PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

The PRIMA programme is supported and funded under Horizon 2020, the Framework European Union's Programme for Research and Innovation

VAL MED ALM

Deliverable Number D.2.3

Report on the impact of intercropping practices implemented in demo sites towards pest and weed management

VALMEDALM: Valorization of **Med**iterranean **Alm**ond orchards through the use of intercropping integrated strategies

Università degli Studi di Palermo
University of Split
Université Sultan Moulay Slimane
Institut National de la Recherche Agronomique
mountains of research
VOLCANI INSTITUTE Agricultural Research Organization
ipb Instituto Politécnico de Bragança
CNCFS

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Document information

Deliverable Number:	2.3
Deliverable name:	Report on the impact intercropping practices implemented in demo sites towards pest and weed management
Contributing WP:	WP2
Contractual delivery date:	M48, May 2026
Actual delivery date	31/05/2026
Dissemination level	Confidential
Responsible partner:	ARO
Reviewers	All partners
Version:	1

1. Executive Summary

The objective of working package number 2 (WP2) was divided into two objectives. The first objective was to "establish a database of main pests affecting almond orchards in Mediterranean regions" – this was covered by D.2.1. The second objective of WP2 is to "evaluate the impact of intercropping practices in almond orchards pest and weed management". This objective is covered by deliverable D.2.2.

The Deliverable D2.3 aims to " Report on the impact intercropping practices implemented in demo sites towards pest and weed management". VALMEDALM aims to study intercropping systems in almond orchards as a potential alternative to the common practice of almond monocultures. Our attempts to collect information and insights regarding the impact of intercropping systems on weed and pest control spanned the four years of this cooperative research, and insights were gained in each field, with the multi-parameter, country-specific conditions of each country. For instance, the ARO research station focused on weed control, using cover crops intercropped along the almond tree row. The ARO research team has established an experimental setup that aimed at studying how fertigation may compensate for the disadvantage of understory annuals as competitors for nutrients and water. The cover crops on the tree row were correlated with a significant reduction in kernel yield. Compensation by improved fertigation did not improve the yield substantially, presumably due to the legacy of tree development in the establishment years. On the positive aspect, cover crops supported biodiversity.

2. Pest and weed management in the intercropping demo sites

2.1 Insights from pest and weed management reported by UNIPA, Italy

The Italian demo site has been managed under organic farming practices for several years prior to the start of the project. The key pests are typically aphids affecting young shoots, for which treatments permitted under EU organic regulations are applied when necessary. For these reasons, monitoring activities focused primarily on the impact of intercropping on weed and arthropod biodiversity. Soil Biological Quality (SQB) was assessed through soil samplings conducted before sowing (November 3, 2023), and in spring in both subsequent years (April 10, 2024, and May 10, 2025).

As a result, the use of *Medicago* spp. as cover crops appeared to promote taxa of higher ecological value in both years. At the same time, SQB values declined in 2024 and 2025 relative to the 2023 baseline, likely reflecting a temporary disturbance associated with management practices, with early signs of recovery already visible within the first year.

Finally, preliminary data have been collected on wild bees occurring on the cover crops, indicating an overall increase in biodiversity compared with the farmer's usual soil management practices, which consist of repeated shallow tillage aimed at eliminating spontaneous herbaceous cover. In particular, wild bees belonging to the genera *Osmia*, *Seladonia*, *Eucera*, *Halictus* and *Andrena* were recorded, indicating a clear positive effect of the flowering cover crops.

Although none of the tested intercropping systems achieved complete weed control (such as that obtained through tillage in the control plots), a clear weed-suppression effect was recognizable in both intercropping systems from the second cultivation year, following the full establishment of the legume cover crops. This effect was particularly evident in *Sulla*, where a substantial increase in forage biomass was accompanied by a reduction in weed incidence (expressed as a percentage of total biomass) from the first to the second year. The relatively higher weed biomass observed in Sulla plots in 2024 may reflect slower canopy closure than in *Medicago* plots. These findings are consistent with previous reports indicating that perennial or biennial legumes establish more gradually but may later outperform annual species under Mediterranean climatic conditions. They also underscore the importance of species-specific growth dynamics in determining competitive interactions with the understory.

2.2 Insights from pest and weed management reported by USMS, Morocco

The USMS demonstration site consisted of an Almond-leguminous crop association trial, conducted in an experimental field in Ain Taoujdate region. The trial involved associating almond trees with fava bean and lentil cultivations. Fava bean treatment involved planting seven lines that are sown from each side of almond trees, while lentil treatment involved planting nine lines that are sown from each side of almond trees. The two leguminous crops were sown at the same time. The trial consisted of three replicates for each species cultivated with almond trees. Main investigations concerned the impact of intercropping on pest, disease and weed management. The main objectives were to explore and to examine the impact of intercrop practice in pest, disease and weed management under the agro-ecosystem environment of the Ain-Taoujdate site.

First, pest (*Aphid* and *Bruchus*) and diseases (*Botrytis* and *Anthracnose*) symptoms and infestation levels were recorded on Fava bean and Lentil during the growing season. For Fava bean, *Aphid*, *Bruchus*, *Botrytis* and *Anthracnose* were recorded as less severe, with a lower number of infested plants in intercropping than in monoculture. For lentil, *Aphid* and *Anthrachnose* were estimated to be similar for both intercropping and monoculture systems. However, *Bruchus* and *Botrytis* infestations were visually assessed as being lower infested plants observed in the intercropping system than in monoculture. Second, botanical quadras were performed to determine weed species and evaluate weed abundance by counting the different species of weeds and weighing them above ground biomass in spring. Our findings indicate that, belonging to 9 different species, 201 weeds were counted in 3 random square meters in fava bean intercrop and 207 weeds were counted in another 3 random square meters in lentil intercrop. Thus, belonging to 10 different species, the results showed that 166 weeds were counted in 3 random square meters in fava bean monoculture and 180 weeds were counted in another 3 random square meters in lentil monoculture. Furthermore, the average of weeds per square meter was calculated to be 68 for intercrops and 58 for monocultures. In terms of drying weight, 50.35 g and 97.96 g were the average of weeds in intercrops and monocultures, respectively. Data collected showed that an overall decrease in weed weight in intercropping system compared to the monoculture system for both leguminous species, fava bean and lentil. As a result, it was determined that weeds were 1.18 times more numerous in the intercropping system than in the control system but weighed 1.96 times less.

According to the overall results obtained, a positive effect of intercropping practices appears on pest, disease and weed management in the intercropping system with a reduced incidence for pest and diseases. The results highlighted that intercropping leguminous crops may be qualified as good agroecological practice in almond orchard, which promote biodiversity thereby reduce incidence of pest and diseases that can cause significant damage to fava bean and lentil crops like a decreased plant growth and crop yield. Interestingly, intercropping practice stand for a promising strategy to reduce environmental impacts.

2.3 Insights from pest and weed management reported by ARO, Israel

The ARO demonstration site focused on weed management by constructing a two-factorial field experiment. The two factors were two levels of fertigation and two weed-control regimes in the tree row: winter cover crops and no vegetation, controlled with herbicides. The results of the experiment are summarized in publications authored by Mrs. Roza Belayneh as part of her PhD studies. While the cover crops (CC) improved biological soil quality, as measured by QBS-ar and other methods, the kernel yield was reduced in almonds treated with CCs. The impact of weeds on almonds is summarized in a manuscript that has now been peer-reviewed for publication. The title of the paper is:

"Impact of Tree Row Cover Crops on Almond Tree Physiology, Productivity, and Resource Efficiency". Briefly, the abstract suggests the following.

This study evaluated the agronomic and environmental viability of extending winter CC into the tree row with a vegetation-free tree row (NCC) in a commercial almond orchard. We monitored soil water storage (SWS) and mineral nitrogen (N) dynamics to a depth of 90 cm, alongside tree physiological status, including stem water potential, stomatal conductance, and maximum daily trunk shrinkage. Results demonstrate that CCs provide a critical ecosystem service by reducing the risk of groundwater pollution. Compared to NCC, which leached up to 114 kg N ha^{-1}, CCs reduced nitrate leaching by 54% in 2023 and 41% in 2024. However, this environmental benefit was offset by a biphasic hydraulic interaction. During spring, CCs acted as a water sink, depleting SWS and inducing tree stress. Conversely, CC residues improved summer water conservation and reduced tree stress compared to NCC plots. Despite improved summer conditions, spring resource competition imposed a structural penalty, reducing total kernel yield by 31–45%. While CCs significantly enhanced kernel quality (protein and weight), these gains did not compensate for the yield gap under current market premiums. Our findings highlight that while tree-row CCs effectively enhance soil N retention, their commercial viability depends on decoupling early-season competition. Optimizing CC termination timing – specifically prior to rapid vegetative growth in trees – and adaptive irrigation are essential for balancing environmental integrity with stable almond production in Mediterranean climates.

2.4 Insights from pest and weed management reported by CNCFS, Portugal

In the Portuguese experimental fields, the assessment of arthropod diversity in the almond tree canopy was carried out to evaluate the trophic relationships established within the orchards under different soil management systems (chickpea cover crop, clover cover crop, and tillage) and water regimes (non-irrigated and irrigated).
Sampling was conducted every two weeks from May to September, between 2022 and 2024. Arthropods were sampled using the branch beating method, with six branch beatings performed per tree and per treatment to assess the arthropod fauna. In addition, 20 leaves were collected from each tree to monitor the populations of *Monosteira unicostata* (Hemiptera: Tingidae), *Panonychus ulmi* (Acari: Tetranychidae), and *Tetranychus urticae* (Acari: Tetranychidae). In the laboratory, all specimens were counted and identified to order and family level for beneficial arthropods, and to species level for pest species.

Monitoring of *M. unicostata* showed a higher abundance of eggs during June and July in the irrigated almond orchard, particularly under the clover treatment. However, the abundance of nymphs and adults decreased sharply, suggesting that eggs hatching were limited. These results indicate the occurrence of factors that may have delayed the normal reproduction and development of this pest. Meteorological conditions, particularly high temperatures, can affect the life cycle of *M. unicostata* and contribute to population decline. During the spring and summer periods of the project, episodes of very high temperatures were recorded, which may have contributed to the reduction of *M. unicostata* populations.

Regarding mites, *T. urticae* showed the highest population levels in both almond orchards, with a population peak recorded in mid-August under the chickpea treatment. Individuals of *P. ulmi* were also observed; however, their frequency was considerably lower than that of *T. urticae* in both orchards and across the different treatments.

With regard to the arthropods captured, greater abundance was observed in the irrigated almond orchard, particularly under the chickpea treatment. In both almond orchards, Hymenoptera was the most abundant order, being particularly representative under the clover treatment. Araneae was the second most abundant arthropod group in both orchards; however, the highest number of individuals was recorded in the non-irrigated almond orchard, especially under the tillage treatment.

In addition, individuals belonging to predatory groups that form part of the beneficial fauna were also recorded, including Neuroptera, Coleoptera (Coccinellidae and Carabidae), Dermaptera, and Heteroptera (Anthocoridae and Miridae).

2.5 Insights from pest and weed management reported by UNIST, Croatia

After monitoring the occurrence of diseases and pests in intensive almond plantations area of Central Dalmatia during several growing seasons problems in protection against certain fungal diseases and pests. From the cause of fungal diseases, we note the occurrence of flower burning and drying of saplings (*Monilinia* spp.), leaf spotting (*Stigmina carpophila* (Lev.) M.B.Ellis), orange leaf spots (*Polystigma fulvum* Pers.ex DC.), rust (*Tranzschelia discolor Tranzschel* & M.A.Litv.), leaf curl (*Taphrina deformans* (Berk.) Tul.), anthracnose (*Collletotrichum acutatum* J.H. Simmonds – see Figure 1) and mainly drying buds and shoots of *Diaporthe amygdali* [(Delacr.) Udayanga, Crous & K. D. Hyde]. Among the pests, there are stronger attacks of the flower-eaters of the bajam (*Anthonomus amygdali* Hustache, 1930), thrips (*Taeniothrips meridionalis* Priesner, 1926) and hairy rose (*Tropinota hirta* Poda, 1761). During July and August, a strong attack of mites (*Tetranychus* spp. and *Panonychus* spp.) was also recorded. Basic the problem in protecting intensive almond plantations is the lack of registered ones means for plant protection.

During 2023 the assesment of the occurence and intensity of attacks of harmfull organisms has been conducted at demo site of almond plantation (*Prunus dulcis* Mill.) in the organic production system. Subcultures were planted in the inter-row area of almond plantations: artichoke (*Cynara scolymus* L.), sage (*Salvia officinalis* L.), lavender (*Lavandula angustifolia* Mill.), rosemary (*Salvia rosmarinus* Spenn.), immortelle (*Helichrysum italicum* Roth.G.Don.Fill.). During the first inspection of the plantations (21 of March 2023) the most sensitive variety in the infection was Ferraduel, then Ferragnes, and no symptoms of infection were observed on the varieties of Texas and Ai (Table 1). Fairyme anthrox (*C. acutatum* J.H.Simmonds) was observed on Ferraduel (5%) and Ferragnes (3%) varieties. Almond leaf cavity (*Stigmina carpophillia* (Lev.) M.B.Ellis.) was also observed exclusively on the varieties Ferraduel (2%) and Ferragnes (3%). The second inspection of the plantations was at 06 of July 2023, when the infection of the varieties Ferraduel and Ferragnes from anthrax (*C. acutatum*) and bajama leaf cavity (*S. carpophillia*). The intensity of anthrax infection on the Ferraduel variety was 7%, on the Ferragnes variety 4%. Almond leaf cavity disease (*S. carpophillia*) was found to a greater extent on the Ferragnes variety (8%), and less on the Ferraduel variety (5%) (Table 2). Symptoms of seizures of harmful organisms were not observed on the Texas and Ai varieties during both examinations. The most effective subculture in prevention from the occurrence of harmful walnuts and almond disease has been shown to lavender (*Lavandula angustifolia* Mill.).

Table 1. Assessment of the presence and intensity of infestation of harmful organisms (21.03.2023).

Hermfull organism	%infected of trees	% infecter of branches
C. acutatum	Ferraduel 5% Ferragnes 3%	Ferraduel 50% Ferragnes 30%
S. carpophillia	Ferraduel 2% Ferragnes 3%	Ferraduel 20% Ferragnes 30%

Table 2. Assesment of the presence and intensity of infestation of harmful organisms (06.07.2023).

Hermfull organism	%infected of trees	% infecter of branches
C. acutatum	Ferraduel 7% Ferragnes 4%	Ferraduel 70% Ferragnes 40%
S. carpophillia	Ferraduel 5% Ferragnes 8%	Ferraduel 50% Ferragnes 80%

C. acutatum and *S. carpophila* were most common almond diseases. Cultivars Ferraduel and Ferragnez are most susceptible (no infestation was recorded on Texas and Ai cultivars) cultivars. Intercrops shows some difference between infestation of *C. acutatum* and *S. carpophila*. No infected trees were recorded in the plots intrecropped with lavandula, rosmarinus and artichok (Figure 2).

Figure 1. *Collletotrichum acutatum* symptoms on almond fruits.

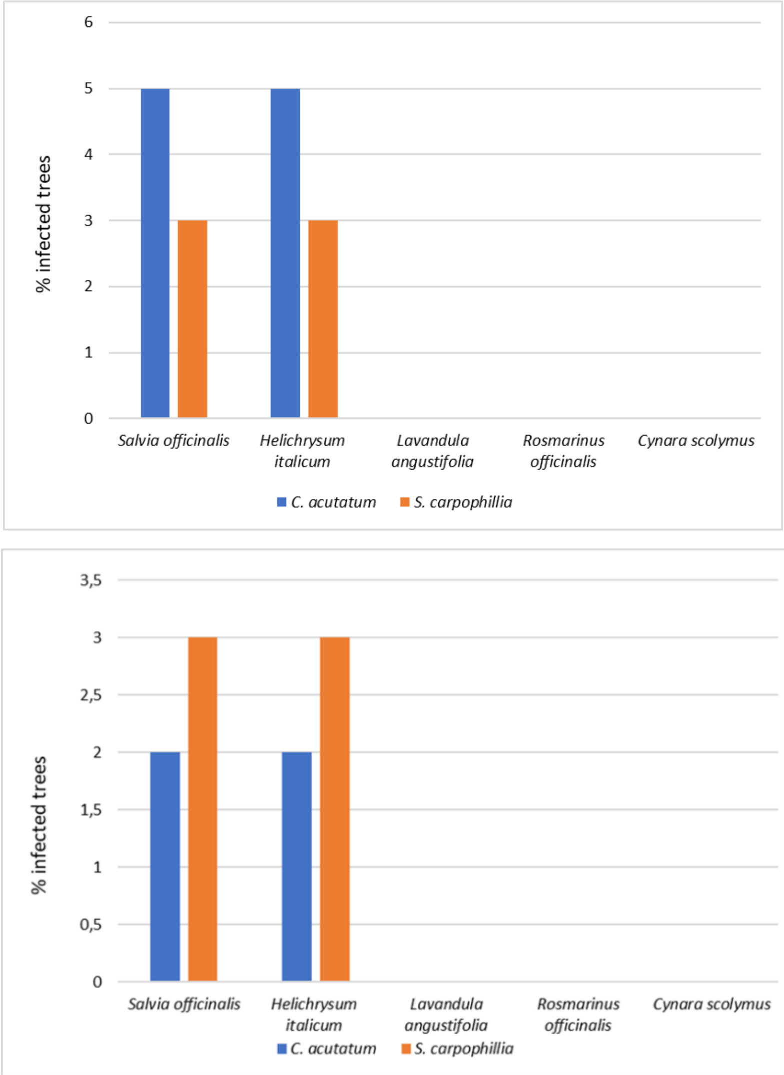


Figure 2. Percentage of Ferraduel and Ferragnez infestation by *C. acutatum* and *S. carpophila*.

Furthermore, we asses the effect of lavender and immortelle essential oils for supression of almond pathogens in laboratory conditions.

A preliminary study of the effect of lavender and immortelle essential oils on the development of selected fungal pathogens was conducted. The isolates used in the study were *Armillaria mellea* AM-Vod and *Verticillium dahliae* Ver/Sg10. Both species and both isolates originated from almond trees, *Armillaria mellea* was isolated from the root collar of a semi-dry tree in an experimental grove. *Verticillium dahliae* was isolated from a tree branch with symptoms of verticillium wilt. Species identification was performed based on morphological characteristics according to descriptions by Volk and Burdall (1995) and Smith (1965). Species identification was confirmed by polymerase chain reaction (PCR) molecular analysis using primers ITS1/ITS4 (White et al., 1990) for *A. mellea* and DF/DR and NDF/NDR (Pérez-Artés et al., 2000) for *V. dahliae*.

Before the experiment, the isolates were inoculated onto potato dextrose agar (KDA) and incubated for 21 days at 22 °C. Lavender and immortelle essential oils were kept at 4 °C before the experiment. Lavender oil was prepared by diluting 500 µl of oil in 10 µl of methanol. The resulting solution was considered a concentrated oil, which was further diluted with sterile water in ratios of 1:5 and 1:10. Immortelle oil was not in a liquid state and was prepared by adding 500 µl of methanol to the entire amount, which was considered a concentrated oil. Such oil was further diluted with sterile water in ratios of 1:5 and 1:10.

The experiment on the effect of essential oils on the growth of *A. mellea* and *V. dahliae* isolates was carried out using a modified volatile disk method according to Tzortzakis and Economakis (2007). A circular slice of the colonies of the experimental isolates *A. mellea* and *V. dahliae* was inoculated onto one side of a Petri dish with KDA. A circular slice of the same dimensions was made diametrically at a distance of 7 cm. 100 µl of:

1. Diluted lavender and immortelle oils in a ratio of 1:5 (equivalent to 20 µl of concentrated oils);
2. Diluted lavender and immortelle oils in a ratio of 1:10 (equivalent to 10 µl of concentrated oils);
3. Sterile water as a control treatment.

The experiment was set up in triplicate. The Petri dishes were incubated for 21 days at 22 °C. After incubation, the radial growth radius of each variant was measured. Growth inhibition was calculated by dividing the growth of the treatment (variant with essential oils) by the growth of the control and converted into percentages. Since inhibition was only 0% and 100%, no statistical analysis was performed at this stage.

Both oils completely inhibited the growth of *A. mellea* at all concentrations (Table 3). On the other hand, neither oil inhibited the growth of *V. dahliae* at any concentration.

Table 3. Inhibition of growth of *Armillaria mellea* and *Verticillium dahliae* by lavender and immortelle.

Pathogen	**Essential oil**	**Quantity (dilution)**		
		100 µl (1:1)	**20 µl (1:5)**	**10 µl (1:10)**
		Growth inhibition		
Armillaria mellea	lavender	100 %	100 %	100 %
Armillaria mellea	immortelle	100 %	100 %	100 %
Verticillium dahliae	lavender	0 %	0 %	0 %
Verticillium dahliae	immortelle	0 %	0 %	0 %

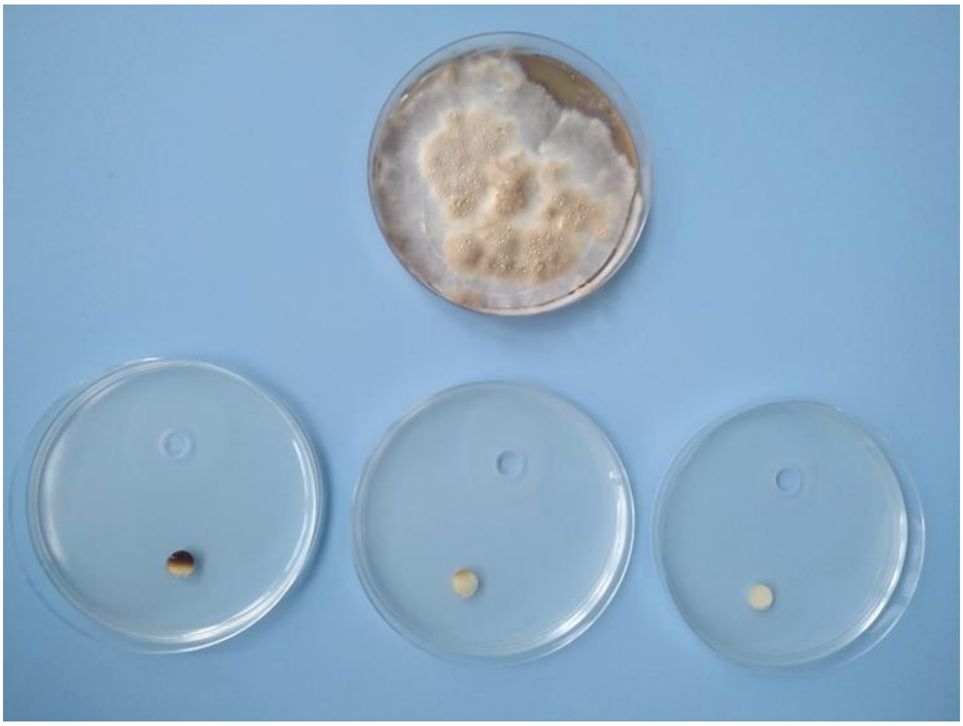


Figure 3. Complete (100%) inhibition of *A. mellea* growth on KDA inoculated with lavender oil (top: control; bottom, left to right: 100 µl; 50 µl; 10 µl).

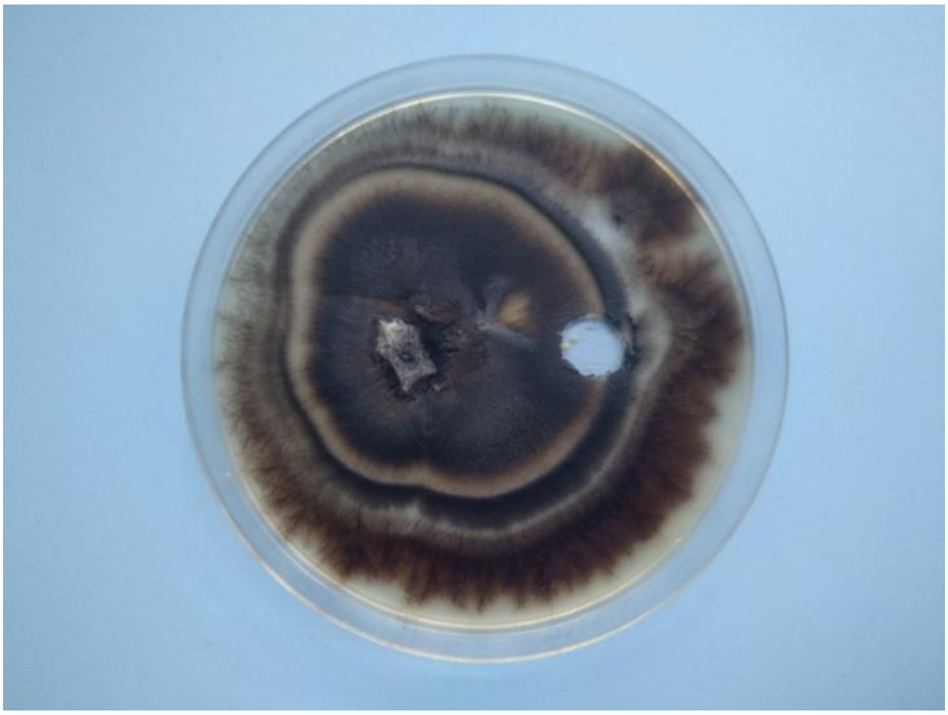
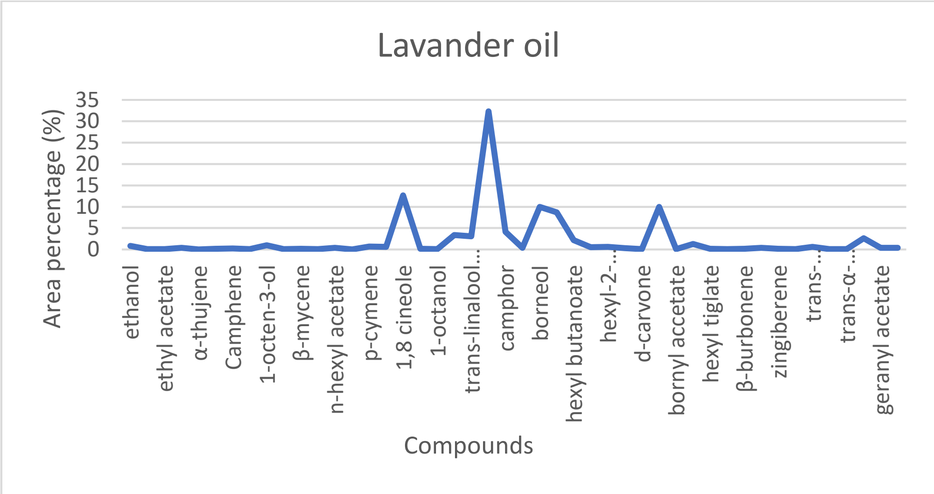


Figure 4. Lack of inhibition of *V. dahliae* growth on KDA inoculated with lavender oil (100 µl).

The experiment showed inconsistent results. The research is planned to be repeated and expanded with an additional method to test the effect of essential oil volatility. In addition to *A. mellea* and *V. dahliae*, the experiment will also include the fungus *Rosellinia necatrix*, also a pathogen of fruit crops.

For the purpose of investigating the effect of intercrop essential oils on pathogenic fungi that cause various diseases in almonds, essential oils were extracted from sage, helichrysum, and lavender flowers using Supercritical CO_2 extraction. Following the extraction, the oils from these intercrops were subjected to chemical composition analysis using gas chromatography–mass spectrometry (GC-MS). In lavender oil, a total of 46 volatile components were detected, with linalool (83.32%) and 1,8-cineole (12.68%) being the most abundant. The content of other volatile compounds is shown in Table 4. A total of 99.97% of all components present in the lavender oil were identified.

Table 4. Composition of lavender oil in the 2024 season.



In the sage oil samples, 24 volatile components were detected. Among them, α-thujone (22.86%), β-thujone (8.10%), and camphor (17.82%) were the most prominent. The chemical composition of sage oil is presented in Figure 5. A total of 91.02% of the volatile components in sage oil were identified.

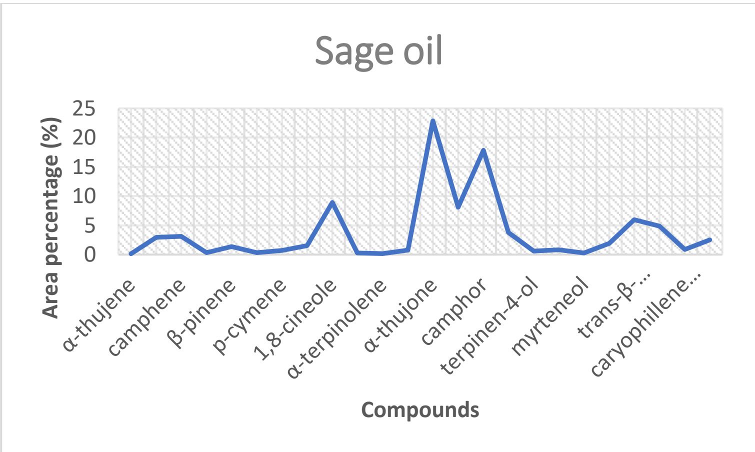


Figure 5. Composition of sage oil in the 2024 season.

In the helichrysum oil sample, 30 different volatile compounds were detected. Among them, the most abundant were the monoterpene alcohols alpha-terpineol (15.67%) and 3-heptanone (10.65%). The results are shown in Figure 6. A total of 100.00% of the volatile components in helichrysum oil were identified.

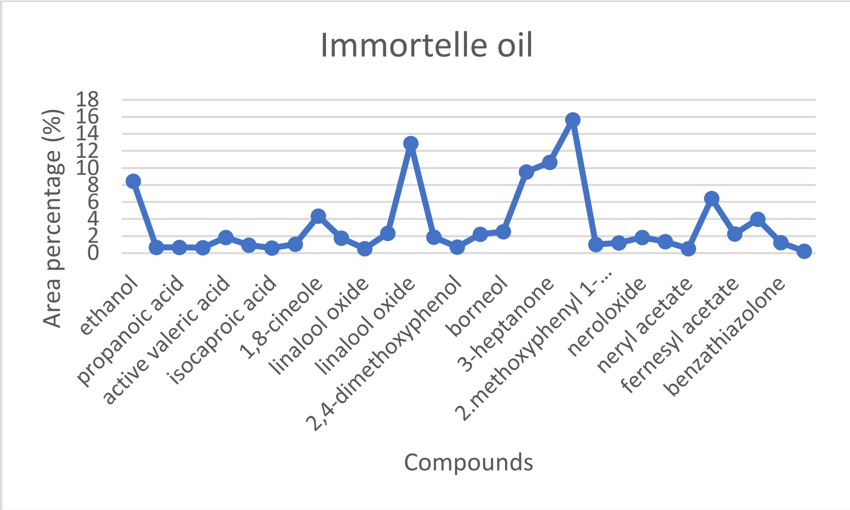


Figure 6. Chemical composition of helichrysum oil in the 2024 season.

The Supercritical CO_2 extraction method yields pure essential oil and provides approximately 25% higher extraction efficiency compared to conventional methods of extracting oil from medicinal and aromatic plant flowers.