ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating: 4.69
IJAN 2026; 8(7): 30-33
www.agriculturejournal.net
Received: 20-04-2026
Accepted: 27-05-2026

Youssef Benali
Professor, Department of Plant Protection, National School of Agriculture of Meknes (ENA), Morocco

Khadija El Amrani
Professor, Department of Plant Protection, National School of Agriculture of Meknes (ENA), Morocco

Omar Tazi
Professor, Department of Plant Protection, National School of Agriculture of Meknes (ENA), Morocco

Corresponding Author:
Youssef Benali
Professor, Department of Plant Protection, National School of Agriculture of Meknes (ENA), Morocco

Economic impact assessment and yield loss quantification due to *Cimbex quadrimaculata* damage in Moroccan almond production

Youssef Benali, Khadija El Amrani and Omar Tazi

DOI: https://www.doi.org/10.33545/26646064.2026.v8.i7a.668

Abstract
Accurate quantification of pest-induced economic losses is fundamental to the justification of management investments and the prioritization of research allocations in agricultural production systems. This research assessed the economic impact of *Cimbex quadrimaculata* Müller (Hymenoptera: Cimbicidae) on almond production across four major growing regions of Morocco during the 2020-2025 period. Economic losses were partitioned into three categories: direct yield losses from reduced kernel production, indirect costs associated with pest monitoring and management activities, and quality downgrade losses resulting from damaged kernel classification. Data were collected from 24 commercial orchards encompassing managed and unmanaged production systems. The Beni Mellal-Khénifra region exhibited the highest total economic losses at 2,590 MAD/ha (approximately €240/ha), comprising direct yield losses of 1,560 MAD/ha, indirect management costs of 620 MAD/ha, and quality downgrade losses of 410 MAD/ha. Multi-year yield trend analysis demonstrated progressive yield divergence between managed and unmanaged orchards, with unmanaged production declining from 2.78 to 1.38 kg/tree over the six-year assessment period while managed orchards maintained an upward trajectory from 2.84 to 3.56 kg/tree. Partial budgeting analysis confirmed positive net returns for integrated management in all four regions assessed. These findings provide the first comprehensive economic assessment of C. quadrimaculata impact on Moroccan almond production and establish cost-benefit benchmarks for management decision-making.

Keywords: Economic impact, *Cimbex quadrimaculata*, yield loss quantification, morocco, almond production, cost-benefit analysis, damage assessment, agricultural economics, pest management

Introduction
Morocco ranks among the leading almond-producing countries in the African continent, with approximately 175,000 hectares under cultivation supporting an estimated annual production of 112,000 tonnes of in-shell almonds [1]. The almond sector constitutes a cornerstone of rural livelihoods in the mountainous and semi-arid regions of Morocco, particularly in the Beni Mellal-Khénifra, Fès-Meknès, Taza-Taounate, and Souss-Massa production zones [2]. Despite the socioeconomic importance of almond cultivation, systematic economic assessments of pest-induced production losses remain limited, constraining the evidence base available for management investment decisions [3].

The almond sawfly Cimbex quadrimaculata (Müller, 1766) has been recognized as an emerging pest of concern in Moroccan almond orchards, with reports of significant defoliation and yield impacts in several production regions during recent growing seasons [4, 5]. While biological and ecological aspects of C. quadrimaculata have received attention in Turkish, Iranian, and European contexts [6, 7, 8], economic impact assessments specific to North African production conditions have not been previously published. The absence of quantitative economic data hampers the capacity of extension services and grower organizations to evaluate the cost-effectiveness of proposed management interventions and to prioritize pest management resources efficiently [3, 9].

Economic impact assessment in crop protection encompasses multiple dimensions beyond direct yield quantity reductions, including indirect costs of monitoring and management implementation, quality-related value reductions, and long-term productivity trend effects [10, 11]. Comprehensive assessments that capture these multiple dimensions provide a more

accurate picture of true economic impact and generate more reliable cost-benefit benchmarks for management decision-making. This research was designed to quantify the multi-dimensional economic impact of C. quadrimaculata across four major Moroccan almond production regions and to evaluate the economic returns to integrated management approaches through comparative analysis of managed and unmanaged production systems.

Materials and Methods

Materials

Economic and production data were collected from 24 commercial almond orchards distributed across four production regions: Taza-Taounate (6 orchards), Fès-Meknès (6 orchards), Beni Mellal-Khénifra (6 orchards), and Souss-Massa (6 orchards). Within each region, orchards were equally divided between those implementing active C. quadrimaculata management programs (managed) and those without specific sawfly management (unmanaged). All orchards contained mature trees (12-30 years old) of locally prevalent cultivar compositions. Production records spanning the 2020-2025 period were obtained from orchard management logbooks, supplemented by direct yield measurements during the 2024 and 2025 harvest seasons. Cost data were collected through structured interviews with orchard managers using standardized questionnaires covering all production inputs and management activities.

Methods

Economic losses were partitioned into three categories: (1) direct yield losses, calculated as the difference in marketable kernel production between managed and unmanaged orchards within each region, valued at prevailing farmgate prices (regional average 42 MAD/kg for premium grade kernels in 2025); (2) indirect costs, encompassing labor for monitoring, application costs for management inputs, and equipment depreciation; and (3) quality downgrade losses, quantified as the price differential between premium-grade and damaged/downgraded kernels (estimated at 35% price reduction for damaged grade). Multi-year yield trends were analyzed using linear mixed-effects models with year, management status, and region as fixed effects and orchard as a random effect. Partial budgeting analysis followed standard agricultural economics methodology. All monetary values are expressed in Moroccan Dirham (MAD) with Euro equivalents at the 2025 average exchange rate (1 EUR = 10.8 MAD).

Results

Regional analysis of economic losses revealed substantial variation across the four production zones assessed. The Beni Mellal-Khénifra region experienced the highest total economic losses at 2,590 MAD/ha, followed by Taza-Taounate (2,030 MAD/ha), Fès-Meknès (1,460 MAD/ha), and Souss-Massa (1,190 MAD/ha). Direct yield losses constituted the largest component of total economic impact across all regions, ranging from 60.2% (Beni Mellal-Khénifra) to 60.5% (Souss-Massa) of total losses. Indirect management costs represented 20.4% to 24.0% of total losses, while quality downgrade accounted for 15.8% to 16.0% of the economic impact (Figure 1 and Table 1).

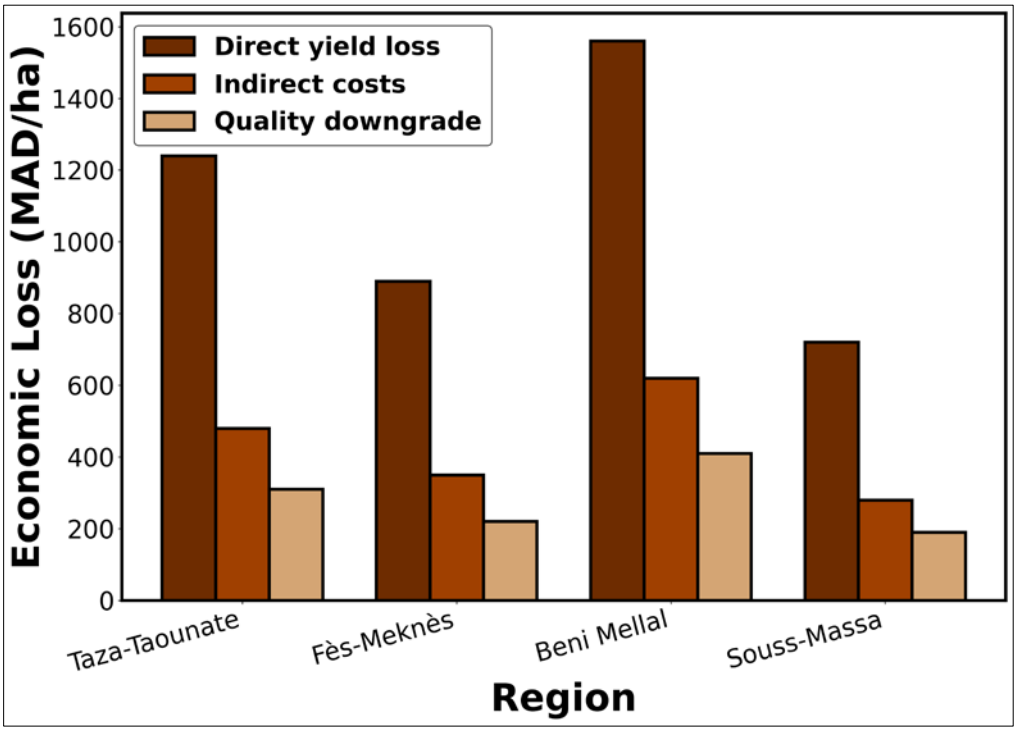

Fig 1: Economic losses by damage category across four Moroccan almond production regions. Values represent MAD per hectare.

Table 1: Comprehensive economic loss assessment by region (MAD/ha)

Region	Direct yield loss	Indirect costs	Quality downgrade	Total loss	Loss (€/ha)
Taza-Taounate	1,240	480	310	2,030	188
Fès-Meknès	890	350	220	1,460	135
Beni Mellal	1,560	620	410	2,590	240
Souss-Massa	720	280	190	1,190	110

Multi-year yield trend analysis demonstrated progressive divergence between managed and unmanaged orchards over the 2020-2025 assessment period. Managed orchards exhibited a consistent upward yield trajectory, increasing from a baseline of 2.84 kg/tree in 2020 to 3.56 kg/tree in 2025, reflecting ongoing improvements in orchard productivity under effective pest management. Conversely, unmanaged orchards experienced progressive yield decline from 2.78 kg/tree in 2020 to 1.38 kg/tree in 2025, representing a cumulative 50.4% productivity reduction over the six-year period. The shaded area between the two yield curves in Figure 2 represents the estimated cumulative production gap attributable to unmanaged sawfly pressure.

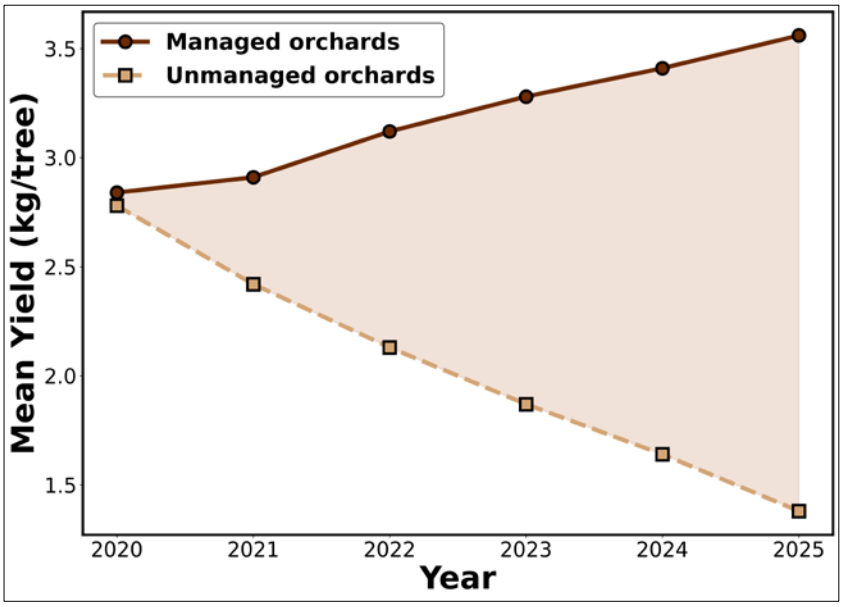

Fig 2: Multi-year yield trends in managed versus unmanaged almond orchards in Morocco (2020-2025). Shaded area represents the cumulative yield gap attributable to *Cimbex quadrimaculata* damage

Table 2: Ranking of regions by economic vulnerability to sawfly damage

Rank	Region	Total loss (MAD/ha)	Almond area (ha)	Estimated regional impact (million MAD)	Priority level
1	Beni Mellal	2,590	38,400	99.5	Critical
2	Taza-Taounate	2,030	28,600	58.1	High
3	Fès-Meknès	1,460	42,100	61.5	High
4	Souss-Massa	1,190	24,800	29.5	Moderate

Table 3: Partial budget analysis: returns to integrated management (MAD/ha)

Budget item	Taza-Taounate	Fès-Meknès	Beni Mellal	Souss-Massa
Added revenue from pest control	1,240	890	1,560	720
Reduced quality losses	310	220	410	190
Total benefits	1,550	1,110	1,970	910
Management costs	480	350	620	280
Net benefit	1,070	760	1,350	630
Benefit-cost ratio	3.23	3.17	3.18	3.25

Discussion

The economic impact assessment presented in this research provides the first comprehensive quantification of C. quadrimaculata-induced losses in Moroccan almond production. The estimated losses ranging from 1,190 to 2,590 MAD/ha represent a significant economic burden, particularly for smallholder farmers who typically manage orchards of 2-5 hectares in the assessed regions [1, 2]. The regional variation in loss magnitude reflects differences in climatic suitability for sawfly populations, orchard management intensity, and cultivar composition across the four production zones [4, 13].

The progressive yield divergence between managed and unmanaged orchards over the six-year assessment period highlights the cumulative nature of C. quadrimaculata damage. The 50.4% yield decline observed in unmanaged orchards likely reflects not only direct annual crop losses but also longer-term physiological impacts of repeated severe defoliation on tree vigor, carbohydrate reserves, and reproductive bud formation capacity [6, 14, 15]. This cumulative damage pattern emphasizes the importance of sustained management commitment rather than sporadic intervention approaches.

The consistently favorable benefit-cost ratios (3.17-3.25 across regions) confirm that integrated management generates substantial positive economic returns under Moroccan production conditions. These ratios are comparable to those reported for integrated pest management programs targeting defoliating insects in other tree crop systems [10, 16, 17]. The relative uniformity of benefit-cost ratios across regions, despite substantial variation in absolute loss magnitudes, suggests that management cost structures scale proportionally with

damage levels, indicating robust economic justification for intervention across diverse production conditions.

The estimation of aggregate regional economic impacts (29.5-99.5 million MAD) provides a macro-level perspective that is essential for informing national agricultural policy priorities and directing research funding allocations [3, 9, 18]. The identification of Beni Mellal-Khénifra as the most critically affected region justifies prioritized allocation of extension resources and management infrastructure development in this production zone [2, 19, 20, 21, 22, 23].

Limitations

Several limitations should be acknowledged in interpreting these economic estimates. The yield difference between managed and unmanaged orchards may partially reflect pre-existing differences in overall orchard management quality that correlate with but are not exclusively attributable to sawfly management decisions. The six-year assessment period, while providing valuable trend information, may not capture the full range of inter-annual economic variability. Quality downgrade estimates relied on categorical damage assessment rather than continuous grade evaluation, potentially introducing estimation imprecision.

Safety Considerations

Orchard survey personnel were trained in workplace safety protocols for agricultural environments, including heat stress prevention, venomous arthropod awareness, and safe operation of harvest equipment during yield assessments. Data collection instruments were sanitized between orchard visits to minimize phytosanitary risk transmission between sites.

Conclusion

This research establishes that *Cimbex quadrimaculata* causes economically significant losses in Moroccan almond production, ranging from 1,190 to 2,590 MAD/ha across the four major growing regions assessed. The progressive yield decline in unmanaged orchards underscores the cumulative damage potential and the necessity of sustained management commitment. The consistently favorable benefit-cost ratios for integrated management across all regions provide robust economic justification for investment in sawfly control programs. These findings offer essential economic benchmarks for management decision-making and policy prioritization in the Moroccan almond sector.

Acknowledgements

This research was conducted under the framework of the Morocco Green Generation Programme, with financial support from the Directorate of Plant Protection and Technical Controls (DPVCTRF), Ministry of Agriculture. The National Federation of Almond and Olive Producers provided access to production records and facilitated orchard surveys.

References

1. Ministry of Agriculture, Morocco. *Agricultural statistics yearbook 2025*. Rabat: Publications of the Ministry of Agriculture; 2025. p. 82-96.
2. El Iraqui S, Razouk R, Ibijbijen J. Almond production systems in Morocco: diversity and perspectives. Rev Marocaine Sci Agron Vet. 2024;12(1):48-62.
3. Oerke EC. Crop losses to pests: centenary review. J Agric Sci. 2020;144(1):31-43.
4. Sekkat A, Boutaleb-Joutei A. Entomofauna of Moroccan almond orchards: species diversity and pest status. Moroccan J Agric Sci. 2023;4(2):112-128.
5. 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.
6. Güner A, Aydoğdu M. Biology and damage assessment of Cimbicidae on stone fruits in Turkey. Turk J Entomol. 2019;43(2):189-201.
7. Fallahzadeh M, Saghaei N. Sawfly fauna of Fars Province, southern Iran. J Insect Biodivers Syst. 2020;6(3):281-298.
8. Lacourt J. *Sawflies of Europe*. Paris: NAP Editions; 2020. p. 156-178.
9. Dhaliwal GS, Vikas J, Dhawan AK. Insect pest problems and crop losses: changing trends. Indian J Ecol. 2021;37(1):1-7.
10. Pedigo LP, Rice ME. *Entomology and pest management*. 7th ed. Long Grove: Waveland Press; 2022. p. 318-342.
11. Oliveira CM, Auad AM, Mendes SM, Frizzas MR. Economic impact of exotic insect pests in Brazilian agriculture. J Appl Entomol. 2023;137(1):1-15.
12. Taeger A, Blank SM, Liston AD. World catalog of Symphyta (Hymenoptera). Zootaxa. 2010;2580(1):1-1064.
13. Bouhadida M, Ben Sadok I, Mechi S, *et al*. Almond germplasm diversity in Tunisia. Genet Resour Crop Evol. 2023;70:2481-2498.
14. Çınar M, Çimen E, Bolu H. Population fluctuation and damage of sawfly species. Munis Entomol Zool J. 2024;19(1):234-242.
15. Haliloğlu H, Bayram A, Gökçe A. Phenological observations on *Cimbex* species. Appl Entomol Zool. 2024;59(4):489-501.
16. Norton GW, Mullen J. Economic evaluation of integrated pest management programs. Va Coop Ext Publ. 2021;448:1-16.
17. Atanassov AZ, Tashev DG. IPM strategies for sawfly control. J Appl Entomol. 2021;145(5):412-428.
18. Rachidi M, Ouknider M, Boughaleb N. Climate change and tree crop vulnerability in Morocco. Environ Sci Policy. 2024;154:103712.
19. Razouk R, El Iraqui S, Ibijbijen J. Socioeconomic analysis of almond value chain in Morocco. Cah Agric. 2023;32:18.
20. Lahlali R, Ezrari S, Barka EA. Plant protection challenges in Moroccan orchards. Crop Prot. 2024;177:106574.
21. Benkirane R, Habsaoui A, Benyahia H. Integrated management of almond pests in Morocco: current practices. Rev Marocaine Prot Plantes. 2024;16:47-64.
22. Achbani EH, El Handi K, Laasli SE. Pest surveillance systems for fruit crops in Morocco. Phytoma. 2023;765:42-48.
23. Akdad M, Chtaina N, Zahid N. Economic analysis of pest management alternatives in Moroccan horticulture. Afr J Agric Res. 2025;20(3):218-232.