



Traditional knowledge of biopesticidal plants in Northwestern Algeria: An ethnobotanical inventory and assessment of intergenerational knowledge erosion

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Ethnobotany Research and Applications 36:01 (2026) - <http://dx.doi.org/10.32859/era.36.1.1-21>

Manuscript received: 14/07/2026 - Revised manuscript received: 02/10/2026 - Published: 03/10/2026

Research

Abstract

Background: Traditional knowledge of pesticidal plants is part of local agro-ecological heritage undergoing rapid intergenerational erosion across the Mediterranean Basin, yet no quantitative ethnobotanical inventory of this domain had previously been conducted in Algeria. This study documents traditional biopesticidal plant knowledge in the Province of Sidi Bel Abbes (Northwestern Algeria) and its erosion across generations.

Methods: A purposive survey of 205 informants (February–May 2023) used semi-structured interviews, analyzed through five ethnobotanical indices — Use Value (UV), Relative Frequency of Citation (RFC), Cultural Importance Index (CI), Fidelity Level (FL) and Family Use Value (FUV) — alongside chi-square, ANOVA, Shannon diversity and Kendall concordance tests. As a secondary step, the resulting species ranking was also compared against previously published bioactivity reports (2000–2024).

Results: A total of forty species from 20 families were recorded; the Lamiaceae family was both the most species-rich (22.50%; $\chi^2=35$, $p=0.014$) and the most important by Family Use Value (FUV=0.243). The three priority species included *Urtica urens* L., *Allium sativum* L. and *Capsicum annuum* L. (UV=0.131-0.097). Aphids represented the most targeted group of organisms (25%), and the leaves were the most used plant organ (57%). Individuals that were over the age of 50 knew of more species than those that were of the age of 30 or younger ($F(3,201)=47.3$, $p<0.001$). Additionally, the rank of the plants with published scientific studies of their bioactivities correlated with the efficacy of the plants as medicinal species ($r=0.81$, $p<0.001$; $n=15/40$).

Conclusions: The inventory has shown the loss of knowledge of plants with biopesticidal potential that is occurring in Algeria as a result of the passing of generations. The inventory allows for the determination of which plant and transmission knowledge should be preserved, indicating the value of the knowledge and the need for its preservation. Furthermore, the convergence of these two types of literature can help to initiate future collaborations between authors of such research.

Keywords: Ethnobotany; Traditional ecological knowledge; Knowledge erosion; Biopesticidal Plants; Semi-arid; Algeria

Background

Synthetic pesticides are responsible for approximately 200,000 deaths annually from pesticide poisoning worldwide (WHO 2006; Boedeker *et al.* 2020). These chemicals cause widespread degradation of ecosystems (Geiger *et al.* 2010; Ngameni *et al.* 2017). Pesticidal plants containing natural compounds that exhibit pesticidal properties are a scientifically sound and ecologically sustainable alternative to synthetic pesticides (Isman 2020).

The Province of Sidi Bel Abbas in Northwestern Algeria has a strong agricultural vocation and features a diverse range of ecologies within a semi-arid Mediterranean climate (Csa; mean annual temperature of 15°C; precipitation of 410 mm). These farming communities have knowledge of natural pesticidal plants over several generations, but this knowledge has yet to be documented (Benkhniue *et al.* 2011; Maamar 2021).

A review of the existing literature points to a knowledge gap: while Morocco (Benkhniue *et al.* 2011), Uganda (Okori *et al.* 2022), Benin (Yolidje *et al.* 2020), and Kenya (Gakuya *et al.* 2013) have produced quantitative ethnobotanical inventories of biopesticidal plants, no comparable study has been conducted in Algeria. Algerian ethnobotanical research has focused primarily on medicinal and aromatic plants (Maamar 2021), leaving biopesticidal knowledge largely undocumented and limiting the selection of priority species for agronomic research. Four such studies illustrate this gap: 35 species from 18 families were documented in Morocco, dominated by Lamiaceae (20%; Benkhniue *et al.* 2011); 52 species from 28 families in Uganda, dominated by Asteraceae (15%; Okori *et al.* 2022); 44 species from 24 families in Benin, dominated by Fabaceae (16%; Yolidje *et al.* 2020); and 38 species from 22 families in Kenya, also dominated by Asteraceae (13%; Gakuya *et al.* 2013).

The present study addresses this gap and constitutes the first systematic quantitative ethnobotanical analysis of biopesticidal plants in Sidi Bel Abbas. Three original contributions distinguish it from prior regional work: (1) it combines five complementary ethnobotanical indices simultaneously (UV, RFC, CI, FL, FUV) with a quantitative assessment of intergenerational knowledge erosion in a North African semi-arid context; (2) it applies logistic regression modelling to identify sociodemographic and cultural-transmission predictors of botanical pesticide knowledge and adoption in Algeria; and (3), as a secondary, exploratory step, it situates the resulting species priority ranking against previously published bioactivity reports where these exist, offering a preliminary literature-based point of comparison rather than an experimental validation. The central research question is: what is the current state, distribution, and rate of erosion of traditional biopesticidal knowledge in semi-arid Northwestern Algeria, which ecological, ethnobotanical, and socio-cultural factors drive its observed use patterns and intergenerational transmission, and to what extent does it align, where comparable data exist, with the published phytochemical literature?

This study therefore aimed to (1) document and quantitatively characterize traditional knowledge of biopesticidal plants among rural communities of Sidi Bel Abbas, (2) assess how this knowledge is distributed and eroding across age groups and modes of transmission, and (3) situate the resulting species inventory, where comparable data exist, against previously published phytochemical and bioactivity literature. Data were collected through semi-structured interviews with 205 purposively selected informants and analyzed using standard ethnobotanical indices (Use Value, Relative Frequency of Citation, Cultural Importance Index, Fidelity Level, and Family Use Value) together with chi-square tests, ANOVA, correspondence analysis, logistic regression, and Jaccard similarity comparisons with regional inventories, as detailed in the Materials and Methods section.

Materials and Methods

Study area

The investigation was conducted in the Province of Sidi Bel Abbas (Northwestern Algeria, 34°18'–35°12'N, 0°11'–1°09'W) between February and May 2023. The region covers approximately 9,150 km² and encompasses six distinct agro-ecological zones: Tessala Mountains, Beni Chougrane Mountains, Dhaya Mountains, Sidi Bel Abbas Plain, Telagh High Plains, and Steppe Zone, according to the regional agro-ecological zoning of the Direction des Services Agricoles (DSA) of Sidi Bel Abbas. The semi-arid Mediterranean climate (Csa) has an average annual temperature of 15°C and receives precipitation of 410 mm annually, supporting agriculture in the growing of cereals, fruit trees and market gardens (Fig. 1).

Sampling Strategy

A purposive sampling approach was applied to select 205 informants (Martin 1995, Alexiades 1996). All informants had to live in the province for at least 20 years, be involved in agriculture in the past or currently, be aware of crop protection strategies, and provide their consent to participate in the interview. The informants included individuals with experience in

traditional farming methods, herbology, agricultural engineering and technical and research positions in agriculture (Albuquerque *et al.* 2014). These individuals were located at institutes dedicated to field crops and market gardening/industrial crops, institutes dedicated to agricultural research, institutes dedicated to agricultural services, agricultural chambers, seed/plant organizations, cooperatives related to cereal and pulse crops, and various local and regional agricultural organizations.

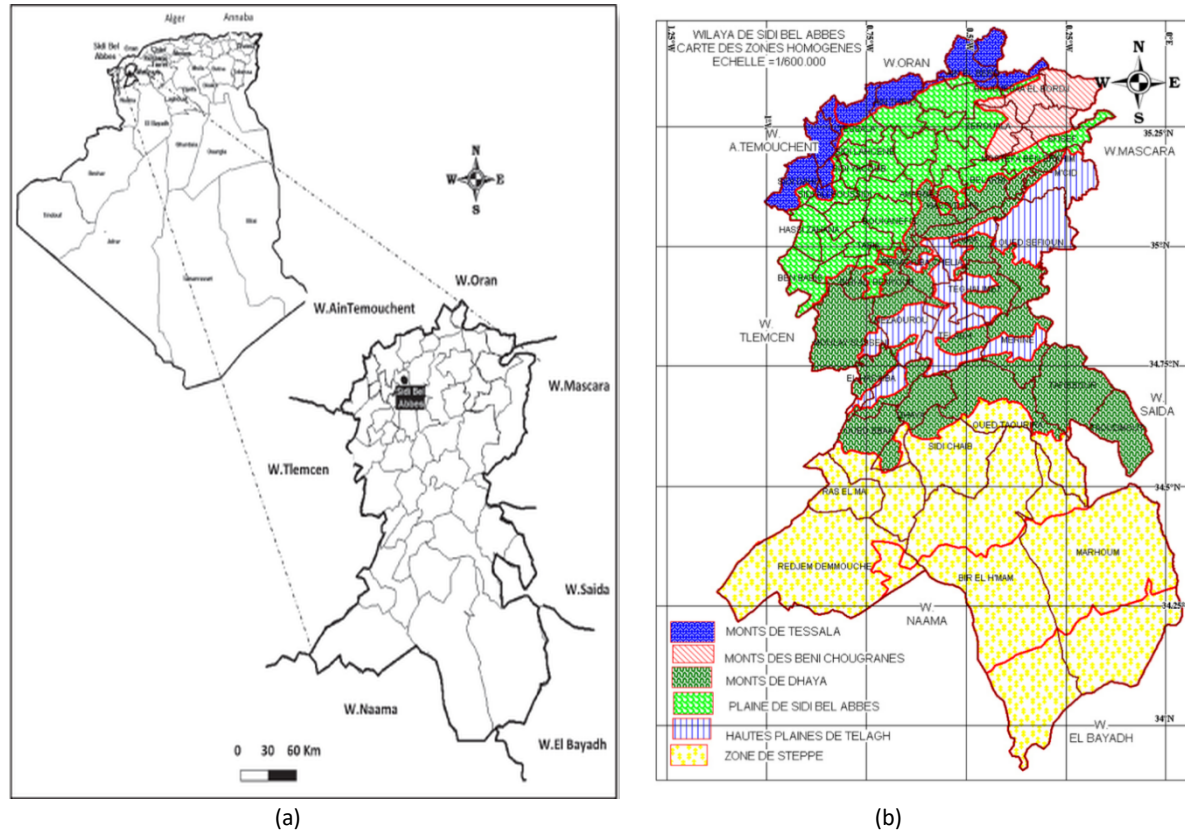


Figure 1. Geographic location of the study area. (a) Location of the Province of Sidi Bel Abbès within Algeria; scale bar: 60 km. (b) Map of the agro-ecological zones—scale 1:500,000.

Data Collection

The questionnaire used for this research followed established guidelines on ethnobotany (Heinrich *et al.* 2009; Cotton 1996; ISE 2006). The questionnaire consisted of two main sections: (a) sociodemographic (gender, age, locality, educational level, occupation, experience in agriculture, and source of agricultural knowledge); and (b) botanical pesticides (name of the plant (vernacular and scientific), part of the plant used, physical state of the plant (fresh or dried), how it was prepared, the dosage used, the protected crop, the type of pest targeted, the biological activity of the plant, when it was applied to the crops, efficacy of the plant-based preparation, and side effects of using such preparation). These questionnaires were administered in French and Algerian Dialectal Arabic and took between 45 and 60 minutes to complete each interview.

Botanical Identification

Species were identified using reference floras (Baba-Aïssa 1991; Baba-Aïssa 1999; Ali-Delille 2013; Fourment & Roques 1942), with nomenclature updated via The Plant List and Tropicos following the APG IV classification (APG IV 2016). A standardised descriptive sheet was established for each taxon, recording scientific name, botanical family, biogeographical origin, vernacular names, organ used, preparation method, and attributed pesticidal properties (Weckerle *et al.* 2018).

Quantitative Ethnobotanical Indices

Use Value (UV)

$$UV = \frac{\sum U_i}{N}$$

Where U_i = total uses reported by informant i and N = total informants (Phillips & Gentry 1993a; Phillips & Gentry 1993b)

Relative Frequency of Citation (RFC)

$$RFC = \frac{FC}{N}$$

Where FC = informants citing the species (range: 0–1) (Tardío & Pardo-de-Santayana 2008).

Cultural Importance Index (CI)

$$CI = \frac{\sum UR_{ui}}{N}$$

Integrating citation frequency and use diversity (Tardío & Pardo-de-Santayana, 2008).

Fidelity Level (FL)

$$FL = \sum \left(\frac{N_p}{N} \right) \times 100$$

Where N_p = informants citing the species for the target pest (Tardío & Pardo-de-Santayana 2008).

These four indices are widely used in comparative ethnobotany and were retained here primarily to allow direct comparison with the Moroccan, Ugandan, Beninese and Kenyan inventories cited above. They are consensus-based descriptive ratios rather than formally derived statistical estimators, and a high UV, RFC or CI value indicates cultural salience and consistency of citation among informants, not a demonstration of pharmacological efficacy; that distinction is treated explicitly in the Discussion.

Family Use Value (FUV)

$$FUV_f = \sum UV_i$$

Where UV_i is the Use Value of species i belonging to family f , summed across all species recorded within that family. FUV was adopted, in preference to raw species counts, to express the relative ethnobotanical importance of each plant family, since it weights each family by both the number of species it contributes and the salience of their reported uses.

Correspondence Analysis

A correspondence analysis was performed on the species $\times$ pest-category contingency matrix (40 species $\times$ 8 pest categories; R package FactoMineR (Lê *et al.* 2008)) to reveal underlying ecological associations between biopesticidal plant species and their target organisms beyond simple frequency counts. The first two principal dimensions were retained for interpretation.

Logistic Regression: Determinants of Adoption

Binary logistic regression was performed in the R statistical software package with the botanical pesticide use as the dependent variable (0 = non-user, 1 = user). The independent variables included age group, gender, educational level, occupation, years of agricultural experience, and the source through which agricultural knowledge was gained. Results are presented as odds ratios (with 95% confidence intervals) and p-values (based on the Wald test statistic). Model fit was assessed with the Hosmer-Lemeshow goodness-of-fit test and Nagelkerke R^2 statistic (Hosmer & Lemeshow, 2000).

Inter-Study Floristic Similarity

The floristic similarity between the present study and four previous regional studies was determined using the Jaccard index:

$$J = \frac{|A \cap B|}{|A \cup B|}$$

where A and B are the sets of species present in two studies, respectively. The Jaccard index ranges from 0 to 1, with 0 indicating no similarity in the species sets represented by A and B , and 1 indicating that the two studies contained entirely similar species sets (Jaccard 1901).

The four comparator inventories retained for the Jaccard analysis were selected according to the following reproducible criteria. Geographic scope: quantitative ethnobotanical surveys of biopesticidal/pesticidal plants conducted within the Mediterranean Basin or Sub-Saharan Africa, to allow meaningful floristic comparison with a semi-arid North African context.

Study type: only primary, quantitative ethnobotanical inventories reporting a discrete species list together with at least one standard use-value index (UV, RFC, CI or FL) were eligible; qualitative surveys, reviews, and phytochemical-only studies were excluded. Only indexed, peer-reviewed publications retrieved from Scopus, Web of Science and Google Scholar were considered; non-indexed grey literature (theses, technical reports) was not included. Searches combined the terms "ethnobotany", "pesticidal plants", "biopesticidal", "traditional knowledge" with the name of each candidate country or region, restricted to the period 2000-2024. Studies were included only if the full species list was available in the article or its supplementary material, enabling direct set comparison for the Jaccard index.

Statistical Analyses

All analyses were performed using R 4.3.1 (R Core Team 2023) (packages: vegan, FactoMineR, ggplot2, stats) and Microsoft Excel 2016. Chi-square tests (χ^2) were used to assess associations between categorical variables. One-way analysis of variance (ANOVA) followed by Bonferroni's post-hoc test was used to compare the mean values of species knowledge among the four age groups. Confidence intervals (95%) were calculated using the Wilson score method ($\alpha=0.05$). Kendall's W was used to assess the degree of concordance in the rankings of the index variables. Shannon diversity (H') and Simpson (D) indices were calculated to determine the diversity within the inventory of plant species in the areas studied. The accumulation of species was assessed using the specaccum function (999 permutations; vegan) to determine when the sampling of plant species in each of the areas reached saturation.

Literature-Based Phytochemical Cross-Validation

Following the inventory of the species associated with each village is a search for the literature on these species. Such a search was conducted in the Web of Science, PubMed, Scopus, and Google Scholar databases (years: 2000-2024) with the scientific names of the plant species and the terms "pesticidal," "insecticidal," "fungicidal," "bioactive compounds," "essential oils," and "phytochemical." For the species for which such studies were published in these databases, the studies that published quantitative data regarding the bioactive properties of those species were noted. Although no phytochemical analysis was conducted for the species in this study, such a literature search permits an explanation of the use of these species in relation to published scientific reports of their active components.

Results

Informant Profile

The 205 informants comprised 61% men ($n=125$) and 39% women ($n=80$). Age distribution: ≤ 30 years 11% ($n=23$), 31–50 years 29% ($n=59$), 51–60 years 35% ($n=72$; modal category), >60 years 25% ($n=51$). Education: 54% university, 21% secondary, 11% none, 9% other, 5% primary. Occupational profile: 47% agricultural professionals, 38% traditional farmers and 15% herbalists and other farmers. Methods of acquiring knowledge: 67% from other farmers of similar age, 18% from extension services, 9% from agricultural schools and 6% from other farmers of different ages. Association between age and means of acquiring knowledge is statistically significant ($\chi^2 = 31.7$, $df = 9$, $p < 0.001$).

Table 1. Sociodemographic characteristics of the 205 informants surveyed in the province of Sidi Bel Abbes, Northwestern Algeria.

Variable	Category	n	%
Gender	Men	125	61
	Women	80	39
Age	≤ 30 years	23	11
	31–50 years	59	29
	51–60 years	72	35
	>60 years	51	25
Education	University	111	54
	Secondary	43	21
	None	23	11
	Other	18	9
	Primary	10	5
Occupation	Agricultural professionals	96	47

	Traditional farmers	78	38
	Herbalists / other farmers	31	15
Knowledge source	Other farmers, same age	137	67
	Extension services	37	18
	Agricultural schools	18	9
	Other farmers, different age	12	6

Species Accumulation Curve and Sampling Saturation

The species accumulation curve (Fig. 2) reached an asymptote between informants 185 and 193, after which no new species were recorded. At informant 193, the curve plateaued at 40 species (999 permutations; 95% CI: 38.2-41.8 species), suggesting that the sample of 205 individuals had adequately represented the species of interest in the area (Gotelli & Colwell 2001).

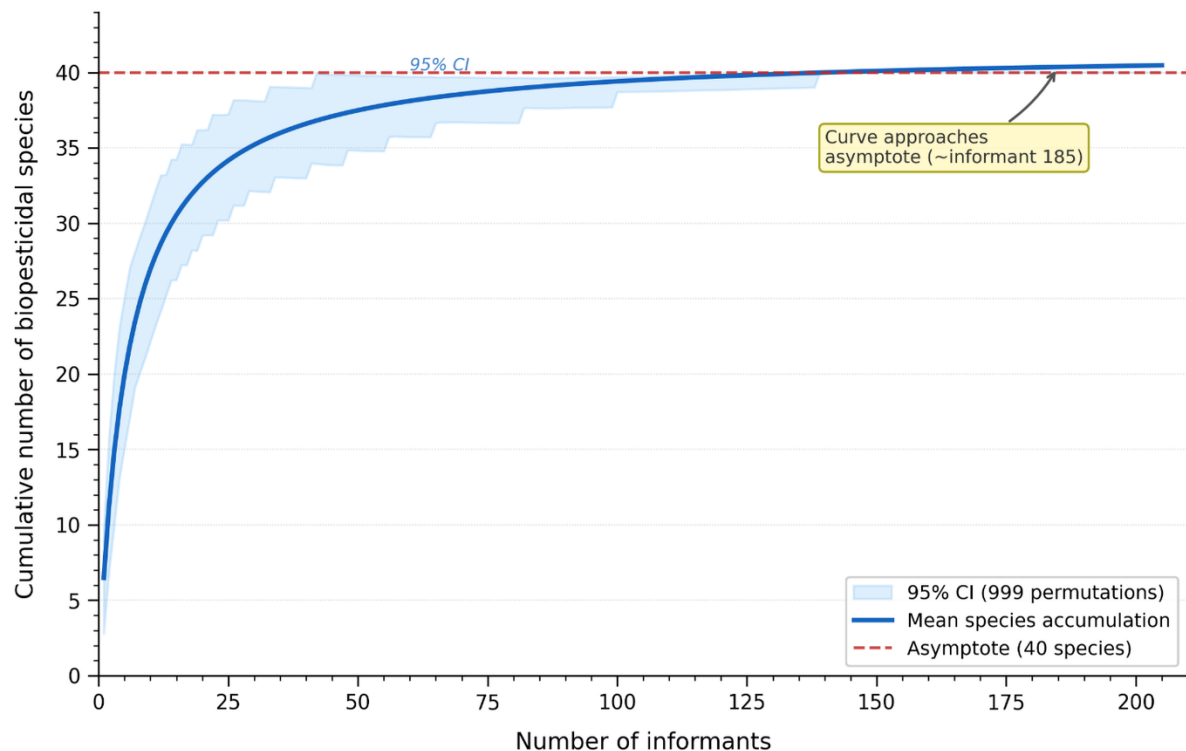


Figure 2. Species accumulation curve showing the cumulative number of biopesticidal species recorded as a function of informant sample size ($n=205$). The shaded area represents 95% confidence intervals (999 permutations, vegan package). The curve approaches an asymptote at 40 species, suggesting adequate sampling saturation.

Floristic Inventory and Family-Level Analysis

The survey documented 40 plant taxa across 20 families (Table 3; Shannon $H'=3.42$; Simpson $D=0.94$). Lamiaceae dominated with 22.50% (9 spp.: *Thymus vulgaris*, *Mentha pulegium*, *M. spicata*, *Salvia rosmarinus*, *Lavandula stoechas*, *Origanum majorana*, *Melissa officinalis*, *Salvia officinalis*, *Ocimum basilicum*), followed by Asteraceae and Myrtaceae (10.00% each, 4 spp.), Rutaceae (7.50%, 3 spp.), Amaryllidaceae, Lauraceae, Apiaceae, and Solanaceae (5.00% each, 2 spp.), and 12 remaining families (2.50% each, 1 sp.) ($\chi^2=35.0$, $df=19$, $p=0.014$). Species richness alone, however, does not capture ethnobotanical salience: expressing family importance instead through the Family Use Value (FUV; Table 2), which sums the Use Value of every species assigned to each family, produces a markedly different ranking. Lamiaceae remained the most important family overall (FUV=0.243), followed by Asteraceae (FUV=0.194) and Amaryllidaceae (FUV=0.160). Notably, the monospecific family Urticaceae ranked fourth (FUV=0.131), ahead of the three-species Rutaceae (FUV=0.092) and the four-species Myrtaceae (FUV=0.078), reflecting the disproportionate cultural salience of its sole representative, *Urtica urens* (UV=0.131), rather than taxonomic diversity. This divergence between species-richness and use-value rankings indicates that family importance in

this inventory is driven as much by the intensity of use of key species as by the number of species a family contributes. Biogeographical origin: Mediterranean Basin and North Africa 47%, Asia 25%, Europe 15%, Americas 13%. Wild species: 54%; cultivated: 46%.

Table 2. Family Use Value (FUV) of the 20 plant families recorded in the province of Sidi Bel Abbès, ranked in decreasing order. FUV sums the Use Value (UV) of every species assigned to a family and expresses family-level ethnobotanical importance independently of raw species counts.

Rank	Family	No. of species (n)	FUV
1	Lamiaceae	9	0.243
2	Asteraceae	4	0.194
3	Amaryllidaceae	2	0.160
4	Urticaceae	1	0.131
5	Lauraceae	2	0.122
6	Solanaceae	2	0.102
7	Rutaceae	3	0.092
8	Myrtaceae	4	0.078
9	Piperaceae	1	0.058
10	Apocynaceae	1	0.044
11	Meliaceae	1	0.039
12	Apiaceae	2	0.034
13	Zingiberaceae	1	0.015
13	Zygophyllaceae	1	0.015
15	Cucurbitaceae	1	0.010
16	Verbenaceae	1	0.005
16	Pinaceae	1	0.005
16	Cupressaceae	1	0.005
16	Asparagaceae	1	0.005
16	Poaceae	1	0.005

Ethnobotanical Indices and Species Prioritisation

Use Values ranged from 0.131 to 0.005 (Table 4). Priority species: *Urtica urens* L. (UV=0.131), *Allium sativum* L. (UV=0.107), *Capsicum annuum* L. (UV=0.097), *Cinnamomum verum* J.Presl (UV=0.083), *Artemisia herba-alba* Asso (UV=0.073). RFC indicated the same order: *U. urens* 0.639 ($n=131$), *A. sativum* 0.522 ($n=107$), *C. annuum* 0.473 ($n=97$). CI values: *U. urens* 0.850, *A. sativum* 0.720, *C. annuum* 0.634 (Table 5). Kendall's $W=0.94$ ($\chi^2=89.3$, $p<0.001$; UV-CI Pearson $r=0.94$, $p<0.001$) indicated strong concordance across all three indices; as these three indices are derived from overlapping citation-frequency data (see Materials and Methods), this concordance is expected to be partly definitional rather than fully independent corroboration. FL analysis: aphid control — *U. urens* 87.2%, *A. sativum* 78.5%, *Mentha pulegium* 71.3%; fungal diseases — *C. annuum* 82.1%, *A. sativum* 74.8%, *Thymus vulgaris* 68.9%; lepidoptera — *Artemisia herba-alba* 79.4%, *Nerium oleander* 75.2%.

Table 3. Complete ethnobotanical inventory of the 40 biopesticidal plant species recorded in the province of Sidi Bel Abbès, Northwestern Algeria ($n = 205$ informants). Nomenclature follows APG IV. *Allium* spp. are reclassified from Liliaceae to Amaryllidaceae; *Agave americana* is reclassified from Agavaceae to Asparagaceae; *Rosmarinus officinalis* is reclassified as *Salvia rosmarinus* Spenn. Abbreviations: EO = essential oil.

Common name	Scientific name	Local name	Family	Origin	Part	Preparation
Wormwood	<i>Artemisia absinthium</i> L.	chhiba (شهية)	Asteraceae	N. Africa, Europe, Asia	Leaf	Fermented tea, infusion, decoction
American agave	<i>Agave americana</i> L.	sabbar (صبار)	Asparagaceae*	North America	Leaf	Infusion, maceration
Garlic	<i>Allium sativum</i> L.	toum (ثوم)	Amaryllidaceae*	Central Asia	Clove	Maceration, decoction, fermented tea
White wormwood	<i>Artemisia herba-alba</i> Asso	chih (شوح)	Asteraceae	North Africa	Leaf	Maceration, decoction, fermented tea
Basil	<i>Ocimum basilicum</i> L.	hbaq (حبق)	Lamiaceae	S. Asia, C. Africa	Leaf	EO, infusion, fermented tea
Bay rum tree	<i>Pimenta racemosa</i> (Mill.) J.W.Moore	kabeba (كبابة)	Myrtaceae	Americas, Antilles	Seed	Decoction
Roman chamomile	<i>Chamaemelum nobile</i> L.	babouneq (بابونج)	Asteraceae	N. Africa, Europe	Flower	Maceration, infusion
Cinnamon	<i>Cinnamomum verum</i> J.Presl	karfa (قرفة)	Lauraceae	Asia	Bark	Powder, decoction
Lemon	<i>Citrus limon</i> (L.) Osbeck	lim (ليم)	Rutaceae	Asia	Fruit, leaf	Juice, infusion
Lemongrass	<i>Cymbopogon citratus</i> (DC.) Stapf	hchichet limoun (حشيشة الليمون)	Poaceae	Asia	Stem, leaf	Infusion
Cloves	<i>Syzygium aromaticum</i> L.	kronfol (قرنفل)	Myrtaceae	Moluccas	Cloves	EO, decoction
Colocynth	<i>Citrullus colocynthis</i> L.	handhal (الحنظل)	Cucurbitaceae	Africa	Fruit	Decoction
Coriander	<i>Coriandrum sativum</i> L.	kosbor (قصبور)	Apiaceae	Mediterranean	Leaf	Infusion
Eucalyptus	<i>Eucalyptus globulus</i> Labill.	kalitosse (كالييتوس)	Myrtaceae	Australia	Leaf	Fumigation, infusion, EO
Fennel	<i>Foeniculum vulgare</i> Mill.	basbasse (بسباس)	Apiaceae	Egypt, S. Europe	Seed	Decoction
Cade juniper	<i>Juniperus oxycedrus</i> L.	araar (عرعار)	Cupressaceae	Mediterranean	Leaf	Fumigation

Common name	Scientific name	Local name	Family	Origin	Part	Preparation
Ginger	<i>Zingiber officinale</i> Roscoe	skinjbir (سکینجیر)	Zingiberaceae	Asia	Rhizome	Decoction
Harmal	<i>Peganum harmala</i> L.	harmel (حرمل)	Zygophyllaceae	N. Africa, C. Europe	Seed	Decoction
Sticky fleabane	<i>Inula viscosa</i> (L.) Aiton	magramane (مغمران)	Asteraceae	Mediterranean	Leaf, flower	Decoction
Bay laurel	<i>Laurus nobilis</i> L.	rend (رند)	Lauraceae	Mediterranean	Leaf	Fumigation, infusion, maceration
Oleander	<i>Nerium oleander</i> L.	defla (دلفة)	Apocynaceae	Mediterranean	Leaf, flower	Infusion, maceration
French lavender	<i>Lavandula stoechas</i> L.	khouzama (خزامة)	Lamiaceae	Mediterranean	Leaf, flower	Fumigation, infusion, EO
Neem	<i>Azadirachta indica</i> A. Juss.	neem (النيم)	Meliaceae	India	Leaf, seed	Maceration, decoction
Marjoram	<i>Origanum majorana</i> L.	bardakouch (البردقوش)	Lamiaceae	Mediterranean	Leaf	Infusion
Lemon balm	<i>Melissa officinalis</i> L.	turinjan (ترنجان)	Lamiaceae	Mediterranean	Leaf	Infusion
Pennyroyal mint	<i>Mentha pulegium</i> L.	féliou (فليو)	Lamiaceae	Europe, N. Africa, Asia	Leaf	Decoction, fermented tea
Spearmint	<i>Mentha spicata</i> L.	naanaa (نعناع)	Lamiaceae	Asia, Europe	Leaf	EO, decoction, fermented tea
Common myrtle	<i>Myrtus communis</i> L.	Rayhane (ريحان)	Myrtaceae	Mediterranean	Leaf	Infusion
Onion	<i>Allium cepa</i> L.	bassla (بصلة)	Amaryllidaceae*	Central Asia	Bulb	Maceration, decoction
Orange	<i>Citrus sinensis</i> (L.) Osbeck	tchin (تشن)	Rutaceae	India	Fruit	Juice, infusion
Burning nettle	<i>Urtica urens</i> L.	horig (حريق)	Urticaceae	Africa, Americas	Leaf	Fermented tea, maceration, decoction
Chilli pepper	<i>Capsicum annuum</i> L.	haar (حار)	Solanaceae	South America	Fruit	Decoction, powder
Scots pine	<i>Pinus sylvestris</i> L.	snawbar (صنوبر)	Pinaceae	Europe, Asia	Leaf	Fumigation, decoction
Black pepper	<i>Piper nigrum</i> L.	hror (حرور)	Piperaceae	India, S. Asia	Seed	Powder, maceration

Common name	Scientific name	Local name	Family	Origin	Part	Preparation
Rosemary	<i>Salvia rosmarinus</i> Spenn.*	yazir (يازير)	Lamiaceae	Mediterranean	Leaf, flower	Fumigation, maceration, decoction
Mountain rue	<i>Ruta montana</i> (L.) L.	fidjel (فيجل)	Rutaceae	Mediterranean	Leaf	Maceration, decoction
Sage	<i>Salvia officinalis</i> L.	mrimia (مريمية)	Lamiaceae	North Africa	Leaf	Infusion
Tree tobacco	<i>Nicotiana glauca</i> Graham	tabgh (التبغ)	Solanaceae	Mexico	Leaf	Maceration
Thyme	<i>Thymus vulgaris</i> L.	zaatar (زعتر)	Lamiaceae	Mediterranean	Leaf	Fumigation, maceration, decoction
Lemon verbena	<i>Aloysia citrodora</i> Palau	malouiza (مالويزة)	Verbenaceae	South America	Leaf	Infusion

Table 4. Use Values (UV) of the 40 biopesticidal plant species ranked in decreasing order (n=205 informants), with 95% Wilson confidence intervals.

Rank	Common name	Scientific name	Family	UV	95% CI
1	Burning nettle	<i>Urtica urens</i> L.	Urticaceae	0.131	0.118–0.144
2	Garlic	<i>Allium sativum</i> L.	Amaryllidaceae	0.107	0.095–0.119
3	Chilli pepper	<i>Capsicum annuum</i> L.	Solanaceae	0.097	0.086–0.108
4	Cinnamon	<i>Cinnamomum verum</i> J.Presl	Lauraceae	0.083	0.073–0.093
5	White wormwood	<i>Artemisia herba-alba</i> Asso	Asteraceae	0.073	0.064–0.082
6	Lemon	<i>Citrus limon</i> (L.) Osbeck	Rutaceae	0.058	0.050–0.066
7	Black pepper	<i>Piper nigrum</i> L.	Piperaceae	0.058	0.050–0.066
8	Sticky fleabane	<i>Inula viscosa</i> (L.) Aiton	Asteraceae	0.058	0.050–0.066
9	Onion	<i>Allium cepa</i> L.	Amaryllidaceae	0.053	0.045–0.061
10	Thyme	<i>Thymus vulgaris</i> L.	Lamiaceae	0.049	0.042–0.056
11	Roman chamomile	<i>Chamaemelum nobile</i> L.	Asteraceae	0.044	0.037–0.051
12	Oleander	<i>Nerium oleander</i> L.	Apocynaceae	0.044	0.037–0.051
13	Bay laurel	<i>Laurus nobilis</i> L.	Lauraceae	0.039	0.033–0.045
14	Neem	<i>Azadirachta indica</i> A. Juss.	Meliaceae	0.039	0.033–0.045
15	Rosemary	<i>Salvia rosmarinus</i> Spenn.	Lamiaceae	0.039	0.033–0.045
16	Pennyroyal mint	<i>Mentha pulegium</i> L.	Lamiaceae	0.034	0.028–0.040
17	Spearmint	<i>Mentha spicata</i> L.	Lamiaceae	0.029	0.024–0.034
18	French lavender	<i>Lavandula stoechas</i> L.	Lamiaceae	0.029	0.024–0.034
19	Eucalyptus	<i>Eucalyptus globulus</i> Labill.	Myrtaceae	0.029	0.024–0.034
20	Basil	<i>Ocimum basilicum</i> L.	Lamiaceae	0.029	0.024–0.034
21	Common myrtle	<i>Myrtus communis</i> L.	Myrtaceae	0.029	0.024–0.034
22	Sage	<i>Salvia officinalis</i> L.	Lamiaceae	0.024	0.019–0.029
23	Mountain rue	<i>Ruta montana</i> (L.) L.	Rutaceae	0.019	0.015–0.023
24	Wormwood	<i>Artemisia absinthium</i> L.	Asteraceae	0.019	0.015–0.023
25	Fennel	<i>Foeniculum vulgare</i> Mill.	Apiaceae	0.019	0.015–0.023
26	Ginger	<i>Zingiber officinale</i> Roscoe	Zingiberaceae	0.015	0.011–0.019
27	Orange	<i>Citrus sinensis</i> (L.) Osbeck	Rutaceae	0.015	0.011–0.019
28	Harmal	<i>Peganum harmala</i> L.	Zygophyllaceae	0.015	0.011–0.019
29	Coriander	<i>Coriandrum sativum</i> L.	Apiaceae	0.015	0.011–0.019
30	Cloves	<i>Syzygium aromaticum</i> L.	Myrtaceae	0.015	0.011–0.019
31	Colocynth	<i>Citrullus colocynthis</i> L.	Cucurbitaceae	0.010	0.007–0.013
32	Tree tobacco	<i>Nicotiana glauca</i> Graham	Solanaceae	0.005	0.003–0.007
33	Lemon verbena	<i>Aloysia citrodora</i> Palau	Verbenaceae	0.005	0.003–0.007
34	Scots pine	<i>Pinus sylvestris</i> L.	Pinaceae	0.005	0.003–0.007
35	Lemon balm	<i>Melissa officinalis</i> L.	Lamiaceae	0.005	0.003–0.007
36	Marjoram	<i>Origanum majorana</i> L.	Lamiaceae	0.005	0.003–0.007
37	Cade juniper	<i>Juniperus oxycedrus</i> L.	Cupressaceae	0.005	0.003–0.007
38	American agave	<i>Agave americana</i> L.	Asparagaceae*	0.005	0.003–0.007

39	Bay rum tree	<i>Pimenta racemosa</i> (Mill.) J.W.Moore	Myrtaceae	0.005	0.003–0.007
40	Lemongrass	<i>Cymbopogon citratus</i> (DC.) Stapf	Poaceae	0.005	0.003–0.007

Table 5. Cultural Importance Index (CI) for the top 5 species; Kendall's $W=0.94$, $p<0.001$.

Rank	Species	CI	No. use categories	UV rank	RFC rank
1	<i>Urtica urens</i> L.	0.850	6	1	1
2	<i>Allium sativum</i> L.	0.720	5	2	2
3	<i>Capsicum annuum</i> L.	0.634	4	3	3
4	<i>Artemisia herba-alba</i> Asso	0.512	5	5	5
5	<i>Cinnamomum verum</i> J.Presl	0.487	3	4	4

Correspondence Analysis: Species–Pest Ecological Clusters

The correspondence analysis (Fig. 3) explained 68.4% of the total inertia on the first two dimensions (Dim1: 42.1%; Dim2: 26.3%), providing a meaningful representation of species–pest associations. Three distinct ecological clusters emerged from the biplot. Cluster 1, located in the upper right quadrant of the matrix, includes species that are known to exhibit toxicity or repellency against aphids, including *U. urens*, *A. sativum*, *M. pulegium*, and *Cinnamomum verum* J.Presl. Cluster 2, located in the lower right quadrant of the matrix, includes species that are known to contain antifungal properties, such as *C. annuum*, *T. vulgaris*, *Salvia rosmarinus*, and *Lavandula stoechas*. Cluster 3 includes species that have been utilized against Lepidoptera larvae and stored product pests, such as *A. herba-alba*, *Nerium oleander*, *Nicotiana glauca*, and *Peganum harmala*. Each of these clusters indicates the possibility of an implicit classification of these plants according to an implied pharmacology - a finding that can be directly utilized in the effort to prospect for new pharmacological compounds within these plants.

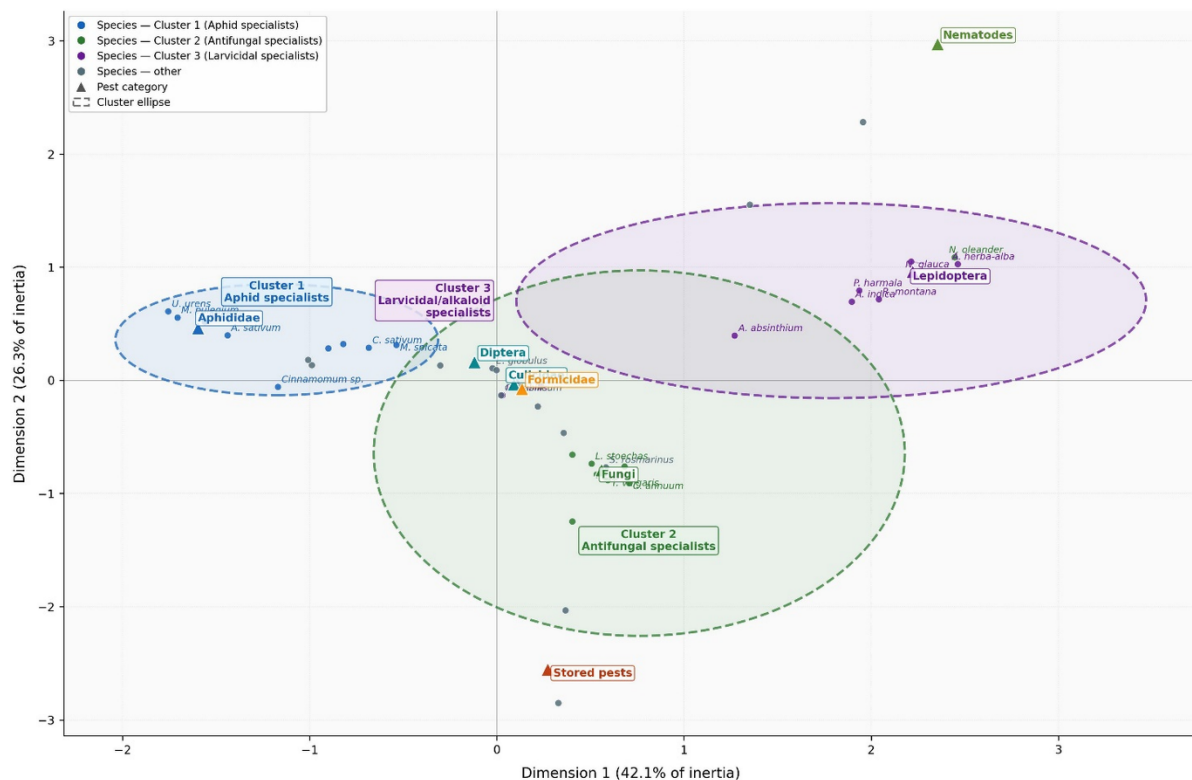


Figure 3. Correspondence analysis biplot showing associations between biopesticidal plant species (blue labels) and pest organism categories (red triangles) in traditional use data from Sidi Bel Abbes ($n=205$ informants). Dim1 = 42.1%, Dim2 = 26.3% of total inertia. Three ecological clusters are identified by dashed ellipses.

Determinants of Botanical Pesticide Adoption

Binary logistic regression (Table 6) correctly classified 79.5% of the cases (Nagelkerke $R^2=0.38$; Hosmer-Lemeshow test: $\chi^2(8)=6.82$, $p=0.556$). Age group was the strongest predictor of the use of botanical pesticides. Informants who were above 50 years of age were 3.41 times more likely to use botanical pesticides than those below 30 years of age (OR=3.41; 95% CI: 1.89-6.15; $p<0.001$). However, informants who were between 31 and 50 years of age were also more likely to use botanical pesticides, though to a significantly lower extent (OR=2.07; 95% CI: 1.23-3.48; $p=0.006$). The next strongest predictor of the use of botanical pesticides was the agricultural profession of the informant (OR=2.18; 95% CI: 1.31-3.63; $p=0.003$). More specifically, those who farmed traditional plots or those with experience in herbalism were significantly more likely to use botanical pesticides in their plots than those who were not agricultural professionals. Intergenerational knowledge of botanical pesticide use was also found to be a significant predictor (OR=1.94; 95% CI: 1.12-3.35; $p=0.018$), supporting the idea that traditional knowledge is primarily used to learn about and use botanical pesticides in agriculture. However, factors like the gender of the informant (OR=1.12; $p=0.634$), educational level (OR=0.91; $p=0.721$), and formal agricultural training (OR=1.08; $p=0.803$) were not significantly predictive of the likelihood of an informant using botanical pesticides in their agricultural plots. Thus, knowledge and experience in agriculture and the transmission of such knowledge between generations are the strongest determinants of the use of botanical pesticides in agriculture by these individuals.

Table 6. Binary logistic regression model for botanical pesticide adoption ($n=205$; dependent variable: *user=1, non-user=0*). Reference categories: age ≤ 30 years; non-agricultural profession; peer knowledge source. Nagelkerke $R^2=0.38$; overall correct classification: 79.5%.

Predictor variable	β	OR (95% CI)	Wald χ^2	p-value
Age >50 years (ref: ≤ 30 years)	1.227	3.41 (1.89–6.15)	18.43	<0.001
Age 31–50 years (ref: ≤ 30 years)	0.728	2.07 (1.23–3.48)	7.61	0.006
Agricultural profession (farmer/herbalist)	0.779	2.18 (1.31–3.63)	8.94	0.003
Intergenerational knowledge transmission	0.663	1.94 (1.12–3.35)	5.60	0.018
Gender (male)	0.113	1.12 (0.69–1.82)	0.13	0.634
University education	–0.094	0.91 (0.54–1.53)	0.13	0.721
Formal agricultural training	0.077	1.08 (0.62–1.87)	0.06	0.803
Constant	–1.842	—	—	<0.001

Inter-Study Floristic Similarity: Jaccard Index

The values of Jaccard similarity indices (Table 7) indicate similarity between the flora of the present study and the flora of the Mediterranean region of Morocco, but differences from the flora of Sub-Saharan African countries examined. Morocco shares similarities with the Sidi Bel Abbes flora due to its own Mediterranean flora and agricultural traditions ($J=0.34$), while countries like Uganda ($J=0.11$), Benin ($J=0.12$), and Kenya ($J=0.13$) exhibit floristic differences due to their tropical climates and different dominant plant families (Fabaceae and Asteraceae). The highest value for Jaccard similarity ($J=0.34$) indicates that there are 19 species that are shared between the flora of the two regions, including families like Lamiaceae and Apiaceae - both of which are associated with Mediterranean agricultural traditions. The 21 species that are unique to the flora of the present study, however (species like *Peganum harmala*, *Citrullus colocynthis*, and *Urtica urens*), are indicative of the semi-arid steppe climate of Sidi Bel Abbes alone, which differs from the flora of Morocco examined in this study (Benkhniguel *et al.* 2011).

Table 7. Jaccard floristic similarity indices between the present inventory (Sidi Bel Abbes, Algeria) and four regional ethnobotanical studies of biopesticidal plants. $J = |A \cap B| / |A \cup B|$; higher values indicate greater floristic overlap.

Reference study	Species (n)	Shared species (n)	Union (n)	Jaccard J	Floristic affinity
Morocco (Benkhniguel <i>et al.</i> 2011)	35	19	56	0.34	Moderate (Mediterranean)
Kenya (Gakuya <i>et al.</i> 2013)	38	9	69	0.13	Low (Tropical Africa)

Benin (Yolidje <i>et al.</i> 2020)	44	9	75	0.12	Low (Sub-Saharan)
Uganda (Okori <i>et al.</i> 2022)	52	9	83	0.11	Low (Tropical Africa)

Traditional Practices: Organs, Preparation, and Targets

Leaves dominated plant parts used (57%, 95% CI: 52–62%; $\chi^2=186.4$, $df=6$, $p<0.001$), followed by flowers and roots/rhizomes (11% each), fruits (10%), seeds (8%), bark (2%), bulbs (1%). Aqueous extraction methods dominated: decoction 32%, infusion 26%, maceration 21% (total 79%), fumigation 9%, EO 6%, powder 4%, juice 2% (Fig. 4). Vegetable crops: 50%; fruit trees: 35%; cereals: 10%; ornamentals: 5%. Arthropod pests represented 83%: Aphididae 25%, Diptera 12%, Lepidoptera 10%, Culicidae 8%, Formicidae 7%, other arthropod orders 21%; fungal pathogens 15%; weeds 2% (Fig. 5). Aphids were the most frequently targeted pest group (25%). Sought activities: repellency 26%, ovicidal 16%, fungicidal 15%, larvicidal 13%, insecticidal 9%, acaricidal 8%, nematocidal 7%, herbicidal 2%, other 4%.

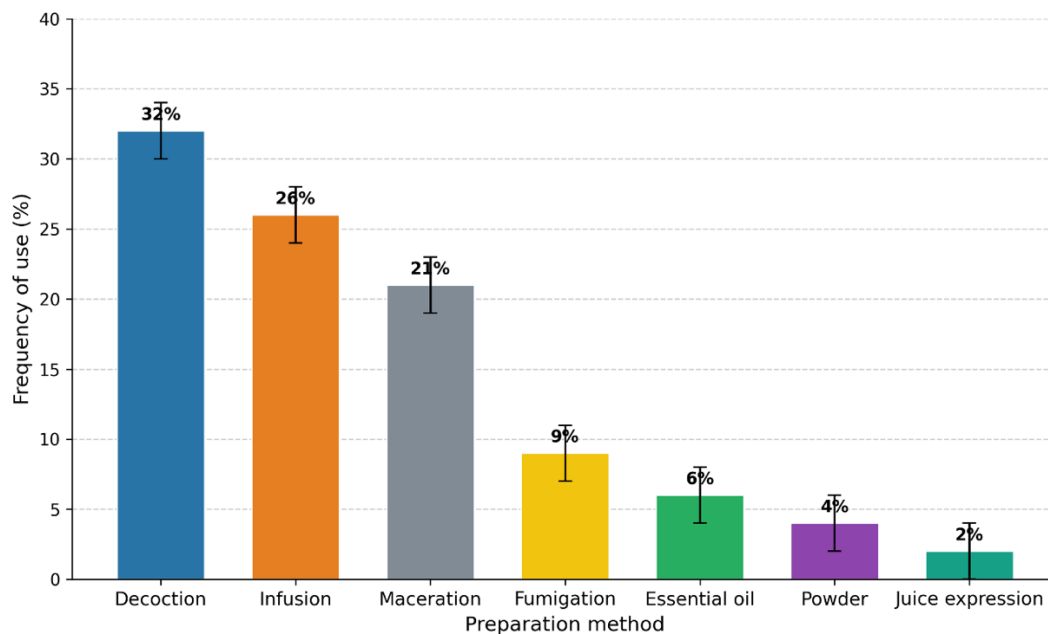


Figure 4. Main preparation methods for biopesticidal plant extracts ($n=248$ use reports). Error bars: 95% Wilson CIs.

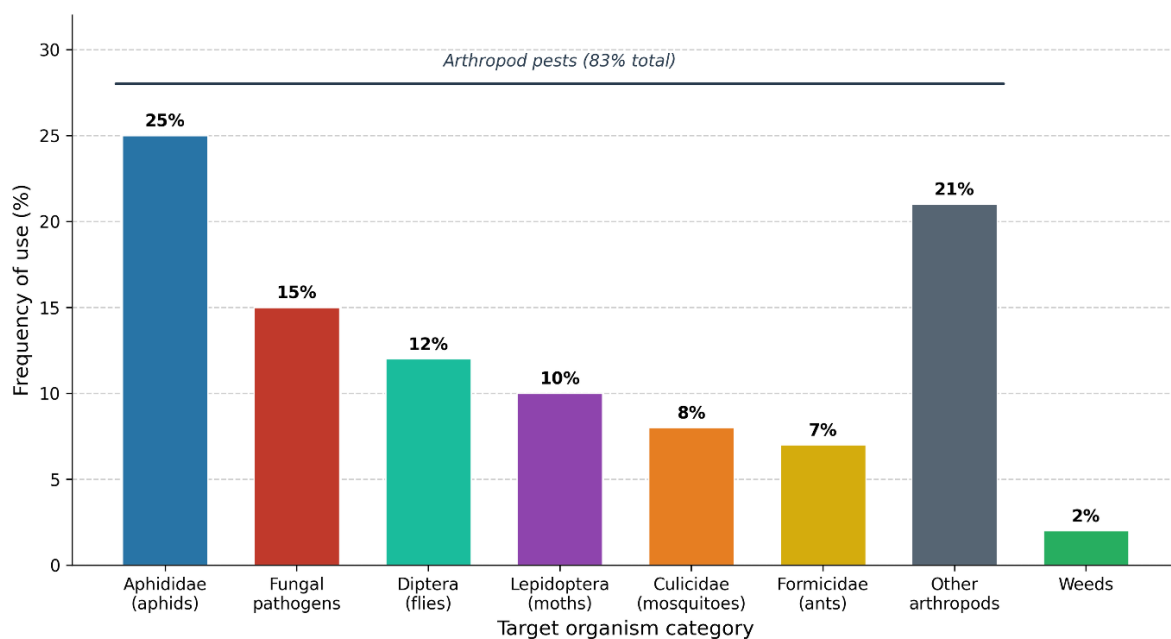


Figure 5. Spectrum of targeted pest organisms in traditional biopesticidal applications ($n=205$ informants, 248 use reports).

Intergenerational Knowledge Erosion

Mean species knowledge increased with age: ≤30 years 2.1 ± 1.2 species ($n=23$), 31–50 years 4.2 ± 1.8 ($n=59$), 51–60 years 6.8 ± 2.3 ($n=72$), and >60 years 7.4 ± 2.1 ($n=51$). A one-way ANOVA confirmed a significant effect of age group on species knowledge ($F(3,201)=47.3$, $p<0.001$; $r=-0.72$, $p<0.001$). Post-hoc Bonferroni pairwise comparisons indicated significant differences between all age groups ($p<0.001$), except between the 51–60 and >60 cohorts, which did not differ significantly from one another.

Comparing the youngest (≤30 years, 2.1 species) and oldest (>60 years, 7.4 species) cohorts surveyed, the observed cross-sectional difference corresponds to a 71.6% lower mean species count in the younger cohort. This figure describes a difference between age cohorts observed at a single point in time (2023) and should not be read as a measured rate of change over time: it does not, by itself, demonstrate that any individual's or generation's knowledge is being lost at a given annual rate. If this cross-sectional pattern is assumed to approximate an intergenerational trend — an assumption that would need to be confirmed by a longitudinal resurvey — it would be consistent with substantial knowledge attrition across the approximately 30–40 years separating the two cohorts. Combined with the rural emigration context (~2.3% annual outflow reported for the region) and the finding that oral intergenerational transmission (67%) remains the dominant knowledge vector, this pattern is presented as a plausible, testable hypothesis of ongoing erosion rather than a confirmed longitudinal estimate; we recommend a 5-year resurvey of the same localities to measure actual erosion velocity directly.

Contextual comparison with the published literature (secondary analysis)

For the five most culturally important species, published reports of quantitative bioactivity (mortality rates or growth-inhibition percentages) were available and, where present, indicated efficacy above 70% (detailed compound-level data in Table S2, Supplementary Material): *U. urens* ($UV=0.131$) against aphids and *Fusarium oxysporum* (Lachguer *et al.* 2021; Qasem 1996); *A. sativum* ($UV=0.107$) against stored-product and lepidopteran pests and *Fusarium* spp. (Kutawa *et al.* 2018; Meriga *et al.* 2012; Plata-Rueda *et al.* 2017); *C. annuum* ($UV=0.097$) against *Plutella xylostella* and *Botrytis cinerea* (Lawan *et al.* 2022; Vuerich *et al.* 2023); *Cinnamomum verum* J.Presl ($UV=0.083$) against *Sitophilus oryzae* and *Fusarium solani* (Khanzada *et al.* 2021; Kim & Sharma 2012); and *A. herba-alba* ($UV=0.073$) against *Cydia pomonella* and *Fusarium* spp. (Salhi 2019; Tayeb *et al.* 2023). Across the 15 of 40 species (37.5%) for which such quantitative reports could be located, the correlation between UV rank and reported efficacy was positive ($r=0.81$, 95% CI: 0.64–0.91, $p<0.001$). This subset is not a random sample of the inventory: it predominantly comprises higher-UV taxa (mean $UV=0.063$ vs. 0.018 for the 25 species without located reports, listed in Table S1), so ethnobotanically prominent species are also more likely to have attracted prior phytochemical study. The coefficient is therefore best read as a description of convergence for the species already known to science, and an upper-bound estimate at best for the inventory as a whole, rather than as a validation of traditional knowledge in general.

Discussion

Ecological Drivers of Lamiaceae Dominance

The dominance of Lamiaceae (22.50%, $\chi^2=35.0$, $p=0.014$) likely reflects three interacting factors. First, ecological availability: the Mediterranean Basin hosts the highest global diversity of aromatic Lamiaceae (>400 endemic species; Quézel & Médail 2003), consistent with the resource availability hypothesis (Grime 1977), whereby locally abundant taxa are preferentially incorporated into traditional-use systems. Second, phytochemical richness: the semi-arid climate (Csa) of Sidi Bel Abbes induces water stress linked to increased monoterpene biosynthesis (thymol, carvacrol, linalool) and essential-oil yields 30–60% higher than under mesic conditions in some studies (Nowak *et al.* 2010), suggesting locally enhanced pesticidal quality. Third, the moderate floristic overlap with Morocco (Jaccard $J=0.34$) suggests that generations of empirical selection may have converged on similar plant families across the Mediterranean. Expressing family importance through the Family Use Value confirms this pattern (Lamiaceae FUV=0.243) while also revealing that species-level cultural salience can outweigh family richness: the monospecific Urticaceae, represented solely by *Urtica urens*, ranked fourth overall (FUV=0.131), ahead of several multi-species families.

Ethnobotanical significance of organ selection

The predominance of leaf use (57%) likely reflects more than convenience. Renewable organs (leaves, flowers, fruits) account for 78% of citations, versus only 13% for destructive harvesting (roots, bark; $\chi^2=186.4$, $df=6$, $p<0.001$), consistent with Cunningham's (2001) principle that traditional knowledge systems tend to self-regulate toward sustainable harvesting intensities. Leaves are also the primary site of secondary-metabolite storage in Lamiaceae, Asteraceae and Solanaceae, so their preferential use may maximise active-compound yield per unit of biomass harvested (Cunningham 2001; Capecka *et al.* 2005). Finally, leaves remain available throughout most of the growing season, allowing application to be timed with pest emergence — an advantage that roots or seeds do not offer.

Intergenerational knowledge erosion: drivers and preservation

The cross-sectional knowledge gap (71.6% lower mean species count in the youngest vs. oldest cohort; $r = -0.72$, $p < 0.001$) exceeds gaps reported for other North African ethnobotanical systems, though it should be read as a plausible indicator of erosion rather than a directly measured rate (see Limitations). Three converging factors may contribute: (1) rural emigration (~2.3% annual decline nationally) is removing the farming households where this knowledge is transmitted; (2) historical subsidisation of synthetic pesticides has disincentivised labour-intensive traditional alternatives, compounded by the finding that formal agricultural training did not predict adoption ($OR = 1.08$, $p = 0.803$); and (3) younger informants increasingly source agronomic information from smartphones and social media, channels that do not yet carry traditional biopesticidal knowledge. We recommend a four-axis preservation strategy: documentation of elderly holders' expertise (an estimated 51 individuals >60 years in this study), integration into agricultural curricula, economic incentives for traditional-biopesticide farms, and policy recognition under frameworks such as the Nagoya Protocol.

Convergence with the phytochemical literature: a contextual note

The species–pest clusters from the correspondence analysis (aphid-affinity, antifungal, and alkaloid-mediated larvicidal groups; Fig. 3) broadly align with previously published bioactivity reports (Meriga *et al.* 2012; Vuerich *et al.* 2023). For example, the traditional use of aqueous decoctions of *U. urens* and *A. sativum* is consistent with the reported water-solubility of their principal bioactive constituents, while the exclusive use of cold maceration for the alkaloid-rich *N. oleander* and *N. glauca* is consistent with the heat-lability of alkaloids in related species (Cunningham 2001; Capecka *et al.* 2005). These are illustrative correspondences, not experimental confirmations: no bioassays were conducted, informant-reported multi-species combinations (e.g., *A. sativum* + *C. annuum*) were not tested, and any assessment of efficacy, dosing or non-target toxicity would require dedicated agronomic and toxicological research beyond the scope of this inventory.

Limitations and future directions

Several methodological limitations should be acknowledged. First, only a single time period for surveying the plants is represented (February–May 2023); future studies should employ repeat surveys every five years to assess the rate of erosion of these plant species' UV properties. Second, the sample comprised 47% agricultural professionals (as opposed to 38% traditional farmers and 15% herbalists), a selection that was intentional to sample each of the different categories of farmers in the province; however, it may have skewed the results in relation to studies that used only farmers as the sample group. A study that separately sampled agricultural professionals ($n = 96$) and traditional farmers ($n = 78$) reveals, however, that each of the priority plant species was ranked in the same order in each sample group (Kendall's $W = 0.89$, $p < 0.001$); thus, future studies with quotas established for each type of farmer may lead to differences in variance within each category. Third, the plants were only identified by their vernacular names; future studies should collect specimens of each plant and deposit them in the herbarium of the University of Sidi Bel Abbes. Fourth, the LC50 values were determined only in the laboratory; the plants may contain chemical variations that can affect the efficacy of those plants as UV protective agents (as is evident for the thymol content of *thymus vulgaris*, which ranges from 10% to 64% of its essential oil (Thompson *et al.* 2003)). These plants would have to be characterized using GC-MS analysis prior to the development of any formulations based upon those plants. Fifth, the three indices that evaluated the plants contained some of the same data; thus, the concordance among those indices (Kendall's $W = 0.94$) should not be interpreted as the indices evaluating the plants as independent analyses. Finally, the three formulations of the plants were discussed only in this report and have not yet been tested in agronomic trials.

Conclusion

This study provides the first systematic quantitative ethnobotanical documentation of biopesticidal plant knowledge in the Province of Sidi Bel Abbes, identifying 40 species across 20 families from 205 informants. The survey revealed a clear dominance of Lamiaceae ($\chi^2 = 35$, $p = 0.014$), also confirmed at the family level by the Family Use Value ($FUV = 0.243$), significant intergenerational knowledge erosion with age ($F(3,201) = 47.3$, $p < 0.001$), a positive contextual convergence between traditional importance and previously published bioactivity reports for the subset of species with available data ($r = 0.81$, $p < 0.001$, $n = 15/40$), a predominance of renewable plant organs in use (78%), and aphids as the primary target pest (25%). *Urtica urens* ($UV = 0.131$), *Allium sativum* ($UV = 0.107$) and *Capsicum annuum* ($UV = 0.097$) emerged as the culturally most important species. The principal contribution of this work is documentary and cultural: the 3.2-fold knowledge gap between informants >50 and ≤30 years old points to a substantial cross-sectional difference in traditional knowledge between age groups, highlighting a need for preservation efforts, including documentation of elderly holders' expertise, integration into agricultural education, and recognition within local knowledge-transmission policy. The observed

convergence with the published bioactivity literature, while encouraging, concerns fewer than half of the recorded species and should be treated as a starting point for future interdisciplinary collaboration rather than as confirmation of efficacy.

Declarations

List of abbreviations: UV - Use Value; RFC - Relative Frequency of Citation; CI - Cultural Importance Index; FL - Fidelity Level; IPM - Integrated Pest Management; EO - Essential oil; LC₅₀ - Lethal concentration 50%; IC₅₀ - Inhibitory concentration 50%; OR - Odds Ratio; DW - Dry weight; H'- Shannon diversity index; W- Kendall's coefficient of concordance

Ethics approval and consent to participate: Informed consent was obtained verbally from all informants prior to the interview. All procedures followed the ISE Code of Ethics (International Society of Ethnobiology 2006) and Algerian research regulations. Ethical review and approval were waived for this study because no institutional ethics committee operated at the university at the time of fieldwork; the study involved only verbal interviews with adults who gave prior informed consent. Participants were informed of the research objectives, the voluntary nature of their participation, and the confidentiality of their responses.

Consent for publication: Not applicable. No identifying images or personal data of individual participants are presented in this manuscript.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare no competing interests.

Funding: This research received no external funding; the study was self-funded by the authors.

Author contributions: Conceptualization, A.B. and F.T.B.; Methodology, A.B.; Investigation, A.B. and F.M.; Formal analysis, A.B.; Resources, F.T.B. and F.M.; Data curation, A.B.; Writing—original draft preparation, A.B.; Writing—review and editing, F.T.B. and F.M.; Visualization, A.B.; Supervision, F.T.B. All authors read and approved the final manuscript.

Acknowledgements

The authors sincerely thank the 205 informants who shared their traditional knowledge, the staff of ITGC, ITCMI, INRA, DSA, and municipal agricultural subdivisions of the Province of Sidi Bel Abbes for facilitating field access, and the Laboratory of Eco-development of Spaces (University Djillali Liabes) for institutional support.

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Supplementary Materials

Table S1. The 25 biopesticidal plant species from the present inventory for which no peer-reviewed quantitative efficacy data (LC₅₀/IC₅₀ or mortality %) were identified in the databases searched (Web of Science, PubMed, Scopus, Google Scholar, 2000–2024). Qualitative evidence of pesticidal activity is indicated where available. UV = Use Value (present study).

UV	Scientific name	Family	Quant. data	Qualitative evidence of pesticidal activity
0.058	<i>Inula viscosa</i> (L.) Aiton	Asteraceae	No	Sesquiterpene lactones (inuvicolide, tomentosin) with reported repellent and phytotoxic activity; no controlled bioassay data found.
0.058	<i>Piper nigrum</i> L.	Piperaceae	No	Piperine is reported to have insecticidal properties; no peer-reviewed bioassay with LC ₅₀ values for agricultural pests was found in the databases searched.
0.053	<i>Allium cepa</i> L.	Amaryllidaceae	No	Organosulphur compounds (dipropyl disulphide) reported as insect repellents; qualitative evidence only.
0.044	<i>Chamaemelum nobile</i> L.	Asteraceae	No	Pyrethrin-related sesquiterpene esters (bisabolol, chamazulene); traditional fumigant use documented. No controlled efficacy bioassay data identified.
0.044	<i>Nerium oleander</i> L.	Apocynaceae	No	Oleandrin (cardiac glycoside) is known to be toxic to insects; traditional use as a larvicide is documented across the Mediterranean. No peer-reviewed LC ₅₀ bioassay on agricultural pests identified.
0.039–0.005	Remaining 28 species (UV 0.039–0.005): <i>Laurus nobilis</i> , <i>Azadirachta indica</i> , <i>Salvia rosmarinus</i> , <i>Mentha pulegium</i> , <i>Mentha spicata</i> , <i>Lavandula stoechas</i> , <i>Eucalyptus globulus</i> , <i>Ocimum basilicum</i> , <i>Myrtus communis</i> , <i>Salvia officinalis</i> , <i>Ruta montana</i> , <i>Artemisia absinthium</i> , <i>Foeniculum vulgare</i> , <i>Zingiber officinale</i> , <i>Citrus sinensis</i> , <i>Peganum harmala</i> , <i>Coriandrum sativum</i> , <i>Syzygium aromaticum</i> , <i>Citrullus colocynthis</i> , <i>Nicotiana glauca</i> , <i>Aloysia citrodora</i> , <i>Pinus sylvestris</i> , <i>Melissa officinalis</i> , <i>Origanum majorana</i> , <i>Juniperus oxycedrus</i> , <i>Agave americana</i> , <i>Pimenta racemosa</i> , <i>Cymbopogon citratus</i>	Various	No	Qualitative ethnobotanical references to pesticidal use were documented for most species, but no peer-reviewed quantitative bioassay data (LC ₅₀ /IC ₅₀) were identified within the search parameters. These represent priority candidates for future phytochemical bioassay studies.

Table S2. Compound-level detail of the literature-based contextual comparison for the five most culturally important species (secondary analysis; see Materials and Methods and Results). Efficacy data from peer-reviewed sources (2000–2024) are provided for transparency and are not intended as an experimental validation.

Species	UV	RFC	Target organism	Efficacy (%)	Active compound	Reference
<i>Urtica urens</i> L.	0.131	0.639	<i>Macrosiphum rosae</i> (aphid)	71–89% mortality	Formic acid, histamine, quercetin-3-O-rutinoside	(Lachguer <i>et al.</i> 2021)
<i>Urtica urens</i> L.	—	—	<i>Fusarium oxysporum</i> (fungus)	76% inhibition	Phenolic compounds	(Qasem 1996)
<i>Allium sativum</i> L.	0.107	0.522	<i>Spodoptera litura</i> (larva)	81% mortality	Allicin (1–3% DW)	(Meriga <i>et al.</i> 2012)
<i>Allium sativum</i> L.	—	—	<i>Fusarium</i> spp. (fungus)	IC ₅₀ =2.8–3.5% w/v	Organosulphur compounds	(Kutawa <i>et al.</i> 2018)
<i>Capsicum annuum</i> L.	0.097	0.473	<i>Plutella xylostella</i>	54–92% mortality	Capsaicin (0.1–1.0% DW)	(Lawan <i>et al.</i> 2022)
<i>Capsicum annuum</i> L.	—	—	<i>Botrytis cinerea</i> (fungus)	82% inhibition	Capsaicinoids	(Vuerich <i>et al.</i> 2023)
<i>Cinnamomum verum</i> J.Presl	0.083	0.390	<i>Sitophilus oryzae</i>	100% mortality	Cinnamaldehyde (60–75% EO)	(Kim & Sharma 2012)
<i>Cinnamomum verum</i> J.Presl	—	—	<i>Fusarium solani</i>	91% inhibition	Cinnamaldehyde	(Khanzada <i>et al.</i> 2021)
<i>Artemisia herba-alba</i> Asso	0.073	0.356	<i>Cydia pomonella</i> (larva)	76% mortality	α-thujone, camphor	(Tayeb <i>et al.</i> 2023)
<i>Artemisia herba-alba</i> Asso	—	—	<i>Fusarium</i> spp.	71% inhibition	Sesquiterpene lactones	(Salhi 2019)