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# Intercropping Perennial Fruit Trees and Annual Field Crops with Aromatic and Medicinal Plants (MAPs) in the Mediterranean Basin

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**Abstract:** The Mediterranean basin (MB), a "climate hotspot", is experiencing faster than average increases in global temperature and water deficit, as well as soil degradation, with detrimental impacts on food crop yield and pest/pathogen incidence. Hence, there is an urgent requisite for sustainable crop diversification strategies to promote crop resilience, soil quality conservation and pest/pathogen control. Intercropping is a strategy that has yet to be widely adopted. Presently, cereal–legume combinations represent the most common intercrops. Of relevance, a large number of medicinal and aromatic plants (MAPs), native to the MB, serve as potentially profitable indigenous resources for intercropping with food crops. Environmentally sustainable benefits of MB MAP intercropping with food crops have ironically been reported largely from research outside the MB. The present study aims to review the published literature from 2003 to 2023 on MAP intercropping with perennial nut/fruit crops and annual field crops in the MB. Published research is scarce but shows a promising upward trend, with 70% and 47% of intercropping studies with perennials and annual field crops, respectively, dated between 2020 and 2023. MAP intercropping shows potential in augmenting yield, pest/pathogen and weed control, soil health and cash crop quality, warranting further research with more widespread adoption in the MB.

**Keywords:** Mediterranean basin; medicinal and aromatic plants (MAPs); intercropping; perennial fruit trees; field crops

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## 1. Introduction

The Mediterranean basin (MB), coined a "climate change hotspot" [1], is experiencing a 25% faster than average increase in global temperatures coinciding with a predicted 30–40% reduction in precipitation, particularly in the southern portion of the MB [2,3]. Climate-related changes in the MB also involve increases in the frequency and severity of extreme weather events, including heat waves, dry spells, drought, unexpected flash floods and frost [4–6]. Given the environmental heterogeneity of the MB, climate-related events occur with differing magnitudes from one region to another [3,6,7]. Together with climate change, unsustainable agricultural management practices have rendered the MB more susceptible to physical (erosion and desertification), chemical (reduction in soil fertility) and biological (biodiversity loss) soil degradation processes [8], with knock-on effects on pest/pathogen and disease incidence [9–12]. Collectively, these multi-faceted challenges pose a major threat to both production yield and quality in the entire MB agricultural sector [5].

Focusing on perennial nut and fruit tree crops, there is no return in investment until several years after planting. Hence, climate change and non-sustainable management effects on phenology, physiological processes, disease–pest frequency, yield and product quality specifically represent major challenges to producers of this agricultural sector within the MB [9,10,13–18]. Important staple cereal and legume field crops in the region, intrinsically linked to food security, are similarly subject to yield fluctuations [19,20] and increasing pathogen/pest pressure [5,21–23]. The spread of broomrape (*Orobanche* spp.), a parasitic achlorophyllous herbaceous weed, also represents a major constraint to legume production in rainfed cropping systems of the MB and Middle East [24]. Hence, there is an urgent requisite to increase food crop resilience to climate change impacts, to shrink the agricultural carbon footprint of unsustainable management practices and to enhance soil and biodiversity conservation whilst guaranteeing crop yield, weed and pest/pathogen control. In response, various adaption strategies, including the selection of more resilient plant material, have been extensively covered in recent reviews and meta-analyses for perennial fruit and nut crops [13,16,17,25–27], including grapes [16,28–31], and for annual field crops [21,24,32].

Of the adaption strategies, crop diversification, defined as the increase in crop diversity through the implementation of practices such as crop rotations, cover crops and intercropping, represents an important approach for sustainable agricultural development [10,33]. Of interest to the present review is intercropping, the agronomic practice of simultaneously growing two or more crop species in the same field in close proximity for a considerable proportion of the growing season [34]. This practice promotes crop resilience, product stability and environmental security though agro-ecosystem benefits (soil quality conservation, biodiversity and pest control) and provides alternative products to increase farmer profitability [34–37]. Common intercropping typologies include, row intercropping (specific row patterns with varying row ratios), strip intercropping (cropping in wide strips to facilitate machine operations), alley intercropping (growing crops in-between trees and bushes), mixed intercropping (sowing two crops on one terrain with no distinct row arrangement) and relay intercropping (growing two or more crops simultaneously during part of the life cycle of each crop).

Throughout the history of agriculture, intercropping has been a key element of traditional, smallholder, farming systems, but has largely been neglected in both scientific-based research and industrialized production [35,36,38]. As such, intercropping has yet to be widely adopted [37]. From a scientometric analysis of global intercropping research between 1992 and 2020, a significant upward trend in research publications was evident from 2015 [34]. Cereal grain–legume combinations constitute the most common intercropping strategy in annual field crops, whereas in agroforestry systems, the intercropping of orchards with legumes, legume mixes, cereals and grasses is reported [26,34,35,37]. Intercropping with medicinal and aromatic plants (MAPs), as a climate change adaptation strategy, was not featured in the aforementioned meta-analyses or reviews for fruit and nut perennials or annual field crops. In a recent meta-analysis published specifically for Mediterranean climate regions in 2020 [26], only a single reference was made to the use of MAPs as an intercrop [39].

A large number of MAPs, comprising anise, basil, caper, caraway, chamomile, chive, coriander, cumin, dill, fennel, fenugreek, lavender, lemon balm, lemon grass, licorice, marigold, marjoram, mint, parsley, rosemary, saffron, sage and thyme, are native to the MB [40]. Sustainable agricultural advantages of MAP cultivation include, improved soil health (soil organic nitrogen and carbon, soil water content, microbial activity and biomass), bio-pesticide and bio-herbicide control by allelopathic secondary metabolites, adaptability to diverse ecological conditions, including semi-arid conditions, with an added advantage to farmer profitability (essentials oil with high economic value) [41–45]. The potential benefits of intercropping with MAPs have been highlighted from studies, conducted mostly on vegetable crops, which have been subject to various reviews [42,43,46,47]. From these latter reviews, as well as from emerging MAP intercropping studies widely available on internet search engines, environmentally sustainable benefits of native MB MAPs have ironically been published in countries that are predominantly located outside the MB, such as China, India and Iran (major producers of MAPs), as well as parts of Africa [43,45,47,48]. To address desirable sustainable agriculture policy objectives in the MB such as improvements to soil quality and biodiversity [6], as well as to take into consideration climate change and unsustainable management risks to the MB, the present study aims to review published literature from 2003 to 2023 on intercropping perennial nut and fruit crops, as well as annual field crops, with native MB MAPs within the MB. Scientific research on MAP intercropping with perennial fruit trees and annual field crops in the MB is shown to be extremely scarce and warrant attention. Nonetheless, where possible, the objective was to provide an overview of benefits from the intercropping of various selected crops and MAPs in land use efficiency (LUE, involving increased yields, economic returns and weed control), soil health (improved physical, chemical and biological properties), bio-control (pathogen/pest and improved fauna biodiversity in natural predator populations and ecosystem services) and product quality (improved yield quality).

## 2. Methods

Using GOOGLE SCHOLAR and SCIENCEDIRECT, a search was conducted separately for each of the most common MB MAPs (anise, basil, caper, caraway, chamomile, chive, coriander, cumin, dill, fennel, fenugreek, lavender, lemon balm, lemon grass, licorice, marigold, marjoram, mint, parsley, rosemary, saffron, sage, tarragon and thyme), always in conjunction with "intercropping". Additional keywords that were entered included "Mediterranean", "perennial nut crops" or "perennial fruit crops" or "field crops" or "medicinal and aromatic plants". Inclusion factors were peer-reviewed published research of open-field studies, and research conducted in any of the 24 MB countries, namely Portugal, Spain, France, Monaco, Italy, Malta, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Greece, Türkiye, Cyprus, Syria, Lebanon, Israel, Jordan, Palestine, Egypt, Libya, Tunisia, Algeria and Morocco. Exclusion factors included laboratory and greenhouse trials (even if conducted in the MB) and work that was not published in the English language.

## 3. Past, Present and Future Impacts of Climate Change in the Mediterranean Basin

The MB lies in a transition zone between mid-latitude and sub-tropical atmospheric circulation regimes. As such, the MB is characterized by significant environmental and geographical gradients from north to south and east to west [5]. Using annual precipitation data combined with temperature minimums and maximums, Köppen established geographic climate zones in 1900 [49]. According to this climate classification, temperate hot dry summers (classified as Csa) and temperate warm dry summers (classified as Csb) were traditional hallmarks of the Mediterranean-type climate, of which the MB represents the largest surface area (60%) [49]. However, from the homogenization of meteorological data, dated back from AD 1500, a distinct increase in daily temperature and reduced precipitation has been evident in the MB over the last 60 years [50]. More specifically, a 0.5 °C increase in both global and MB temperatures was shown to occur between 1980–1990 compared to late 19th-century levels [3,5]. By 2020, this had escalated to unprecedented increases of 1.6 and 1.2 °C for the MB and global temperatures, respectively [5]. The main drivers are linked to anthropogenic forces that are specifically linked to energy demand and electricity generation, as well as to population growth since the 1960s [5]. Moreover, sea surface temperatures have similarly been rising over the last decades at a rate of about 0.4 °C, with mean annual temperatures exceeding 20 °C for much of the eastern and south-eastern MB [5]. Currently, large regions of Spain, Türkiye, Greece, the MB islands, and coastal regions of Italy, Morocco, Tunisia and the Middle East are still classified as Köppen Mediterranean Csa and Csb. However, Libya and Egypt are presently largely hot arid steppe (BWh), whereas regions of Spain, Morocco, Tunisia, Libya, Sicily, Crete, Türkiye and the Middle East are hot arid desert (BSh) [51,52]. Future predictions (2071 to 2100) show increases specifically in hot arid steppe and hot arid desert, for North Africa, the Middle East, Türkiye and parts of Spain [52], all currently at the strongest risk for increases in heat wave intensity [5,53]. Although the overall amount of precipitation is predicted to decrease, particularly in Italy, Portugal, Spain, and parts of Greece and Türkiye, extreme rainstorms are expected to prevail in these northern MB countries. Aside from droughts, floods are and will likely remain the most dangerous meteorological hazards [5,53].

Approximately 40% of the Mediterranean agricultural production value is derived from four crops: grapes (14%), wheat, tomatoes, and olives (9% each), of which the three latter crops constitute about 90% of the total global supply [53]. Given the environmental heterogeneity of the MB, and the propensity of climate-related events occurring with differing magnitudes from one region to another [3,6,7], it is evident that intercropping experiments with MAPs must be optimized for each cultivation area.

## 4. Intercropping with Aromatic and Medicinal Plants (MAPs) in the Mediterranean Basin

A total of 37 articles were found on intercropping MAPs with either perennial fruit crops (17 articles) or annual field crops (20 articles). Of the 37 articles published, 20 were conducted in Egypt alone. Of the published articles on woody perennials, 71% of the research was conducted in the northern (European) MB, being represented predominantly by Spain (7 articles) and Italy (3 articles). For the field crops, 95% of the published articles were from research conducted in the southern MB, represented by Egypt (16 articles) and Tunisia (3 articles), respectively.

### *4.1. MAP Intercropping in Perennial Woody Nut and Fruit Crops*

Perennial woody fruit and nut crops are among the most bio-diverse agricultural systems in the MB, and include a wide range of deciduous (almond, chestnut, hazelnut, pine nut, pistachio, pecan, walnut, grape, cherry, apple, apricot, peach, plum, pear, fig, persimmon and pomegranate) and evergreen (olive, date palm and citrus fruit) species. Deciduous and evergreen perennials can be further classified into climatic zones which include warm temperature to subtropical (pistachio, pecan, persimmon, fig, olive, citrus fruits and date palm) and temperate (warm to cool temperate, chestnut, almond, grape, peach, hazelnut, cherry, apple and pear).

Climate change and non-sustainable agricultural management practices impact various aspects of perennial cultivation. Phenology in perennial fruit and nut crops is driven by temperature which regulates dormancy periods. Endodormancy is induced under cold temperatures rendering the trees, bushes or vines cold hardy, and chilling units (the number varying between different species) are then employed by the plant to track the passage of time over winter. Upon the completion of the required chilling units, the plants enter ecodormancy (requiring species-specific levels of heat), necessary to resume growth and production which also coincides with increased sensitivity to colder temperatures [17,54]. Rising temperatures in the MB are currently compromising the chilling unit requirements, leading to developmental abnormalities affecting yield and quality specifically in the temperate tree crops [7,17,54]. Since fruit trees in the MB are often grown in marginal and unfertile lands with low levels of soil organic matter [13] and are also traditionally cultivated at a low plant density [25,39], increased temperatures combined with variable and unpredictable precipitation events (drought, flooding) have accelerated water erosion and worsened soil degradation [18,26]. Moreover, the implementation of non-sustainable agronomic practices such as tillage to remove weeds on exposed land between trees, as well as the use of chemical fertilizers have collectively contributed to anthropogenic greenhouse gas (GHG) emissions and reduced agro-ecosystem fauna services [10,13,26]. Reduced ecosystem services and climate change (more specifically rising temperatures) aggravate pest outbreaks, which are currently spreading in Mediterranean orchards [9,10].

Considering the diversity of nut and fruit crops cultivated in the MB, published research on intercropping with MAPs as a crop diversification strategy under field conditions within this region is particularly scarce and warrant attention as a new potential sustainable strategy. The research will be covered in the following subsections for deciduous perennials and evergreen perennials, respectively. However, given that among the deciduous fruit crops, grapes have the largest area and the highest economic importance globally [15], grape was reviewed in a separate subsection from the remaining deciduous perennials.

#### 4.1.1. Deciduous Perennials (Almond, Pomegranate, Apple)

The only published articles for MAP intercropping with deciduous tree crops in the MB are for almond (*Prunus dulcis* [Miller] D.A. Webb; four articles), pomegranate (*Punica granatum* L.; one article) and apple (*Malus domestica* [Suckow] Borkh.; one article) (Table 1). Almond cultivation in the Mediterranean basin is extensive. Spain represents the second largest global producer, with Morocco, Türkiye, Italy, Algeria and Tunisia all ranking within the top ten global producers for 2023 [55]. The articles on intercropping MAPs with almond trees were all performed in semi-arid rainfed regions of Spain, facing severe land degradation problems [18]. The first published article in 2008 was aimed at identifying the best soil management strategy, using non-tillage strip intercropping with rosemary, sage and thyme, compared to conventional tillage with no intercrops over a four-year period on hill slopes [39]. All MAPs selected were perennials, requiring much less maintenance and management practices after crop establishment than annuals. Thyme was shown to outperform rosemary, and more specifically sage, in significantly reducing runoff, annual soil loss as well as N, P, and K nutrient losses, even though all MAPs significantly improved the aforementioned parameters compared to the control. The denser morphology of thyme (also an evergreen), followed by rosemary, ensured better soil cover. Although, the almond yield was slightly lower when intercropped with the MAPs (attributable to water competition), almond losses could be completely offset economically by the gain in thyme and rosemary essential oil yields [39].

**Table 1.** Improved economic, environmental and quality aspects of deciduous perennial cash crops (almond, pomegranate and apple) intercropped with aromatic and medicinal plants (MAPs) compared to the cash crop (or MAPs) in monoculture.

| Deciduous Tree Crops | MAP Intercrops (Intercropping Type) | Country/ Agronomic Practices | Improved Land Use Efficiency (LUE); ↑ Cash Crop/MAP Yields; ↑ Economic Return; and ↑ Weed Control | Improved Soil Health ↑ Soil Organic C (SOC) + Org Matter/Minerals/Beneficial Organisms/C Sequestration ↓ Erosion, ↓ GHG | Bio-control ↓ Pests/Pathogens/ Disease Symptoms; ↑ Natural Enemies (Parasitism and Predators) | Improved Quality of Cash/MAP Crop ↑ Nutritional/ Functional Properties |
|---|---|---|---|---|---|---|
| Almond | Rosemary, Sage and Thyme (strip) [39] | Spain (rainfed, no tillage) | ↓ almond yield offset by ↑ MAP oil yield: thyme and rosemary, res. | ↓ erosion and nutrient losses: thyme, rosemary and sage, res. | No information provided | No information provided |
| Almond | Caper and Thyme (alley) [18,56,57] | Spain (rainfed, no tillage) | ↑ LUE: ns almond yield, ↑ thyme oil [18,57] | ↑ soil $H_2O$ + stability + aggregation: thyme and caper, res.; ↑ SOC and avail. macro-nutrients: thyme and caper, res. [18] ↑ SOC: thyme only; ↓ $CO_2$: thyme + caper [56,57]; ↑ soil C balance: thyme and caper, res. [56] | No information provided | No information provided |
| Pomegranate | Basil and Rosemary (alley) [58] | Egypt (irrigated) | ↑ LUE (1:4 plant ratio): rosemary and basil, res.; ↑ pomegranate yield | No information provided | No information provided | ↑ Brix, anthocyanin content and ↓ abiotic injury of fruit ↑ volatile oils, volatile oil yield for both MAPs |

**Table 1.** *Cont.*

| Deciduous Tree Crops | MAP Intercrops (Intercropping Type) | Country/ Agronomic Practices | Improved Land Use Efficiency (LUE); ↑ Cash Crop/MAP Yields; ↑ Economic Return; and ↑ Weed Control | Improved Soil Health ↑ Soil Organic C (SOC) + Org Matter/Minerals/Beneficial Organisms/C Sequestration ↓ Erosion, ↓ GHG | Bio-control ↓ Pests/Pathogens/ Disease Symptoms; ↑ Natural Enemies (Parasitism and Predators) | Improved Quality of Cash/MAP Crop ↑ Nutritional/ Functional Properties |
|---|---|---|---|---|---|---|
| Apple | Basil and Marigold (row) [59] | France (peri-urban and irrigated) | No information provided | No information provided | ↑ parasitism of coddling moth, ns predators: basil only; ↓ pests + predators: marigold only. Ns for disease symptoms | No information provided |

The most successful MAP is listed first followed by the remaining MAPs, respectively (res.), in descending order. A + sign is inserted between the respective MAPs where performance is equivalent. ↑ Denotes increases and ↓ denotes decreases.

The sustainable benefits of thyme, compared with the performance of the evergreen perennial caper, were further investigated under no-tillage conditions over a two-year period (Table 1) [56,57]. Taking into account soil carbon fluxes (outputs and inputs), it was shown that thyme, followed by caper, significantly improved C balance [56]. Both thyme and caper were also significantly shown to reduce soil $CO_2$ emissions, related to no-till practices, whereas no $N_2O$ emissions were observed due to the lack of chemical fertilization [57]. Only thyme, as an evergreen crop, was shown to improve soil organic carbon and moisture. The presence of thyme and caper alley crops had no effect on almond yield, but thyme essential oil yield improved the overall productivity of the agro-ecosystem in terms of LUE [57]. These results were corroborated by Almagro et al., 2023 [18]. After three years, both thyme and caper significantly improved both soil aggregate stability and water availability in the topsoil (at 0–10 cm depth), whereas only thyme improved those properties in the subsoil (10–30 cm depth). Mineral element content was improved by MAPs in both topsoil and subsoil [18]. Collectively, these results showed that, for almond cultivation, the use of the perennial evergreen MAPs (in this instance thyme) can significantly improve LUE and soil properties. What is yet lacking and warranting of research is the effect of these perennial MAPs as bio-control agents. Also warranting attention are MAP intercropping studies on other perennial fruit crops, especially nut crops which are completely lacking.

For pomegranate, sweet basil and rosemary were used as intercrops at different row ratios (1:1, 1:2 and 1:4 for pomegranate: MAP) over a two-year period in Egypt (Table 1) [58]. When intercropped, pomegranate fruit quality was significantly improved, with the best results evident for rosemary at a planting density of 1:3 and sweet basil at a planting density of 1:4. The combined yield advantage in terms of land equivalent ratio (LER), area time equivalent ratio (ATER) and LUE indices was the greatest for 1:4 for the rosemary, followed by 1:4 for the sweet basil intercropping pattern arrangement [58]. The sole focus of a one-year study conducted in a semi-urban field area in France was to investigate the biological control of the codling moth *Cydia pomonella* L. (a pest causing high damage to various perennial crops worldwide, particularly to apple orchards) by intercropping apple with sweet basil and French marigold (positioned in pots) [59]. Results of the study showed that intercropping with basil increased codling moth parasitism, but did not affect arthropod predator abundances, whereas intercropping with French marigold, decreased both pests and predators (Table 1). This paper highlights the requisite for more studies on field-cultivated crops intercropped with MAPs, selected as either attractants or repellents for specific pest or predator requirements in the cultivation area.

4.1.2. Deciduous Perennials (Grape)

Viticulture and wine making play a crucial role in the socio-economy of the MB, with Italy, Spain, Portugal and Greece jointly producing 38% of the global wine production [31]. Aside from wine production, overall grape (*Vitis vinifera* L.) production in the MB is extensive, with the leading countries, in descending order, being Italy, Spain, France, Türkiye, Egypt, Portugal, Greece, Algeria, Morocco, Syria, Tunisia, Croatia and Slovenia [60]. Lebanon, Jordan, Israel, Bosnia and Herzegovina, Palestine, Libya, Cyprus and Montenegro represented minor grape producers within the Mediterranean basin [60]. Collectively, climate change impacts specific for viticulture include the following aspects: vine phenology (advancing the date of bud break, flowering and véraison or onset of ripening), grape yield (impaired photosynthesis) and quality (decreasing anthocyanin content, aroma compounds and acidity), and pest and disease pressures (increasing parasitic plant nematodes and soil-borne fungal pathogens) [16,28,30,31]. Viticulture is also facing emerging challenges because of a social demand for environmentally friendly agricultural management, such as non-chemical pest management [30,31]. Given the projected risks to viticulture, there is a requisite for the implementation of timely, suitable and cost-effective adaption techniques/technologies which should be planned and tuned to local climatic conditions [26,31]. Since MAPs have not yet been considered as viable intercropping options for vineyards [61], published research for this agronomic sector is negligible, with only four articles published from studies conducted in the MB (Table 2).

**Table 2.** Improved economic, environmental and quality aspects of grape crops intercropped with aromatic and medicinal plants (MAPs) compared to the grape crop in monoculture.

| Grape Crops | MAP Intercrops (Intercropping Type) | Country/ Agronomic Practices | Improved Land Use Efficiency (LUE); ↑ Cash Crop/MAP Yields; ↑ Economic Return; and ↑ Weed Control | Improved Soil Health ↑ Soil Organic C (SOC) + Org Matter/Minerals/Beneficial Organisms/C Sequestration ↓ Erosion, ↓ GHG | Fauna Bio-Control ↓ Pests/Pathogens/ Disease Symptoms; ↑ Natural Enemies (Parasitism and Predators) | Improved Quality of Cash/MAP Crop ↑ Nutritional/ Functional Properties |
|---|---|---|---|---|---|---|
| Thompson seedless grapevines | Anise, Black Cumin, Fenugreek and Parsley (row) [62] | Egypt (irrigated) | ↑ Grape yield: fenugreek, anise, parsley and cumin, res. ↑ economic return: fenugreek, cumin, parsley and cumin, res. | ↑ OM: fenugreek and anise ↑ N, P and K: fenugreek, anise, parsley and cumin, res. ↑ microbes: fenugreek, anise, parsley and cumin, res. | No information provided | ↑ sugars, Brix and acidity: fenugreek and anise, res. |
| Flame seedless grapevines | Garlic (row) [63] | Egypt (irrigated) | Ns effect on grape and garlic yield; ↑ LUE and ↑ economic return | No information provided | ↓ Parasitic nematode infestation | Ns effect on Brix and anthocyanin of grape |
| Sangiovese; Trebbiano Romagnolo | Basil-Lemon-Balm-Sage; (row) [64] Sage (row) [65] | Italy (no irrigation + fertilization) | Ns effect on grape yield [60] | No information provided | No information provided | ↑ Volatile organic compounds (VOCs) [60,61] |

The most successful MAP is listed first followed by the remaining MAPs, respectively (res.) in descending order. A + sign is inserted between the respective MAPs where performance is equivalent. ↑ Denotes increases and ↓ denotes decreases.

To the best of our knowledge, the first study reporting multiple beneficial sustainable effects of intercropping grapevine (mature 12-year-old Thompson seedless grapevine) with different MAPs (anise, black cumin, fenugreek and parsley) was conducted over two successive seasons in Egypt [62] (Table 2). Grape yield was significantly higher for grapevines intercropped with fenugreek, anise, parsley and black cumin (in descending order) than in monoculture. Although the yield for all MAP crops intercropped with grape was lower, the estimated combined net profit (grape + MAP) was highest for fenugreek, followed by black cumin, parsley, and anise [62]. Grape quality was improved by intercropping with only fenugreek and anise [62]. Additionally, compared to grape in monoculture, both soil microbial count and activity (based on symbiotic associations with soil microbes) were higher for grape intercropped with fenugreek, followed by anise, parsley, and black cumin [62]. This paper clearly shows the enormous potential of MAP intercropping in viticulture. The legume MAP fenugreek was shown to not only provide the best benefits to soil health but also the best potential economic benefits to growers. The role of this MAP in insect pest control, therefore, warrants attention. Garlic was given consideration as a MAP in Egypt since utilization by the ancient Egyptians is widely reported, providing evidence of the early movement of garlic into the MB from the native origins in south-central Asia. The intercropping performance of garlic as a sustainable bio-control alternative to nematicides and chemical soil fumigants was evaluated using Flame Seedless grapevines (9-year-old cultivar) over two consecutive seasons in Egypt (Table 2). Garlic showed promise by significantly reducing the number of plant parasitic nematodes (PPNs), specifically *Meloidogyne incognita* which is considered the most destructive PPN [63]. This is relevant since PPNs on vines are increased by climate change [12]. Although intercropping with garlic had no effect on either grape yield or quality, the LER and LUE were significantly increased, showing that this combination is a viable sustainable management option [63].

Very recently in Italy (Table 2), intercropping grapevine with MAPS was shown as a potential enological practice to influence the accumulation of volatile organic compounds (VOCs) in grape berries that are considered neutral ("non-aromatic") such as Sangiovese (the most cultivated red grape variety in Italy) and Trebbiano Romagnolo in the protected designation of origin "Romagna" [64,65]. The selection of basil, lemon balm and sage as an intercropping mixture was based on the richness in aromatic compounds such as linalool, citronellal, thujone and camphor and the high potential of these VOCs to be emitted into the environment. In fact, the MAP mixture enhanced Sangiovese berry concentration of C13-norisoprenoids, various phenols and aliphatic alcohols, thereby evidencing the absorption of VOCs by the vine plants, either through the leaves, berries or roots [64]. Interestingly, the MAPs in the vineyards also slowed down technological ripening [64]. This is favorable in the context of climate-induced temperature change which shifts the berry maturation phase to warmer periods in the summer, adversely affecting grape composition, in particular, with respect to aromatic compounds [28]. Similarly, intercropping Trebbiano Romagnolo with sage alone influenced VOCs in grape berries [65], providing exciting prospects towards improving wine quality. Intercropping with MAPs promises innovative future prospects for the viticulture sector. By extension this will also include environmentally sustainable benefits that as of yet remain to be determined.

#### 4.1.3. Evergreen Perennials (Olive and Date Palm)

Together with wheat, both grape and olive (*Olea europaea* L.) are commonly referred to as the Mediterranean triad, being the traditional emblematic crops with immense cultural, economic and ecological importance [15]. Similar to grape, olive production in the MB is extensive [53], with the first nine top global producers being represented in descending order by Spain, Italy, Morocco, Türkiye, Greece, Egypt, Portugal, Tunisia and Algeria [66]. Producing less olive oil in the global rankings are Jordan, Libya, Israel, Palestine, Croatia, Cyprus, Macedonia and Slovenia [66]. Olive agroforestry is a traditional, sustainable practice involving the intercropping of predominantly cereals and legumes to increase farmer profitability as well as to enhance soil and biodiversity conservation [67]. Although agroforestry practices are minimal compared to olive in monoculture, little research has been conducted on the productivity of such systems, especially with MAPs as understory crops [68]. As such, only six articles to date have been published for the Mediterranean basin (Table 3).

In an earlier study conducted in Morocco, where intercropping olive with annuals (especially wheat and barley, food legumes and vegetables) dates back to antiquity, it was shown that olive yield was not compromised by intercropping with the MAP, coriander, whereas sowing distance (degree of shading) influenced coriander yield [69]. To improve land use efficiency and economic returns, the optimal distances for sowing annuals including MAPs are deemed essential [69]. In a more recent study conducted in an agroforestry system in Greece, the sole objective of intercropping olive with MAPs as understory crops was to ascertain the effect of fertilization and shading on the quality of MAP essential oils [68]. Both shading and fertilization of chamomile and anise, respectively, were shown to either increase or decrease various essential oil components, rich in the substances defined by commercial specifications [68]. No information on sustainable benefits to the agroforestry system was provided.

Three studies conducted in Spain [70–72] and a single study in Italy [73] aimed to investigate the environmental benefits of MAP intercropping with olive on soil properties and insect populations (Table 3). In a very complex study performed on hill slopes investigating the SOC stratification index (SR-COS), a mixture of saffron–lavandin intercropped with olive was shown to improve the formation of stable aggregates and the microbial and fauna communities of the soil on the back slopes, which provide protection against organic matter (OM) decomposition [70]. Using lavandin (hybrid cross between *Lavandula angustifolia* Mill. and *Lavandula latifolia* Medik.) and saffron (no tillage), it was shown that after four years the olive–saffron combination improved soil properties in terms of fertility (total N and soil organic carbon (SOC)), SOC sequestration and soil aggregation [71] compared to the no-tillage control. Although the olive–lavandin combination did not improve soil aggregation processes or structural stability and SOC sequestration, there were no severe losses as compared to the control [71]. To assess increases in entomological diversity [72], olive tree intercropping with lavandin, rosemary and lavender was performed. In addition to the above-mentioned pollinator attractant and insect repellent MAPs, beehives were also positioned in the orchards. Given that this is an ongoing project, only preliminary data were presented. In a single orchard, lavandin intercropping resulted in increased predator and parasitoid numbers of olive pests in the month of April 2022. It was predicted that the arthropod community structure would have changed over the following months after flowering [72]. Interestingly, the rosemary and lavender plots did not survive, clearly showing that the selection of MAPs requires a prior in-depth analysis of the local abiotic and biotic conditions [72], as climate change impacts in the MB may be very heterogeneous [7]. From a preliminary two-year study conducted in Sicily (Italy), sage, thyme and lemongrass intercropped with young olive trees guaranteed an almost full soil cover, reducing the need for weed management along the intra-rows (forming a hedge row) [73]. The MAPs also increased insect (predator and pollinator) richness without influencing olive tree growth [73]. Given the importance of olive cultivation in the MB, the environmental benefits of MAP intercropping in terms of LUE and economic returns warrant further research in this sector.

Egypt is the world's largest producer of dates, with Algeria, Algeria and Tunisia, respectively, among the top producers in the Mediterranean basin [74]. The impact of intercropping three legumes, including fenugreek, as understory crops with Sewy date palms (*Phoenix dactylifera* L.) was conducted over two seasons in Egypt [75]. Although clover outperformed fenugreek, fenugreek intercropping was shown to significantly increase Sewy date palm yield, LER and gross profits on both crops, as well as improving date quality [75].

**Table 3.** Improved economic, environmental and quality aspects of evergreen perennial cash crops (olive and date palm) intercropped with aromatic and medicinal plants (MAPs) compared to the cash crop or MAP in monoculture.

| Evergreen Tree Crops | MAP Intercrops (Intercropping Type) | Country/ Agronomic Practices | Improved Land Use Efficiency (LUE); ↑ Cash Crop/MAP Yields; ↑ Economic Return; and ↑ Weed Control | Improved Soil Health ↑ Soil Organic C (SOC) + Org Matter/Minerals/Beneficial Organisms/C Sequestration ↓ Erosion, ↓ GHG | Fauna Bio-Control ↓ Pests/Pathogens/ Disease Symptoms; ↑Natural Enemies (Parasitism, Predators) | Improved Quality of Cash/MAP Crop ↑ Nutritional/ Functional Properties |
|---|---|---|---|---|---|---|
| Olive | Coriander (alley, various distances) [69] | Morocco (rainfed, no tillage) | Ns effect on Olive yield: ↑ shading and ↓ coriander yield | No information provided | No information provided | No information provided |

**Table 3.** *Cont.*

| Evergreen Tree Crops | MAP Intercrops (Intercropping Type) | Country/ Agronomic Practices | Improved Land Use Efficiency (LUE); ↑ Cash Crop/MAP Yields; ↑ Economic Return; and ↑ Weed Control | Improved Soil Health ↑ Soil Organic C (SOC) + Org Matter/Minerals/Beneficial Organisms/C Sequestration ↓ Erosion, ↓ GHG | Fauna Bio-Control ↓ Pests/Pathogens/ Disease Symptoms; ↑Natural Enemies (Parasitism, Predators) | Improved Quality of Cash/MAP Crop ↑ Nutritional/ Functional Properties |
|---|---|---|---|---|---|---|
| Olive | Anise and Chamomile (alley) [68] | Greece | Ns shading effect on MAP seed + oil yields: anise + chamomile | No information provided | No information provided | Shading ↑ or ↓ certain MAP oil components; no quality changes for both MAPs |
| Olive | Mix: Saffron-Lavandin (alley) [70] | Spain (rainfed, no tillage) | No information provided | ↑ SOC stratification index: saffron–lavandin | No information provided | No information provided |
| Olive | Saffron and Lavandin [71] | Spain (rainfed, no tillage) | No information provided | ↑ soil SOC stocks: saffron and lavandin, res. | No information provided | No information provided |
| Olive | Lavandin, Lavender and Rosemary (alley) [72] | Spain (rainfed, no tillage) | No information provided | No information provided | ↑ Predator + parasitoid: lavandin, one orchard | No information provided |
| Olive | Lemongrass, Sage and Thyme (row) [73] | Italy (irrigated, min–no tillage) | ↑ Weed control: lemongrass + sage. No effect on tree growth | No information provided | ↑ Pollinators + predators: lemongrass + sage + thyme | No information provided |
| Date Palm | Fenugreek [75] | Egypt | ↑ Date yield, Ns fenugreek forage yield, ↑ LER and ↑ net profit | No information provided | No information provided | ↑ Date fruit weight, ↑ TSS, ↑ total sugars and ↓ tannins |

The most successful MAP is listed first followed by the remaining MAPs, respectively (res.), in descending order. A + sign is inserted between the respective MAPs where performance is equivalent. ↑ Denotes increases and ↓ denotes decreases.

### *4.2. MAP Intercropping in Annual Field Crops*

Field crops cultivated in the MB are very diverse and include the cereal crops with durum wheat, bread wheat and barley being the most cultivated cereal crops, traditionally grown under rainfed conditions [20,76]. Durum wheat represents around 6% of the total wheat cultivation but has an important economic and cultural relevance in the MB, where it represents a staple crop that is increasingly threatened by drought and insect pests [23]. Additional field grain crops produced in the MB include rye, oats and maize, rice, sorghum and triticale. Sunflower is the most widely cultivated oilseed crop, whilst industrial crops include rapeseed, cotton and tobacco. Alternative, innovative field crops introduced into the MB as contributions to climate change mitigation, in compliance with the EU (European Union) Green Deal objectives, include teff, quinoa, camelina, black cumin, chia, emmer and flax [77].

Dry legume pulses (lentils, chickpeas, peas and beans) are representative field crops that form the backbone of the Mediterranean agro-ecosystems from ancient times, yet the unique and broad biodiversity of legumes has not been sufficiently valorized in the MB [78]. Among the legume crops, faba bean (*Vicia faba* L., also known as faba bean or broad bean) represents an excellent, untapped, source of sustainable and quality dietary proteins, with potential as a functional food [79]. In Egypt, the faba bean represents an important source of food and feed protein but remains an underutilized crop in Western countries [79].

#### 4.2.1. Cereal, Sugar and Non-Food Crops (Durum Wheat, Triticale, Maize, Sugar Beet and Cotton)

Only three published reports for cereal grain field crops reported in the MB were collectively centered on yield improvements (Table 4). In an experiment conducted in Tunisia in two locations (sub-humid and semi-arid), durum wheat (*Triticum turgidum* subsp. *durum* [Desf.] Husn.) was intercropped with a clover–fenugreek mix and singularly with the two species alone under different herbicide and/or N regimes [80]. Overall, although the clover–fenugreek mix outperformed fenugreek in improving wheat yield and grain protein content, a significant improvement was demonstrated with fenugreek alone compared to the sole wheat crop. The contribution of fenugreek biomass was instrumental in weed control and in preserving soil moisture in the semi-arid site. Both fenugreek alone and the fenugreek–clover mix impacted positively, compared to the wheat crop in monoculture [80]. Mixed intercropping is projected to be important in areas with low water and nutrient inputs where climate change will force larger areas to become forage systems [81]. To investigate the efficacy of mixed intercropping, fenugreek considered as a forage legume, was intercropped with triticale (X *Triticosecale* Wittm.) and compared to triticale–vetch intercropping in different seeding percentage mixes. Overall, results showed that, compared to the respective crops in monoculture, the mixtures improved crop yield regardless of the seeding percentage. However, vetch demonstrated a greater competitive ability to exploit resources in a mixture with triticale, compared to fenugreek [81]. For maize (*Zea mays* L.) intercropping, sweet basil was used in different percentage mixes with the objective of establishing both which maize cultivar and percentage seeding mix provided the best gross income and yield [81]. The highest LER was obtained with the Giza-2 variety when intercropped with basil (100% basil + 33% maize), and the highest gross income occurred at 100% basil + 25% Giza 2, even if the percentage of basil volatile oils was lower in intercropping [82].

**Table 4.** Improved economic, environmental and quality aspects of annual field cash crops (durum wheat, triticale, maize, sugar beet and cotton) intercropped with aromatic and medicinal plants (MAPs) compared to the cash crop in monoculture.

| Field Cereal, Sugar and Non-Food Crops | MAP Intercrops (Intercropping Type) | Country/ Agronomic Practices | Improved Land Use Efficiency (LUE); ↑ Cash Crop/MAP Yields; ↑ Economic Return; and ↑ Weed Control | Improved Soil Health ↑ Soil Organic C (SOC) + Org Matter/Minerals/Beneficial Organisms/C Sequestration ↓ Erosion, ↓ GHG | Fauna Bio-Control ↓ Pests/Pathogens/ Disease Symptoms; ↑ Natural Enemies (Parasitism and Predators) | Improved Quality of Cash/MAP Crop ↑ Nutritional/ Functional Properties |
|---|---|---|---|---|---|---|
| Durum wheat | Fenugreek and Fenugreek–clover mix (inter-row) [80] | Tunisia rainfed | ↑ Weed control: fenugreek–clover and fenugreek, res. ↑ Grain yield: fenugreek–clover and fenugreek, res. | ↑ Soil moisture: fenugreek mix and fenugreek, res. | No information provided | ↑ Grain quality (protein) fenugreek–clover and fenugreek, res. |
| Triticale | Fenugreek and Vetch + mix [81] | Tunisia rainfed | ↑ LER, ↑ forage yield: vetch and fenugreek, res. | No information provided | No information provided | No information provided |
| Maize | Sweet Basil (row) [82] | Egypt | ↑ LER (basil: maize 100:33) and ↑ gross income (basil: 100:25) | No information provided | No information provided | ↓ Volatile basil oil in intercropping compared to basil alone |
| Sugar beet | Garlic (row, different distances) [83] | Egypt | ↓ Sugar beet yield and ↑ gross return both crops at 25 cm and 50 cm distance | No information provided | ↓ Tortoise beetle pest, cotton leaf worm and beet moth pests | Ns on sugar percentage and ↑ juice quality |
| Sugar beet | Fennel, Coriander, Dill and Marjoram (row) [84,85] | Egypt no pesticide use | ↑ Sugar beet yield: fennel, dill, coriander and marjoram, res. [84] | No information provided | ↓ Tortoise beetle coriander, fennel, dill and marjoram, res. [84] ↓ Cotton leaf worm: fennel, dill, coriander and marjoram, res. ↓ Sugar beet fly pests: dill, fennel, coriander and marjoram, res. [84] Predators: all but specific for each MAP [85] | ↑ Sucrose: fennel, dill, coriander and marjoram, res. [84] |

**Table 4.** *Cont.*

| Field Cereal, Sugar and Non-Food Crops | MAP Intercrops (Intercropping Type) | Country/ Agronomic Practices | Improved Land Use Efficiency (LUE); ↑ Cash Crop/MAP Yields; ↑ Economic Return; and ↑ Weed Control | Improved Soil Health ↑ Soil Organic C (SOC) + Org Matter/Minerals/Beneficial Organisms/C Sequestration ↓ Erosion, ↓ GHG | Fauna Bio-Control ↓ Pests/Pathogens/ Disease Symptoms; ↑ Natural Enemies (Parasitism and Predators) | Improved Quality of Cash/MAP Crop ↑ Nutritional/ Functional Properties |
|---|---|---|---|---|---|---|
| Cotton | Sweet Basil (Row: low + high basil density; 60 and 90 cm) [86] | Egypt irrigated and no pesticide use | ↑ Cotton yield, ↑ LER: all except low density at 90 cm and ↑ gross income: low density at 60 cm is the best | No information provided | ↓ Pink bollworm: high basil density at 60 cm. ↓ Spiny bollworm: low basil density at 90 cm. ↑ Arthropod and spider predators: 60 cm and 90 cm, res. | No information provided |

The most successful MAP is listed first followed by the remaining MAPs, respectively (res.), in descending order. A + sign is inserted between the respective MAPs where performance is equivalent. ↑ Denotes increases and ↓ denotes decreases.

Research on sugar beet (three articles) and the most widespread profitable non-food crop, cotton (one article), were primarily centered on insect pest bio-control and improved LUE (Table 4). Sugar beet (*Beta vulgaris* L.) is subject to numerous insect pests, and the three published papers in Egypt addressed the effects of intercropping with MAPs on selective pest populations and their respective natural predators [83–85]. Garlic was shown to significantly reduce larvae of the tortoise beetle (*Cassida vittata* Vill), beet moth (*Scrobipalpa ocellatella* Boyd) and the Egyptian cotton leafworm (*Spodoptera littoralis* Boisduval) over two seasons [83]. Although sugar beet yield was significantly lower with garlic intercropping, the gross income from the combined crops was higher at intercrop planting distances of 25 cm and 50 cm. In contrast, significantly increased sugar beet yield and quality (sugar percentage), associated with significantly reduced tortoise beetle infestations, were evident in sugar beet intercropped with fennel, followed by dill, coriander and marjoram [84]. Fennel and dill intercropped with sugar beet were also shown to be the most effective MAPs against cotton leafworm and the sugar beet fly [85]. Interestingly, fennel, dill, coriander and marjoram showed distinctive capacities in attracting different predator populations [85], evidencing the need for more field studies on interactions between MAPs and insect predators. In cotton (*Gossypium barbadense* L.), sweet basil was used as an intercrop in three different intercropping regimes (absent, low and high basil area fraction) and two row distances (60 and 90 cm). Intercropping improved LER and cotton yield, thereby improving cotton production both ecologically and economically (gross margin, highest at the low density and 60 cm row distance) [86]. Moreover, the basil-induced pest repellence served to reduce both pink (*Pectinophora gossypiella* Saunders) and spiny (*Earias insulana* Boisduval) bollworm numbers compared to cotton in monoculture. The highest density of 60 m was more effective against pink bollworm and in attracting more arthropod and spider predators to cotton plants [86].

#### 4.2.2. Legume Field Crops (Lentil, Soybean and Faba Bean)

Damping-off and root rot, predominantly caused by the fungi, *Rhizoctonia solani* (Cooke) Wint. and Fusarium spp, are primarily responsible for disease-associated reductions in lentil (*Lens esculenta* Moench.) yield. In a study conducted in Egypt, it was shown that over two consecutive years, intercropping with anise, garlic and cumin (in descending order), significantly decreased dampening off and root rot disease in lentils compared to lentil as a sole crop [87] (Table 5). Increased lentil yield compared to the sole crop was also evident for intercropping with garlic and anise, respectively [87]. In the case of peppermint–soybean intercropping, the cash crop was peppermint, and the presence of soybean was shown to improve N availability to the peppermint [88]. The yield and essential oil components of peppermint were significantly increased when intercropped. Although the aim of the study was not intended to evaluate soybean responses to peppermint intercropping, it was noted that soybean was less prone to pest attack and fruit set was unaffected, raising the interesting possibility of a soybean–peppermint combination as a sustainable practice for both crops [88].

**Table 5.** Improved economic, environmental and quality aspects of annual legume cash crops (lentil, soybean and faba bean) intercropped with aromatic and medicinal plants (MAPs) compared to the cash crop in monoculture.

| **Field Legume Crops** | **MAP Intercrops (Intercropping Type)** | **Country/ Agronomic Practices** | **Improved Land Use Efficiency (LUE); ↑ Cash Crop/MAP Yields; ↑ Economic Return; and ↑ Weed Control** | **Improved Soil Health ↓ Soil Organic C (SOC) + Org Matter/Minerals/Beneficial Organisms/C Sequestration↓ Erosion, ↓ GHG** | **Fauna Bio-Control ↓ Pests/Pathogens/ Disease Symptoms; ↑Natural Enemies (Parasitism and Predators)** | **Improved Quality of Cash/MAP Crop ↑ Nutritional/ Functional Properties** |
|---|---|---|---|---|---|---|
| Lentil | Anise, Cumin and Garlic (row) [87] | Egypt | ↑ Lentil seed yield: garlic and anise, res. | No information provided | ↓ Dampening off and root rot: anise, garlic and cumin, res. | No information provided |
| Soybean | Peppermint (row) [88] | Italy irrigated | No information provided | No information provided | No information provided | ↑ Leaf yield and ↑ essential oil components of peppermint |
| Faba bean | Coriander (ridge row) [89] | Egypt no pesticide use | ↑ Bean yield | No information provided | ↓ Aphid numbers and ↑ ladybird and lacewing hoverfly predators | No information provided |
| Faba bean | Garlic (2 varieties row) [90] | Egypt | ↑ Economic return: Balady garlic and Sids-40 garlic, res. | No information provided | ↓ Aphid, leafhopper and whitefly infestation: Balady garlic and Sids-40 garlic, res. | No Information provided |
| Faba bean | Coriander and Fenugreek (ridge row, high + low density) [91] | Egypt no pesticide use | ↑ Bean yield: only fenugreek, low density only | No information provided | ↓ Aphid numbers: fenugreek and coriander, res. | No information provided |
| Faba bean | Anise (row, different densities) [92] | Egypt irrigated | ↑ LUE: anise: faba bean, 1:1 and 1:2 | No information provided | No information provided | No information provided |
| Faba bean | Fenugreek + mixes [93] | Egypt conducted in infested field | ↓ Broomrape parasite emerged shoots | No information provided | No information provided | No information provided |
| Faba bean | Fenugreek (row) [94] | Egypt | Ns effects on broomrape infestation in farmer's field: all intercrops | No information provided | No information provided | No information provided |
| Faba bean | Fenugreek (row) [95] | Egypt different row width + density combinations | ↑ LER and ↑ economic return: 100% fenugreek, 100% faba bean in wide ridges and other combinations, res. ↓ Broomrape infestation: all combination treatments | ↑ Soil phenol content: all combination treatments | No information provided | No information provided |
| Faba bean | Fenugreek (row) [96] | Egypt, +/-herbicide treatment | ↓ Broomrape parasite: herbicide + fenugreek and fenugreek alone, res. | No information provided | No information provided | No information provided |

**Table 5.** *Cont.*

| Field Legume Crops | MAP Intercrops (Intercropping Type) | Country/ Agronomic Practices | Improved Land Use Efficiency (LUE); ↑ Cash Crop/MAP Yields; ↑ Economic Return; and ↑ Weed Control | Improved Soil Health ↓ Soil Organic C (SOC) + Org Matter/Minerals/Beneficial Organisms/C Sequestration↓ Erosion, ↓ GHG | Fauna Bio-Control ↓ Pests/Pathogens/ Disease Symptoms; ↑Natural Enemies (Parasitism and Predators) | Improved Quality of Cash/MAP Crop ↑ Nutritional/ Functional Properties |
|---|---|---|---|---|---|---|
| Faba bean | Fenugreek, Garlic and Parsley (trap intercropping) [97] | Egypt comparisons made to herbicide applications | ↑ Faba bean biological yield: fenugreek and garlic, res. ↓ Broomrape infestation: garlic + fenugreek and parsley, res. | No information provided | No information provided | No information provided |
| Faba Bean | Fenugreek and Garlic (row) [98] | Egypt fields naturally infested and comparison to herbicides | ↑ LER ↑ economic return: garlic + AMF and fenugreek + AMF ↓ Broomrape infestation: fenugreek + AMF and garlic + AMF, res. | No information provided | ↓ Dampening off and root rot: fenugreek + AMF and garlic + AMF, res. | No information provided |
| Faba bean | Fenugreek (inter-row) [99] | Tunisia rainfed | ↑ Faba bean yield ↓ Broomrape parasite spikes | No information provided | No information provided | No information provided |

The most successful MAP is listed first followed by the remaining MAPs, respectively (res.), in descending order. A + sign is inserted between the respective MAPs where performance is equivalent. ↑ Denotes increases and ↓ denotes decreases.

Given the importance of the faba bean in the southern MB, 10 studies were conducted in Egypt. Faba bean is susceptible to aphids as a key pest (*Aphis craccivora* Koch), as well as to leafhopper (*Emposca lybica* De Berg) and whitefly (*Bemisia tabaci* Gennadius). Using five varieties of faba bean intercropped with coriander over two consecutive seasons, a significant reduction in aphid pest infestation was observed compared to faba bean in monoculture [89] (Table 5). The same was evident when intercropped with garlic [90] as well as with fenugreek, followed by coriander (each at low- and high-density intercrops) [91]. Moreover, predator populations, including lacewing, ladybirds and hover flies were significantly increased by intercropping with coriander [89] and garlic (with Balady garlic outperforming Sids-40 garlic) [90]. Faba bean yield increases and improved LUE were evident with coriander [89] and for anise at a density of 1:1 and 1:2 for anise to faba bean [92]. The faba bean yield was reduced when intercropped with garlic; however, the net economic return was higher due to higher garlic yields [90].

Faba bean is also widely reported as being very susceptible to the root-parasitic weed, broomrape (*Orobanche* spp.). Although several authors described fenugreek as a suitable crop for intercropping with legumes, to reduce the infection level of *O. crenata*, a lack of experimental data was highlighted [93]. In a field experiment conducted over a two-year period in Egypt, fenugreek was shown to significantly reduce crenate broomrape shoot emergence attributable to allelochemicals released by fenugreek roots that interfere with the parasitic life cycle at the level of germination [93] (Table 5). Interestingly, in a later study, it was shown that faba bean genotype effect was a key factor in the faba bean-*O. crenata* crop allelopathic effect [94]. Using fenugreek in different plant densities and ridge widths, it was shown that two rows of faba bean (100% of sole cropping) on both sides of a wide ridge (120 cm width) with four rows of fenugreek (100% of sole cropping) in the middle of the ridge, could be an integrated control strategy to increase faba bean productivity, land usage and economic return whilst reducing broomrape infestation [95].

The efficacy of fenugreek in significantly reducing crenate broomrape infestation on faba beans cultivated in Egypt was verified in further field experiments but in comparison to synthetic herbicide treatments [96–98]. The application of herbicides (either Imazapic or glyphosate, twice in the season) together with fenugreek–faba bean intercropping was shown to suppress broomrape [96]. In response to fenugreek or garlic intercropping, broomrape biomass and spike numbers were significantly reduced (comparable to the effect of a single glyphosate application alone). This was also associated with a significant increase in faba bean yield [97]. A second application of glyphosate alone exceeded the suppression of broomrape (89%) compared to that induced by garlic or fenugreek (73%) [97]. With the objective of introducing environmentally friendly alternatives to herbicides, arbuscular mycorrhiza fungi (AMF) and yeast as bio-control agents were used. The latter were compared to the chemical application of herbicides (glyphosate) and fungicides (Rizolex-T50) in controlling crenate broomrape weeds and fungal root diseases, respectively [98]. Intercropping with fenugreek followed by garlic (both integrated with AMF application), promoted crop growth and significantly enhanced seed yield/ha whilst significantly decreasing both broomrape infestation and root rot, compared to the untreated controls [98]. Interestingly, AMF integrated with either fenugreek or garlic, performed equally well in reducing broomrape infestation when compared to the glyphosate integrated with either fenugreek or garlic. This shows that AMF together with MAPs could effectively replace the use of glyphosate. Higher economic returns were evident from the faba bean–garlic combination than the faba bean–fenugreek combination [98]. For sustainable agriculture, bio-control agents are superior to synthetic herbicides and pesticides. This very recent paper provides an incentive for the use of natural products in conjunction with MAP intercropping towards eradicating weeds and pests. Fetid broomrape (*Orobanche foetida* Poir) is a devastating faba bean parasite in Tunisia, and intercropping fenugreek with both a susceptible (Badi) and resistant (Najeh) faba bean cultivar was shown to significantly reduce field *O. foetida* plant numbers, especially on Najeh, with a concomitant increase in bean yield [99].

## 5. Assessment of MAP Intercropping in the Mediterranean Basin for Perennial Fruit and Nut and Annual Field Crops

As a sustainable agricultural diversification strategy, intercropping has yet to be widely adopted [37]. From the articles presented, intercropping indigenous MB MAPs with woody perennial fruit and nut crops in the MB is a relatively new field of research, with 70% of the mere 17 peer-reviewed studies published between 2020 and 2023. Similar to woody perennials, published research on MAP intercropping with field crops in the MB is very scarce. Of the 16 articles published, 47% were published between 2020 and 2023.

Despite the scarcity of work, intercropping with MAPs in the MB shows exciting potential for the total of 22 different MAPs native to the MB (Table 6). Intercropping with fenugreek as a legume choice was the most widely reported [62,75,80,81,91,93–99] and was also exclusive to the southern MB (Table 6). Collectively, the publications presented from research conducted in Egypt and Tunisia on annual field crops showed that fenugreek improved LUE in terms of combined yield and economic returns (cash crop + fenugreek (forage biomass or seed essential oils)). Improvements in weed control were also evident, specifically against broomrape for faba bean production (due to the secretion of allelopathic secondary metabolites), but also in general weed control in cereals (based on the biomass of fenugreek). From the studies on grape and cereals, improved soil health (water retention, increased mineral elements and microbial biomass) and cash crop quality was demonstrated. Interestingly, notwithstanding the great abundance of wild populations and local landraces in the MB, fenugreek is a neglected and underutilized species (NUS), despite the inherent potential both to survive in extreme conditions (adaptable to climate change) and to improve the yield of companion crops in intercropping systems through improvements in soil quality [100,101]. An urgent appeal has been made to introduce fenugreek in local agriculture [99]. Moreover, the medicinally important phytochemicals, contained in the leaves and seeds of this NUS MAP are important incentives for more extensive intercropping cultivation [101], especially in European and Middle Eastern MB countries, where to date there is no published information on the use of fenugreek as a legume intercrop choice. Garlic, the second most abundant MAP intercropping choice exclusive to the southern MB (Table 6), was similarly effective in improving LUE and potential economic returns, as well as in both insect pest and broomrape weed control [63,83,87,90,97,98].

**Table 6.** Number of article citations for the types of aromatic and medicinal plants (MAPs) intercropped with various perennial fruit tree crops and annual field crops in counties of the Mediterranean basin.

| MAP Intercrop Common (Scientific) Name, Category | MAP Intercropped with: | Article Citations | Research Countries |
|---|---|---|---|
| Fenugreek (*Trigonella foenum-graecum* L.), Annual legume | Grape, Durum wheat, Triticale, Date palm and Faba bean | 12 [62,75,80,81,91,93–99] | Egypt and Tunisia |
| Garlic (*Allium sativum* L.), Annual bush | Grape, Sugar beet, Lentil and Faba bean | 6 [63,83,87,90,97,98] | Egypt |
| Coriander (*Coriandrum sativum* L.), Herbaceous annual herb | Olive, Sugar beet and Faba bean | 5 [69,84,85,89,91] | Egypt and Morocco |
| Thyme (*Thymus baeticus* L. and *T. hyemalis* Lange), Evergreen perennial shrub | Almond and Olive | 5 [18,39,56,57,73] | Spain, Italy |
| Sweet Basil (*Ocimum basilicum* L.), Herbaceous annual herb | Pomegranate, Apple, Grape Maize and Cotton | 5 [58,59,64,82,86] | Egypt, France and Italy |
| Anise (*Pimpinella anisum* L.), Herbaceous annual herb | Grape, Olive, Lentil and Faba bean | 4 [62,68,87,92] | Egypt and Greece |
| Sage (*Salvia lavandulifolia* L.), Evergreen perennial shrub | Almond, Grape and Olive | 4 [39,64,65,73] | Spain, Italy and Egypt |
| Caper (*Capparis spinosa* L.), Evergreen perennial bush | Almond | 3 [18,56,57] | Spain |
| Lavandin (*Lavandula × intermedia* Emeric ex Loisel.), Evergreen perennial shrub | Olive | 3 [70–72] | Spain |
| Rosemary (*Rosmarinus officinalis* L.), Evergreen perennial shrub | Almond, Pomegranate and Olive | 3 [39,58,72] | Spain and Egypt |
| Black cumin (*Nigella sativa* L.), Herbaceous annual herb | Grape and Lentil | 2 [62,87] | Egypt |
| Dill (*Anethum graveolens* L.), Herbaceous annual herb | Sugar beet | 2 [84,85] | Egypt |
| Fennel (*Foeniculum vulgare* L.), Deciduous perennial herb | Sugar beet | 2 [84,85] | Egypt |
| Marjoram (*Origanum majorana* L.), Herbaceous annual herb | Sugar beet | 2 [84,85] | Egypt |
| Parsley (*Petroselinum sativum* L.), Biennial herb | Grape and Faba bean | 2 [62,97] | Egypt |
| Saffron (*Crocus sativus* L.), Deciduous perennial herb | Olive | 2 [70,71] | Spain |
| Chamomile (*Matricaria recutita* L.), Herbaceous annual herb | Olive | 1 [68] | Greece |
| Lavender (*Lavandula angustifolia*), Evergreen perennial shrub | Olive | 1 [72] | Spain |
| Lemon balm (*Melissa officinalis* L.), bushy perennial herb | Grape | 1 [64] | Italy |
| Lemongrass (*Cymbopogon citratus* L.), Evergreen perennial grass | Olive | 1 [73] | Italy |
| Marigold (*Tagetes patula* L.), Annual bush | Apple | 1 [59] | France |
| Peppermint (*Mentha × piperita* L.), Evergreen perennial herb | Soybean | 1 [88] | Italy |

Exciting prospects were also evident from thyme–almond intercropping. As a perennial evergreen, thyme (with less management input) ensured a better ground cover thereby improving soil properties and reducing erosion, simultaneously increasing LUE and potential economic return from a combined nut-essential oil harvest [18,39,56,57]. Thyme was also shown to improve fauna biodiversity in an olive grove [73]. Given that the secondary metabolite and essential oil content of thyme has pathogen/insecticidal properties [43,44], that are increased under drought stress [41], the bio-control and marketing potential of thyme as a perennial tree intercrop is warrant future study.

Anise, basil, fennel, lemon balm, marigold, marjoram, rosemary and sage are all representative MAPs with pathogen/pest bio-control properties [43,44], for which more studies on intercropping bio-control are warranted. Interestingly, the allelopathic secondary metabolites emitted by basil, sage and lemon balm were also shown to improve the VOCs in neutral ("non-aromatic") grapevine varieties [64,65]. Aside from potential farmer profitability, sustainable environmental benefits of MAP intercropping in the viticulture sector present a new field of study with exciting future prospects [56]. Both sweet basil and coriander are NUS with insect control properties, hardiness to drought and sources of essential oils with high economic value [102,103], thereby also showing potential for exploitation as intercrops in the MB.

The majority of the MAPs have appeared in only one to three published articles, evidencing the scarcity of research on MAP intercropping with perennial fruit and annual field crops (Table 6). Given that the conservation and use of legume and nut species are of increasing national and regional importance in the MB [104], adaption diversification strategies such as intercropping warrant attention in view of climate change impacts. The same is evident for cereal crops, especially as the MB is among the few areas in the world where the climate is suitable for growing durum wheat [20]. Hence, it goes without saying that in these agricultural sectors, more extensive studies are required, not only on the aforementioned crops for sustainable benefits that have not yet been covered, but also in providing a greater representation of different perennial nut and fruit crops, as well as annual field crops, considering the species diversity cultivated in the MB. As an example, the MB (Spain, Türkiye, Egypt, Morocco, Italy, Greece, Israel and France as the highest producers, respectively) collectively contribute 20% of the world citrus production [105], yet there are no reports of intercropping MAPs with citrus crops within the MB.

Other than expanding on studies to cover a greater diversity of perennial and annual crops intercropped with MAPs, there are various additional "must do" research-based avenues requiring attention. Intercropping MAPs with trees and other crops is practiced traditionally in smallholder farming systems, with an existing knowledge base [35,36,38]. This is also evident from numerous sources of information published on the internet, suggesting which MAPs make the best companion plants for various fruit tree crops, for which published scientific knowledge is lagging. Hence, there is a need for a greater contribution of farmer knowledge in research and an exchange of information between farmers and researchers to bridge the gap between traditional knowledge and scientific-based research on MAP intercropping in the MB. Of the MB countries, Egypt is a forerunner in published MAP intercropping research, highlighting the evident collective scarcity of published research from the European and Middle Eastern MB countries. Since climate change impacts on the MB are very heterogeneous, and given the environmental heterogeneity of the MB, more widespread involvement by MB countries in MAP intercropping research is a prerequisite.

An additional "must do" requirement for MAP intercropping studies relates to the economic analysis, necessary for the adoption of MAP intercropping by farmers [37]. Although, all 37 articles showed environmental benefits focusing either singularly or collectively on aspects related to the soil health, weed control and pest control, only 9 articles (all conducted in Egypt) showed that the combined cash crop plus MAP intercrop provided higher monetary economic returns [58,62,63,75,82,83,86,90,95]. A further two articles [98,99] showed increased monetary economic return on the cash crop in fields infested with broomrape where fenugreek and garlic were cultivated with the sole purpose of weed control. Of the aforementioned articles, two presented costs related to the purchase of seed material and necessary cultural practices [62,86]. From research in Spain [18,39,57] and Tunisia [81], economic benefits were inferred (increased combined yields of cash crop + MAP crop) but not presented in monetary terms. Any economic profits can be offset by losses that may be incurred through unpredicted climatic events, increased labor costs when challenges arise in management (need for multiple harvests) and crop competition leading to reduced yields [37]. In a single paper, complete failure of two MAP crops were reported presumably due to abiotic factors [72], whereas unpublished studies similarly showed that rosemary and lavender (intercropped with almond in Spain) and lavender (intercropped with cherry trees in Spain and Greece) did not survive [106,107]. At present, it is not possible to objectively weigh up the benefits of MAP intercropping (weed, pathogen, insect pest control, relative yield and gross profitability) against the risks and barriers (troubleshooting site-specific complexities, climatic factors, challenges of managing multiple cultures and labor costs) [18,37,54]. Such an assessment can only be made once more extensive and long-term studies are made available. However, as a practice, intercropping can help reduce the risk of crop failure by diversifying the range of crops grown in the same field. Intercropping protects against crop failure or unstable market prices for a particular commodity, particularly in areas subject to extreme weather conditions such as frost, drought and flooding. If one crop fails, the other crops can still be harvested. It is especially suited for labor-intensive small farms since it offers more financial security than single-crop farming. The environmental effect of agriculture is minimized by intercropping since it necessitates less inputs in the form of fewer pesticide and fertilizer applications [108]. Moreover, by taking advantage of complementary resource use between different crops, intercropping can lead to higher crop yields. For example, reducing water loss and increasing soil moisture by allowing one crop to provide shade to the other. As growth resources such as water, nutrients, and light are more effectively absorbed and converted into plant biomass by the intercrop throughout time and space, yield advantage is also gained [108]. Overall, intercropping perennial fruit trees, annual field crops, and MAPs in the MB offers numerous benefits, including reduced pests and diseases, enhanced weed control, improved crop yields, elevated nutritional properties, increased mineral content and better soil health (Figure 1).

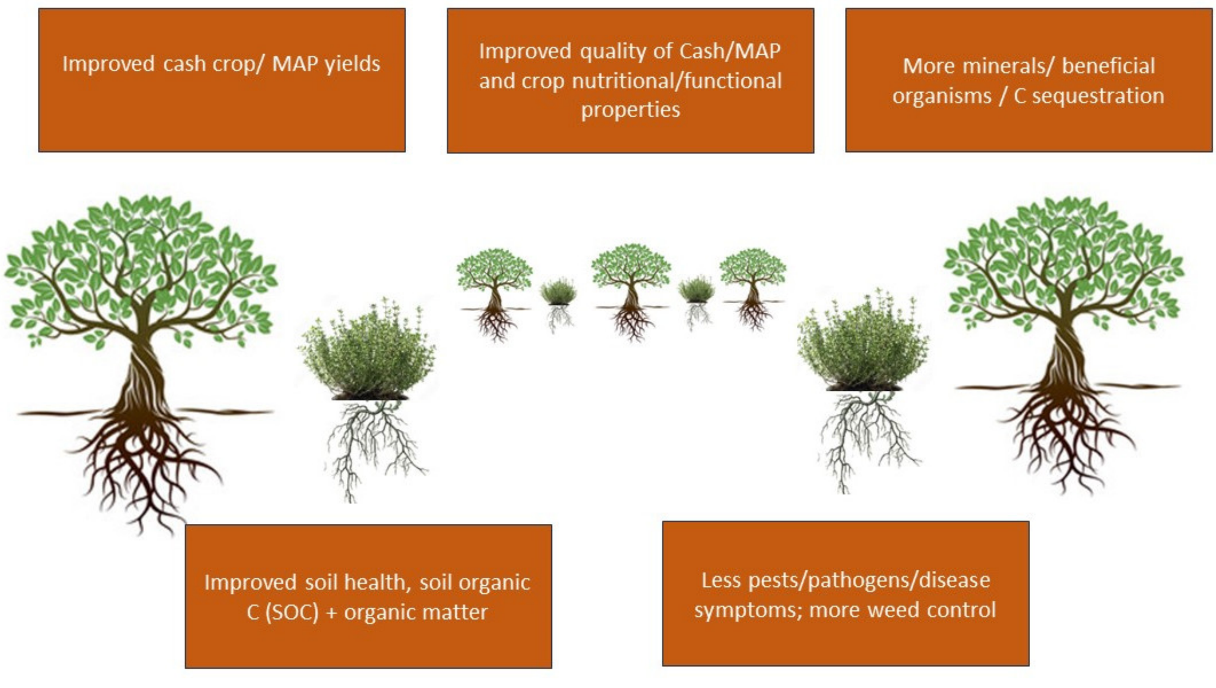


**Figure 1.** Potential benefits of intercropping perennial fruit trees and annual field crops with MAPs in the Mediterranean basin.

Regarding the immediate future, before initiating any study on MAP intercropping, the careful selection of the most appropriate MAPs as a secondary crop must be made, requiring preliminary assessments of local climate, soil conditions, crop nutrient requirements and pest/pathogen incidence [18]. The requisite for a prior in-depth analysis of the local abiotic and biotic conditions has been raised from failed studies [72,106,107]. Although the introduction of unexploited species of MAPs in cultivation schemes is presently receiving attention, the most suitable varieties and the environmental/cultivation practices for optimum yield and quality of MAPs remain largely unknown [109]. Aside from the environmental benefits of MAP cultivation, there is increasing interest in MAPs on the part of industry, agriculture and health sciences due to the significant biological properties of these plants [109], which potentially serve as an alternative source of income for growers.

To conclude, intercropping MAPs with perennial fruit and nut trees as well as annual field crops in the MB shows potential in augmenting yield, pest/pathogen and weed control, soil health and cash crop quality. This integrated approach holds great promise as a sustainable and efficient agricultural strategy in the region. For the successful adoption of MAPs in farming systems in the MB, more research is required to provide an objective analysis of economic profits/losses. Thereafter, collaboration between researchers and farmers will require effective planning to potentially minimize losses.

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## References

1. Giorgi, F. Climate change Hot-Spots. *Geophys. Res. Lett.* **2006**, *33*, L08707. [CrossRef]
2. Cramer, W.; Guiot, J.; Fader, M.; Garrabou, J.; Gattuso, J.-P.; Iglesias, A.; Lange, M.A.; Lionello, P.; Llasat, M.C.; Paz, S.; et al. Climate change and interconnected risks to sustainable development in the Mediterranean. *Nat. Clim. Change* **2018**, *8*, 972–980. [CrossRef]
3. Alrteimei, H.A.; Ash'aari, Z.H.; Muharram, F.M. Last decade assessment of the impacts of regional climate change on crop yield variations in the Mediterranean region. *Agriculture* **2022**, *12*, 1787. [CrossRef]
4. Michaelides, S.; Karacostas, T.; Sánchez, J.L.; Retalis, A.; Pytharoulis, I.; Homar, V.; Romero, R.; Zanis, P.; Giannakopoulos, C.; Bühl, J.; et al. Reviews and perspectives of high impact atmospheric processes in the Mediterranean. *Atmos. Res.* **2018**, *208*, 4–44. [CrossRef]
5. Lange, M.A. Climate Change in the Mediterranean: Environmental Impacts and Extreme Events. IEMed Mediterranean Yearbook 2020. Available online: https://www.iemed.org/publication/climate-change-in-the-mediterranean-environmental-impacts-and-extreme-events/ (accessed on 6 July 2023).
6. Antonelli, M.; Basile, L.; Gagliardi, F.; Isernia, P. The future of the Mediterranean agri-food systems: Trends and perspectives from a Delphi survey. *Land Use Policy* **2022**, *120*, 106263. [CrossRef]
7. Fraga, H.; Moriondo, M.; Leolini, L.; Santos, J.A. Mediterranean olive orchards under climate change: A review of future impacts and adaptation strategies. *Agronomy* **2021**, *11*, 56. [CrossRef]
8. Ferreira, C.S.S.; Seifollahi-Aghmiuni, S.; Destouni, G.; Ghajarnia, N.; Kalantari, Z. Soil degradation in the European Mediterranean region: Processes, status and consequences. *Sci. Total Environ.* **2022**, *805*, 150106. [CrossRef]
9. Caselli, A.; Petacchi, R. Climate change and major pests of Mediterranean olive orchards: Are we ready to face the global heating? *Insects* **2021**, *12*, 802. [CrossRef]
10. Martin-Gorriz, B.; Zabala, J.A.; Sánchez-Navarro, V.; Gallego-Elvira, B.; Martínez-García, V.; Alcon, F.; Maestre-Valero, J.F. Intercropping practices in Mediterranean mandarin orchards from an environmental and economic perspective. *Agriculture* **2022**, *12*, 574. [CrossRef]

11. Ahmed, A.; Elbushra, A.; Elrasheed, M. Implications of climate change on agriculture and food security. In *Cultivation for Climate Change Resilience*; Taylor & Francis Group, LLC.: London, UK; Boca Raton, FL, USA; New York, NY, USA, 2023; pp. 2–27.
12. Dutta, T.K.; Phani, V. The pervasive impact of global climate change on plant-nematode interaction continuum. *Front. Plant Sci.* **2023**, *14*, 1143889. [CrossRef]
13. Sofo, A.; Palese, A.M.; Casacchia, T.; Dichio, B.; Xiloyannis, C. Sustainable fruit production in Mediterranean orchards subjected to drought stress. In *Abiotic Stress Responses in Plants*; Ahmad, P., Prasad, M., Eds.; Springer: New York, NY, USA, 2012; pp. 105–129. [CrossRef]
14. Ames, G.K.; Dufour, R.; NCAT Agriculture Specialists ATTRA Specialists. Climate Change and Perennial Fruit and Nut Production: Investigating Resilience in Uncertain Times. Available online: https://attra.ncat.org/publication/climate-change-perennial-fruit-and-nut-production/ (accessed on 9 May 2023).
15. Ponti, L.; Gutierrez, A.P.; Boggia, A.; Neteler, M. Analysis of grape production in the face of climate change. *Climate* **2018**, *6*, 20. [CrossRef]
16. Santos, J.A.; Fraga, H.; Malheiro, A.C.; Moutinho-Pereira, J.; Dinis, L.-T.; Correia, C.; Moriondo, M.; Leolini, L.; Dibari, C.; Costafreda-Aumedes, S.; et al. A review of the potential climate change impacts and adaptation options for European viticulture. *Appl. Sci.* **2020**, *10*, 3092. [CrossRef]
17. Medda, S.; Fadda, A.; Mulas, M. Influence of climate change on metabolism and biological characteristics in perennial woody fruit crops in the Mediterranean environment. *Horticulturae* **2022**, *8*, 273. [CrossRef]
18. Almagro, M.; Diaz-Pereira, E.; Boix-Fayos, C.; Zornoza, R.; Sánchez-Navarro, V.; Re, P.; Fernández, C.; Martínez-Mena, M. The combination of crop diversification and no tillage enhances key soil quality parameters related to soil functioning without compromising crop yields in a low-input rainfed almond orchard under semiarid Mediterranean conditions. *Agric. Ecosyst. Environ.* **2023**, *345*, 108320. [CrossRef]
19. Ray, D.; Gerber, J.; MacDonald, G.; West, P. Climate variation explains a third of global crop yield variability. *Nat. Commun.* **2015**, *6*, 5989. [CrossRef]
20. Zampieri, M.; Toreti, A.; Ceglar, A.; Naumann, G.; Turco, M.; Tebaldi, C. Climate resilience of the top ten wheat producers in the Mediterranean and the Middle East. *Reg. Environ. Change* **2020**, *20*, 41. [CrossRef]
21. Karkanis, A.; Ntatsi, G.; Lepse, L.; Fernández, J.A.; Vågen, I.M.; Rewald, B.; Alsiņa, I.; Kronberga, A.; Balliu, A.; Olle, M.; et al. Faba Bean cultivation–revealing novel managing practices for more sustainable and competitive European cropping systems. *Front. Plant Sci.* **2018**, *2*, 1115. [CrossRef]
22. Skendžić, S.; Zovko, M.; Živković, I.P.; Lešić, V.; Lemić, D. The Impact of Climate Change on Agricultural Insect Pests. *Insects* **2021**, *12*, 440. [CrossRef]
23. Pérez-Méndez, N.; Miguel-Rojas, C.; Jimenez-Berni, J.A.; Gomez-Candon, D.; Pérez-de-Luque, A.; Fereres, E.; Catala-Forner, M.; Villegas, D.; Sillero, J.C. Plant breeding and management strategies to minimize the impact of water scarcity and biotic stress in cereal crops under Mediterranean conditions. *Agronomy* **2022**, *12*, 75. [CrossRef]
24. Rubiales, D.; Fondevilla, S.; Fernández-Aparicio, M. Development of pea breeding lines with resistance to *Orobanche crenata* Derived from pea landraces and wild *Pisum* spp. *Agronomy* **2021**, *11*, 36. [CrossRef]
25. Gómez, J. Sustainability using cover crops in Mediterranean tree crops, olives and vines–challenges and current knowledge. *Hung. Geogr. Bull.* **2017**, *66*, 13–28. [CrossRef]
26. Morugán-Coronado, A.; Linares Pérez, C.; Gómez-López, M.D.; Faz, Á.; Zornoza, R. The impact of intercropping, tillage and fertilizer type on soil and crop yield in fruit orchards under Mediterranean conditions: A meta-analysis of field studies. *Agric. Syst.* **2020**, *178*, 102736. [CrossRef]
27. Swain, R.; Praveena, J.; Behera, M.; Rout, G.R. Instigating adaptation and mitigation strategies to combat impact of global climate change in fruit crops. In *Cultivation for Climate Change Resilience*; Taylor & Francis Group, LLC.: London, UK; Boca Raton, FL, USA; New York, NY, USA, 2023; pp. 28–67.
28. Sabir, A.; Kucukbasmaci, A.; Taytak, M.; Bilgin, O.F.; Jawshle, A.I.M.; Mohammed, O.J.M.; Gayretli, Y. Sustainable viticulture practices on the face of climate change. *Agric. Res. Technol. Open Access J.* **2018**, *17*, 556033. [CrossRef]
29. van Leeuwen, C.; Destrac-Irvine, A.; Dubernet, M.; Duchêne, E.; Gowdy, M.; Marguerit, E.; Pieri, P.; Parker, A.; de Rességuier, L.; Ollat, N. An update on the impact of climate change in viticulture and potential adaptations. *Agronomy* **2019**, *9*, 514. [CrossRef]
30. Marin, D.; Armengol, J.; Carbonell-Bejarano, P.; Escalona, J.M.; Gramaje, D.; Hernandez-Montesa, E.; Intrigliolo, D.S.; Martínez Zapater, J.M.; Medrano, H.; Mirás-Arevalos, J.M.; et al. Challenges of viticulture adaptation to global change: Tackling the issue from the roots. *Aust. J. Grape Wine Res.* **2021**, *27*, 8–25. [CrossRef]
31. Dinis, L.-T.; Bernardo, S.; Yang, C.; Fraga, H.; Malheiro, A.; Moutinho Pereira, J.; Santos, J. Mediterranean viticulture in the context of climate change. *Ciência Téc. Vitiv.* **2022**, *37*, 139–158. [CrossRef]
32. Di Bene, C.; Dolores Gómez-López, M.; Francaviglia, R.; Farina, R.; Blasi, E.; Martínez-Granados, D.; Calatrava, J. Barriers and opportunities for sustainable farming practices and crop diversification strategies in Mediterranean cereal-based systems. *Front. Environ. Sci.* **2022**, *10*, 861225. [CrossRef]
33. Morugán-Coronado, A.; Pérez-Rodríguez, P.; Insolia, E.; Soto-Gómez, D.; Fernández-Calviño, D.; Zornoza, R. The impact of crop diversification, tillage and fertilization type on soil total microbial, fungal and bacterial abundance: A worldwide meta-analysis of agricultural sites. *Agric. Ecosyst. Environ.* **2022**, *329*, 107867. [CrossRef]

34. Lv, W.; Zhao, X.; Wu, P.; Lv, J.; He, H. A Scientometric analysis of worldwide intercropping research based on web of science database between 1992 and 2020. *Sustainability* **2021**, *13*, 2430. [CrossRef]
35. Bybee-Finley, K.A.; Ryan, M.R. Advancing intercropping research and practices in industrialized agricultural landscapes. *Agriculture* **2018**, *8*, 80. [CrossRef]
36. Maitra, S.; Hossain, A.; Brestic, M.; Skalicky, M.; Ondrisik, P.; Gitari, H.; Brahmachari, K.; Shankar, T.; Bhadra, P.; Palai, J.B.; et al. Intercropping—A low input agricultural strategy for food and environmental security. *Agronomy* **2021**, *11*, 343. [CrossRef]
37. Huss, C.P.; Holmes, K.D.; Blubaugh, C.K. Benefits and risks of intercropping for crop resilience and pest management. *J. Econ. Entomol.* **2022**, *115*, 1350–1362. [CrossRef] [PubMed]
38. Jodha, N.S. Intercropping in traditional farming systems. *J. Dev. Stud.* **1980**, *16*, 427–442. [CrossRef]
39. Hugo, V.; Zuazo, D.; Rocío, C.; Pleguezuelo, R.; Ramón, J.; Martínez, F.; Raya, A.M.; Panadero, L.A.; Cárceles Rodríguez, B.; Concepción, M.; et al. Benefits of plant strips for sustainable mountain agriculture. *Agron. Sustain. Dev.* **2008**, *28*, 497–505. [CrossRef]
40. Carrubba, A.; Scalenghe, R. Scent of Mare Nostrum- Medical and aromatic plants (MAPs) in Mediterranean soils. *J. Sci. Food Agric.* **2012**, *92*, 1150–1170. [CrossRef]
41. Kleinwächter, M.; Selmar, D. New insights explain that drought stress enhances the quality of spice and medicinal plants: Potential applications. *Agron. Sustain. Dev.* **2015**, *35*, 121–131. [CrossRef]
42. Golijan, J.; Markovic, D. The benefits of organic production of medicinal and aromatic plants in intercropping system. *Acta Agric. Serb.* **2018**, *23*, 61–76. [CrossRef]
43. Karkanis, A.C.; Athanassiou, C.G. Natural insecticides from native plants of the Mediterranean Basin and their activity for the control of major insect pests in vegetable crops: Shifting from the past to the future. *J. Pest. Sci.* **2021**, *94*, 187–202. [CrossRef]
44. Maurya, P.; Mazeed, A.; Kumar, D.; Ahmad, I.; Suryavanshi, P. Medicinal and aromatic plants as an emerging source of bioherbicides. *Curr. Sci.* **2022**, *122*, 258–266. [CrossRef]
45. Greff, B.; Sáhó, A.; Lakatos, E.; Varga, L. Biocontrol activity of aromatic and medicinal plants and their bioactive components against soil-borne pathogens. *Plants* **2023**, *12*, 706. [CrossRef]
46. Rawat, N.; Puni, L. Intercropping of medicinal and aromatic plants with vegetable crops–a review. *MFP News* **2009**, *19*, 14–18.
47. Dikir, W. Role of intercropping some aromatic and medicinal plants with fruit vegetables crops, a Review. *Glob. Acad. J. Agric. Biosci.* **2022**, *4*, 22–30. [CrossRef]
48. Rao, S.G.R.; Radhika, R.M. Prospects for sustainable cultivation of medicinal and aromatic plants in India. In *Sustainable Uses and Prospects of Medicinal Plants*; Kambizi, L., Bvenura, C., Eds.; Taylor & Francis Group, LLC.: Boca Raton, FL, USA, 2023; pp. 227–244.
49. Joffre, R.; Rambal, S. Mediterranean Ecosystems. In *Encyclopedia of Life Sciences*; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2001; pp. 1–7. [CrossRef]
50. Ulbrich, U.; Xoplaki, E.; Dobricic, S.; García-Herrera, R.; Lionello, P.; Adani, M.; Baldi, M.; Barriopedro, D.; Coccimiglio, P.; Dalu, G.; et al. Past and current climate changes in the Mediterranean region. In *Regional Assessment of Climate Change in the Mediterranean. Volume 1: Air, Sea and Precipitation and Water*; Navarra, A., Tubiana, L., Eds.; Springer Nature: London, UK, 2013; pp. 9–51. [CrossRef]
51. New, M.; Hulme, M.; Jones, P. Representing twentieth-century space–time climate variability. Part II: Development of 1901–96 monthly grids of terrestrial surface climate. *J. Clim.* **2000**, *13*, 2217–2238. [CrossRef]
52. Beck, H.; Zimmermann, N.; McVicar, T.; Vergopolan, N.; Berg, A.; Wood, E.F. Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Sci. Data* **2018**, *5*, 180214. [CrossRef]
53. McKinsey Global Institute. A Mediterranean Basin without a Mediterranean Climate? A Case Study. 2020. Available online: https://www.mckinsey.com/capabilities/sustainability/our-insights/a-mediterranean-basin-without-a-mediterranean-climate (accessed on 6 July 2023).
54. Fernandez, E.; Mojahid, H.; Fadón, E.; Rodrigo, J.; Ruiz, D.; Egea, J.A.; Ben, M.M.; Kodad, O.; El Yaacoubi, A.; Ghrab, M.; et al. Climate change impacts on winter chill in Mediterranean temperate fruit orchards. *Reg. Environ. Change* **2023**, *23*, 7. [CrossRef]
55. World Population Review. 2023. Available online: https://worldpopulationreview.com/country-rankings/almond-production-by-country (accessed on 12 May 2023).
56. Martínez-Mena, M.; Boix-Fayos, C.; Carrillo-López, E.; Díaz-Pereira, E.; Zornoza, R.; Sánchez-Navarro, V.; Acosta, J.A.; Martínez-Martínez, S.; Almagro, M. Short-term impact of crop diversification on soil carbon fluxes and balance in rainfed and irrigated woody cropping systems under semiarid Mediterranean conditions. *Plant Soil* **2021**, *467*, 499–514. [CrossRef]
57. Sánchez-Navarro, V.; Shahrokh, V.; Martínez-Martínez, S.; Acosta, J.; Almagro, M.; Martínez-Mena, M.; Boix-Fayos, C.; Diaz-Pereira, E.; Zornoza, R. Perennial alley cropping contributes to decrease soil $CO_2$ and $N_2O$ emissions and increase soil carbon sequestration in a Mediterranean almond orchard. *Sci. Total Environ.* **2022**, *845*, 157225. [CrossRef]
58. Elmasry, S.; Abdelfatah, A.; Abdelkader, M. Response of productivity and competitive indices of pomegranate trees and sweet basil and rosemary to different intercropping systems. *Int. J. Environ.* **2019**, *8*, 1–11.
59. Laffon, L.; Bischoff, A.; Gautier, H.; Gilles, F.; Gomez, L.; Lescourret, F.; Franck, P. Conservation biological control of codling moth (*Cydia pomonella*): Effects of two aromatic plants, basil (*Ocimum basilicum*) and French marigolds (*Tagetes patula*). *Insects* **2022**, *13*, 908. [CrossRef]

60. FAOSTAT. Crops and Livestock Products. Countries–Select All; Regions–World + (Total); Elements–Production Quantity; Items–Grapes; Years–2020. Available online: https://www.fao.org/faostat/en/#data/QCL (accessed on 30 April 2023).
61. Dittrich, F.; Iserloh, T.; Treseler, C.-H.; Hüppi, R.; Ogan, S.; Seeger, M.; Thiele-Bruhn, S. Crop diversification in viticulture with aromatic plants: Effects of intercropping on grapevine productivity in a steep-slope vineyard in the Mosel area, Germany. *Agriculture* **2021**, *11*, 95. [CrossRef]
62. Belal, B.; El Kenawy, M.; Ismail, S.; El-Hameed, A. Effect of intercropping of Thompson seedless grapevines with some medicinal plants on vine nutritional status, yield, berry quality and the microbiological activity of the soil. *J. Plant Prod.* **2017**, *8*, 495–501. [CrossRef]
63. Mohsen, F.; Elashry, R.; Zyada, H.; El-akhrasy, R.M. Evaluation the effect of intercropping garlic with grapevines on productivity, phytoremediation, competitive indices and plant parasitic nematode community. *J. Plant Prod.* **2021**, *12*, 407–414. [CrossRef]
64. Mota-Segantini, D.; Lombini, A.; Rodríguez Declet, A.; De Giorgio, R.; D'Onofrio, C.; Rombolà, A.D. Effects of intercropping medicinal and aromatic plants (MAPs) on grapevine cv. Sangiovese berry volatile compounds. *Agroecol. Sustain. Food Syst.* **2022**, *46*, 452–462. [CrossRef]
65. Rodríguez-Declet, A.; Castro-Marín, A.; Lombini, A.; Sevindik, O.; Selli, S.; Chinnici, F.; Rombolà, A.D. Characterization of berry aromatic profile of cv. Trebbiano Romagnolo grapes and effects of intercropping with *Salvia officinalis* L. *Agronomy* **2022**, *12*, 344. [CrossRef]
66. World Population Review. 2023. Available online: https://worldpopulationreview.com/country-rankings/olive-oil-production-by-country (accessed on 12 May 2023).
67. Tziolas, E.; Ispikoudis, S.; Mantzanas, K.; Koutsoulis, D.; Pantera, A. Economic and environmental assessment of olive agroforestry practices in northern Greece. *Agriculture* **2022**, *12*, 851. [CrossRef]
68. Katsoulis, G.I.; Kimbaris, A.C.; Anastasaki, E.; Damalas, C.A.; Kyriazopoulos, A.P. Chamomile and anise cultivation in olive agroforestry systems. *Forests* **2022**, *13*, 128. [CrossRef]
69. Razouk, R.; Daoui, K.; Ramdani, R.; Chergaoui, A. Optimal distance between olive trees and annual crops in rainfed intercropping system in northern Morocco. *JOCSR* **2016**, *1*, 23–32.
70. Aguilera-Huertas, J.; Lozano-García, B.; González-Rosado, M.; Parras-Alcántara, L. Effects of management and hillside position on soil organic carbon stratification in Mediterranean centenary olive grove. *Agronomy* **2021**, *11*, 650. [CrossRef]
71. González-Rosado, M.; Parras-Alcántara, L.; Aguilera-Huertas, J.; Lozano-García, B. Crop diversification effects on soil aggregation and aggregate-associated carbon and nitrogen in short-term rainfed olive groves under semiarid Mediterranean conditions. *Horticulturae* **2022**, *8*, 618. [CrossRef]
72. Moreno-Delafuente, A.; Antón, O.; Bienes, R.; Borrego, A.; Cuevas, A.; García-Díaz, A.; Sastre, B. Introduction of aromatic plants and beehives to enhance ecosystem services in traditional olive orchards. *Acta Hortic.* **2022**, *1355*, 55–62. [CrossRef]
73. Las Casas, G.; Ciaccia, C.; Iovino, V.; Ferlito, F.; Torrisi, B.; Lodolini, E.M.; Giuffrida, A.; Catania, R.; Nicolosi, E.; Bella, S. Effects of different inter-row soil management and intra-row living mulch on spontaneous flora, beneficial insects, and growth of young olive trees in southern Italy. *Plants* **2022**, *11*, 545. [CrossRef]
74. Statistica. 2023. Harvested Area of Dates Worldwide. Available online: https://www.statista.com/statistics/960426/harvested-area-of-dates-by-leading-country-worldwide/ (accessed on 15 April 2023).
75. Nagwa, R.A.; Ahmed, F.F.; Hamad, A.S.A. Physiological studies on intercropping of some legumes on Sewy date palms. *World Rural Observ.* **2014**, *6*, 81–88.
76. Mefleh, M. Cereals of the Mediterranean region: Their origin, breeding history and grain quality Traits. In *Cereal-Based Foodstuffs: The Backbone of Mediterranean Cuisine*; Boukid, F., Ed.; Springer: Cham, Switzerland, 2021; pp. 1–18. [CrossRef]
77. Kakabouki, I.; Tataridas, A.; Mavroeidis, A.; Kousta, A.; Roussis, I.; Katsenios, N.; Efthimiadou, A.; Papastylianou, P. Introduction of alternative crops in the Mediterranean to satisfy EU Green Deal goals. A review. *Agron. Sustain. Dev.* **2021**, *41*, 71. [CrossRef]
78. Martinelli, F.; Vollheyde, A.-L.; Cebrián-Piqueras, M.A.; von Haaren, C.; Lorenzetti, E.; Barberi, P.; Loreto, F.; Piergiovanni, A.R.; Totev, V.V.; Bedini, A.; et al. LEGU-MED: Developing biodiversity-based agriculture with legume cropping systems in the Mediterranean basin. *Agronomy* **2022**, *12*, 132. [CrossRef]
79. Martineau-Côté, D.; Achouri, A.; Karboune, S.; L'Hocine, L. Faba Bean: An untapped source of quality plant proteins and bioactives. *Nutrients* **2022**, *14*, 1541. [CrossRef]
80. Toukabri, W.; Ferchichi, N.; Hlel, D.; Jadlaoui, M.; Kheriji, O.; Zribi, F.; Taamalli, W.; Mhamdi, R.; Trabelsi, D. Improvements of durum wheat main crop in weed control, productivity and grain quality through the inclusion of fenugreek and clover as companion plants: Effect of N fertilization regime. *Agronomy* **2021**, *11*, 78. [CrossRef]
81. Kchaou, R.; Benyoussef, S.; Jebari, S.; Harbaoui, K.; Berndtsson, R. Forage potential of cereal–legume mixtures as an adaptive climate change strategy under low input systems. *Sustainability* **2023**, *15*, 338. [CrossRef]
82. Lamlom, M.M.; Hafez, Y.A.M. Evaluation of some maize cultivars under different intercropping patterns with basil. *J. Product. Dev.* **2018**, *23*, 253–259. [CrossRef]
83. Badawy, S.; Shalaby, G. Effect of intercropping of sugarbeet with onion and garlic on insect infestation, sugar beet yield and economics. *J. Plant Prod.* **2015**, *6*, 903–914. [CrossRef]
84. Khafagy, I.F.; Samy, M.A.; Hamza, A.M. Intercropping of some aromatic plants with sugar beet, its effects on the tortoise beetle *Cassida vittata* Vill. infestation, appearance predators and sugar beet yield. *J. Plant Prot. Pathol.* **2020**, *11*, 103–110. [CrossRef]

85. Khafagy, I.F.; Abd El-Aty, H.S.; Ramadan, G.M. Impact of aromatic plants intercropped with sugar beet on infestation by cotton leafworm, sugar beet fly and associated predators. *Egypt. J. Plant Prot. Res. Inst.* **2022**, *5*, 40–46.
86. Schader, C.; Zaller, J.G.; Köpke, U. Cotton-basil intercropping: Effects on pests, yields and economical parameters in an organic field in Fayoum, Egypt. *Biol. Agric. Hortic.* **2005**, *23*, 59–72. [CrossRef]
87. Abdel-Monaim, M.F.; Abo-Elyousr, K.A.M. Effect of preceding and intercropping crops on suppression of lentil damping-off and root rot disease in New Valley–Egypt. *Crop Prot.* **2012**, *32*, 41–46. [CrossRef]
88. Maffei, M.; Mucciarelli, M. Essential oil yield in peppermint/soybean strip intercropping. *Field Crops Res.* **2003**, *84*, 229–240. [CrossRef]
89. Rizk, A.M. Effect of strip-management on the population of the aphid, *aphis craccivora* koch and its associated predators by intercropping faba bean, *Vicia faba* L. with coriander, *Coriandrum sativum* L. *Egypt. J. Biol. Pest Control.* **2011**, *21*, 81–87.
90. El-Shamy, M.A.; Abd El-Aty, H.S. Effect of intercropping between garlic and faba bean on yield and infestation by some piercing-sucking insect pests. *J. Plant Prot. Pathol.* **2021**, *12*, 663–670. [CrossRef]
91. Abdullah, S.; Fouad, H.A. Effect of intercropping agroecosystem on the population of black legume aphid, *Aphis craccivora* Koch and yield of faba bean crop. *J. Entomol. Zool.* **2016**, *4*, 1367–1371.
92. Hassan, H.M.S.; Abou El-kasem, S.A.A.; El-kassas, M.S.A. Influence of intercropping system, water intervals and their interaction on growth, yield, and some competitive indices of broad bean and anise plants. *Plant Arch.* **2021**, *21*, 1240–1256. [CrossRef]
93. Fernández-Aparicio, M.; Emeran, A.A.; Rubiales, D. Control of *Orobanche crenata* in legumes intercropped with fenugreek (*Trigonella foenum-graecum*). *Crop Prot.* **2008**, *27*, 653–659. [CrossRef]
94. Zeid, M.; Komeil, D. Same-hill intercropping of different plant species with faba bean for control of *Orobanche Crenata*. *Alex. Sci. Exch.* **2019**, *40*, 228–238. [CrossRef]
95. Abdel-Wahab, S.; Abdel-Wahab, E. Cropping systems of fenugreek with faba bean to reduce broomrape infestation. *Legum. Res.* **2021**, *44*, 579–592. [CrossRef]
96. Ghalwash, A.; Gharib, H.; Khaffagy, A. Integrated broomrape (*Orobanche crenata* Forsk.) control in faba bean (*Vicia faba* L.) with nitrogen fertilizer, intercropping and herbicides. *Egypt. J. Agron.* **2012**, *34*, 301–319. [CrossRef]
97. EL-Sherbeni, A.; Hamed, S.; Khaffagy, A.; ELkmash, R. Effect of cultivars, intercropping and glyphosate herbicide on broomrape (*Orobanche crenata* Forsk) and faba bean productivity. *Arch. Agric. Sci. J.* **2021**, *4*, 235–250. [CrossRef]
98. El-Mehy, A.A.; El-Gendy, H.M.; Aioub, A.A.A.; Mahmoud, S.F.; Abdel-Gawad, S.; Elesawy, A.E.; Elnahal, A.S.M. Response of faba bean to intercropping, biological and chemical control against broomrape and root rot diseases. *Saudi J. Biol. Sci.* **2022**, *29*, 3482–3493. [CrossRef]
99. Abbes, Z.; Trabelsi, I.; Kharrat, M.; Amri, M. Intercropping with fenugreek (*Trigonella foenum-graecum*) enhanced seed yield and reduced *Orobanche foetida* infestation in faba bean (*Vicia faba*). *Biol. Agric. Hortic.* **2019**, *35*, 238–247. [CrossRef]
100. Mikić, A. Brief but alarming reminder about the need for reintroducing 'Greek hay' (*Trigonella foenum-graecum* L.) in Mediterranean agricultures. *Genet. Resour. Crop. Evol.* **2015**, *62*, 951–958. [CrossRef]
101. Ayilara, M.; Abberton, M.; Oyatomi, O.; Odeyemi, O.; Babalola, O. Potentials of underutilized legumes in food security. *Front. Soil Sci.* **2022**, *2*, 1020193. [CrossRef]
102. Kalamartzis, I.; Dordas, C.; Georgiou, P.; Menexes, G. The use of appropriate cultivar of basil (*Ocimum basilicum*) can increase water use efficiency under water stress. *Agronomy* **2020**, *10*, 70. [CrossRef]
103. Kassahun, B. Unleashing the exploitation of coriander (*Coriander sativum* L.) for biological, industrial and pharmaceutical applications. *Int. J. Agric. Sustain.* **2020**, *8*, 552–564. [CrossRef]
104. Hernández-López, I.; Ortiz-Solà, J.; Alamprese, C.; Barros, L.; Shelef, O.; Basheer, L.; Rivera, A.; Abadias, M.; Aguiló-Aguayo, I. Valorization of local legumes and nuts as key components of the Mediterranean diet. *Foods* **2022**, *11*, 3858. [CrossRef]
105. Duru, S.; Hayran, S.; Gul, A. The analysis of competitiveness of Mediterranean countries in the world citrus trade. *Mediterr. Agric. Sci.* **2022**, *35*, 21–26. [CrossRef]
106. Losada, M.R.M.; Domínguez, N.F.; Fernández Lorenzo, J.L.; Hernández, P.G.; Rigueiro Rodríguez, A. Lessons Learnt: Medicinal Plants in Silvoarable Systems Galicia, Spain. AGFORWARD (613520) Project. Available online: https://www.agforward.eu/documents/LessonsLearnt/WP4_ES_Medicinal_plants_lessons-learnt.pdf (accessed on 20 April 2023).
107. Mantzanas, K.; Papanastasis, V.; Pantera, A.; Papadopoulos, A. Lessons Learnt. Silvoarable AGROFORESTRY Systems in Greece. AGFORWARD (613520) Project. Available online: https://www.agforward.eu/documents/LessonsLearnt/WP4%20GR_Silvoarable_lessons_learnt.pdf (accessed on 20 April 2023).
108. Lithourgidis, A.S.; Dordas, C.A.; Damalas, C.A.; Vlachostergios, D. Annual intercrops: An alternative pathway for sustainable agriculture. *Aust. J. Crop Sci.* **2011**, *5*, 396–410.
109. Chrysargyris, A.; Skaltsa, H.; Konstantopoulou, M. Medicinal and aromatic plants (MAPs): The connection between cultivation practices and biological properties. *Agronomy* **2022**, *12*, 3108. [CrossRef]


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