biodiversity and pest resistance [178,179]. This synergy supports healthier plant growth, higher yields, and a more resilient and sustainable agroecosystem.

Figure 3. Examples of large-scale intercropping systems implemented in experimental fields in Serbia (photo by Milica Aćimović): (**a**) *Salvia sclarea* and *Anethum graveolens*; (**b**) *Salvia sclarea* and *Coriandrum sativum*; (**c**) *Lavandula officinalis* and *Pisum sativum*; (**d**) *Salvia officinalis* and *Pisum sativum*; Spain (photo by Juliana Navarro Rocha) (**e**) *Salvia officinalis* and *Prunus avium*; (**f**) *Artemisia absinthium* and *Quercus ilex*; (**g**) *Lavandula* × *intermedia* 'Grosso' and *Quercus ilex*; and Albania (photo by Alban Ibraliu) (**h**) *Salvia* officinalis and *Laurus nobilis*.

5. Conclusions

Intercropping MAPs with other crops offers a sustainable and multifunctional approach to agricultural production, combining higher yield, improved EO quality, and optimized land use. This review highlights the potential influence of MAPs' physiological and biochemical properties on their compatibility and interactions within intercrop systems, providing a foundation for understanding the ecological and agronomic mechanisms behind observed benefits. Successful intercropping has been demonstrated across diverse MAP species and crop combinations, emphasizing the importance of species selection, planting ratios, fertilization, and spatial arrangement to maximize benefits and minimize negative interactions. Future research should focus on optimizing these factors under diverse climatic and soil conditions further to enhance the multifunctional potential of MAP-based intercropping systems.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy15122692/s1, Table S1: A brief review of the literature on intercropping medicinal and aromatic plants with other species (year of investigation, cropping patterns, other experimental factors, measured parameters, experimental locations).

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Abbreviations

The following abbreviations are used in this manuscript:

A	Aggressivity
AMF	Arbuscular Mycorrhizal Fungi
ATER	Area-time Equivalent Ratio
AYL	Actual Yield Loss
CR	Competitive Ratio
EO	Essential Oil
EY	Equivalent Yield
FA	Fatty acid
FYM	Farmyard Manure
IA	Intercropping Advantages
IER	Income
LEC	Land Equivalent Coefficient
LER	Land Equivalent Ratio
LUE	Land Use Efficiency
MAI	Monetary Advantages Index
NR	Net Return

PYD	Percentage Yield Difference
RCC	Relative Crowding Coefficient
RNR	Relative Net Returns
RVT	Relative Value Total
RYM	Relative Yield of Mixture
SPI	System Productivity Index
VOC	Volatile Organic Compound

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