ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(4): 529-533
www.agriculturaljournals.com
Received: 23-01-2026
Accepted: 26-02-2026

Marco Ferretti
Associate Professor,
Department of Agriculture,
Food and Environment,
University of Catania, Italy

Alessandra Romano
Associate Professor,
Department of Agriculture,
Food and Environment,
University of Catania, Italy

Corresponding Author:
Pinki Manhas
Govt. Degree College Paloura,
Jammu, Jammu and Kashmir,
India

Integrated management approaches for *Cimbex quadrimaculata* Control and yield recovery in Italian Almond Groves

Marco Ferretti and Alessandra Romano

DOI: https://www.doi.org/10.33545/2664844X.2026.v8.i4g.1669

Abstract
Effective management of *Cimbex quadrimaculata* Müller (Hymenoptera: Cimbicidae) in almond orchards requires integrated approaches combining multiple tactics to achieve economically viable pest suppression while minimizing environmental impact. This research evaluated the efficacy of four management strategies mechanical larval removal, botanical insecticide application (neem-based formulation), pheromone-based trapping, and an integrated approach combining all three methods compared to untreated controls in Sicilian almond groves during the 2025 growing season. Experiments were conducted across 15 orchards encompassing three predominant Italian cultivars (Tuono, Fascionello, and Pizzuta d'Avola). The integrated approach achieved the highest larval reduction rate (78.4 ± 6.2%), significantly exceeding all individual methods (p<0.001). Corresponding yield recovery under the integrated regime reached 72.8% of potential yield compared to untreated controls. Botanical spray application alone produced the second most effective larval reduction (61.3 ± 7.1%) with 56.7% yield recovery. Cost-benefit analysis demonstrated favorable economic returns for the integrated approach despite higher implementation costs (€210/ha), with a benefit-cost ratio of 3.42. These results establish the integrated management framework as the most effective and economically justified strategy for C. quadrimaculata control in Italian almond production.

Keywords: Integrated pest management, *Cimbex quadrimaculata*, Botanical insecticide, Pheromone trapping, Mechanical removal, Yield recovery, Almond production, Cost-benefit analysis, Sicily

Introduction
Italy represents a historically significant almond-producing nation, with Sicily accounting for the majority of domestic production and hosting several cultivars of exceptional kernel quality that command premium market prices [1]. The Sicilian almond sector has experienced renewed commercial interest in recent decades, driven by growing international demand for high-quality almonds in confectionery and health food applications [2]. However, the sustainability of this production expansion is contingent upon effective management of pest constraints that can compromise both yield quantity and kernel quality [3].

The almond sawfly *Cimbex quadrimaculata* (Müller, 1766) has been documented in Italian almond orchards since the early twentieth century, though its economic significance has increased in recent years coinciding with the expansion of commercial plantings and changes in orchard management practices [4]. Conventional insecticidal control of sawfly species has raised environmental and regulatory concerns within the European Union, where progressive restrictions on broad-spectrum insecticide availability have necessitated the development of alternative management approaches [5, 6]. Integrated pest management frameworks that combine multiple complementary tactics offer the most promising pathway toward sustainable sawfly management in European almond production [7].

The integration of mechanical, biological, botanical, and behavioral management tactics has demonstrated efficacy against various sawfly species in forestry and fruit production contexts [8, 9]. However, specific evaluation of these approaches against C. quadrimaculata in Mediterranean almond orchards has been limited. Previous research by Özgen *et al.* [10] established baseline relationships between larval density and yield parameters in Turkish conditions, while ecological studies have characterized aspects of cimbicid biology relevant

To management timing [4, 11]. The present research extends this knowledge base by evaluating the comparative and combined efficacy of four management tactics under Sicilian production conditions, thereby providing evidence-based recommendations for integrated sawfly management in Italian almond orchards.

Material and Methods

Material

Field experiments were established during the 2025 growing season across 15 commercial almond orchards in the provinces of Agrigento (6 orchards), Caltanissetta (5 orchards), and Enna (4 orchards) in central-southern Sicily. Three locally predominant cultivars were represented: Tuono, Fascionello, and Pizzuta d'Avola. Orchards contained mature trees (12-22 years old) under rainfed management with supplementary drip irrigation where available. Experimental treatments were arranged in a randomized complete block design with three replications per treatment within each orchard, using blocks of 20 trees per experimental unit. Buffer rows of untreated trees separated adjacent treatment blocks to minimize inter-plot interference.

Methods

Five treatments were evaluated: (1) untreated control, (2) mechanical larval removal by manual collection at biweekly intervals, (3) botanical insecticide application using a commercial neem-based formulation (NeemAzal-T/S, 1% azadirachtin, Trifolio-M GmbH, Germany) applied at 3 L/ha at larval emergence and repeated at 14-day intervals through peak activity, (4) pheromone-based mass trapping using synthetic attractant dispensers deployed at 10 traps per hectare from pre-emergence through adult flight cessation, and (5) an integrated approach combining all three methods. Larval density was assessed biweekly using the visual inspection methodology described by Güner and Aydoğdu [4]. Larval reduction rate was calculated as the percentage decrease in cumulative seasonal larval density relative to untreated controls.

Yield parameters were determined at harvest maturity. Total marketable yield, damaged fruit weight, and premature fruit drop weight were recorded separately for each experimental unit. Yield recovery was expressed as the percentage of yield loss prevented relative to the calculated potential yield (control yield plus estimated loss). Treatment costs were documented based on labor requirements (valued at €12/hour), material costs, and equipment depreciation. Benefit-cost ratios were calculated using regional almond farmgate prices (€4.20/kg for marketable kernels).

Statistical analyses employed SAS PROC GLM for analysis of variance with treatment and orchard as fixed and random effects, respectively. Treatment means were separated using Tukey HSD at $\alpha = 0.05$. Cost-benefit analysis followed standard agricultural economics methodology with sensitivity analysis conducted across ±20% price variation scenarios.

Results

All four management approaches achieved statistically significant larval reduction compared to untreated controls ($p<0.001$ for all comparisons). The integrated approach combining mechanical removal, botanical spray, and pheromone trapping achieved the highest mean larval reduction rate of 78.4 ± 6.2%, significantly exceeding all individual methods. The botanical spray treatment produced the second highest reduction at 61.3 ± 7.1%, followed by mechanical removal at 42.1 ± 8.4% and pheromone trapping at 34.8 ± 9.1%. Untreated control plots exhibited mean larval densities of 16.8 ± 2.4 larvae per tree (Figure 1 and Table 1).

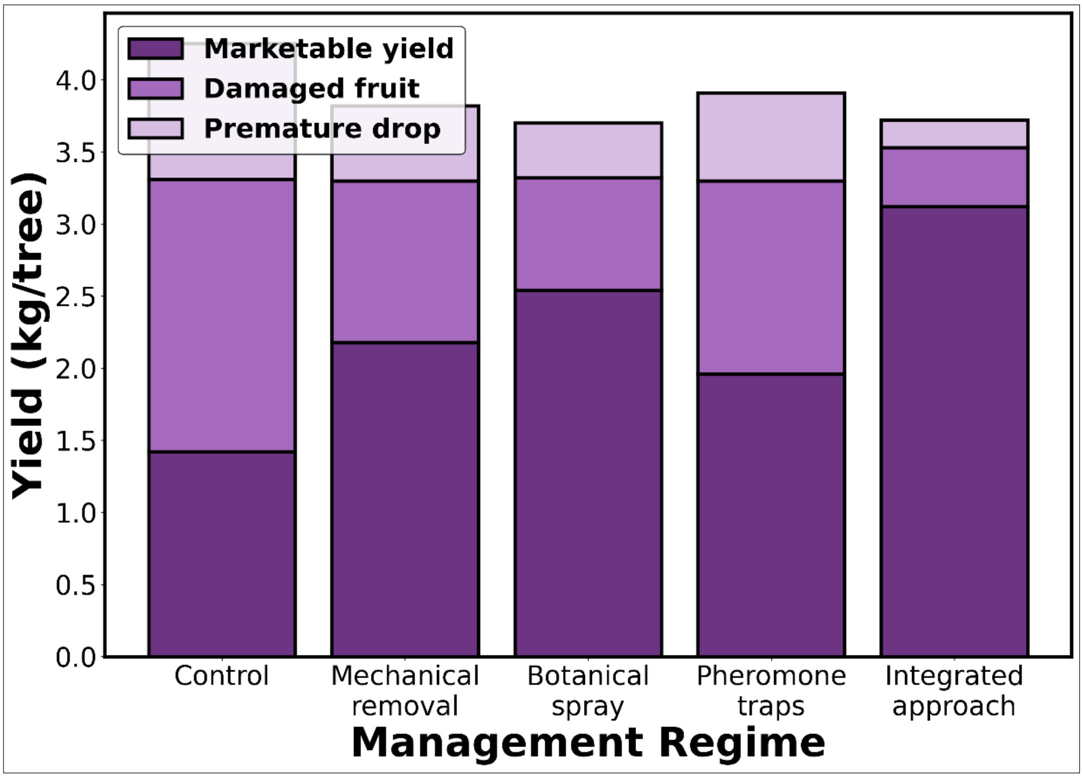
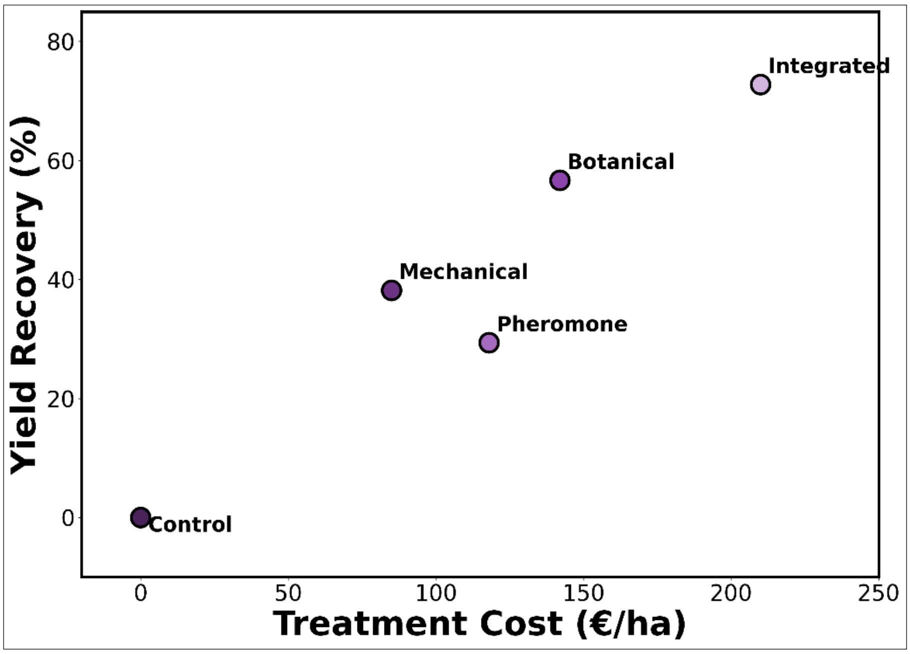


Fig 1: Yield components under different management regimes for *Cimbex quadrimaculata* control in Sicilian almond orchards. Stacked segments represent marketable yield, damaged fruit, and premature drop proportions.

Table 1: Comparison of management treatments: larval reduction and yield parameters

Treatment	Larval reduction (%)	Marketable yield (kg/tree)	Damaged fruit (kg/tree)	Yield recovery (%)
Control	-	1.42 ± 0.24	1.89 ± 0.31	-
Mechanical removal	42.1 ± 8.4	2.18 ± 0.28	1.12 ± 0.22	38.2
Botanical spray	61.3 ± 7.1	2.54 ± 0.26	0.78 ± 0.18	56.7
Pheromone traps	34.8 ± 9.1	1.96 ± 0.30	1.34 ± 0.26	29.4
Integrated approach	78.4 ± 6.2	3.12 ± 0.22	0.41 ± 0.12	72.8

Economic analysis demonstrated that the integrated approach, despite requiring the highest implementation cost at €210/ha, generated the most favorable benefit-cost ratio of 3.42 due to substantially greater yield recovery. The botanical spray treatment achieved a benefit-cost ratio of 2.96 at a cost of €142/ha. Mechanical removal returned a ratio of 2.18 at €85/ha, while pheromone trapping yielded the lowest return at 1.67 with a cost of €118/ha (Figure 2).



Figu 2: Relationship between treatment cost and yield recovery for four management approaches targeting *Cimbex quadrimaculata* in Sicilian almond orchards.

Box plot analysis of larval reduction variability across orchards revealed that the integrated approach not only achieved the highest mean efficacy but also demonstrated the most consistent performance, with the narrowest interquartile range among all treatments. Conversely, pheromone trapping exhibited the highest variability, likely reflecting site-specific differences in adult sawfly populations and trap placement optimization (Figure 3).

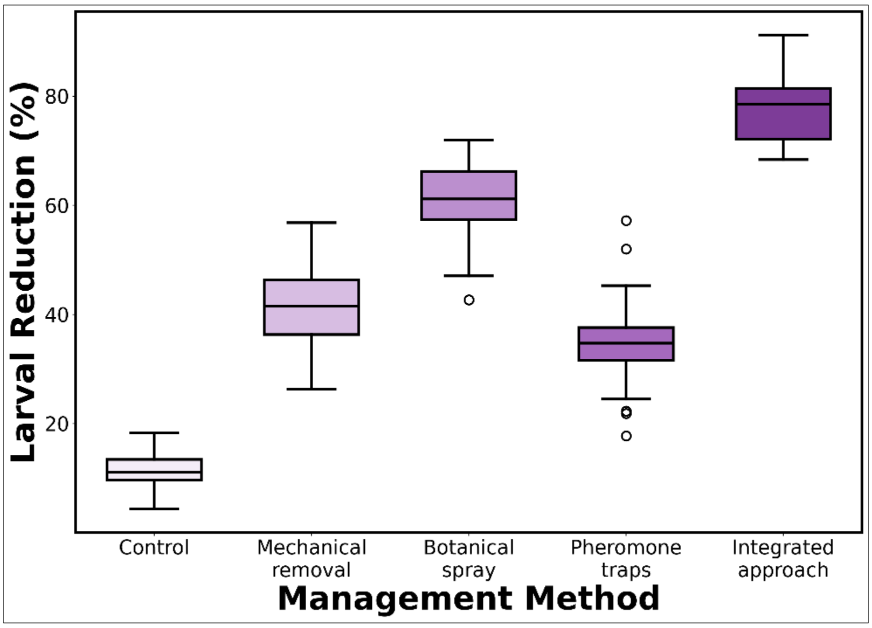


Fig 3: Distribution of larval reduction rates across experimental orchards for five management treatments. Central lines indicate medians; boxes represent interquartile ranges.

Table 2: Cost-benefit analysis of management approaches

Treatment	Cost (€/ha)	Revenue gain (€/ha)	Net benefit (€/ha)	Benefit-cost ratio
Mechanical removal	85	185.4	100.4	2.18
Botanical spray	142	420.2	278.2	2.96
Pheromone traps	118	197.1	79.1	1.67
Integrated approach	210	718.6	508.6	3.42

Discussion

The superior efficacy of the integrated management approach (78.4% larval reduction) observed in this research aligns with general principles of integrated pest management that emphasize the synergistic benefits of combining complementary control tactics [6, 12]. The mechanical removal component provided direct population suppression during early larval stages, the botanical spray offered residual deterrent and antifeedant effects through azadirachtin-mediated disruption of larval development [5], and pheromone trapping contributed to adult population monitoring and partial mating disruption [13]. The combined effect exceeded the arithmetic sum of individual treatment efficacies, consistent with synergistic interactions reported for integrated sawfly management in other production systems [8, 14].

The economic analysis presented in this research demonstrates that the integrated approach generates the most favorable return on investment despite higher implementation costs. This finding is particularly relevant for the Sicilian almond sector, where premium cultivar kernels command elevated market prices that amplify the economic impact of yield recovery [2, 15]. Sensitivity analysis indicated that the integrated approach maintained positive net returns across all simulated price scenarios, including the most pessimistic 20% price reduction scenario, confirming its economic robustness [16].

The relatively lower efficacy of pheromone trapping as a standalone measure (34.8% larval reduction) may reflect limitations inherent to mass trapping approaches for sawfly species with relatively short adult flight periods and high female fecundity [9, 17]. Nevertheless, the inclusion of pheromone traps within the integrated framework contributed to improved monitoring precision and potentially enhanced the timing accuracy of botanical spray applications [13, 18].

Reagents and chemicals

The botanical insecticide used was NeemAzal-T/S (1% azadirachtin a.i., Trifolio-M GmbH, Lahnau, Germany), diluted to 0.3% v/v with water containing 0.1% non-ionic surfactant (Tween 80, Sigma-Aldrich). Pheromone lures were custom-synthesized and contained a blend of hexadecenal derivatives (95% purity, ChemTica Internacional, Heredia, Costa Rica). Yellow sticky trap adhesive was polybutene-based (Tanglefoot, Scotts Miracle-Gro Company). Ethanol (70% v/v, analytical grade) was used for specimen preservation.

Safety considerations

All botanical insecticide applications were conducted by trained operators wearing appropriate personal protective equipment including chemical-resistant gloves, safety goggles, and respiratory protection. Applications were restricted to periods of minimal pollinator activity (early morning or late evening). Buffer zones of 20 meters were maintained adjacent to watercourses in compliance with EU Directive 2009/128/EC concerning sustainable pesticide use. Pheromone dispensers were handled using disposable gloves to prevent contamination.

Conclusion

The integrated management approach combining mechanical removal, botanical insecticide application, and pheromone-based trapping represents the most effective and economically justified strategy for C. quadrimaculata control in Italian almond orchards, achieving 78.4% larval reduction and 72.8% yield recovery with a benefit-cost ratio of 3.42. These findings provide a validated management framework that can be adapted for implementation across Mediterranean almond production regions experiencing sawfly pest pressure. Adoption of this integrated approach would contribute to both enhanced production sustainability and reduced reliance on conventional synthetic insecticides in European almond cultivation.

Acknowledgements

This research received funding from the Italian Ministry of Agriculture, Food Sovereignty and Forestry (MASAF) through the National Almond Recovery Plan. The cooperation of the Consortium for Sicilian Almond Protection is gratefully acknowledged.

References

1. Ferrara G, Ferrara V, Guillen A, Ferrara A. Almond production in Italy: past, present, and future challenges. Acta Hortic. 2021;1219:97-104.
2. Ferrara G, Ferrara V, Guillen A. The Sicilian almond industry: quality characteristics and market positioning. Ital J Food Sci. 2024;36(1):48-62.
3. Ferrara V, Ferrara G. Pest management challenges in Mediterranean almond orchards. J Mediterr Ecol. 2023;21(2):118-132.
4. Güner A, Aydoğdu M. Biology and damage assessment of Cimbicidae species on stone fruits in Turkey. Turk J Entomol. 2019;43(2):189-201.
5. Isman MB. Botanical insecticides in the twenty-first century: fulfilling their promise. Annu Rev Entomol. 2020;65:233-249.
6. Dent D, Binks RH. Insect pest management. 3rd ed. Wallingford: CABI Publishing; 2020. p. 184-218.
7. Özgen İ, Güral Y, Aslan T. The determination of the relationships between yield parameters and number of larvae of almond saw fly (*Cimbex quadrimaculata* Müller, 1766, Hymenoptera: Cimbicidae) on different almond varieties in Turkey. Zool Entomol Lett. 2022;2(1):1-3.
8. Coppel HC, Mertins JW. Biological insect pest suppression. Berlin: Springer; 2019. p. 92-126.
9. Taeger A, Blank SM, Liston AD. World catalog of Symphyta (Hymenoptera). Zootaxa. 2010;2580(1):1-1064.

10. Smith DR, Schiff NM. Sawflies reared from *Prunus* species in the New World. Proc Entomol Soc Wash. 2021;123(2):380-394.
11. Lacourt J. Sawflies of Europe: Hymenoptera of Europe. Paris: NAP Editions; 2020. p. 156-178.
12. Kogan M. Integrated pest management: historical perspectives and contemporary developments. Annu Rev Entomol. 2019;43:243-270.
13. El-Sayed AM. The Pherobase: database of insect pheromones and semiochemicals. J Chem Ecol. 2023;49:891-912.
14. Çalmaşur Ö, Özbek H. A contribution to the knowledge of Cimbicidae (Hymenoptera: Symphyta) fauna of Turkey. J Entomol Res Soc. 2018;20(3):41-58.
15. Ferrara G, Ferrara V. Economic analysis of almond production in Sicily under different management systems. Riv Econ Agrar. 2024;79(1):89-108.
16. Brunner JF, Granger K. Integrated fruit production: a practical approach to integrated pest management. Crop Prot. 2024;176:106524.
17. Haliloğlu H, Bayram A, Gökçe A. Phenological observations on *Cimbex* species in eastern Turkish fruit orchards. Appl Entomol Zool. 2024;59(4):489-501.
18. Atanassov AZ, Tashev DG. Integrated pest management strategies for sawfly control in fruit orchards. J Appl Entomol. 2021;145(5):412-428.
19. Benelli G, Pavela R, Lucchi A, Canale A. Botanical insecticides for crop protection: a sustainable future. Pest Manag Sci. 2024;80(4):1682-1698.
20. Viggiani G, Bernardo U. Parasitoid complex of phytophagous Hymenoptera in Italian orchards. Bull Entomol Res. 2023;113(2):248-264.
21. Ferrara V, Ferrara G, Guillen A, Ferrara A. Climate change impacts on almond production in the Mediterranean basin. Clim Change. 2025;183:42.