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Faculty of Natural and Life Sciences
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About the journal

Agronomy and Biological Sciences Insights (ABSI) is an international peer-reviewed research journal, open-access, published by the Laboratory of Management, Conservation and Valorization of Agricultural and Natural Resources 'LMCVANR' (University of Khenchela - Algeria). It publishes original research, short communication, and reviews in all areas of agricultural and biological sciences, in addition to the proceedings of seminars. Manuscripts submitted to the journal are subject to rigorous and unbiased peer review. The journal is published twice a year.

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ABSI journal is striving to disseminate recent techniques and applications in agriculture and applied biology for researchers, students, and scholars in research institutes and universities worldwide. The journal publishes manuscripts that report recent findings in the following areas: Agronomy & Horticulture, Crop Protection, Soil Fertility & Organic Farming, Plant Biology, Plant Biotechnology, Agroforestry, Biochemistry, Microbiology, Genetics, Food sciences and Other fields of agronomic and biological sciences.

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Inaugural message by the rector of Abbes Laghrour University of Khenchela

On the Occasion of the Launch of the Scientific Journal of "Agronomy and Biological Sciences Insights"

Dear Members of the Academic Community and Esteemed Colleagues,

It is with immense pride and a profound sense of purpose that I address this message to celebrate the launch of the Scientific Journal '*Agronomy and Biological Sciences Insights*'. This moment marks a significant milestone in the intellectual and scientific journey of our university, as we take a bold step toward advancing knowledge.

Agriculture and biological sciences lie at the heart of sustainable development, food security, environmental conservation, and the well-being of societies worldwide. As we confront numerous challenges such as climate change, population growth, and biodiversity loss, the need for rigorous scientific inquiry and evidence-based solutions has never been more urgent. In this context, this journal represents our commitment to contributing to this global endeavour, providing a platform for cutting-edge research, interdisciplinary collaboration, and the dissemination of knowledge that can transform lives and ecosystems.

As a university, we are deeply committed to the principles of innovation, sustainability, and social responsibility. This journal embodies these values, reflecting our dedication to creating knowledge that serves the greater good.

To the authors who will contribute their research, to the reviewers who will ensure the integrity and quality of the journal, and to the readers who will engage with its content, I extend my heartfelt gratitude. Your participation is vital to the success of this endeavour, and I am confident that together, we will create a lasting impact on the scientific community and beyond.

Thank you, and may this journal contribute toward a more sustainable and prosperous world.

With warm regards,

Prof. Abdelouahad CHALA

Rector of Abbas Laghrour University - Khenchela

Welcome Message from the Editor-in-Chief

Dear Readers,

It is with much joy and anticipation that we celebrate the launch of Journal of *Agronomy and Biological Sciences Insights (ABSI)* with this inaugural issue. I take this opportunity to thank our editors and the members of the editorial team, all of whom have volunteered to contribute to the success of the journal. I am also grateful to the Rector and the staff at the University of Khenchela for making *ABSI* a reality.

Journal of *Agronomy and Biological Sciences Insights (ABSI)* is primarily focused on research in the fields of agricultural and biological sciences. The topics covered in the journal include but not limited to: Agronomy & Horticulture, Crop Protection, Soil Fertility & Organic Farming, Plant & Animal Biology, Plant & Animal Biotechnology, Agroforestry, Biochemistry, Microbiology, Genetics, Food sciences and other fields of agronomic and biological sciences.

ABSI provides an ideal forum for exchange of information on all of the above topics and more, in various formats: full length research papers, short communications, review papers, ….

ABSI is published two times a year. To ensure rapid dissemination of information, we aim at completing the review process of each paper within 3 months of initial submission.

I close this message by inviting everyone to submit their exciting research to *ABSI*. All papers receiving a high degree of enthusiasm in the peer-review process will find a home in *ABSI*. We also welcome comments and suggestions that could improve the quality of the journal.

Thank you.

Prof. Salim LEBBAL

Editor-in-Chief of *Agronomy and Biological Sciences Insights*

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Agronomy and Biological Sciences Insights (ABSI)

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Interactions between Aphids and Their Natural Enemies on Aleppo Pine: A Lever for the Sustainable Management of Forest Resources in Semi-Arid Environments

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ABSTRACT

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The Aleppo pine (*Pinus halepensis* Mill.), an emblematic species of Mediterranean forests, plays a crucial ecological and economic role in semi-arid regions. This study investigates the ecological interactions between aphids colonizing *P. halepensis* and their natural enemies across three forest zones in north eastern Algeria. Sampling was conducted seasonally between 2019 and 2021 in urban, semi-urban, and natural Aleppo pine stands. Two aphid species were identified *Cinara maghrebica* and *Eulachnus tuberculostemmatus*. A diverse community of 17 natural enemy species was recorded, dominated by Coccinellidae (10 species) and the primary specialist parasitoid *Pauesia silana*. Results revealed that aphid populations and their antagonists peak during spring, showing a strong and significant positive correlation (R= 0.31, P < 0.01), particularly in semi-urban areas. However, this biological regulation was noticeably weaker in urban sites (R=0.31, P= 0.09), likely due to anthropogenic disturbances. These findings emphasize the importance of conserving functional biodiversity and habitat complexity as sustainable alternatives to chemical control in Mediterranean pine forests.

KEY WORDS: Aleppo pine, antagonists, functional biodiversity, sustainable forest management, semi-arid environment.

1. INTRODUCTION

The Aleppo pine (*Pinus halepensis* Mill., 1768) is one of the most widely distributed conifer species in the Mediterranean Basin, extending from Spain to Syria and North Africa (FAO, 2020). It plays a crucial ecological role in semi-arid and arid regions, contributing to soil stabilization, erosion control, and the maintenance of biodiversity (Novak et al., 2016).

Moreover, this species represents an important economic resource, providing timber, resin, and non-timber forest products while sustaining rural livelihoods (Chambel et al., 2013).

However, Aleppo pine forests are increasingly threatened by multiple stress factors associated with climate change, including recurrent droughts, rising temperatures, and pest outbreaks (Kadik, 1987; Bentouati, 2006). Among the insect pests affecting *P. halepensis*, aphids (Hemiptera: Aphididae) are of particular concern due to their ability to form large colonies that weaken host trees by extracting phloem sap, reducing growth, and promoting the development of sooty molds (Blackman & Eastop, 1994).

Several aphid species have been reporte don Aleppo pine, including *Cinaria maghrebica*, *C. palaestinensis*, *Eulachnus agilis*, and *Essigella californica* (Kanturski et al., 2016; Oğuzoğlu & Avcı, 2019; Ben Halima et al., 2019, 2020; Oğuzoğlu et al., 2023). These species are often associated with outbreaks that can affect forest health and productivity, particularly under drought stress, which favors their population growth and survival (Blackman & Eastop, 1994).

Natural enemies such as lady beetles (Coccinellidae), hoverflies (Syrphidae), lacewings (Chrysopidae), and hymenopteran parasitoids (Braconidae: Aphidiinae) play a major role in the natural regulation of aphid populations (Saharaoui & Gourreau, 2000; Oğuzoğlu & Avcı, 2019). These antagonists constitute a key component of functional biodiversity and act as biological control agents that canhelp maintain ecological balance within forest ecosystems (Brodeur & Rosenheim, 2000).

Understanding the diversity, abundance, and trophic interactions of aphids and their natural enemies is essential for the development of sustainable forest management strategies. In particular, the conservation of natural enemies offers an environmentally friendly alternative to chemical control, aligning with the principles of integrated pest management (IPM) and biodiversity conservation (Nchu, 2024).

This study aims to investigate the ecological interactions between aphids infesting *P. halepensis* and their natural enemies in forest stands of northeastern Algeria. The objective of this study was to identify the aphid and antagonist species present, to quantify their abundance and dynamics across forest stations, and to analyze how environmental stress may mediate these interactions. Ultimately, we seek to evaluate the potential of natural enemy-driven regulation of aphids as a viable lever for sustainable forest resource management in semi-arid ecosystems.

2. MATERIALS AND METHODS

Study area

The study was conducted in three forest zones of the Khenchela region (northeastern Algeria), representing different degrees of urbanization and ecological disturbance:

(i) Urban zone (Kais): located in proximity to the city, this area is characterized by fragmented pine stands and strong anthropogenic influence;

(ii) Semi-urban zone (Khenchela): subject to moderate human pressure, it comprises partially connected forest patches with intermediate levels of disturbance; and

(iii) Natural zone (El Hamma): consisting of dense and relatively undisturbed *Pinus halepensis* stands, representing a well-preserved natural habitat (**Figure 1**).

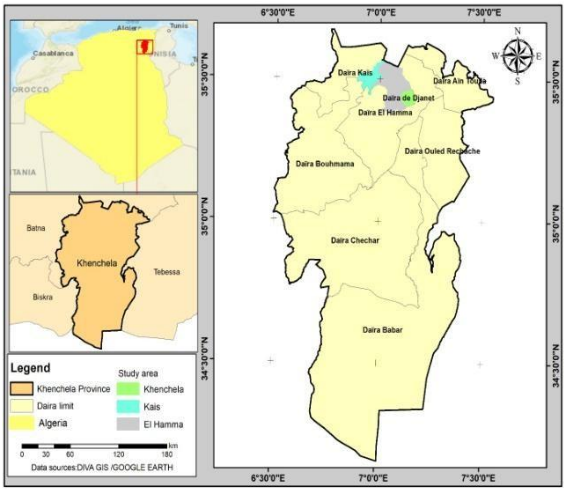

Figure 1. Location of the study sites in Khenchela region (Northeastern Algeria), showing the three sampling zones: urban, semi-urban, and natural.

The region is characterized by a semi-arid climate, with cold winters, hot and dry summers, and an annual mean precipitation of approximately 400–500 mm, mostly concentrated between November and March. The mean annual temperature ranges between 12 and 17 °C, with frequent summer droughts. These climatic conditions make *P. halepensis* particularly vulnerable to drought-induced stress and pest infestations.

Sampling design

Sampling was carried out over three consecutive years (2019–2021) during the four main seasons to cover the phenological cycle of both aphids and their natural enemies. In each forest zone, ten trees of *P. halepensis* were selected at random and permanently marked for repeated observations.

From each selected tree, four branches were sampled following the cardinal directions (North, South, East, and West) to ensure representative coverage of microclimatic variability. Each branch sample (approximately 20–30 cm in length), was examined in the laboratory under a stereomicroscope to detect aphid colonies and their associated natural enemies.

Identification of aphids

In the laboratory, aphids collected from *P. halepensis* were gently removed from needles using a fine brush and transferred to Petri dishes for counting under a stereomicroscope. After enumeration, specimens were preserved in microtubes containing 75% ethanol, labeled with collection date and site. For slide preparation, aphids were dissected to remove embryos, cleared in 10% KOH for 24–48 hours depending on size and pigmentation, rinsed in distilled water, and transferred to chloral phenol for at least 24 hours. Individuals were then mounted dorsally in Hoyer's medium, with antennae positioned anteriorly and siphunculi posteriorly, and dried at 25 °C for four days. Identification was carried out under an optical microscope using diagnostic keys, including Blackman & Eastop (1994) ; Blackman & Eastop (2024).

Identification of natural enemies

Natural enemies associated with aphid colonies were categorized into predators and parasitoids.

Aphid mummies were kept on their plant substrate in Petri dishes until parasitoid emergence. Emerged parasitoids were preserved in 75% ethanol. Predatory larvae and pupae found in aphid colonies were collected and reared individually in ventilated containers until adult emergence. The diversity and abundance of natural enemies (Coccinellidae, Syrphidae, Chrysopidae) were quantified by counting individuals per group.

Parasitoids and hyperparasitoids were obtained from mummies reared in aerated Petri dishes covered with fine mesh to prevent adult escape under controlled conditions (23±2°C, 60±10%RH, 16L:8D photoperiod). Specimens preserved in ethanol were dissected into separate body parts (head, wings, first abdominal tergite, propodeum, genitalia) and mounted in Hoyer's medium for detailed microscopic examination. Predators were not slide-mounted; their identification was performed directly on intact adults using optical microscope based on morphological keys focusing on coloration, body shape, and wing venation.

Predator identification relied on taxonomic keys for Coccinellidae (Bensusan et al., 2006 ; Derolez et al., 2014 ; Biranvand et al., 2017 ; Saharaoui, 2017 ; Bienkowski, 2018 ; Poorani, 2023), Syrphidae (Matile, 1993 ; Speight & Sarthou, 2014 ; Speight, 2014), and Chrysopidae (San Martin,2004).

Parasitoids and hyperparasitoids were identified based on antenna morphology, wing venation, and genital structures, using keys by Gibson & Vikberg (1998), Gibson (2001), Farrokhzadeh et al. (2014), Shen et al. (2019), and Rakhshani et al. (2019).

The identification of representative specimens was validated by Professor Laamari M., and the material was archived in the ATPPAM Laboratory (University of Batna 1).

3. RESULTS AND DISCUSSION

Aphid diversity and seasonal dynamics

A total of two aphid species belonging to the family Aphididae were recorded on *Pinus halepensis* across the three studied zones (urban, semi-urban, and natural) during the 2019–2021 survey. The aphid community was dominated by *Cinara maghrebica*, which accounted for 2,050 individuals (59.8% of the total aphid population), followed by *Eulachnus tuberculostemmatus*with1, 381individuals (40.2%) (**Figure 2**, **Figure 3**), which are commonly associated with Mediterranean pine species (Ben Halima-Kamel, 2019).

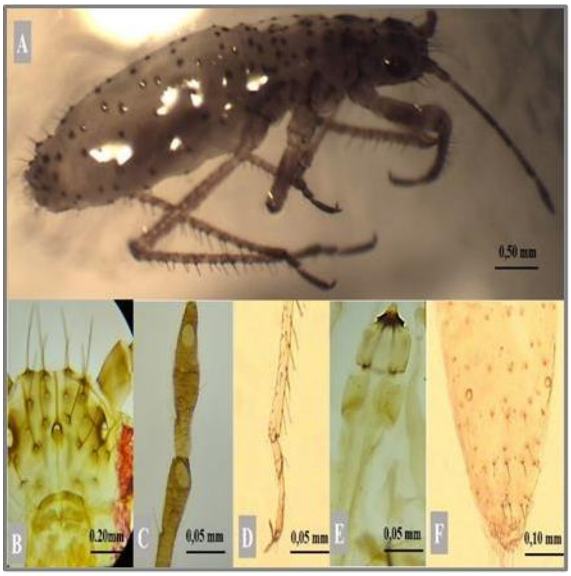

Figure 2. Morphological characters of the species *E. tuberculostemmatus*. A: Adult apteral, B: Forehead, C: Last antennal segment, D: Posterior tibia, E: Rostrum, F: Corniculus and cauda.

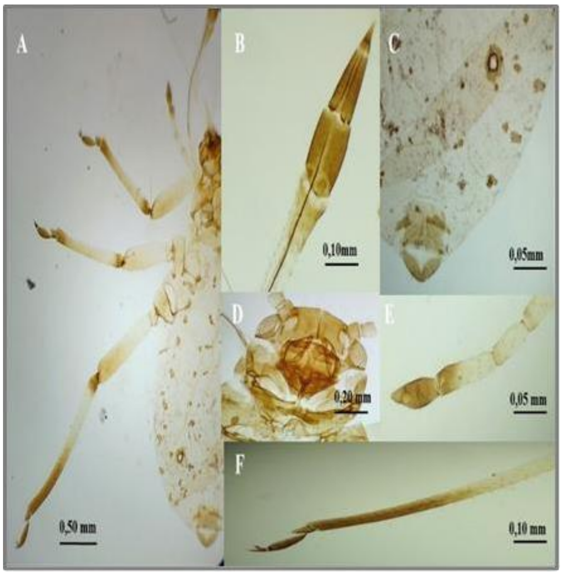

Figure 3. Morphological characters of the species *Cinara maghrebica*. A: Abdomen and legs, B**:**Rostre, C:Cornicule and cauda, D**:** Front, E: Antenna, F**:** Posterior tibia.

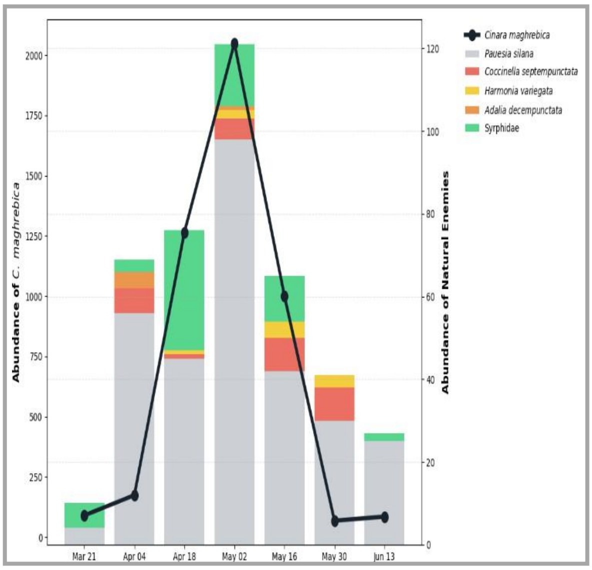

Figure 4. Seasonal abundance of *Cinara maghrebica* and its natural enemy complex in the urban site (Kais).

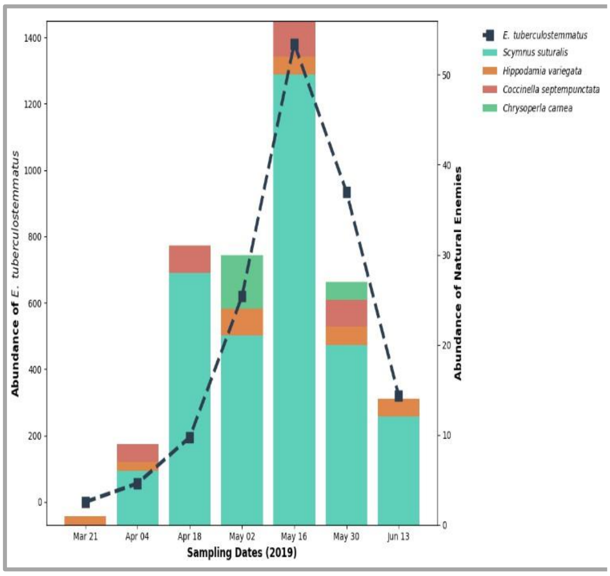

Figure 5. Population dynamics of *Eulachnus tuberculostemmatus* and associated predatory guilds in the semi- urban site (Khenchela).

At the urban site (Kais), *C. maghrebica* exhibited a pronounced seasonal peak in early May, reaching a cumulative total of 2,050 individuals during the study period (Figure 4).

The exclusive presence of *C. maghrebica* in the urban pines and appears to be driven by microclimatic conditions and the nutritional status of host trees. Previous studies (Ahmed et al., 2019; Mooney et al., 2021) have demonstrated the major influence of temperature, host vigor and urban heat island effects on aphid distribution and population growth, while warmer urban microclimates and the availability of tender shoots create highly favorable conditions for *Cinara* species (Dixon, 1998; Hullé et al., 2010).

Conversely, a population peak of *E. tuberculostemmatus* was recorded in mid-May at the semi-urban site, reaching a maximum of 1,381 individuals (Figure 5). This species appears to exhibit a relatively high tolerance to thermal and hydric stress, as evidenced by its persistence under the semi-arid conditions of the study area (Kanturski et al., 2017; Hosseini & Poorjavad, 2020). Such resilience may be linked to its specialized ecological niche on pine needles rather than branches. Feeding on needles likely reduces sensitivity to sap pressure fluctuations and enhances adaptation to foliage desiccation. Moreover, the widespread occurrence of *E. tuberculostemmatus* at the semi-urban site, which is more exposed to solar radiation, further supports its thermal adaptability and ability to withstand elevated evaporative demand. Comparable patterns were reported by Heidari Latibari et al. (2022), who identified this species as one of the dominant aphids on pines in urban and peri-urban environments.

The absence of aphid infestations in the natural pine forest may be explained by harsher macroclimatic conditions in this semi-arid region, reduced availability of young shoots, and stronger biotic regulation. Several authors (Hosseini & Poorjavad, 2020; Barczak et al., 2021) highlighted the importance of habitat structure and biotic interactions in shaping aphid communities on conifers. Natural, undisturbed forests typically support higher trophic diversity and stronger top-down control by predators and parasitoids. Increased plant diversity is also associated with reduced herbivore damage approximately 20% less in mixed-species forests due to associational resistance (Jactel et al., 2021), whereby non-host plants and complex vegetation reduce visual and olfactory cues used by specialized aphids to locate their hosts (Hertzog et al., 2021). In addition, the structural complexity of natural stands (dense canopy, developed understory) may limit aphid dispersal and colonization success. Together, these factors indicate that habitat naturalness through vegetation diversity, low anthropogenic disturbance, dense canopy structure and stronger biotic interactions play a key role in determining aphid assemblages across pine ecosystems.

Diversity and abundance of natural enemies

A total of 661 individuals belonging to 17 species, six families, and four insect orders were recorded as natural enemies of aphids on *Pinus halepensis* (Table 1). Coleoptera was the most species-rich order, represented exclusively by the family Coccinellidae, which accounted for 10 species and 54.1% of the total abundance. Within this family, *Scymnus suturalis* was the dominant predator (148individuals; 22.4%), followed by *Hippodamia variegata* (64 individuals; 9.7%) and *Coccinella septempunctata* (58 individuals; 8.8%).

The order Hymenoptera exhibited the highest overall abundance (240 individuals; 36.3%), largely driven by the parasitoid *Pauesia silana*, which represented the single most abundant species (185 individuals; 28.0%). Other hymenopteran parasitoids, including *Asaphes vulgaris*, *Pachyneuron aphidis*, and *Syrphophagus aphidivorus*, were present at lower but consistent frequencies.

Diptera (Syrphidae) were represented by two species (*Helophilus* sp. and *Eristalis* *arbustorum*), accounting for 4.7% of the total abundance, while Neuroptera was represented by *Chrysoperla carnea*, contributing 6.4% of the recorded individuals.

When data were aggregated by habitat type, clear differences in the total abundance of natural enemies were observed among the three zones (Figure 6).

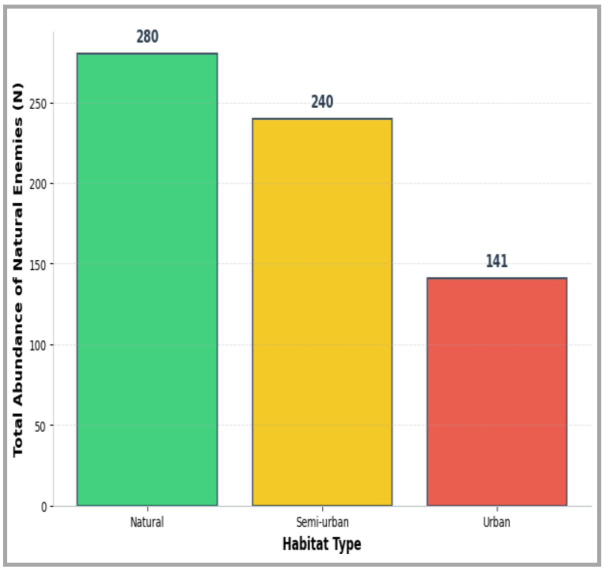

Figure 6. Total abundance of natural enemies collected from *P. halepensis* across the three study sites.

Overall, the abundance and diversity of natural enemies were higher in the natural and semi-urban zones, particularly during spring, suggesting that these habitats offer more favorable conditions for sustaining predator and parasitoid populations. Such conditions may be associated with greater microclimatic stability, the availability of alternative prey, and the presence of flowering resources. These patterns are consistent with the hypothesis that increased habitat complexity enhances biological control potential (Landis et al., 2000; Gardiner et al., 2009).

Within this context, the high abundance of *Pauesia silana* underscores its importance in the regulation of *Cinara maghrebica*. This specialist parasitoid has been widely recognized as an effective biological control agent in coniferous ecosystems of the Maghreb and other Mediterranean regions (Mifsud & Starý, 2009; Havelka et al., 2021; Bourouba & Laamari, 2025).

Table 1. Taxonomic composition, species richness, and abundance of natural enemies associated with aphids on *Pinus halepensis* in the Khenchela region, 2019–2021.

Orders	Families	Species	Total (N)	Relative Abundance (%)
Coleoptera	Coccinellidae	*Adalia decempunctata* (Linnaeus,1758)	14	2.1%
		Coccinella algerica (Kovar,1977)	9	1.4%
		Coccinella septempunctata (Linnaeus, 1758)	58	8.8%
		Exochomus anchorifer (Lacordaire, 1842)	12	1.8%
		Harmonia quadripunctata (Pontoppidan, 1763)	7	1.1%
		Hippodamia variegata (Goeze,1777)	64	9.7%
		Hyperaspis duvergeri (Linnaeus,1758)	5	0.8%
		Myrrha octodecimguttata (Fürsch,1985)	11	1.7%
		Scymnus nubilus (Thunberg,1795)	22	3.3%
		Scymnus suturalis (Mulsant,1850)	148	22.4%
Diptera	Syrphidae	*Helophilus* sp.	18	2.7%
		Eristalisar bustorum (Linnaeus,1758)	13	2.0%
Neuroptera	Chrysopidae	*Chrysoper lacarnea* (Stephens, 1836)	42	6.4%
Hymenoptera	Braconidae	*Pauesia silana* (Tremblay,1969)	185	28.0%
	Pteromalidae	*Asaphes vulgaris* (Walker,1834)	24	3.6%
		Pachyneuron aphidis (Bouché,1834)	19	2.9%
	Encyrtidae	*Syrphophagus aphidivorus* (Mayr,1876)	12	1.8%
Total	**17 Species**		**661**	**100%**

Correlation between aphids and natural enemies

Pearson’s correlation analysis revealed a strong and significant positive correlation between aphid abundance and the abundance of their natural enemies (R= 0.68, $p < 0.01$) (**Table 2**).

Table2. Pearson correlation coefficients (R) between aphid abundance and natural enemies

Study site	Correlation pair	R	*p*-value	Significance
Global (all sites)	Aphids vs. natural enemies	0.68	<0.01	**
Semi-urban	Aphids vs. natural enemies	0.74	<0.01	**
Urban	Aphids vs. natural enemies	0.31	0.09	ns
Specific groups	*C. maghrebica* vs. *P. silana*	0.82	<0.01	**
Specific groups	Aphids vs. Coccinellidae	0.65	<0.05	*

ns: not significant; *p<0.05; **p<0.01

This association was particularly evident for Coccinellidae and the specialist parasitoid *P. silana*, whose population peaks closely followed those of *Cinara* aphids. The predator–parasitoid response was most pronounced during the spring months (April–June), a period characterized by rapid aphid population growth and favorable climatic conditions enhancing natural enemy activity.

This synchrony between prey and natural enemy populations reflects a classical numerical and functional response typical of well-established aphid–enemy systems, in which predators and parasitoids adjust their abundance and foraging intensity in response to increases in aphid density (Honek et al., 2017). The slight time lag observed where natural enemy peaks occurred 1–2 weeks after aphid maximal so aligns with expected biological patterns, as predators require time for searching, oviposition, and larval development before exerting significant regulation pressure.

In the urban zone, however, the aphid–natural enemy relationship was noticeably weaker (R = 0.31, p = 0.09). This reduced association is likely linked to anthropogenic factors such as pesticide applications, habitat fragmentation, air pollution, and decreased floral diversity. These conditions are known to disrupt predator recruitment and reduce parasitoid efficiency, limiting the establishment of stable biological control interactions (Gagic et al., 2011).

The consistently strong presence of *P. silana* throughout the study period highlights its ecological importance as a key specialist parasitoid regulating *Cinara* populations on *P. halepensis*. Similar findings were reported by Starý (2006) and Havelka et al. (2021), who demonstrated the central role of *Pauesia* species in suppressing conifer-feeding aphids across Mediterranean and European pine forests.

Overall, the positive correlation observed in semi-urban forest stations strongly suggests that biocontrol processes are actively operating, and that maintaining environmental quality particularly avoiding pesticide use and preserving vegetation complexity is essential for sustaining effective aphid regulation.

4. CONCLUSIONS

This study demonstrates that aphid populations on *Pinus halepensis* in semi-arid environments are strongly influenced by habitat structure and the availability of natural enemies. The dominance of *Cinara maghrebica* and *Eulachnus tuberculostemmatus*, coupled with the high abundance of predators and parasitoids particularly *Pauesia silana*, highlights the key role of trophic interactions in regulating aphid outbreaks. The significant positive correlations observed, especially in semi-urban forest stands, indicate that functional biodiversity can provide effective top-down control under moderate disturbance. In contrast, the weakened aphid–enemy relationships in urban areas underline the negative impact of anthropogenic pressures on biological regulation. Overall, these findings emphasize that conserving natural enemy communities and maintaining habitat complexity are essential for sustainable forest management. Promoting conservation biological control represents a viable, environmentally sound alternative to chemical treatments for preserving the health of Mediterranean pine forests under increasing climatic stress.

5. REFERENCES

Ahmed, N., Darshanee, H.L.C., Khan, I. A., Zhang, Z. F., & Liu, T. X. (2019). Host selection behavior of the green peach aphid (*Myzus persicae*) in response to volatile organic compounds and nitrogen contents of cabbage cultivars. *Frontiers in Plant Science*, *10*, 79.

Barczak, T., Bennewicz, J., Korczyński, M., Błażejewicz-Zawadzińska, M., & Piekarska-Boniecka, H. (2021). Aphid assemblages associated with urban park plant communities. *Insects*, *12*(2), 173.

Ben Halima-Kamel, M., Kavallieratos, N. G., Starý, P., & Rakhshani, E. (2020). First record of *Diaeretus leucopterus* (Haliday) Hymenoptera, Braconidae, Aphidiinae), parasitoid of *Eulachnus agilis* (Kaltenbach) (Hemiptera, Aphididae) in North Africa. *Egyptian Journal of Biological Pest Control*, *30*(1), 53.

Ben Halima-Kamel, M., Zouari, S., Mdellel, L., & Rekik, A. (2019). *Eulachnus tuberculostemmatus* (Lachninae: Eulachnini) sur pin d'Alep: premier signalement en Tunisie. *Bulletin OEPP/EPPO*, *49*(2), 336–337.

Bensusan, K. J., Muñoz Batet, J., & Perez, C. E. (2006). *Coccinella algerica* Kovar, 1977: A new species to the fauna of mainland Europe, and a key to the *Coccinella* Linnaeus, 1758 of Iberia, the Maghreb and the Canary Islands (Coleoptera: Coccinellidae). *Boletín de la SEA*, *39*, 323–327.

Bentouati, A. (2006). *Croissance, productivité et aménagement des forêts de pin d'Alep (Pinus halepensis* Mill.*) du massif de Ouled Yagoub (Khenchela-Aurès).* Thèse de Doctorat en Sciences Agronomiques, Université de Batna 1, 115 p.

Bienkowski, A. O. (2018). Key for identification of the ladybirds (Coleoptera: Coccinellidae) of European Russia and the Russian Caucasus (native and alien species). *Zootaxa*, *4472*(2), 233–260.

Biranvand, A., Fekrat, L., Hamidi, E., Hanley, G., Nedvíd, O., Shakarami, J., & Volf, M. (2017). The ladybeetle community (Coleoptera: Coccinellidae) in north east of Iran. *Baltic Journal of Coleopterology*, *17*(1), 49–67.

Blackman, R.L., & Eastop, V.F. (1994). Aphids on the world's trees: An identification and information guide. CAB International.

Blackman, R. L., & Eastop, V. F. (2024). Aphids on the World's Plants: An online identification and information guide. https://www.aphidsonworldsplants.info

Bourouba, L., & Laamari, M. (2025). *Pauesia silana* Tremblay, 1969: Biological control agent for the Maghreb pine aphid *Cinara maghrebica* Mimeur, 1934 on *Pinus halepensis* Mill., 1768 in Algeria. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, *73*(1).

Brodeur, J., & Rosenheim, J. A. (2000). Intraguild interactions in aphid parasitoids. *Entomologia Experimentalis et Applicata*, *97*(1), 93–108.

Brodeur, J., Boivin, G., Bourgeois, G., Cloutier, C., Doyon, J., Grenier, P., & Gagnon, A. È. (2013). *Impact des changements climatiques sur le synchronisme entre les ravageurs et leurs ennemis naturels: conséquences sur la lutte biologique en milieu Agricole*. OURANOS / Fonds vert Québec.

Chambel, M. R., Climent, J., Pichot, C., & Ducci, F. (2013). Mediterranean pines (*Pinus halepensis* Mill. and *P. brutia* Ten.). Dans L. E. Parker (Ed.), *Forest tree breeding in Europe: Managing Forest ecosystems* (pp. 229–265). Springer.

Derolez, B., Orczyk, N., & Declercq, S. (2014). *Clé d'identification des coccinelles du Nord–Pas-de-Calais* (Version 4). Groupe Coccinelles Nord–Pas-de-Calais.

Dixon, A. F. G. (1998). *Aphid ecology: An optimization approach* (2nd ed.). Chapman & Hall.

FAO. (2020). *Global forest resources assessment 2020*: *Main report*. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/forest-resources-assessment

Farrokhzadeh, H., Moravvej, G., Awal, M.M., & Karimi, J. (2014). Molecular and morphological identification of hymenopteran parasitoids from the pomegranate aphid, *Aphis punicae*, in Razavi Khorasan Province, Iran. *Turkish Journal of Entomology*, *38*(3), 291–306.

Gagic, V., Tscharntke, T., Dormann, C. F., Gruber, B., Wilstermann, A., & Thies, C. (2011). Food web structure and biocontrol in a four- trophic level system across a land scape complexity gradient. *Proceedings of the Royal Society B: Biological Sciences*, *278* (1720), 2946-2953.

Gardiner, M.M., Landis, D.A., Gratton, C., DiFonzo, C.D., O'Neal, M., Chacon, J.M., Wayo, M.T., Schmidt, N. P., Mueller, E. E., & Heimpel, G. E. (2009). Land scape diversity enhances biological control of an introducedcroppest in the north-central USA. *Ecological Applications*, *19*(1), 143–154.

Gibson, G. A. P. (2001). The Australian species of *Pachyneuron* Walker (Hymenoptera: Chalcidoidea: Pteromalidae). *Journal of Hymenoptera Research*, *10*(1), 29–54.

Gibson, G. A. P., & Vikberg, V. (1998). The species of *Asaphes* Walker from America north of Mexico, with remarks on extralimital distributions and taxa (Hymenoptera: Chalcidoidea, Pteromalidae). *Journal of Hymenoptera Research*, *7*, 207–256.

Harrington, R., Clark, S. J., Welham, S. J., Verrier, P. J., Denholm, C. H., Hulle, M., Maurice, D., Rounsevell, M. D. A., Cocu, N., & European Union Examine Consortium. (2007). Environmental change and the phenology of European aphids. *Global Change Biology*, *13*(8), 1550–1564.

Havelka, J., Kaliuzhna, M., Danilov, J., & Rakauskas, R. (2021). *Pauesia* species (Hymenoptera: Braconidae: Aphidiinae) attacking *Eulachnini* aphids (Hemiptera: Aphididae: Lachninae) on coniferous plants in Lithuania: Ecological and mitochondrial COI diversity. *Organisms Diversity & Evolution*, *21*(3), 561–573.

Heidari Latibari, M., Kavallieratos, N. G., & Ghafouri Moghaddam, M. (2022). Impact of seasonality and ladybird predators on the population dynamics of Mugo pine aphids. *International Journal of Tropical Insect Science*, *42*(3), 2651–2662.

Hertzog, L. R., Vandegehuchte, M. L., Dekeukeleire, D., Dekoninck, W., De Smedt, P., van Schrojenstein Lantman, I., Proesmans, W., Baeten, L., Bonte, D., Martel, A., Verheyen, K., & Lens, L. (2021). Mixing of tree species is especially beneficial for biodiversity in fragmented landscapes, without compromising forest functioning. *Journal of Applied Ecology*, *58*(12), 2903-2913.

Honek, A., Dixon, A. F., Soares, A. O., Skuhrovec, J., & Martinkova, Z. (2017). Spatial and temporal changes in the abundance and compostion of ladybird (Coleoptera: Coccinellidae) communities. *Current opinion in insect science*, *20*, 61-67.

Hosseini, S. L., & Poorjavad, N. (2020). The biology and ecology of pine aphid, *Eulachnus tuberculostemmatus* (Hemiptera: Aphididae) and its demographic responses to environmental changes. *Agricultural and Forest Entomology*, *22*(4), 349–357.

Hullé, M., Coeur d'Acier, A. C., Bankhead-Dronnet, S., & Harrington, R. (2010). Aphids in the face of global changes. *Comptes Rendus Biologies*, *333*(6–7), 497–503.

Jactel, H., Moreira, X., & Castagneyrol, B. (2021). Tree diversity and forest resistance to insect pests: Patterns, mechanisms, and prospects. *Annual Review of Entomology*, *66*(1), 277–296.

Kadik, B. (1987). Influence du climat sur la répartition naturelle du pin d'Alep (*Pinus halepensis* Mill.) en Algérie. *Annales de la Recherche Forestière en Algérie*, *2*(1), 61–106.

Kanturski, M., Bugaj-Nawrocka, A., & Wieczorek, K. (2016). Pine pest aphids of the genus *Eulachnus* (Hemiptera: Aphididae: Lachninae): How far can their range extend? *Agricultural and Forest Entomology*, *18*(4), 398–408.

Landis, D. A., Wratten, S.D., & Gurr, G.M. (2000).

Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annualreview of entomology*, *45*(1), 175-201.

Martin, G. (2004). *Clé de détermination des Chrysopidae de Belgique*. Jeune et Nature ASBL.

Matile, L. (1993). *Les diptères d'Europe occidentale* (Vol. 1). Société nouvelle des éditions Boubée.

Mifsud, D., Pérez Hidalgo, N., & Barbagallo, S. (2009). Aphids (Hemiptera: Aphidoidea) associated with native trees in Malta (Central Mediterranean). *Bulletin of the Entomological Society of Malta*, *2*, 87–106. Mifsud, D., & Starý, P. (2009). Pauesia silana Tremblay, 1969 – a parasitoid of Cinara-aphids on conifers in Malta (Hymenoptera: Braconidae: Aphidiinae). *Bulletin of the Entomological Society of Malta, 2, 77–80.*

Mooney, E., Mullins, M., Den Uyl, J., Trail, S., Nguyen, P., Owens, J., Godtfredsen, E. & Heschel, S. (2021). Early snowmelt reduces aphid abundance *(Aphis asclepiadis)* by creating water- stressed host plants *(Ligusticum porteri)* and altering interactions with ants. Arthropod-Plant Interactions 15, 33–46.

Nchu, F. (2024). Sustainable Biological ControlofPests.*Applied Sciences*, *14*(7), 2669.

Novak, K., De Luis, M., Saz, M. A., Longares, L. A., Serrano-Notivoli, R., Raventós, J., Čufar, K., Gričar, J., Di Filippo, A., Piovesan, G., Rathgeber, C. B. K., Papadopoulos, A., & Smith, K. T. (2016). Missing rings in *Pinus halepensis*: The missing link to relate the tree-ring record to extreme climatic events. *Frontiers in Plant Science*, *7*, 660.

Oğuzoğlu, Ş., & Avcı, M. (2019). Distribution, biology, morphology and damage of *Cinara cedri* Mimeur, 1936 (Hemiptera: Aphididae) in the Isparta Regional Forest Directorate. *Forestist*, *69*(1), 1–10.

Oğuzoğlu, Ş., & Avcı, M. (2019). Natural enemies of *Cinara cedri* Mimeur 1936 (Hemiptera: Aphididae) in cedar forests in Isparta regional forest directorate. *Kastamonu University Journal of Forestry Faculty*, *19*(2), 173–185.

Oğuzoğlu, Ş., Avcı, M., & Şenol, Ö. (2023). New contributions to the Turkish aphid fauna and species composition (Hemiptera: Aphididomorpha) in Isparta forests. *Turkish Journal of Entomology*, *46*(4), 453–467.

Poorani, J. (2023). An illustrated guide to ladybeetles (Coleoptera: Coccinellidae) of the Indian Subcontinent (Part 1). Tribe Coccinellini. *Zootaxa*, *5332*(1), 1–307.

Rakhshani, E., Barahoei, H., Ahmad, Z., Stary, P., Ghafouri Moghaddam, M.,Mehrpavar, M., Kavallieratos, N.G., Čkrkić, G., & Tomanovic, Z. (2019). Review of Aphidiinae parasitoids (Hymenoptera: Braconidae) of the Middle East and North Africa: Key to species and host associations. *European Journal of Taxonomy*, *552*, 1–132.

Saharaoui, L. (2017). *Les coccinelles algériennes (Coleoptera, Coccinellidae): Analyse faunistique et structure des communautés*. Thèse de doctorat, Université Toulouse III - Paul Sabatier, 185 p.

Saharaoui, L., & Gourreau, J. M. (2000). Les Coccinelles d'Algérie : inventaire et régime alimentaire (Coleoptera, Coccinellidae). *Recherche Agronomique*, *4*(6), 11–27.

Shen,S.,Wu,W.,Zhang,Z.,Wang,Y., Kong, X. B., Liu, F., & Zhang, S. (2019). Morphological analysis of sensilla on different organs in *Pachyneuron aphidis*, a hyperparasitoid of *Myzus persicae*. *Microscopy Research and Technique*, *82*(10), 1810–1818.

Speight, M.C.D. (2014). *Species accounts of European Syrphidae (Diptera)*. Syrph the Net, the Database of European Syrphidae. Dublin: Syrph the Net Publications.

Speight, M.C.D., & Sarthou, J.P. (2014). *StN keys for the identification of the European species of various genera of Syrphidae (Diptera)*. Syrph the Net, the Database of European Syrphidae. Dublin: Syrph the Net Publications.

Starý, P. (2006). *Aphid parasitoids of the Czech Republic (Hymenoptera: Braconidae, Aphidiinae).* Academia.

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The effects of fish water irrigation on soil physicochemical properties on an agricultural farm in Baghai (North-eastern Algeria).

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Abstract

This study evaluates the effects of fishpond water irrigation on soil physicochemical properties in Baghai, northeastern Algeria, a semi-arid region facing water scarcity and soil degradation. Comparing soils irrigated with aquaculture effluents versus groundwater, the research reveals that fishwater irrigation: (1) maintains near-neutral soil pH (7.2), contrasting with slight alkalinity in groundwater-irrigated soils; (2) significantly reduces soil salinity (66% of samples <1500 µS/cm vs. 62% >1500 µS/cm in groundwater plots), suggesting organic matter from aquaculture mitigates salt accumulation; and (3) improves water quality, with fishpond water exhibiting higher dissolved oxygen (82.2% vs. 7.6%) and lower salinity (EC: 916 µS/cm vs. 960 µS/cm). Spatial analysis showed more uniform salinity and pH distribution in aquaculture-irrigated soils, highlighting its potential for sustainable land management. Despite COVID-19-related constraints limiting analyses to pH and EC, the results support integrated aquaculture-agriculture systems (IAAS) as a strategy to enhance soil health and water efficiency in arid regions. Future studies should expand to nutrient cycling and long-term monitoring to optimize IAAS implementation.

Key words: Integrated Aquaculture-agriculture, soil salinity, pH, water reuse, semi-arid ecosystems, Baghaï.

1. INTRODUCTION

Integrated aquaculture-agriculture systems (IAAS) represent an innovative approach to sustainable food production that has gained increasing attention in the context of global environmental challenges and food security concerns. These systems synergistically combine aquatic and terrestrial food production, creating circular economies where waste streams are transformed into valuable inputs (Hasimuna et al., 2023). The fundamental principle of IAAS lies in its biomimicry of natural ecosystems, where nutrient flows are optimized through the strategic integration of fish farming with crop cultivation and livestock rearing (Goddek et al., 2019a).

Contemporary research has demonstrated that IAAS offer multiple advantages over conventional monoculture practices. From an ecological perspective, these systems significantly reduce nutrient discharge while improving water use efficiency (Dauda et al., 2019). Economically, they provide smallholder farmers with diversified income streams and enhanced resilience to market fluctuations (Béné et al., 2015). Nutritionally, the incorporation of aquaculture components addresses protein and micronutrient deficiencies prevalent in many developing regions (Bogard et al., 2018). Furthermore, recent studies have highlighted their potential in climate change adaptation, particularly in water-scarce regions (Partelow et al., 2023).

The Algerian context presents particular relevance for IAAS implementation. With increasing water scarcity and soil degradation challenges, the need for sustainable intensification of agricultural systems has become imperative (Salim & KhÉloufi, 2021). While preliminary initiatives have demonstrated the technical feasibility of integrated systems in the region (Zohra et al., 2021), critical knowledge gaps persist regarding their long-term agroecological impacts. Specifically, the effects of continuous aquaculture effluent application on soil physicochemical properties and microbial communities remain insufficiently characterized (Guan et al., 2022).

In northeastern Algeria, particularly in the region of Baghai, agriculture is a key economic activity but is challenged by limited water availability and declining soil quality. Investigating the physicochemical effects of fish water on soils in this area could offer insights into the viability of integrated aquaculture-agriculture systems in arid and semi-arid environments. This study aims to assess how the application of fish pond water influences soil physicochemical parameters of soil, thereby contributing to a better understanding of its role in sustainable land management strategies.

2. MATERIALS AND METHODS

2.1. Presentation of the study area

The Municipality of Baghaï is located in the extreme north of Khenchela Province in northeastern Algeria, within the administrative district of El Hamma. It is bordered by several municipalities: M'toussa and Ain Touila to the east, El Hamma to the west, M'toussa and Oum El Bouaghi Province to the north, and Khenchela and Ensigha to the south. This strategic position gives it a central role in inter-provincial exchanges (Khabtane, 2014).

The area features high plain topography, with elevations ranging between 850 and 1000 meters and slopes less than 3%, making it suitable for mechanized agriculture. The soils are predominantly Quaternary alluvial deposits rich in sand, gravel, and silt. The municipality has significant water resources, including 8 springs, 100 boreholes, and 240 wells. Several wadis (Boughaguel, Mellh, Marir, FidhHriz) cross the region, although some are contaminated, such as Wadi Boughaguel (Fig. 1) (Nedjar et al., 2022).

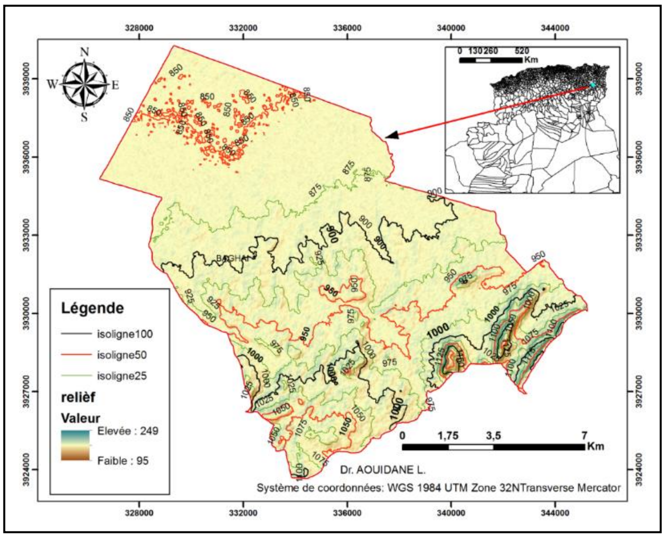

Figure 1. Map of altitude and relief of the Baghaï province.

The climate is classified as upper semi-arid with cool winters according to the Emberger climagram. Average temperatures range from 6.6°C in January to 26.2°C in July. The average annual rainfall is 462.8 mm, with a PAHE seasonal pattern (Spring > Autumn > Winter > Summer). The dry season extends from June to August, while the wet season lasts from September to May (HWS, 2019).

Baghaï has approximately 7,340 inhabitants, with 1,825 workers employed in the agricultural sector. The municipality has strong agro-pastoral characteristics: 86% of its land is agricultural. Cereal farming (barley, durum wheat) predominates, followed by arboriculture (olive and apricot trees) and market gardening. Baghaï also stands out for its significant contribution to poultry production in Khenchela Province, accounting for 63.8% of egg production and 19.4% of white meat production (DSAK, 2018). Despite its modest size, Baghaï plays a major agricultural role in the region. It has significant development potential due to its natural resources (water, soils, climate) and active agricultural workforce. Its integration into local agricultural development policies is therefore essential.

2.2. Selection of the Experimental Site

The study was conducted during the 2019/2020 agricultural season on a private farm located in the southeast of the municipality of Baghaï, within a semi-arid climatic region. During the study period, the average temperatures ranged from 10 to 18 °C, with relative humidity between 40% and 60%, an average wind speed of 3 m/s, and an estimated evapotranspiration rate of 12 mm/day. The soil at the study site is occupied by a diversified orchard plantation (apple, apricot, fig trees, etc.) and subsistence vegetable crops, all irrigated using a drip irrigation system.

2.3. Sampling and Data Collection

The experimental farm consists of two distinct plots: one hectare irrigated with aquaculture water from a fish pond, and a second, larger plot of two hectares irrigated using groundwater from a borehole. Soil at the site is classified as humus-rich calcareous soil to calcareous soil, with a sandy loam texture. Composite soil sampling was conducted in april, 2020. Sampling was conducted in accordance with recognized standards (Mathieu & Pieltain, 2003; Rodier et al., 2009). Two water samples were collected, one from the fish pond and the other from the borehole. In addition, 25 soil samples were collected from a depth of 30 cm, distributed across both irrigation systems. Each soil sample was composed of a composite of four sub-samples collected from the same location (Fig. 2).

2.4. Sample Preparation and Laboratory Analysis

Due to COVID-19-related restrictions, laboratory access was limited, and analyses were restricted to basic parameters. For water samples, only in situ measurements were carried out, including pH, temperature, dissolved oxygen, total dissolved solids (TDS), and electrical conductivity (EC), using a multi-parameter probe. The soil samples were air-dried, sieved to 2 mm, and prepared using the 1:5 aqueous extract method prior to laboratory analysis. Only two parameters: electrical conductivity (EC) and pH were measured, following the procedures described by (Mathieu & Pieltain, 2003).

Figure 2. Map and method of collecting water and soil samples.

2.5. Methodological Objective

The primary objective of this methodological approach is to compare the impact of two types of irrigation water, fish-farming water and groundwater on agricultural soil quality by analysing key physicochemical parameters. The study also aimed to ensure methodological rigour in sampling protocols despite logistical constraints and to spatially map the distribution of these parameters using Geographic Information Systems (GIS), specifically ArcGIS 10.3.

3. Resultants and discussion

The data obtained from both in situ and laboratory measurements are summarised in Table 1. Due to field constraints and logistical limitations, soil analyses were restricted to pH and electrical conductivity (EC), while water analyses included pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO) content.

3.1. Interpretation of Water Quality

The assessment of water quality for irrigation purposes is based on the analysis of key physicochemical parameters. The measured values indicate minimal variation across the different water sources, suggesting a relatively stable water quality status.

3.1.1. Hydrogen potential (pH)

The pH is a critical parameter that determines whether water is acidic, neutral, or alkaline, on a scale ranging from 0 (highly acidic) to 14 (highly alkaline), with 7 representing a neutral state. For aquatic ecosystems, a pH range between 6.5 and 8.0 is generally considered optimal, as it supports the survival of most aquatic species. In the present study, the pH values of both fish pond and groundwater sources

Table 1. Analytical results of water and soil samples (Baghai).

Samples	**Soil**		**Water**					
Parameters	**CE (µS/cm)**	**pH**		**T (°C)**	**DO %**	**CE (µS/cm)**	**TDS (mg/l)**	**pH**
Mean	1560	7.20	Borehole	23.4	7.6	960	624	6.96
Max	1700	7.41	Pond (F)	22.3	82.2	916	595	7.36
Min	1400	6.72						

Were found to be close to neutrality, classifying them as suitable for irrigation and aquaculture. Such pH levels are considered ideal for fish growth and contribute positively to the development of aquaculture in the region.

3.1.2 Temperature

Water temperature is a fundamental factor influencing both the hydro chemical and biological properties of aquatic systems. It affects dissolved oxygen levels and the degree of mineralisation (Rajendiran et al., 2023). The measured temperatures were 23.4 °C for groundwater and 22.3 °C for fish pond water, values that are close to ambient conditions. These results indicate that the water is suitable for both irrigation and aquaculture activities, as the temperature supports biological processes essential for plant and fish development.

3.1.3 Dissolved Oxygen (DO)

Dissolved oxygen (DO), referring to molecular oxygen present in water, plays a vital role in sustaining aquatic life and supporting biological processes. DO concentration is influenced by a combination of physical (temperature, salinity, water mixing), chemical, and biological factors (Larance et al., 2025). The results reveal a significant difference between the two sources: DO in groundwater was low (7.6%), which is expected due to its isolation from atmospheric oxygen. Conversely, DO levels in the fish pond water were considerably higher (82.2%), likely due to aeration practices and exposure to the atmosphere. These high DO concentrations make fish pond water more favourable for aquaculture, supporting fish metabolism and growth.

3.1.4 Salinity (EC and TDS)

Electrical conductivity (EC) is a rapid and reliable proxy for estimating water salinity, expressed in microsiemens per centimetre (µS/cm). It measures the water's capacity to conduct electrical current, which increases with higher concentrations of dissolved salt (Dahaan et al., 2016). The results indicate similar salinity levels in both water sources: EC was 916 µS/cm in fish pond water and slightly higher at 960 µS/cm in groundwater. These values categorise both waters as having low salinity, making them suitable for irrigation. The marginally lower EC in fish pond water may be attributed to the biological activity of fish, which could influence the ionic composition.

Total dissolved solids (TDS), expressed in mg/L, provide a direct measure of the salt concentration in water. TDS values were 595 mg/L for fish pond water and 624 mg/L for groundwater. These results confirm the EC measurements and suggest a slight reduction in salinity due to the integration of fish farming activities. Overall, the data support the hypothesis that aquaculture integration contributes to salinity reduction, enhancing the suitability of irrigation water.

3.2. Evaluation of the Impact of Aquaculture Integration

The interpretation of the measured parameters does not allow for a precise assessment of soil quality but provides a general overview of their condition. The recorded data show only minor variations, which are analysed as follows:

3.2.1. Soil Salinity (Electrical Conductivity)

Soil salinity is typically evaluated based on the concentration of soluble salts (g/L) or, more commonly, through its electrical conductivity (EC), expressed in dS/m or µS/cm. Controlling soil salinity is essential for maintaining agricultural productivity and preventing land degradation, particularly in irrigated systems. Anthropogenic factors, especially irrigation with saline water, are among the main drivers of soil salinization (Scudiero et al., 2016).

According to the results, salinity values vary slightly from one sampling point to another, ranging between 1400 and 1700 µS/cm, with a mean value of 1560 µS/cm. Based on established soil salinity classification systems, such as those proposed by Riverside (USA), Servant (1975), and FAO (1999) (as referenced in Mathieu & Pieltain, 2003), the analysed soils can be categorised as slightly to moderately saline. Specifically, 66% of the soils irrigated with aquaculture water exhibited EC values below 1500 µS/cm, while 34% exceeded this threshold. In contrast, among the soils irrigated directly with groundwater, 62% had EC values above 1500 µS/cm, and only 38% were below. These findings suggest that soil salinity is more spatially homogeneous and lower in areas irrigated with aquaculture water compared to those irrigated solely with groundwater (Fig. 3). This may indicate a mitigating effect of fish farming on salt accumulation in irrigated soils.

3.2.2. Soil pH

Soil pH reflects its degree of acidity or alkalinity, which is a key indicator of soil chemical balance. It significantly influences nutrient availability and microbial activity and is closely related to the clay-humus complex. The pH measurement is considered a sensitive indicator of soil evolution and chemical changes (Kicińska et al., 2022).

Measured pH values ranged from 6.72 to 7.40, with an average of 7.20. These values categorise the soils as neutral, which is generally considered optimal for crop development. The spatial distribution of pH shows a trend toward neutrality in areas irrigated with aquaculture water, whereas soils irrigated with groundwater tend to be slightly more alkaline (Fig. 4).

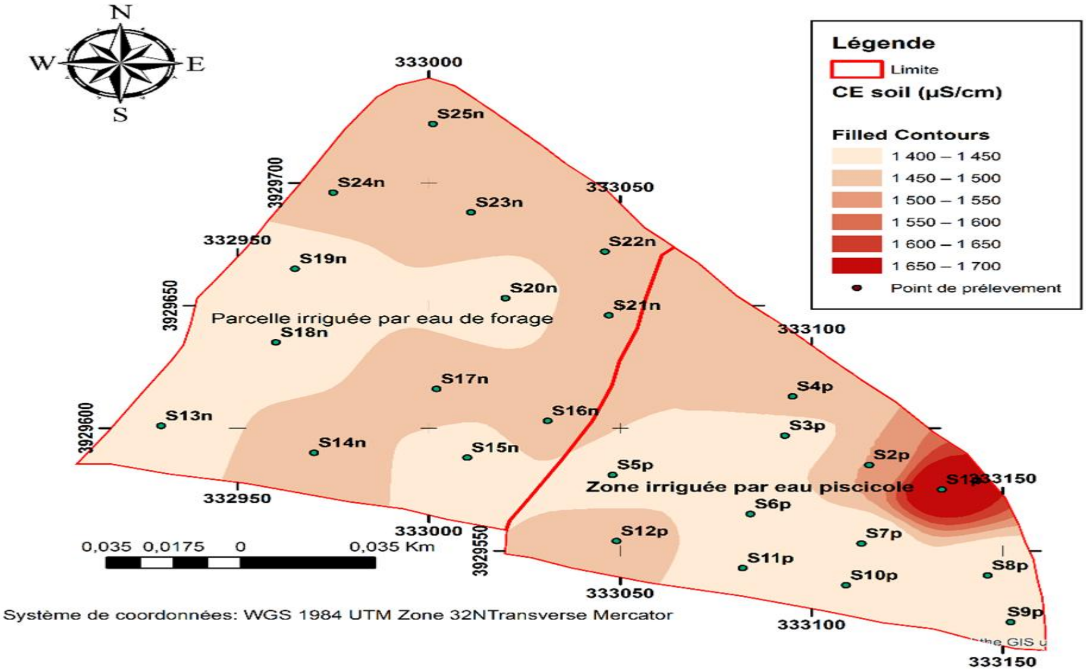

Figure 3. Spatial distribution map of soil salinity in the study area (Baghai).

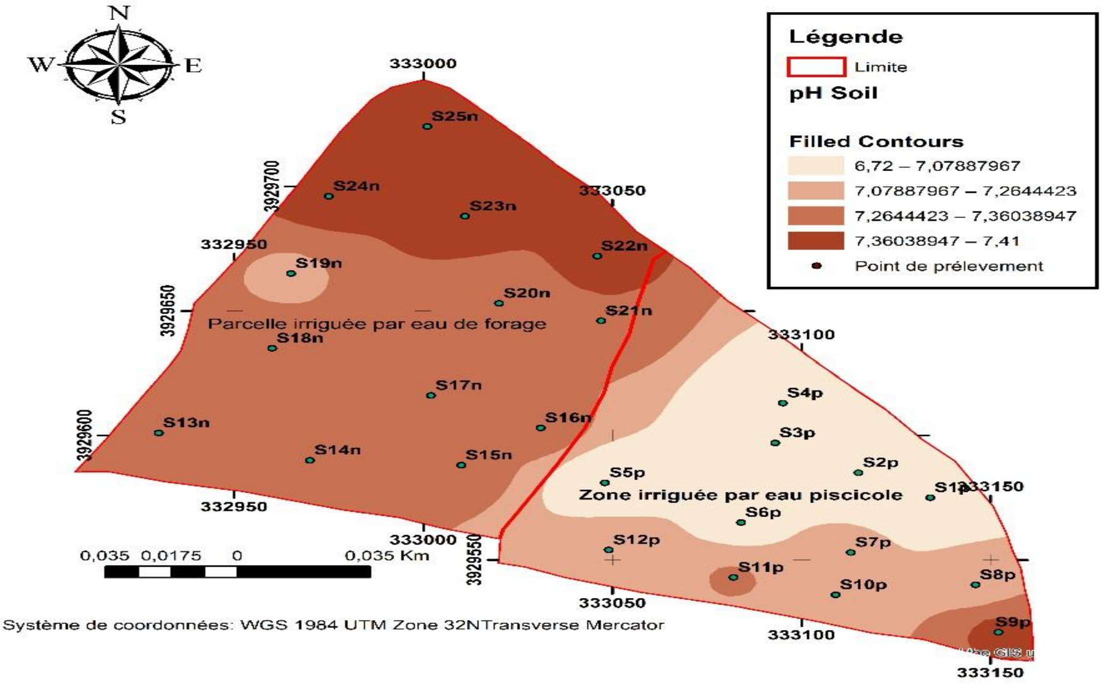

Figure 4. Spatial distribution map of the soil pH in the study area (Baghai).

These observations suggest that irrigation with fish pond water may contribute to improving soil chemical properties, potentially through an increase in organic matter content. The presence of organic Inputs from aquaculture may positively influence the clay-humus complex and help stabilise the soil pH, contributing to a more favourable environment for plant growth.

4. Conclusion

This study assessed the effects of fish pond water irrigation on the physicochemical properties of agricultural soils in the semi-arid region of Baghai, northeastern Algeria. The integration of aquaculture into agricultural practices, characterised by the reuse of nutrient-rich effluents from fish farming, demonstrated potential agroecological benefits, particularly in maintaining soil salinity at acceptable levels and sustaining a neutral pH conducive to crop growth.

The analysis of soil samples, revealed that plots irrigated with aquaculture water exhibited significantly lower and more spatially homogeneous salinity levels compared to those irrigated with groundwater. This finding suggests a possible dilution or buffering effect attributable to organic matter inputs from aquaculture effluents. Additionally, the pH values of soils irrigated with fish pond water remained within the optimal neutral range (mean pH ≈ 7.2), contrasting with the slightly alkaline trend observed in groundwater-irrigated plots. These results align with existing literature on the positive influence of integrated aquaculture-agriculture systems on soil chemistry through nutrient recycling and organic enrichment (Goddek et al., 2019b; Wang et al., 2024).

The physicochemical characterisation of irrigation water further supports the viability of aquaculture integration. Both water sources were found to be suitable for irrigation, with low salinity and pH values within the agronomic norms. Notably, dissolved oxygen levels were significantly higher in aquaculture water, reflecting enhanced biological activity and potential for improved water quality dynamics.

Despite the limitations posed by the COVID-19 pandemic, which restricted the scope of laboratory analyses to basic parameters, this study provides preliminary evidence that aquaculture effluents can be safely and beneficially reused in crop irrigation under semi-arid conditions. These results support the implementation of Integrated Aquaculture in Agriculture Systems (IAAS) as a sustainable land management strategy in arid and semi-arid environments, contributing to water use efficiency, soil quality preservation, and circular economic principles.

Future research should incorporate a broader range of soil health indicators (e.g., organic matter, nitrogen, phosphorus, potassium, microbial biomass, nutrient cycling) and assess long-term impacts through seasonal monitoring. Furthermore, the development and application of an integrated Water Quality Index (WQI) for aquaculture effluents and validation of soil trends via remote sensing techniques and statistical analyses are recommended. This would enable a more comprehensive understanding of the ecological and agronomic implications of IAAS and guide policymakers in the development of sustainable agricultural practices adapted to climatic and environmental constraints in North Africa.

References

Béné, C., Barange, M., Subasinghe, R., Pinstrup-Andersen, P., Merino, G., Hemre, G. I., & Williams, M. (2015). Feeding 9 billion by 2050 – Putting fish back on the menu. Food Security, 7(2), 261–274. https://doi.org/10.1007/S12571-015-0427-Z/FIGURES/6

Bogard, J. R., Marks, G. C., Wood, S., & Thilsted, S. H. (2018). Measuring nutritional quality of agricultural production systems: Application to fish production. Global Food Security, 16, 54–64. https://doi.org/10.1016/J.GFS.2017.09.004

Dahaan, S. A. M. Al, Al-Ansari, N., Knutsson, S., Dahaan, S. A. M. Al, Al-Ansari, N., & Knutsson, S. (2016). Influence of Groundwater Hypothetical Salts on Electrical Conductivity Total Dissolved Solids. Engineering, 8(11), 823–830. https://doi.org/10.4236/ENG.2016.811074

Dauda, A. B., Ajadi, A., Tola-Fabunmi, A. S., & Akinwole, A. O. (2019). Waste production in aquaculture: Sources, components and managements in different culture systems. Aquaculture and Fisheries, 4(3), 81–88. https://doi.org/10.1016/j.aaf.2018.10.002

Goddek, S., Joyce, A., Kotzen, B., & Dos-Santos, M. (2019a). Aquaponics and Global Food Challenges. Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future, 3–18. https://doi.org/10.1007/978-3-030-15943-6_1/FIGURES/3

Goddek, S., Joyce, A., Kotzen, B., & Dos-Santos, M. (2019b). Aquaponics and Global Food Challenges. Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future, 3–18. https://doi.org/10.1007/978-3-030-15943-6_1/FIGURES/3

Guan, W., Li, K., & Li, K. (2022). Bacterial communities in co-cultured fish intestines and rice field soil irrigated with aquaculture wastewater. AMB Express, 12(1), 1–10. https://doi.org/10.1186/S13568-022-01475-X/TABLES/2

Hasimuna, O. J., Maulu, S., Nawanzi, K., Lundu, B., Mphande, J., Phiri, C. J., Kikamba, E., Siankwilimba, E., Siavwapa, S., & Chibesa, M. (2023). Integrated agriculture-aquaculture as an alternative to improving small-scale fish production in Zambia. Frontiers in Sustainable Food Systems, 7, 1161121. https://doi.org/10.3389/FSUFS.2023.1161121/BIBTEX

Kicińska, A., Pomykała, R., & Izquierdo-Diaz, M. (2022). Changes in soil pH and mobility of heavy metals in contaminated soils. European Journal of Soil Science, 73(1). https://doi.org/10.1111/EJSS.13203

Larance, S., Wang, J., Delavar, M. A., & Fahs, M. (2025). Assessing Water Temperature and Dissolved Oxygen and Their Potential Effects on Aquatic Ecosystem Using a SARIMA Model. Environments 2025, Vol. 12, Page 25, 12(1), 25. https://doi.org/10.3390/ENVIRONMENTS12010025

Mathieu, C., & Pieltain, F. (2003). Analyse chimique des sols - Clément Mathieu , Françoise Pieltain - Librairie Eyrolles.

Nedjar, Y., Ouldjaoui, A., & Boulahbel, S. (2022). Water Quality Assessment for Irrigation Purposes in a Semi-Arid Region: Wadi Baghai (North East of Algeria). 26(5), 1289–1302. www.ejabf.journals.ekb.eg

Partelow, S., Asif, F., Béné, C., Bush, S., Manlosa, A. O., Nagel, B., Schlüter, A., Chadag, V. M., Choudhury, A., Cole, S. M., Cottrell, R. S., Gelcich, S., Gentry, R., Gephart, J. A., Glaser, M., Johnson, T. R., Jonell, M., Krause, G., Kunzmann, A., … Turchini, G. M. (2023). Aquaculture governance: five engagement arenas for sustainability transformation. Current Opinion in Environmental Sustainability, 65, 101379. https://doi.org/10.1016/J.COSUST.2023.101379

Rajendiran, T., Sabarathinam, C., Panda, B., & Elumalai, V. (2023). Influence of Dissolved Oxygen, Water Level and Temperature on Dissolved Organic Carbon in Coastal Groundwater. Hydrology, 10(4), 85. https://doi.org/10.3390/HYDROLOGY10040085/S1

Rodier, J., Legube, B., & Merlet, N. (2009). l'analyse de l'eau: Vol. 9éme (9th ed.). Dunod. https://fr.scribd.com/document/400832529/l-analyse-de-l-eau-dunod-pdf

Salim, B., & KhÃ©loufi, B. (2021). Water resources and food security in Algeria: Diagnosis and new strategy proposition. African Journal of Agricultural Research, 17(3), 414–424. https://doi.org/10.5897/AJAR2020.15125

Scudiero, E., Skaggs, T. H., & Corwin, D. L. (2016). Comparative regional-scale soil salinity assessment with near-ground apparent electrical conductivity and remote sensing canopy reflectance. Ecological Indicators, 70, 276–284. https://doi.org/10.1016/J.ECOLIND.2016.06.015

Wang, H. B., Liu, X. P., Jin, B. J., Shu, Y. C., Sun, C. L., Zhu, Y. G., & Lin, X. Y. (2024). High-molecular-weight dissolved organic matter enhanced phosphorus availability in paddy soils: Evidence from field and microcosm experiments. Soil and Tillage Research, 240, 106099. https://doi.org/10.1016/J.STILL.2024.106099

Zohra, B. F., Sameut, K. M., Beya, A. A., & Imad, H. (2021). The integration of aquaculture with agriculture in a semi-arid region in Northwest of Algeria. 25(4), 981–1001. www.ejabf.journals.ekb.eg

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Insecticidal and repellent activities of turpentine tree (*Pistacia terebinthus* L.) essential oils

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Abstract

The green peach aphid *Myzus persicae* (Sulzer, 1776), belonging to **Aphididae** Family, is among the most damaging crop pests. Due to the negative effects of chemical pesticides, the search of other control method is encouraged. Thus, the present investigation aims to test the effect of (*Pistacia terebinthus* L.1753), belonging to the Anacardiaceae family, essential oils (EOs) on this aphid species. A test of toxicity and another of repellency were conducted *in vitro*. The results showed a moderate aphicidal impact with the highest aphid mortality rate recorded for the bio-pesticide (61.51%) and the concentration 1000 ppm of EOs (42.83%), while the repellency percentage was weak (20%). These findings suggest combining the EOs of *P. terebinthus* with other control methods.

Key words: *Myzus persicae,* peach, corrected mortality, bio-aphicide, secondary metabolites

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1. INTRODUCTION

The green peach aphid *Myzus persicae* is an exceptional species in many respects as it is cosmopolitan, very polyphagous, highly efficient as a virus vector, and with a wide range of genetically-based variability in numerous properties (Blackman and Eastop, 2007). It is one of the most important pests of economic crops, as it damages them by consuming nutrients and water and by transmitting plant viruses. It is responsible for both qualitative and quantitative losses in agricultural production by causing chlorosis, necrosis, wilting, defoliation, and fruit abortion (Ali et al., 2023).

The use of pesticides, though effective in pest control, disturbs the soil health and biodiversity, as well as water quality, besides leading to high public health fears for long term exposure to poisonous substances (Sarkar et al., 2024). Moreover, *M. persicae* has the unenviable title of having resistance to more insecticides than any other herbivorous insect pest, which make necessary the finding of other control options and consequently, increased efforts have been undertaken to develop new management approaches (Ali et al., 2023).

Due to current changes over the decades, researchers, policymakers and farmers have begun searching for safer substitutes in place of environmentally harmful chemical pesticides (Sarkar et al., 2024). A promising strategy to mitigate the reliance on chemical pesticides involves the adoption of novel insecticides, specifically semi-chemicals derived from plants, commonly known as botanical insecticides (Siregar et al., 2024). Botanical pesticides are receiving increasing attention from researchers and growers as an alternative to synthetic pesticides (Bourenane et al., 2025). They are an important tool in integrated pest management and the implementation of botanical pesticides is expected to increase in the next decade of development and expansion of organic agriculture (Guo et al., 2024). Botanicals and essential oils (EOs) are emerging as promising alternatives that offer a safer and more sustainable approach to pest management (Sarmah et al., 2025). Assessing the toxicity of EOs on different test subjects is a crucial aspect in evaluating their biological activity, and numerous studies have already demonstrated significant variations in the toxicity of different EOs on various tested pests (Zhu et al., 2024).

On the other hand, the genus *Pistacia* (Bauhin) belonging to the family of Anacardiaceae, is noteworthy for its numerous species and varieties of wild-growing plants, including some endemics of the Mediterranean area (Dhifi et al., 2012). Thanks to their biological activities (antioxidant, antimicrobial, anti-inflammatory and cytotoxic potentials), *Pistacia* species have attracted the attention of researchers (Dhifi et al., 2012). *Pistacia terebinthus* L. is evergreen shrubs or small trees native to the Mediterranean countries (Kıvçak et al., 2004). It is commonly known as terebinth or turpentine tree it is used as a traditional medicine in different countries (Pulaj et al., 2016), as stimulants, diuretics, and astringents (Bellifa et al., 2021) and in human nutrition (Özcan et al., 2009).

Several studies mentioned the insecticidal potential of essential oils from different plant species. However, the effect of ***P. terebinthus*** is not known against insects. In this context, the purpose of this study is to evaluate the repellent and aphicidal activity of the essential oils of this species against *M. persicae*.

2. MATERIALS AND METHODS

Essential Oils 'EOs' from *P. terebinthus* were obtained using hydrodistillation method. Afterward, five dilutions (100, 500, 1000, 5000 and 10000 ppm) were prepared.

Furthermore, leaves of Peach *Prunus persica* (L. 1801)(*Nectarine* Cultivar), belonging to the Rosaceae family, and Green Peach Aphid colony were collected from an orchard in the region of Khenchela (eastern Algeria) and used in the experiments.

2.1 Test of toxicity

The bioassay was carried out under *in vitro* conditions. A total of 21 Petri dishes were prepared with three repetitions for each treatment. The tested treatments were: 5 dilutions of the EOs, control, a bio-insecticide (Vegex Crisflor®, targeting a wide range of pests, including aphids).

Leaf discs were dipped in each treatment for few seconds. Then each treated disc was kept in the Petri dish with 15 aphids *M. persicae*. Mortality was observed 3, 6, 12 and 24H after treatment.

Corrected mortality was calculated through Abbots formula (1925).

2.2. Test of repellency

Repellency effect of the dilution 10000 ppm of *P. terebinthus* was tested. A total of 18 Petri dishes were prepared with six repetitions for each treatment. Data were taken for each. Each replicate, consisted of a dish separated into two equal parts, contained two discs (one dipped in the solution and the other untreated) and 10 aphids placed in the center. The procedure is repeated six times. The number of insects in each side was noted after 24 H.

Percentage of repellency was calculated according to the following formula:

PR = [(NC – NT) / (NC + NT)] × 100 (Singh et al., 2012).

2.3 Statistical analysis

Analysis of variance with one factor (ANOVA) coupled with the test Student-Newman-Keuls was used to compare the results of the toxicity bioassay. Besides, the assessment of LC50 was carried out, via SPSS, using *Probit* option.

3. RESULTS AND DISCUSSION

3.1 Effect of essential oils of *P. terebinthus* on the mortality of *M. persicae*

Statistical analysis ANOVA revealed significant differences in mortality of *M. persicae* between the different treatments. The mortality rate was low (not exceeding 20%) for the treatments 100 and 500 ppm, while it was greater than 30 % for the treatments 1000, 5000 and 10000 ppm (were 42.83, 38.49and 36.16%, respectively) (Table 1).

In addition, the estimated LC 50 of the studied extracts was 31848 ppm.

Table 1. Mortality rates of *M. persicae* after 24 hours of exposure to *P. terebinthus* EOs

Treatments	Corrected mortality (M ± SE)
100 ppm	13.65 ± 8.08 a
500 ppm	15.67 ± 8.09 a
1000 ppm	42.83 ± 5.25ab
5000 ppm	38.49± 4.31ab
10000 ppm	36.16 ± 9.53ab
Bio-pesticide	61.51 ± 7.55 b
Signification	0,006 *

** Values indicated with different letters are significantly different at P< 0, 05*

The aphicidal effect recorded in the present study is lower in comparison with other plants studied earlier against ***M. persicae,*** such as ***Cotula cinerea*** EO recording 75.95% of mortality in the 3rd dose with a lethal concentration (LC50) equal to 302.4 µl (Dehliz et al., 2022), *Cymbopogon winterianus* EO at 1% (w v-1) causing mortality at 96.9% with LC50 was 0.36% and the crude aqueous extracts from *Cassia angustifolia* seeds and *C. angustifolia* leaves were the most effective causing up to 96.67and 93.33% mortality, respectively (Yadav & Patel, 2017). These differences are due to the different chemical composition, especially in secondary metabolites content. The large group of secondary plant metabolites are the most promising compounds in the management of insect pests (Tlak Gajger & Dar, 2021). Results demonstrated that essential oils and their main components could be applicable to the management of insect pests to decrease ecologically detrimental effects of synthetic insecticides (Sendi & Ebadollahi, 2014). For instance, a study investigating the insecticidal effects of the *Thuja occidentalis* L. (Cupressaceae) essential oil, against the peach aphid, confirmed that its compounds terpinyl acetate and bornyl acetate can be used as environmentally friendly insecticidal-active compounds (Song et al., 2022). A previous study found among the compounds characterized in the essential oil of *P. terebinthus*, bornyl acetate as major constituents (Kıvçak et al., 2004), even though results confirm the effect of locality on the *P. terebinthus* oil content and composition (Özcan et al., 2009). Furthermore, an antibacterial assay showed that *P. terebinthus* seed essential oil was moderately active against the tested microorganisms due to its low amount of oxygenated monoterpenes (Dhifi et al., 2012).

On the other hand, Wróblewska-Kurdyk et al. (2015) mentioned that the application of caraway essential oil and its main components, carvone and limonene, to plant surface caused significant changes in aphid probing at the level of non-vascular tissues as well as sieve elements.

3.2. Effect of essential oils of *P. terebinthus* on the repellency of *M. persicae*

The results of the test of repellency revealed that the studied extract is ranged under the class I according to the classification of McDonald et al. (1970), with a PR of 20 %. Although *P. terebinthus* can be considered as an alternative source of oil rich in phytochemicals including carotenoids and phenolic compounds (Durmaz & Gökmen, 2011), it didn’t show an important repellent impact in our case comparatively with other extracts. For instance, Dehliz et al. (2022) indicated that *Cotula cinerea* EO has a significant repellency against *M. persicae* **s**howing a high rate in the 2^{nd} dose (64.6%). Whereas, the repellent activity of *Cassia angustifolia* against the same aphid species was inversely related to concentration of plant extract (Yadav & Patel, 2017).

4.CONCLUSIONS

The moderate aphicidal efficiency of the *P. terebinthus* against *M. persicae suggests using it combined with other control tools to limit the aphid populations. Besides, further field and lab investigations are recommended to screen accurately the* insecticidal potential of the terebinth tree.

5. REFERENCES

Abbott, W.S. (1925). A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology*, 18, 265-267.

Ali, J., Bayram, A., Mukarram, M., Zhou, F., Karim, M. F., Hafez, M. M. A., ...& Shamsi, I. H. (2023). Peach–potato aphid *Myzus persicae*: Current management strategies, challenges, and proposed solutions. *Sustainability*, *15*(14), 11150.

Blackman, R.L. & Eastop, V.F.(2007), Aphids on the World's Herbaceous Plants and Shrubs. John Wiley & Sons, Ltd.

Bellifa, N., Benhaddou, A. I., Ferkous, H. E., Selka, M. A., Toumi, H., & Achouri, M. Y. (2021). Antioxidant activity and polyphenol composition of *Pistacia terebinthus* fruit from Tessala (Western Algeria). *The North African Journal of Food and Nutrition Research*, *5*(11), 30-34.

Bourenane, E., Mohammedi, A., Amokrane, D., Mekideche, S., Mezani, S., & Ababou, A. (2025). Inventory and diversity of botanical pesticides: a case study of the Blidian Atlas, North-Central Algeria. *Applied Ecology & Environmental Research*, *23*(3).

Dehliz, A., Lakhdari, W., Mlik, R., Chahbar, N., Acheuk, F., Mekhadmi, N. E., & Badjadi, Z. (2022). Chemical composition and bioactivity of essential oil against the green peach aphid (*Myzus persicae*). *Organic Agriculture*, *12*(3), 411-418.

Dhifi, W., Mnif, W., Ouerhani, B., & Ghrissi, K. (2012). Chemical composition and antibacterial activity of essential oil from the seeds of *Pistacia terebinthus* grown in Tunisia. *Journal of Essential Oil Bearing Plants*, *15*(4), 582-588.

Durmaz, G., & Gökmen, V. (2011). Changes in oxidative stability, antioxidant capacity and phytochemical composition of *Pistacia terebinthus* oil with roasting. *Food chemistry*, *128*(2), 410-414.

Guo, C., Wang, L., Chen, N., Zhang, M., Jia, J., Lv, L., & Li, M. (2024). Advances in research and utilization of botanical pesticides for agricultural pest management in inner Mongolia, China. *Chinese Herbal Medicines*, *16*(2), 248-262.

Kıvçak, B., Akay, S., Demirci, B., & Başer, K. (2004). Chemical composition of essential oils from leaves and twigs of *Pistacialentiscus*, *Pistacia lentiscus* var. chia, and *Pistacia terebinthus* from Turkey. *Pharmaceutical biology*, *42*(4-5), 360-366.

McDonald, L.L., Guy, R.H. & Speirs, R.D. (1970). Preliminary evaluation of new candidate materials as toxicants, repellents, and attractants against stored-product insects. Marketing Research Report No. 882. US Agricultural Research Service: USA.8 p.

Özcan, M. M., Tzakou, O., & Couladis, M. (2009). Essential oil composition of the turpentine tree (*Pistacia terebinthus* L.) fruits growing wild in Turkey. *Food Chemistry*, *114*(1), 282-285.

Pulaj, B., Mustafa, B., Nelson, K., Quave, C. L., & Hajdari, A. (2016). Chemical composition and in vitro antibacterial activity of *Pistacia terebinthus* essential oils derived from wild populations in Kosovo. *BMC complementary and alternative medicine*, *16*, 1-9.

Sarmah, K., Anbalagan, T., Marimuthu, M., Mariappan, P., Angappan, S., & Vaithiyanathan, S. (2025). Innovative formulation strategies for botanical-and essential oil-based insecticides. *Journal of Pest Science*, *98*(1), 1-30.

Sarkar, S., Sultana, S., Hembram, S., Saha, S., Ganguly, B., Barman, P., & Pal, P. K. (2024). Natural Pesticides in Indian Agriculture Sector: A Minireview.*Uttar Pradesh Journal of Zoology Volume 45, Issue 24, Page 90-104.*

Sendi, J. J., & Ebadollahi, A. S. G. A. R. (2014). Biological activities of essential oils on insects. *Recent Progress in Medicinal Plants (RPMP): Essential Oils II*, *37*, 129-150.

Siregar, R. S., Bangun, I. H., Saleh, A., Silalahi, M., Apriyanti, I., Kamaludin, M., & Abogazia, A. H. (2024). Exploring ginger as botanical pesticides for sustainable maize protection, economic growth, and landscape planning strategies for maize in North Sumatra, Indonesia. *ARPHA Preprints*, *5*, e122499.

Singh, A., Kataria, R., & Kumar, D. (2012). Repellence property of traditional plant leaf extracts against *Aphis gossypii* Glover and *Phenacoccus solenopsis* Tinsley. *African Journal of Agricultural Research*, *7*(11), 1623-1628.

Song, H. J., Yong, S. H., Kim, H. G., Kim, D. H., Park, K. B., Shin, K. C., & Choi, M. S. (2022). Insecticidal activity against *Myzus persicae* of terpinyl acetate and bornyl acetate in *Thuja occidentalis* essential oil. *Horticulturae*, *8*(10), 969.

Tlak Gajger, I., & Dar, S. A. (2021). Plant allelochemicals as sources of insecticides. *Insects*, *12*(3), 189.

Wróblewska-Kurdyk, A., Nowak, L., Dancewicz, K., Szumny, A., & Gabrys, B. (2015). In search of biopesticides: The effect of caraway *Carum carvi* essential oil and its major constituents on peach potato aphid *Myzus persicae* probing behavior. *Zeszyty Naukowe. Acta Biologica. Uniwersytet Szczeciński*, *22*.

Yadav, S. K., & Patel, S. (2017). Insecticidal and repellent activity of some plant extracts against *Myzus persicae* (Sulzer) and *Brevicoryne brassicae* (Linnaeus). *Journal of entomology and zoology studies*, *5*(2), 1434-143.

Zhu, Y., Wu, T., Hu, Q., He, W., Zheng, Y., Xie, Y., & Liu, X. (2024). Plant essential oils: Dual action of toxicity and egg-laying inhibition on *Tetranychus urticae* (Acari: Tetranychidae), unveiling their potential as botanical pesticides. *Plants*, *13*(6), 763.

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Effect of Olive Pomace Amendment on Earthworm Activity: A Dose-Response Study

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Abstract

Olive pomace, the main solid residue of olive oil extraction, accumulates widely in Mediterranean agroecosystems and requires sustainable valorisation. This study assessed the dose-dependent effects of pomace incorporation on soil properties and on two earthworm species with contrasting ecological strategies. In a 60-day microcosm experiment, *Aporrectodea trapezoides* and *Eisenia fetida* were exposed to six amendment rates (0–100 % v/v). Pomace significantly modified soil conditions: pH and carbonates decreased, while electrical conductivity and organic matter increased, with minimal texture changes. Biological responses revealed a toxicity gradient. The 12.5% dose stimulated growth and maintained high survival and reproduction. At 25%, survival declined sharply and reproduction ceased, whereas ≥50% caused complete mortality. *A. trapezoides* was more tolerant than *E. fetida*. Multivariate analysis linked high doses to salinity and organic overload negatively correlated with biological parameters. Olive pomace can therefore serve as a soil amendment only at low rates (≤12.5%), while higher applications pose significant ecotoxicological risks to soil fauna and soil quality.

Key words: Olive pomace; *Aporrectodea trapezoides*; *Eisenia fetida*; soil amendment; ecotoxicology; dose-response.

18 INTRODUCTION

The olive tree (*Olea europaea* L.) is one of the most ancient cultivated species in the Mediterranean basin, where over 98% of the world's 805 million olive trees are concentrated (Gomes et al., 2012). Mediterranean countries account for more than 90% of global olive production (FAO, 2008). In Algeria, olive farming represents a deeply rooted tradition with historical continuity spanning millennia, having played a fundamental role in rural economies (Alloum, 1974). Currently, Algeria is implementing ambitious expansion programs aiming to reach one million hectares of olive cultivation (Missat, 2012).

Beyond olive oil production, the olive industry generates substantial quantities of by-products, including olive pomace the solid residue comprising pits, pulp, and skin remaining after olive crushing, sometimes mixed with olive mill wastewater (FAO, 2008). Olive pomace represents one of the most abundant agricultural residues in olive-producing countries, yet it is frequently discarded without proper management, leading to significant environmental pollution with adverse consequences for human health (Djadouf et al., 2011).

Earthworms constitute the predominant soil invertebrate biomass in most terrestrial ecosystems, playing exclusive roles in soil structure formation, organic matter decomposition, and nutrient cycling (Puga-Frettas, 2012). Their sensitivity to environmental perturbations makes them excellent bioindicators of soil quality, with their abundance and reflecting ecosystem health status (Fründ et al., 2010; Tondoh et al., 2007). Representing 40 to 90% of total soil animal biomass, earthworms are fundamental drivers of soil functional processes.

Previous studies have documented soil acidification following olive mill waste application (Levi-Minzi et al., 1992; Lachguer et al., 2002; Taamallah, 2007), increased salinity (Moumni, 2014), and potential toxicity from phenolic compounds (Moco et al., 2010). The dose-response relationship between earthworm biological parameters and pomace concentration is still unclear, though, and sensitivity models tailored to individual species have not been thoroughly examined.

This study aimed to evaluate the effects of olive pomace amendment at varying concentrations on the activity of two earthworm species with: the endogeic/aneciuc *Aporrectodea trapezoides* and the epigeic *Eisenia fetida*. Specifically, we assessed: (1) changes in soil physicochemical properties following pomace application across a concentration gradient; (2) earthworm growth, survival, and reproduction responses to increasing pomace concentrations; and (3) differential sensitivity between earthworm species to identify tolerance thresholds and bioindicator potential.

19 MATERIALS AND METHODS

2.1. Experimental Design

A laboratory microcosm assay was established using a completely randomized design including six pomace amendment and two earthworm species. Each treatment–species combination was replicated three repetitions, resulting in 36 experimental units. Each unit consisted of a 2L container filled with 1 kg of soil–pomace substrate and inoculated with 10 adult clitellate of a single species with comparable size. Microcosms were maintained for 60 days under controlled conditions (20 to 22 °C). Moisture was standardized by adding 50 ml of distilled water weekly, and containers were fitted with perforated lids to ensure aeration.

2.2. Collection and Preparation of Materials

- Black Oleaster olive pomace collected from El HadjaYamina oil mill (Baghai, Khenchela, Algeria); cold-pressed extraction ≤25 °C (4 qx·h^{-1}); stored in darkness at 4 °C; initial properties: pH 4.7 ± 0.02, EC 2.85 ± 0.15 dS·m^{-1}.
- *Aporrectodea trapezoides* collected in N'sigha and *Eisenia fetida* in Kais (Khenchela province); transported in native soil, rinsed with distilled water, acclimated 48 h in control soil; identification based on morphological criteria (Bouché, 1972); ecology: *E. fetida* epigeic (4–5 cm, purplish), *A. trapezoides* epi-anecic (80–140 mm, greenish).
- Soil sampled from 0–20 cm depth at Kais site; air-dried 72 h, gently crushed, sieved (2 mm), homogenized and stored in sealed containers before use.

2.3. Treatments

Six substrates were formulated by mixing soil and olive pomace at volumetric ratios: 0% (control), 12.5%, 25%, 50%, 75%, and 100% pomace. An additional control composed of soil only and without earthworms was established for each treatment to evaluate physicochemical changes independent of biological activity.

2.4. Physicochemical Analyses

- Soil pH measured potentiometrically in a 1:2.5 soil-to-water suspension using a calibrated pH meter.

- Electrical conductivity determined in 1:5 soil-to-water extracts with a conductimeter at 25 °C.
- Organic matter estimated via total organic carbon (Walkley–Black method); oxidation by potassium dichromate and titration with ferrous ammonium sulfate; OM calculated as TOC × 1.72.
- Total calcium carbonate quantified using a Bernard calcimeter; CO_2 release after acid reaction compared with pure $CaCO_3$ standard.
- Soil texture assessed by hydrometer method: 50 g air-dried soil dispersed in 5% sodium hexametaphosphate; hydrometer readings at 40 s (sand) and h (clay); silt calculated by difference; textural class assigned using USDA triangle.
- All measurements performed in triplicate.

2.5. Earthworm biological responses

Were monitored throughout the experiment. At day 0, individuals were counted, collectively weighed per microcosm, and introduced into the substrate. At day 60, microcosms were carefully hand-sorted to recover all adult earthworms and cocoons. The following endpoints were quantified:

- Survival (%): (Number of surviving individuals/10) × 100.
- Growth (g): mean final individual weight − mean initial individual weight.
- Reproduction: total number of cocoons recovered per microcosm.

2.6. Statistical analyses

Data were analyzed using SAS software (v. 9.3.1). Normality of residuals was assessed with the Shapiro–Wilk test, and homogeneity of variances was verified using Levene's test. Soil parameters were evaluated by one-way ANOVA with treatment as a fixed factor. Earthworm endpoints were analyzed via two-way ANOVA with species and treatment as fixed factors, including their interaction. Significant differences ($\alpha = 0.05$) were further assessed using Tukey's Honestly Significant Difference (HSD) test.

Regression analyses were conducted to examine the relationship between exposure time and earthworm growth and survival. Multivariate relationships among soil properties and earthworm responses were explored using Principal Component Analysis (PCA) in XLStat (2014), with separate analyses for each species. All variables were standardized prior to PCA. Results are reported as mean ± standard deviation (SD).

3. RESULTATS

3.1. Effect of Olive Pomace on Soil Physicochemical Parameters

3.1.1. Soil pH

Pomace application significantly affected soil pH ($F_{5,12} = 73.34$, $p < 0.0001$; Table 1). Control soil (T0) exhibited slightly alkaline pH (7.24 ± 0.22). All pomace-amended treatments showed significantly lower pH values, decreasing progressively with increasing pomace concentration (Figure 1). The most acidic pH (6.36 ± 0.16) was observed in T4 (75% pomace). The relationship between pomace concentration and pH followed a negative linear trend ($R^2 = 0.94$).

Table 1. Analysis of variance for effect of olive pomace on soil pH.

Source	df	Sum of squares	Mean square	F	p-value
Pomace effect	5	10.990	2.198	73.34	<0.0001
Error	12	0.360	0.030		
Total	17	11.350			

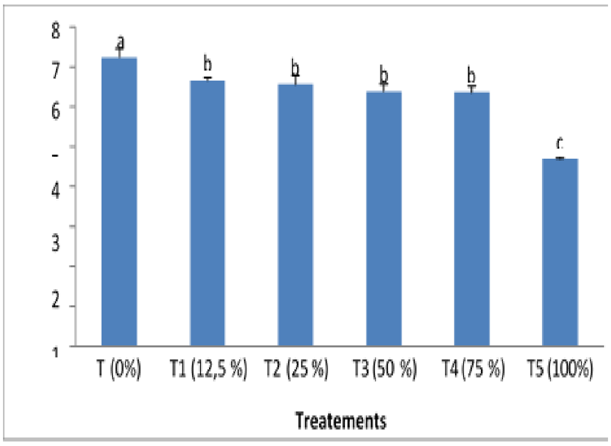

Figure 1. Effect of pomace on the soil pH.

3.1.2. Electrical Conductivity (EC)

Electrical conductivity differed highly significantly among treatments ($F_{5,12} = 28.22$, $p < 0.0001$; Table 2). Control soil showed low EC (0.21 ± 0.02 dS/m). EC increased progressively with pomace concentration (Figure 2), reaching 0.77 ± 0.13 dS/m in T1, 1.15 ± 0.15 dS/m in T2, and 1.72 ± 0.20 dS/m in T5. The relationship followed a positive exponential trend ($R^2 = 0.96$).

Table 2. Variance Analysis for effect of olive pomace on soil electrical conductivity.

Source	df	Sum of squares	Mean square	F	p-value
Pomace effect	5	4.751	0.950	28.22	<0.0001
Error	12	0.404	0.034		
Total	17	5.155			

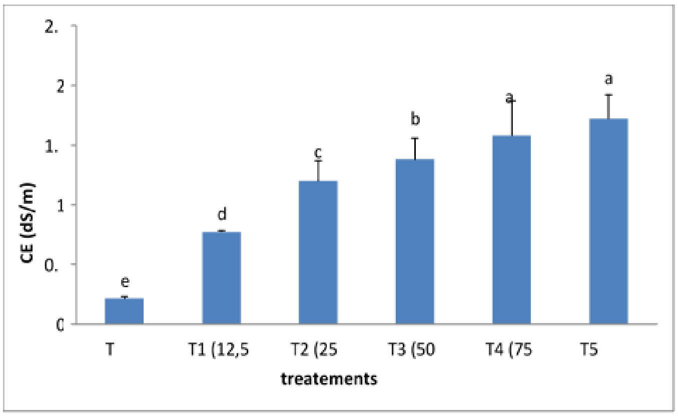

Figure 2. Effect of pomace on the soil EC.

3.1.3 Organic Matter

Soil organic matter content showed highly significant differences among treatments ($F_{5,12} = 11.59$, $p = 0.0003$; Table 3). OM increased with pomace concentration (Figure 3), ranging from 12.3 ± 1.2% in T0 to 28.7 ± 2.1% in T5.

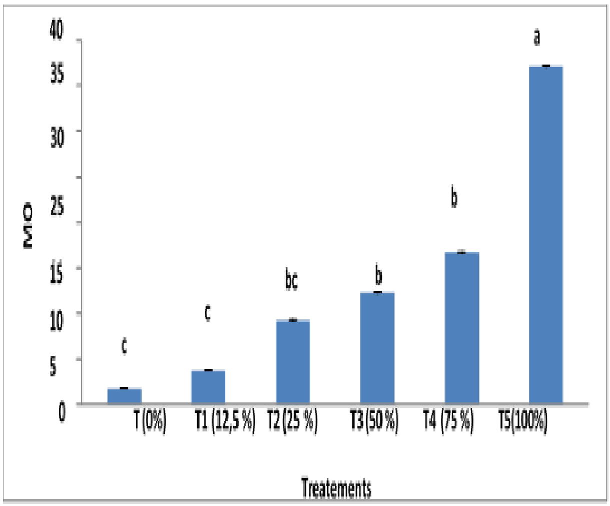

Figure 3. Effect of pomace on the soil OM.

3.1.4. Total limestone

Highly significant differences in total limestone content were observed among treatments ($F_{5,12} = 65.92$, $p < 0.0001$; Table 3). Control soil contained 30.00 ± 2.59% $CaCO_3$. Total limestone decreased progressively with increasing pomace concentration (Figure 4), reaching 17.83 ± 1.75% in T3 and 0% in T5. The relationship followed a negative linear trend ($R^2 = 0.93$).

Table 3. Analysis of variance for effect of olive pomace on total soil limestone.

Source	df	Sum of squares	Mean square	F	p-value
Pomace effect	5	874.4	174.8	65.92	<0.0001
Error	12	31.8	2.653		
Total	17	906.2			

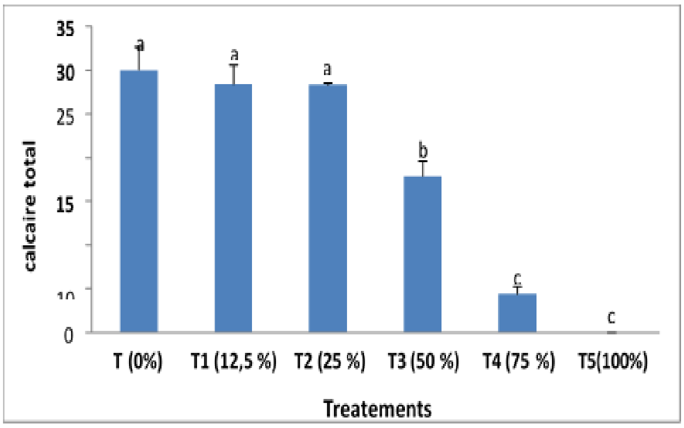

Figure 5. Effect of pomace on total soil limestone.

3.1.5. Soil Texture

Pomace application did not alter overall soil textural classification across treatments (Table 4). Control soil (T0) exhibited 14.9 ± 0.1% sand, 23.8 ± 0.3% clay, and 49.5 ± 0.2% silt, classifying as sandy loam. However, significant treatment effects were detected for individual fractions: silt content showed highly significant differences ($F_{4,10} = 18.2$, $p < 0.0001$), sand content showed significant differences ($F_{4,10} = 4.8$, $p = 0.0098$), while clay content remained unaffected ($F_{4,10} = 2.1$, $p = 0.1156$).

Silt content increased markedly in T2 (55.2 ± 2.6%) compared to control, while decreasing dramatically in T3 (6.3 ± 0.3%) and T4 (9.1 ± 0.3%) where earthworm mortality occurred. All treatments maintained sandy loam texture classification despite these component variations.

Table 5: Particle size distribution (mean ± SD) across pomace treatments.

Treatment	Sand (%)	Clay (%)	Silt (%)
T0 (0%)	14.9 ± 0.1c	23.8 ± 0.3	49.5 ± 0.2a
T1 (12.5%)	51.2 ± 0.3ab	7.5 ± 0.4	23.4 ± 0.4b
T2 (25%)	47.7 ± 3.2bc	9.5 ± 0.8	55.2 ± 2.6a
T3 (50%)	82.6 ± 0.5a	9.0 ± 0.2	6.3 ± 0.3c
T4 (75%)	77.4 ± 0.5ab	2.7 ± 0.5	9.1 ± 0.3c

Means within columns followed by different letters differ significantly (Tukey's HSD, $p < 0.05$).

3.2. Effect of Olive Pomace on Earthworm Activity

3.2.1 Earthworm Growth

Two-way ANOVA revealed highly significant effects of species ($F_{1,24} = 333.42$, $p < 0.0001$), treatment ($F_{6,24} = 273.53$, $p < 0.0001$), and their interaction ($F_{6,24} = 53.96$, $p < 0.0001$) on earthworm growth (Table 5).

A. trapezoides showed significantly higher mean growth (6.366 ± 0.42 g) compared to *E. fetida* (2.744 ± 0.31 g; $p < 0.0001$). Growth varied significantly across treatments (Table 6). T1 (12.5% pomace) produced the highest mean growth (9.195 ± 0.51 g), significantly exceeding control (8.458 ± 0.44 g; $p = 0.023$). T2 (25% pomace) reduced growth to 6.467 ± 0.38 g, while T3-T5 resulted in complete mortality.

The species × treatment interaction significantly influenced growth patterns (Table 8). A. trapezoides maintained positive growth across T0, T1, and T2, while E. fetida growth declined markedly in T2 (1.35 ± 0.12 g) compared to T1 (6.72 ± 0.35 g; $p < 0.0001$).

Table 5. Two-way ANOVA for effects on earthworm growth.

Source	df	Sum of squares	Mean square	F	p-value
Species	1	137.705	137.705	333.42	<0.0001
Treatment	6	677.810	112.968	273.53	<0.0001
Species × Treatment	6	133.716	22.153	53.96	<0.0001

Table 6. Mean earthworm growth across pomace treatments

Treatment	Mean growth (g)	Homogeneous group
T0 (0%)	8.458 ± 0.44	ab
T1 (12.5%)	9.195 ± 0.51	a
T2 (25%)	6.467 ± 0.38	c

T3 (50%)	0	d
T4 (75%)	0	d
T5 (100%)	0	d

Table 7. Mean growth (g) by species across treatments.

Treatment	*A. trapezoides*	*E. fetida*
T0 (0%)	10.85 ± 0.62b	6.06 ± 0.41b
T1 (12.5%)	11.67 ± 0.71a	6.72 ± 0.35a
T2 (25%)	11.57 ± 0.68ab	1.35 ± 0.12
T3-T5	0c	0c

3.2.2. Earthworm Survival

Survival analysis revealed highly significant treatment effects ($F_{6,24}$ = 278.43, p < 0.0001), but no significant species effect (p = 0.2103) or species × treatment interaction (p = 0.6664; Table 8).

Table 8. Two-way ANOVA for effects on earthworm survival.

Source	df	Sum of squares	Mean square	F	p-value
Species	1	0.820	0.820	1.64	0.2103
Treatment	6	833.7	138.962	278.43	<0.0001
Species × Treatment	6	2.039	0.340	0.68	0.6664

Survival rates differed markedly among treatments (Table 10). Control (T0) showed near-complete survival (99.37 ± 0.63%), followed closely by T1 (97.47 ± 2.50%). T2 exhibited substantially reduced survival (37.02 ± 5.23%). Treatments ≥50% pomace resulted in complete mortality.

Table 9. Mean earthworm survival (%) across treatments.

Treatment	Survival (%)	Homogeneous group
T0 (0%)	99.37 ± 0.63	a
T1 (12.5%)	97.47 ± 2.50	ab
Positive control	90.40 ± 3.15	b
T2 (25%)	37.02 ± 5.23	c
T3-T5	0	d

3.2.3. Earthworm Reproduction

Reproduction was significantly affected by species ($F_{1,24}$ = 51.20, p < 0.0001), treatment ($F_{6,24}$ = 304.20, p < 0.0001), and their interaction ($F_{6,24}$ = 21.80, p < 0.0001; Table 10).

Table 10. Two-way ANOVA for effects on earthworm reproduction

Source	df	Sum of squares	Mean square	F	p-value
Species	1	6.095	6.095	51.20	<0.0001
Treatment	6	217.285	36.214	304.20	<0.0001
Species × Treatment	6	15.571	2.595	21.80	<0.0001

E. fetida exhibited significantly higher mean cocoon production (1.810 ± 0.15) compared to *A. trapezoides* (1.047 ± 0.11; p < 0.0001). Cocoon production occurred exclusively in T0 and T1 (Table 11).

Control produced 5.50 ± 0.55 cocoons, followed by T1 (4.50 ± 0.50). No cocoons were observed in T2-T5.

Table 11. Mean cocoon production across treatments.

Treatment	Mean cocoons	Homogeneous group
T0 (0%)	5.50 ± 0.55	a
T1 (12.5%)	4.50 ± 0.50	b
T2-T5	0	c

The species × treatment interaction revealed that both species produced cocoons only in T0 and T1, with E. fetida consistently showing higher numbers (Table 12).

Table 12. Mean cocoon production by species across treatments.

Treatment	*A. trapezoides*	*E. fetida*
T0 (0%)	4.00 ± 0.00a	7.00 ± 1.00a
T1 (12.5%)	3.33 ± 0.57b	5.66 ± 0.57b
T2-T5	0c	0c

3.3. Principal Component Analysis

For *A. trapezoides*, the first two principal components explained 85.34% of total variance (PC1: 65.85%, PC2: 19.49%). PC1 was positively correlated with EC (r = 0.92), OM (r = 0.89), and sand (r = 0.86), and negatively correlated with pH (r = -0.88), total limestone (r = -0.91), and all earthworm parameters (growth: r = -0.94; survival: r = -0.91; reproduction: r = -0.87).

Treatment projection revealed clear separation: T3-T5 (≥50% pomace) showed positive scores on PC1 (high EC, OM, sand; low earthworm activity), while T0-T2 (≤25% pomace) showed negative scores (Figure 1).

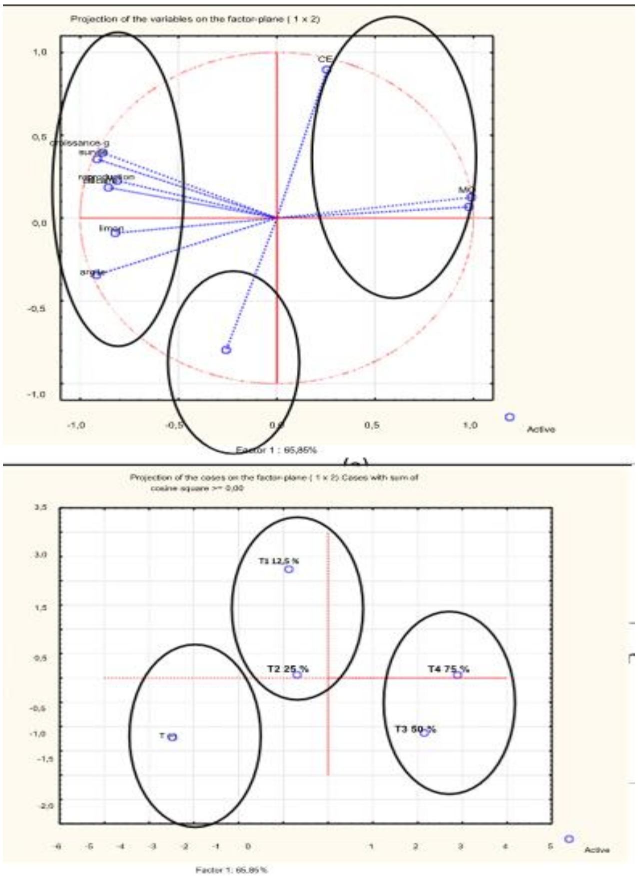

Figure 6. PCA of the effect of the pomace on the earthworm activity of the species *A.T.* on the factorial plans F1-F2.

For *E. fetida*, the two principal axes explained 85.62% of total variance (PC1: 65.07%, PC2: 20.55%). Similar patterns emerged, with T2 occupying an intermediate position consistent with reduced but non-zero earthworm activity.

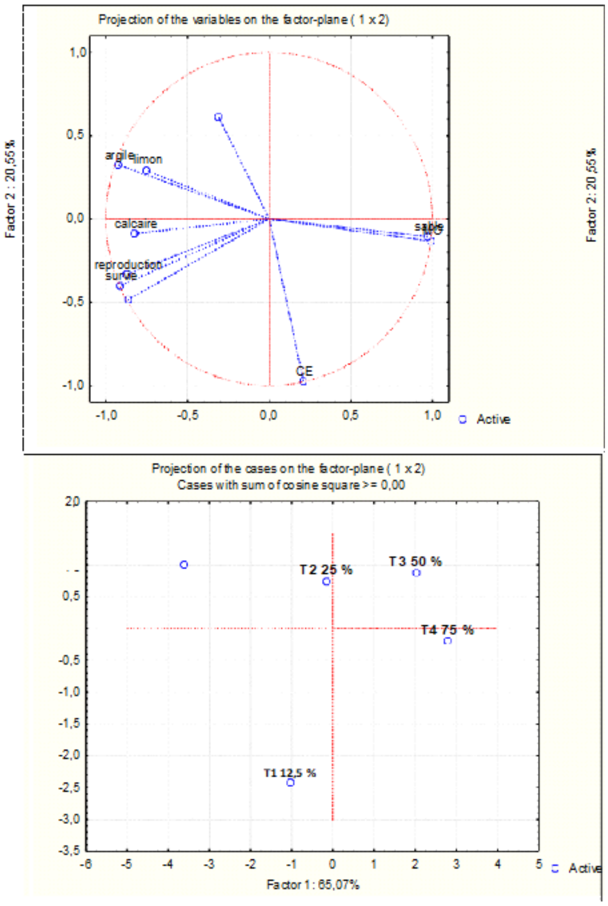

Figure 7. PCA of the effect of the pomace on the Earthworm activity of the EF species on the factorial plans F1-F2parameter distribution.

4. DISCUSSION

4.1. Dose-Dependent Effects on Soil Properties

The progressive soil acidification observed with increasing pomace concentration (from pH 7.24 to 6.36) aligns with previous studies reporting pH decreases following olive mill waste application (Levi-Minzi et al., 1992; Lachguer et al., 2002; Taamallah, 2007). This acidification results from organic acids present in pomace, particularly phenolic and fatty acids (de la Fuente et al., 2011; Aviani et al., 2010). The magnitude of pH change (ΔpH = -0.88 units at 75% pomace) reflects the inherent acidity of pomace (pH 4.7).

Concurrent increases in electrical conductivity (from 0.21 to 1.72 dS/m) demonstrate progressive salinization, crossing thresholds from non-saline to saline conditions. This dose-dependent EC increase reflects the high salt content of olive pomace (Moumni, 2014) and represents a significant stress factor for soil organisms. The EC values observed at ≥50% pomace (1.15-1.72 dS/m) exceed levels known to affect earthworm osmoregulation and survival (Ivask et al., 2012; Tao et al., 2012).

Organic matter enrichment following pomace application confirms the potential value of this by-product as an organic soil amendment. However, the non-linear relationship between application rate and final OM contentwith lower-than-expected values at intermediate doses where earthworms remained activesuggests that earthworm activity modulates OM dynamics through consumption and incorporation.

The reduction in total limestone with increasing pomace concentration (from 30.0% to 0%) is primarily a dilution effect, as pomace contains no carbonate. Soil texture classification remained unchanged despite significant shifts in individual particle size fractions. The increase in silt content at 25% pomacethe highest concentration permitting earthworm survivallikely reflects earthwormmediated aggregate formation (Six et al., 2004; Pulleman et al., 2005). The absence of this effect at higher concentrations (≥50%) where earthworms died confirms the essential role of earthworm activity in soil structure dynamics.

4.2. Earthworm responses: threshold effects and species sensitivity

The consistent pattern across all earthworm endpoints identifies 12.5% pomace as the optimal concentration for both species. This treatment produced growth exceeding control values (+8.5%), maintained near-complete survival (>97%), and supported substantial cocoon production (82% of control). The beneficial effect at low concentration likely reflects organic matter input providing nutritional resources without reaching toxic thresholds for salinity, acidity, or phenolic compounds. Edwards and Bohlen (1996) documented increased earthworm growth with organic fertilizer applications, while Chen et al. (2017) observed biomass increases in *A.trapezoides* with low C/N ratio organic residues.

The sharp decline in earthworm performance between 12.5% and 25% pomace, followed by complete mortality at ≥50%, indicates a narrow window between beneficial and toxic concentrations. The 25% treatment presents an intermediate condition: permitting survival of *A. trapezoides* (though with reduced growth) and partial survival of *E. fetida* (37%), but completely inhibiting reproduction. This reproductive inhibition at sublethal concentrations is particularly significant for population sustainability.

Multiple factors likely contribute to toxicity at higher concentrations: salinity stress (Ivask et al., 2012; Tao et al., 2012), acid stress, and phenolic compound toxicity (Moco et al., 2010; Babić et al., 2019). The simultaneous occurrence of multiple stressors likely produces synergistic effects exceeding those predicted from individual factors (Frouz et al., 2005). PCA confirmed that high-dose treatments were associated with multiple adverse factors that collectively eliminated earthworm activity.

Clear differences emerged between species. *A. trapezoides* demonstrated greater tolerance, maintaining positive growth at 25% pomace (99% of T1 growth) where *E. fetida* growth declined to 20% of optimal. This differential sensitivity likely reflects contrasting ecological strategies: *A. trapezoides* as an endo-aneciuc species with geophagous feeding mode and larger body size (reducing surface area-to-volume ratio and relative chemical exposure), versus *E.*

fetida as an epigeic species specialized for surface litter consumption with closer association with fresh organic matter (Bouché, 1972; Klaassen, 1991).

The higher reproductive output of *E. fetida* in control and optimal treatments (7.0 vs. 4.0 cocoons) aligns with its life history strategy as an r-selected species. However, this advantage was nullified at higher concentrations, where both species failed to reproduce. The complete inhibition of reproduction at 25% pomace, despite 37% survival, indicates that population sustainability is compromised at concentrations below those causing acute mortality.

4.3. Ecological and agronomic implications

These findings have several practical implications: (1) olive pomace can be beneficially used as a soil amendment only at low concentrations (≤12.5% v/v), corresponding to approximately 125 g pomace kg^{-1} soil; (2) repeated applications without adequate dilution could rapidly accumulate pomace to harmful levels; (3) *E. fetida* may serve as an effective bioindicator for early warning of pomace toxicity; and (4) reproductive endpoints should be included in ecotoxicological assessments, as they are more sensitive than acute mortality.

4.4. Study Limitations

Limitations include laboratory conditions that may not fully represent field situations, single application without long-term monitoring, and use of a single pomace type and soil. Future research should include field validation, processed pomace comparisons, and mechanistic studies identifying specific toxicants.

5. CONCLUSIONS

This study demonstrates that olive pomace application significantly affects soil properties and earthworm responses in a dose-dependent manner. Key findings are:

1. Pomace application progressively decreases soil pH and total limestone while increasing EC and OM.

2. The 12.5% pomace treatment optimally enhances earthworm growth (+8.5%), survival (>97%), and reproduction (82% of control).

3. Concentrations ≥25% negatively affect earthworm performance, with complete reproductive inhibition at 25% and complete mortality at ≥50%.

4. *A. trapezoides* exhibits greater tolerance than *E. fetida*, which may serve as a more sensitive bioindicator.

5. Multiple stressors (acidity, salinity, phenolics) act synergistically, with

reproduction being the most sensitive endpoint.

Olive pomace can be valorized as a soil organic amendment only at low concentrations (≤12.5%). Higher application rates pose significant ecotoxicological risks to soil fauna, compromising population sustainability. Sustainable pomace management requires careful rate control and monitoring.

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REFERENCES

Alloum, D. (1974). L'oléiculture algérienne. Options Méditerranéennes, (24), 45-48.

Aviani, I., Raviv, M., Hadar, Y., Saadi, I., &Laor, Y. (2010). Effects of olive mill solid waste on soil organic matter, microbial biomass, and soil biological activity. Bioresource Technology, 101(19), 7340-7347.

Babić, S., Barišić, J., Bielen, A., Bošnjak, I., Klobučar, R. S., Ujević, I., ... & Klobučar, G. (2019). Assessment of olive mill wastewater ecotoxicity. Ecotoxicology and EnvironmentalSafety, 170, 272-280.

Bonneau, M., & Souchier, B. (1994). Pédologie: 2. Constituants et propriétés du sol (2nd ed.). Masson.

Bouché, M. B. (1972). Lombriciens de France: Ecologie et systématique. INRA.

Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analyses of soils. Agronomy Journal, 54(5), 464-465.

Campani, T., Caliani, L., Pozzuolli, C., Romi, M., Fossi, M. C., &Casini, S. (2017). Assessment of toxicological effects of raw and bioremediated olive mill waste in Eisenia fetida. Applied Soil Ecology, 119, 18-25.

Chen, C., Tao, Y., Ding, W., & Liu, Z. (2017). Effects of organic residue quality on growth and reproduction of *Aporrectodea trapezoides*. Soil Biology and Biochemistry, 53, 103-113.

de la Fuente, C., Clemente, R., Martínez-Alcalá, I., Tortosa, G., & Bernal, M. P. (2011). Impact of fresh and composted solid olive husk on soil heavy metal fractionation. Journal of Hazardous Materials, 186(2-3), 1283-1289.

Denis, B. (2000). Guide des analyses enpédologie (2nd ed.). INRA.

Djadouf, S., Tahakourt, A., Chelouah, N., & Merabet, D. (2011). Utilisation du grignon d'olive comme ajouts dans la fabrication des briques de terre cuite. Séminaire International, Université de Bejaïa, 10, 5.

Dugain, F. (1961). Les méthodes d'analyses utilisées au laboratoire de physico-chimie des sols. ORSTOM.

Edwards, C. A., & Bohlen, P. J. (1996). Biology and ecology of earthworms (3rd ed.). Chapman & Hall.

FAO. (2008). Le rendement de l'olivier. Food and Agriculture Organization.

Frouz, J., Elhottová, D., Kuráž, V., & Šourková, M. (2005). Development of soil microbial properties during spontaneous succession in heaps after coal mining. Geoderma, 129(1-2), 54-64.

Fründ, H. C., Butt, K., Capowiez, Y., Eisenhauer, N., Emmerling, C., Ernst, G., ... & Schrader, S. (2010). Using earthworms as model organisms in the laboratory. Pedobiologia, 53(2), 119-125.

Gomes, S., Martins-Lopes, P., & Guedes-Pinto, H. (2012). Olive tree genetic resources characterization. In M. Caliskan (Ed.), Genetic Diversity in Plants (pp. 1-16). InTech.

Ivask, A., Bondarenko, O., Jepihhina, N., & Kahru, A. (2012). Profiling of ROS-related ecotoxicity of nanoparticles. Ecotoxicology and Environmental Safety, 84, 171-177.

Klaassen, C. D. (1991). Casarett and Doull's toxicology (4th ed.). McGraw-Hill.

Lachguer, K., Lafhal, S., & El Youssoufi, M. (2002). Effet de l'épandage des margines sur un sol cultivé en olivier. Étude et Gestion des Sols, 9(1), 35-46.

Levi-Minzi, R., Saviozzi, A., Riffaldi, R., & Falzo, L. (1992). Dynamique des margines épandues sur le sol. Agriculture et Développement, 47(7), 459-463.

Missat, L. (2012). Perspectives de développement de l'olivier dans les Monts des Ksour [Master'sthesis]. Université Abou BekrBelkaid.

Moco, S., Bino, R. J., De Vos, R. C. H., & Vervoort, J. (2010). Metabolomics technologies and metabolite identification. Trends in Analytical Chemistry, 29(9), 978-991.

Moumni, M. H. (2014). Molecular characterization of olive cultivars in

Palestine using SSR markers [Master's thesis]. An-Najah National University.

Oliver, R. (1978). Méthodes d'analyse des sols. ORSTOM.

Puga-Frettas, J. (2012). Effet du ver de terre *Aporrectode acaliginosa* sur la croissance des plantes [Doctoral dissertation]. Université de Paris-Est.

Pulleman, M. M., Six, J., van Breemen, N., &Jongmans, A. G. (2005). Soil organic matter distribution and microaggregate characteristics. European Journal of Soil Science, 56(4), 453-467.

Six, J., Bossuyt, H., Degryze, S., & Denef, K. (2004). A history of research on the link between (micro) aggregates, soil biota, and soil organic matter dynamics. Soil and Tillage Research, 79(1), 7-31.

Taamallah, H. (2007). Impact des margines sur les propriétés du sol et sur la croissance de l'olivier [Doctoral dissertation]. École Supérieure d'Horticulture de Chott Mariem.

Tao, Y., Long, R. J., Liu, Z. Y., Ding, W. R., & Zhang, Y. (2012). Aspects of lipid oxidation of meat from free-range broilers. Poultry Science, 91(1), 224-231.

Tondoh, J. E., Monin, L. M., Tiho, S., & Csuzdi, C. (2007). Can earthworms be used as bioindicators of land-use perturbations? Biology and Fertility of Soils, 43(5), 585-592.

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Numerical Study of the Effect of Ventilation Opening Locations on Air Quality in Greenhouses

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Abstract

This numerical study investigates the effect of ventilation opening locations on airflow distribution, temperature, and relative humidity inside an agricultural greenhouse with dimensions of 5 × 3 × 2.5 m, equipped with square ventilation openings measuring 0.25 × 0.25 m. Three configurations were analyzed: a greenhouse with front openings, a greenhouse with side openings, and a combination of both, using three-dimensional Computational Fluid Dynamics (CFD) simulation. The standard k–ε turbulence model and the Species Transport model were applied to represent airflow, gas movement, and humidity distribution. The results show that combining front and side openings improves air exchange, ensures a more uniform temperature distribution, and reduces relative humidity, thereby improving greenhouse performance. The study highlights that optimizing the design and placement of ventilation openings through numerical analysis is an effective approach to enhance indoor air quality and create more suitable environmental conditions for plant growth.

Key words: Greenhouses, Air Quality, Ventilation Opening, CFD.

4. INTRODUCTION

Maintaining suitable indoor environmental conditions in greenhouses is essential to ensure optimal plant growth. Factors such as temperature, relative humidity, and carbon dioxide concentration have a significant impact on plant physiological processes, including transpiration and photosynthesis. Poor ventilation can lead to elevated temperatures and humidity levels, as well as uneven carbon dioxide distribution, negatively affecting crop health. Therefore, ventilation plays a crucial role in maintaining air quality, and several studies have investigated the effect of inlet and outlet locations on airflow distribution and indoor air quality in buildings and cavities. Among the published studies, the research conducted by Younsi et al. [1] investigated the effect of outlet air location on thermal comfort and indoor air quality in ventilated cavities filled with a mixture of air and carbon dioxide under mixed convection conditions. The authors examined the influence of outlet location through four different output ports configurations. Three of these configurations were placed on the upper side of the cavity, while the fourth configuration on the top of the opposite side of the inlet opening. A uniform heat source and carbon dioxide contaminant source were applied along the left vertical wall, whereas the remaining walls were considered impermeable and thermally insulated.

Numerical simulations were performed using the CFD software scSTREAM V11. Their results revealed that the configuration in which the air outlet was positioned near the heat and contaminant source provided better airflow distribution and higher ventilation efficiency compared to the other configurations.

The study conducted by Dhahri et al. [2] aimed to analyze the effect of window opening locations in a naturally ventilated building, as well as their impact on airflow patterns and temperature distribution, using a commercial Computational Fluid Dynamics (CFD) software. Their results generally indicated that the positions of the inlet and outlet openings have a significant influence on thermal comfort performance, whereas their effect on the average air velocity within the occupied zone is relatively minor.

Another study [3] aimed to investigate numerically the heat transfer within a ventilated cavity filled with a mixture of air and carbon dioxide using numerical simulation. The mixture (air-CO_2) enters in the cavity at a temperature of 288 K and a carbon dioxide concentration of 350 ppm. A uniform temperature equal to the inlet temperature was applied on all walls, except for the bottom wall, which was maintained at a higher temperature of 308.5 K. The finite volume method was employed to solve the governing equations for continuity, energy, and species concentration, incorporating the RNG k–ε turbulence model.

Their results indicated that increasing the contaminant concentration for each Reynolds number had a negligible effect on contaminant concentration, velocity components, and temperature at the mid-plane of the cavity (Y = H/2) for all Reynolds numbers considered.

The study conducted by Rafaela et al [4]. aimed to examine the experimental methodologies used to investigate natural ventilation in large air volumes, along with the techniques employed to validate CFD models.

In a similar study, the research conducted by Anaebonam et al [5]. focuses on the importance of implementing natural ventilation strategies to create healthy indoor environments. The study also discusses the fundamental principles of natural ventilation, including factors such as building orientation, window locations, airflow patterns, and achieving an optimal balance between fresh air supply and thermal comfort. It emphasizes the critical role of natural ventilation in maintaining healthy indoor spaces and highlights that understanding these design principles is essential for effective ventilation planning.

Another study [6] addressed the displacement ventilation system in an office-scale model, taking into account variations related to heat sources, outlet locations, and other factors. Different scenarios were simulated, considering various outlet positions and numbers of heat sources.

Al-Helal et al. [7] conducted an experimental study on a curved-roof greenhouse equipped with ventilation openings in the roof and side walls. They examined five different ventilation configurations and measured environmental parameters inside and outside the greenhouse while calculating the ventilation rate. Their results showed that the orientation of the greenhouse is related to the prevailing wind direction. They also stated that combining roof vents with side vents is the optimal solution for achieving the best ventilation in arid environments.

Singh et al. [8] conducted a comprehensive review of the impact of ventilation rate on the microclimate of greenhouses and their energy consumption. They discussed the factors affecting ventilation performance, such as air exchange rate, wind speed and direction, the design, size, and location of ventilation openings, as well as the dimensions of the greenhouse. They also outlined the ideal characteristics required to achieve effective natural ventilation in greenhouses.

The study conducted by Stefano et al. [9] aimed to identify the optimal configurations of ventilation openings and opening management strategies to control the indoor environment of an Italian greenhouse used for horticultural crop production. They performed numerical simulations of airflow and temperature distribution using a finite element Computational Fluid Dynamics (CFD) program.An automatic control system for the greenhouse vents was programmed to fully open all windows in each section when the indoor air temperature exceeded a specified threshold value. Some of their results showed that keeping the side vents open while closing the windward roof vent achieved the best performance. They also stated that improving the ventilation control system requires considering wind direction as an input parameter.

The numerical study conducted by Fragos et al. [10] aimed to investigate how the position of ventilation openings affects the pressure coefficient values inside and outside of a greenhouse. They used Computational Fluid Dynamics (CFD) to examine the effect of steady airflow at different Reynolds numbers on the local pressure coefficients calculated for a double-sloped roof greenhouse, both with and without roof ventilation openings. Their results were presented in the form of streamlines, pressure coefficient distributions, and velocity profiles in the direction of airflow.

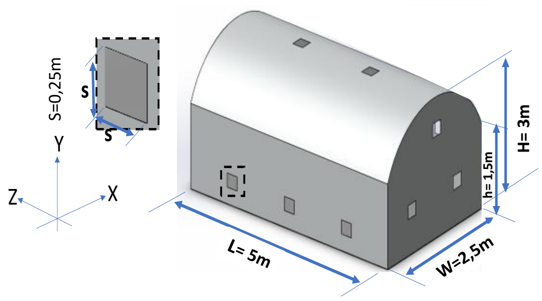
Another study conducted by K. shi et al. [11] studied the effect of ventilation opening design and size on the greenhouse microclimate. They developed a three-dimensional model using Computational Fluid Dynamics (CFD), which was validated with measured indoor air temperature and relative humidity data. Their results showed that the design of the ventilation openings influences the local microclimate patterns inside the greenhouse, the findings also indicated that a combination of a roof vent with a side vent is most suitable for summer cooling, whereas a roof vent alone is optimal for winter moisture removal.

In the present study, we focus on investigating the effect of square ventilation openings measuring 0.25 × 0.25 m² on airflow patterns and air quality within a greenhouse. Unlike previous studies, which primarily examined ventilation strategies in buildings or cavities without specifically addressing greenhouse environments, this research considers the geometrical shape of greenhouses and analyses the influence of ventilation opening location on airflow distribution, temperature and humidity, this study aims to provide practical insights into optimizing natural ventilation for improved indoor environmental quality. The outcomes are expected to guide greenhouse design by enhancing thermal comfort, ensuring air quality.

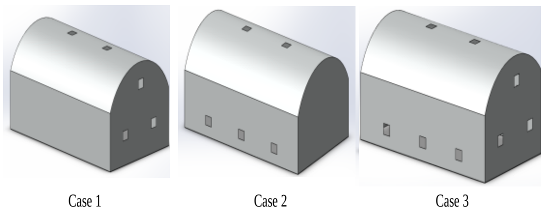
5. GEOMETRIC CONFIGURATION OF THE GREENHOUSE

Figure 1 illustrates a three-dimensional model of the studied greenhouse with geometric dimensions of 5 m in length, 3 m in width, and 2.5 m in height. The greenhouse is equipped with a natural ventilation system, consisting of front, side, and roof openings. The side openings are square, measuring 0.25 × 0.25 m, and are evenly distributed along the longitudinal walls of the greenhouse.

In this study, three ventilation configurations were investigated: front openings only, side openings only, and a combined configuration incorporating both front and side openings, as shown in Figure 1b.



(**a**)



(**b**)

Figure 1. **(a)** Three-dimensional model of the studied greenhouse. **(b)** The three investigated ventilation configurations: side openings only, front openings only, and a combined configuration with both side and front openings.

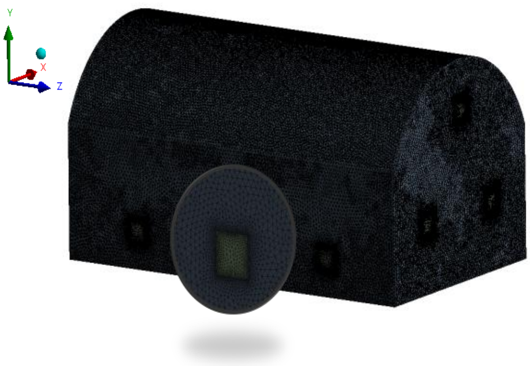


Figure 2. Mesh of the greenhouse

The mesh generation was performed using ANSYS Workbench. Based on the previously defined geometry, named selections were first assigned to all boundaries. The mesh sizing and the type of surface bodies were then specified. The module enabled the generation of a three-dimensional tetrahedral mesh.

3. MATERIAL PROPERTIES

Air was selected as the working fluid and polycarbonate was used for the greenhouse covering. This material is transparent, and its properties are presented in Table 1

Table 1. Properties of air and Polycarbonate

Properties	Air	Polycarbonate
Density (kg/m^3)	1,225	1400
Specific heat (j/kg.K)	1006,43	1046
Thermal conductivity (W/m.K)	0,0242	0,17
Dynamic viscosity (kg/m.s)	1,7894 E-5	--

4. BOUNDARY CONDITIONS

The boundary conditions can be summarized in the following table 2.

Table 2. Boundary conditions used in the simulation

Inlet	V_{in}= constant; T_{in} = constant
Outlet	Pressure =0
Soil	Opaque solid wall
walls (Polycar-bonate)	Wall (Semi-Transparent); Solar radiation and Convection

The boundary conditions can also be illustrated in the following figure 3:

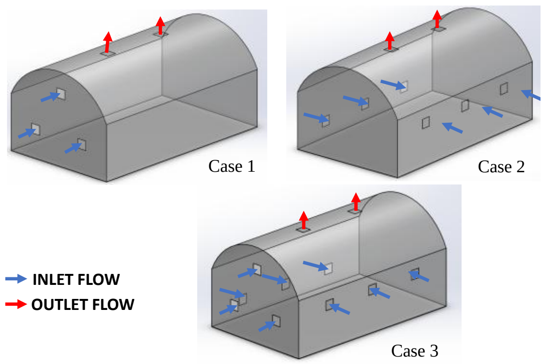


Figure 3. Boundary conditions (case 1, 2, and 3)

The greenhouse cover is considered a semi-transparent solid, contributing to solar radiation and convective heat transfer. The heat transfer coefficient is set to h=5 w/m^{2}K

Soil condition: The soil does not participate in solar radiation and is considered as a solid opaque surface. The soil temperature is set to T=282.15 K for the month of January (Khenchela region).

4. NUMERICAL MODEL AND METHODOLOGY

This study is based on the development of a three-dimensional numerical model to represent the internal environment of the greenhouse using CFD, with the aim of investigating airflow patterns, temperature distribution, and humidity. The standard k–ε turbulence model was employed to describe the turbulent airflow within the greenhouse. The model is based on a set of fundamental physical equations that govern fluid behavior as well as heat and mass transfer. Specifically, the continuity and momentum equations were used to represent airflow inside the greenhouse, while the energy equation was applied to study temperature distribution within the internal space.

Additionally, the species transport model was used to calculate gaseous species concentration and relative humidity inside the greenhouse.

To analyze the effect of ventilation design on air quality and indoor climatic conditions, three ventilation configurations were tested, as illustrated in Figure 1. Boundary conditions for the model were set based on external environmental data, including air inlet velocity and outside air temperature, to ensure realistic simulation of actual conditions.

The study relied on several simplifications to facilitate the simulation process. The initial conditions were selected to mimic the climate of the Khenchela region in terms of ambient temperature, solar radiation, and humidity, making the results suitable for local conditions, but limiting their generalizability to different time periods or varying climatic conditions. A turbulent flow model was used to represent air mixing more realistically inside the greenhouse.

A constant solar radiation was assumed, even though in reality it varies over time, which may lead to differences in the actual temperature values. Likewise, fixed inlet conditions (air velocity, temperature, and humidity) were adopted because the study focused on a short time period to understand flow behaviour and the distribution of temperature and humidity, rather than analysing temporal variations. The presence of crops was also neglected to simplify calculations and reduce simulation time, although plants actually influence airflow and humidity levels. Therefore, the results represent the behavior of air inside an empty greenhouse.

Nevertheless, these simplifications do not significantly affect the results, and the findings remain consistent with previous studies regarding the effect of the ventilation openings’ position on airflow patterns and the distribution of temperature and humidity.

6. RESULTS AND DISCUSSION

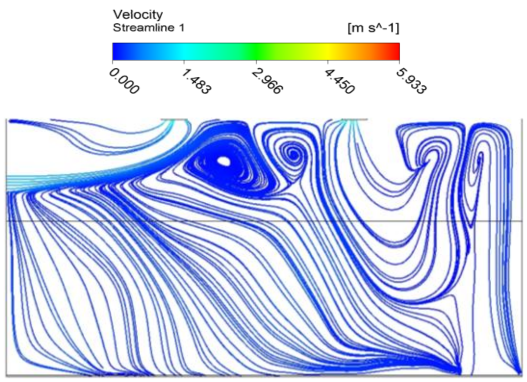
6.3 Airflow Distribution

Figure 4 presents the airflow velocity streamlines at a plane located at x = 1.5 m for the three studied configurations. The numerical simulation results clearly demonstrate that the position of the ventilation openings has a significant impact on the internal airflow patterns. Variations in vent locations lead to noticeable changes in velocity distribution, flow direction, and vortex formation within the greenhouse.

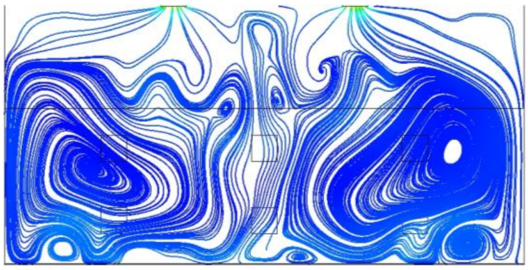
Changing the position of the ventilation openings alters the local pressure field inside the greenhouse, generating different driving forces for the airflow. When air enters through the front openings (first configuration), a pressure difference is created between the inlet area and the interior space, producing a high-speed air. This jet carries linear momentum and forms a shear layer with the surrounding air. When the number of openings is small and concentrated in one location, a dominant flow path develops, characterized by limited vortex formation and the emergence of stagnant zones far from the flow path. The velocity gradient is localized and directed along a single path, resulting in a non-uniform velocity distribution, poor air renewal in some areas, and relatively stable air layers due to weak mixing.

Distributing the openings along the sides (second configuration) spreads the pressure difference across multiple entry points, forming several jets. These jets interact and generate greater turbulence due to the multiplication of shear regions, leading to a more uniform velocity distribution and enhanced mixing intensity, which reduces differences between air layers compared to the first configuration.

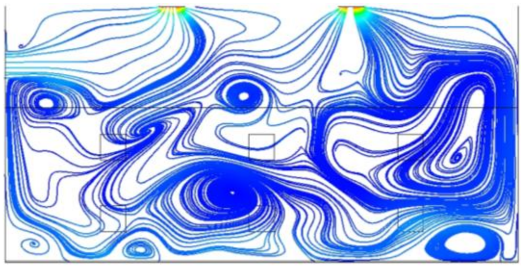
When the openings are arranged both along the sides and at the front (third configuration), airflow patterns become more complex and better distributed throughout the greenhouse. The pressure differences at multiple entry points generate several interacting jets, which increases turbulence and promotes the formation of vortices. This design reduces stagnant zones, and enhances the overall renewal of air. Large-scale vortex structures are formed within the greenhouse, ensuring efficient mixing of air layers. This is attributed to the airflow dynamics, where the highest average velocity of air inside the greenhouse was recorded for Configuration 3 compared with Configurations 1 and 2, reaching 0.30 m/s, 0.18 m/s, and 0.32 m/s, respectively. These results indicate that Configuration 3 provides more effective air circulation and improves the overall ventilation performance of the greenhouse.



Case 1



Case 2

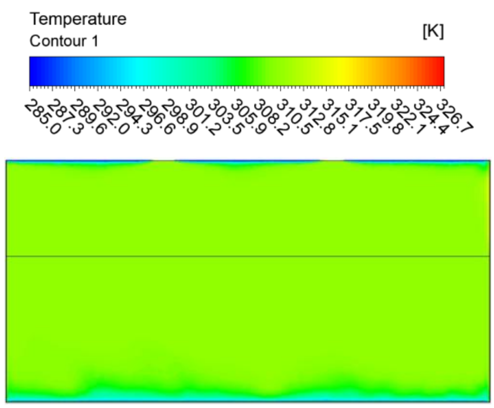


Case 3

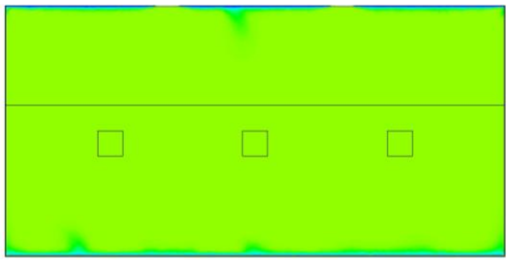
Figure 4. Streamlines of airflow velocity inside the greenhouse under different ventilation configurations at a plane x=1.5 m

3.2 Temperature Distribution

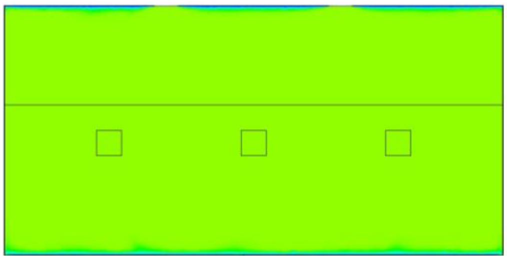
Figure 5 presents the temperature distribution at a plane x=1.5 m for three cases. The simulation results indicate that the air temperature inside the greenhouse is nearly uniform, particularly in Configurations 2 and 3. This thermal uniformity is attributed to the effectiveness of air mixing and the convective heat transfer coefficient, which directly depends on airflow velocity and turbulence intensity. When velocities are high and well-distributed, the convective coefficient increases, making heat removal from surfaces more efficient. In the first configuration with front openings, the distribution of openings is insufficient, leading to poor mixing and the formation of thermal stratification due to buoyancy effects; hot air rises and accumulates at the top. However, when the number of openings is increased and distributed along the sides, as in configurations 2 and 3, the forced convection generated by the airflow becomes stronger than buoyancy effects, redistributing heat and resulting in better thermal uniformity.



Case 1



Case 2



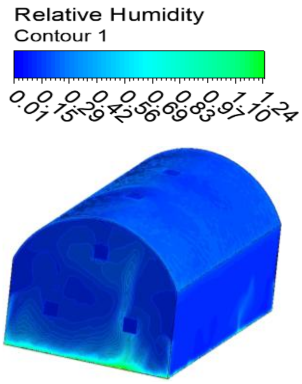
Case 3

Figure 5. The temperature distribution at a plane x=1.5 m

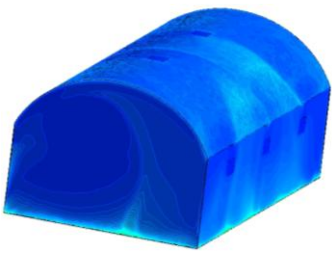
The boundary conditions selected in the numerical model play a key role in achieving a uniform thermal distribution. The inlet air velocity was set to 1 m/s while considering other initial conditions, such as the relative humidity and temperature of the incoming air, in order to obtain an average temperature inside the greenhouse of approximately 309 K. Overall, the results confirm that both the ventilation openings in the selected configurations and the imposed operating conditions are crucial factors in controlling the thermal environment inside the greenhouse.

3.3 Relative Humidity

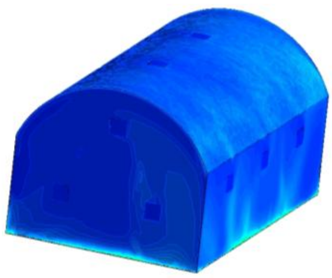
Air transport depends on concentration differences and the heat transfer coefficient associated with velocity and turbulence. In stagnant regions, air renewal slows down and local humidity increases. Increasing the mixing intensity enhances the rate of water vapor dilution, leading to a more uniform humidity distribution. The location of the openings also affects the direction of moist air movement; warm, humid air tends to rise, so the presence of upper outlets promotes its removal, while proper distribution of openings reduces accumulation at certain levels.



Case 1

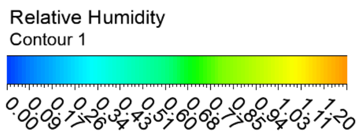


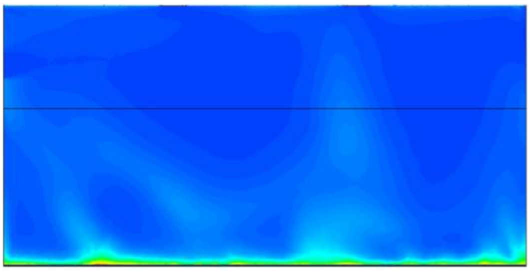
Case 2



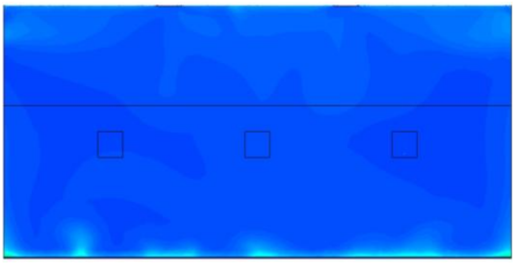
Case 3

(a)

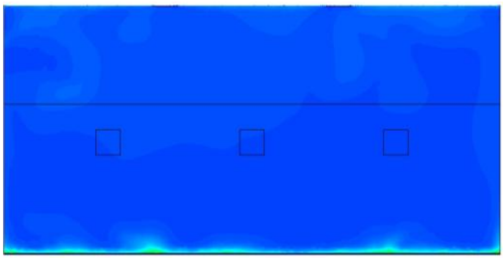




Case 1



Case 2



Case 3

(b)

Figure 6. **(a)** Distribution of relative humidity 3D, **(b)** Distribution of relative humidity at a plane x=1.5 m

In the present simulation (Figure 6), the relative humidity levels are generally low throughout the greenhouse. Moisture concentration is mainly observed near soil level, where airflow velocity is relatively weak. In contrast, the upper and central regions of the greenhouse exhibit lower humidity levels.

IIn the first configuration, a clear humidity gradient is observed, with the average relative humidity reaching approximately 28.87%. In the second configuration, the distribution becomes more homogeneous, although some local variations persist near certain walls; the average relative humidity in this design is estimated at about 11.7%. In the third configuration, the humidity distribution is nearly uniform throughout the greenhouse, with an average relative humidity of around 11%. This indicates a high efficiency of convective mass transfer due to improved air mixing and increased air renewal in this design, which significantly reduces the risk of plant diseases associated with excessive humidity.

Our results are consistent with some previous studies [7, 11, and 12] regarding the impact of ventilation openings on air quality inside greenhouses. These studies confirm that the position and distribution of ventilation openings directly influence the airflow pattern. Additionally, studies [7, 11 and 12] showed that combining roof and side openings is the optimal solution for achieving the best ventilation. Furthermore, another study conducted by Stefano et al. [9] indicated that keeping the side wall ventilation openings open while closing the wind-facing roof vent produced the best results, which supports our numerical findings. Nevertheless, our results contribute to a better understanding of the effect of the position and distribution of square-shaped openings on airflow, temperature, and humidity inside the greenhouse, using numerical simulations that allow for predicting the internal air distribution based on external climatic conditions.

7. CONCLUSIONS

The current study aims to analyze the effect of the positions of square-shaped openings on airflow velocity, temperature, and humidity inside the greenhouse. The results showed that the distribution of ventilation openings in the third configuration Achieved a turbulent airflow, which enhanced air mixing and prevented humidity accumulation, thereby improving natural ventilation efficiency and providing a favorable environment for plant growth.

The results also showed that the first design did not achieve good air mixing, indicating that air entering from a single direction reduces the formation of cross-currents, leading to a non-optimal distribution of humidity. Therefore, this design is less efficient in creating a balanced internal environment.

In contrast, the greenhouse equipped with side openings proved effective in improving temperature and humidity distribution compared to the first design. This can be explained by the fact that side openings allow air to pass along a longer path inside the space, which enhances mixing and reduces stagnation zones, resulting in better uniformity in temperature and humidity. These findings provide valuable guidelines for the design and optimization of naturally ventilated greenhouses to improve plant growth conditions.

Based on the numerical simulation results, it is recommended that the design include integrated openings, with the side ventilation openings positioned high above the ground and distributed evenly. Integrated openings are particularly beneficial in dry conditions, such as during the summer. It is also preferable to support them with automatic control for opening and closing the ventilation openings, coupled with temperature and humidity sensors for smart management essentially integrating artificial intelligence to control natural ventilation in greenhouses based on measured external climatic conditions.

8. Acknowledgments

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9. REFERENCES

[1] Z. Younsi, L. Koufi, H. Naji,"Numerical study of the effects of ventilated cavities outlet location on thermal comfort and air quality", International Journal of Numerical Methods for Heat & Fluid Flow, Vol. 29 No. 11 pp. 4462–4483, 2019, https://doi.org/10.1108/HFF-09-2018-0518

[2] D.Maher, A.Hana, J. T.Arjmand, A.Issakhov, H.Sammouda, M. Sheremet, S.Sharma, "Effect of inlet/outlet on thermal performance of naturally ventilated building", International Journal of Low-Carbon Technologies, Volume 16, Issue 4, December Pages 1348–1362, 2021, https://doi.org/10.1093/ijlct/ctab055

[3] I. M. Tounsi, M. Boussoufi, A.Sabeur, M.El Ganaoui, "Numerical analysis of indoor air quality in an open room: Effect of the outlet opening", International Journal of Thermofluids,Vol.18, 100356, 2023, https://doi.org/10.1016/j.ijft.2023.100356

[4] R. Mateus, J.M.C. Pereira, A.Pinto, "Natural ventilation of large air masses: Experimental and numerical techniques review", Energy and Buildings, Vol.291, 113120, 2023, https://doi.org/10.1016/j.enbuild.2023.113120

[5] C. K. Anaebonam, J. Barnaby & C. Okafor, "Exploring the use of natural ventilation strategies to create a healthy indoor environment", International Journal of Innovative Environmental Studies Research 11(3):109-117, July-Sept, 2023,

[6] A. H. Naidu, A. Singh, T V S. Yaswanth Mohan, K. K. Murthy, M. Mallela and R. Choudhary, "Numerical analysis of displacement ventilation for different locations of the outlets", IOP Conference Series Materials Science and Engineering 1116(1):012060, 2021, DOI:10.1088/1757-899X/1116/1/012060

[7] I.M. Al-Helal, A.A. Alsadon, A.A. Ibrahim, M.R. Shady, "Optimizing vents opening configurations and orientations for effective natural ventilation in sustainable greenhouses: A case study", journal of Agronomy 15, 2454,2025, https://doi.org/10.3390/agronomy15112454

[8] M. Singh, K. Sharma, & V. Prasad, "Impact of ventilation rate and its associated characteristics on greenhouse microclimate and energy use", Arab J Geosci 15, 288, 2022, https://doi.org/10.1007/s12517-022-09587-1

[9] B. Stefano, T. Patrizia, B. Filippo, B. Alberto, T. Daniele, "Efficacy of greenhouse natural ventilation: Environmental monitoring and CFD simulations of a study case", Energy and Buildings, Vol. 125, Pages 276-286,2016,

https://doi.org/10.1016/j.enbuild.2016.05.014.

[10] V.P. Fragos, D. Kateris, G.K. Ntinas, V. Firfiris, and T.A. Kotsopoulos, "Investigation of ventilation opening positions effect on the airflow inside and outside of a greenhouse", Acta Hortic. 1170, 151-158,2017, https://doi.org/10.17660/ActaHortic.2017.1170.17

[11] K. shi. He, D. yue. Chen, L. juan. Sun, Z. lu. Liu, Z. yu. Huang, "The effect of vent openings on the microclimate inside multi-span greenhouses during summer and winter seasons", Engineering Applications of Computational F. M., 9(1), 399–410,2015,

https://doi.org/10.1080/19942060.2015.1061553

[12] N. Katsoulas, T. Bartzanas, T. Boulard, M. Mermier, C. Kittas, "Effect of vent openings and insect screens on greenhouse ventilation", Biosystems Engineering, Vol. 93, Issue 4, Pages 427-436, 2006,

https://doi.org/10.1016/j.biosystemseng.2005.01.001.

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