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Review

Sonchus Species of the Mediterranean Region: From Wild Food to Horticultural Innovation—Exploring Taxonomy, Cultivation, and Health Benefits

Adrián Ruiz-Rocamora [1,*], Concepción Obón [2], Segundo Ríos [3], Francisco Alcaraz [1] and Diego Rivera [1,*]

[1] Departamento de Biología Vegetal, Facultad de Biología, Campus de Espinardo, Universidad de Murcia, 30100 Murcia, Murcia, Spain; falcaraz@um.es
[2] Instituto de Investigación e Innovación Agroalimentario y Agroambiental (CIAGRO), Escuela Politécnica Superior de Orihuela, Universidad Miguel Hernández, Ctra. Beniel, Km 3,2, 03312 Orihuela, Alicante, Spain; cobon@umh.es
[3] I.U. de Investigación—CIBIO, Universidad de Alicante, Carretera San Vicente del Raspeig s/n, 03690 San Vicente del Raspeig, Alicante, Spain; s.rios@ua.es
* Correspondence: ruiz.rocamora@yahoo.es (A.R.-R.); drivera@um.es (D.R.); Tel.: +34-868884994 (D.R.)

Abstract

The genus *Sonchus* (Asteraceae) comprises 98 species, including 17 predominantly herbaceous taxa native to the Mediterranean region. These plants have long been utilized as traditional wild food sources due to their high nutritional value, as they are rich in vitamins A, C, and K, essential minerals, and bioactive compounds with antioxidant and anti-inflammatory properties. This review aims to provide a comprehensive synthesis of the taxonomy, geographic distribution, phytochemical composition, traditional uses, historical significance, and pharmacological properties of *Sonchus* species. A systematic literature search was conducted using PubMed, Scopus, Web of Science, and Google Scholar, focusing on studies from 1980 to 2024. Inclusion and exclusion criteria were applied, and methodological quality was assessed using standardized tools. A bibliometric analysis of 440 publications (from 1856 to 2025) reveals evolving research trends, with *S. oleraceus*, *S. arvensis*, and *S. asper* being the most extensively studied species. The review provides detailed taxonomic insights into 17 species and 14 subspecies, emphasizing their ecological adaptations and biogeographical patterns. Additionally, it highlights the cultural and medicinal relevance of *Sonchus* since antiquity while underscoring the threats posed by environmental degradation and changing dietary habits. *Sonchus oleraceus* and *S. tenerrimus* dominate the culinary applications of the genus, likely due to favorable taste, wide accessibility, and longstanding cultural importance. The comprehensive nutritional profile of *Sonchus* species positions these plants as valuable contributors to dietary diversity and food security. Finally, the study identifies current knowledge gaps and proposes future research directions to support the conservation and sustainable utilization of *Sonchus* species.

Keywords: culinary tradition; diet; domestication; ethnobotany; ethnopharmacology; local food; modern cuisine; nutraceuticals; weeds; Asteraceae; sow thistle; functional foods; traditional knowledge; sustainable agriculture; bioactive compounds; wild edibles

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1. Introduction

Currently, global food systems exhibit an excessive reliance on a limited number of plant species, a trend that poses significant risks to food security, human health, and environmental sustainability. Broadening the scope of both agricultural production and dietary consumption to incorporate a wider array of plant taxa—particularly those considered underutilized—holds considerable potential for enhancing nutritional quality, supporting livelihoods, and promoting ecological resilience [1]. In this regard, wild plant species have historically played a vital role in complementing staple foods by providing essential micronutrients, including trace elements, vitamins, and minerals, necessary for a balanced diet. Their reintegration into contemporary diets may once again prove indispensable in addressing nutritional challenges [1].

The Mediterranean region, with its rich ethnobotanical heritage, offers a particularly valuable reservoir of such underexploited species. Many plants traditionally consumed as part of the Mediterranean diet may serve as important genetic resources for the innovation and development of novel food products [2,3]. In this context, the systematic review of various species within the genus *Sonchus*, which have been historically utilized in this region, becomes particularly relevant. Such an examination may shed light on their ethnobotanical significance, nutritional potential, and applicability in sustainable food systems.

The genus *Sonchus* (Asteraceae) comprises 98 species, of which 17 are predominantly herbaceous and native to the Mediterranean region [4–10]. These species include 12 monotypic (*Sonchus briquetianus* Gand., *S. crassifolius* Willd., *S. erzincanicus* V. A. Matthews, *S. fragilis* Ball, *S. macrocarpus* Boulos & C. Jeffrey, *S. maculigerus* H.Lindb., *S. masguindalii* Pau & Font Quer, *S. mauritanicus* Boiss. & Reut., *S. microcephalus* Mejías, *S. oleraceus* L., *S. pustulatus* Willk., *S. suberosus* Zohary & P.H.Davis) and 5 polytypic (*Sonchus arvensis* L., *S. asper* (L.) Hill, *S. bulbosus* (L.) N. Kilian & Greuter (≡*Aetheorhiza bulbosa* (L.) Cass. in Cuvier), *S. maritimus* L., *S. palustris* L., *S. pustulatus* Willk., *S. suberosus* Zohary & P. H. Davis, and *S. tenerrimus* L.) with 14 subspecies. These species exhibit remarkable adaptability, thriving in a wide range of habitats, from natural environments such as rocky outcrops, wetlands, and springs to seminatural and anthropized landscapes, including cultivated fields where they often grow as weeds.

Sonchus species have served as valued wild food plants in Mediterranean rural communities for centuries, consumed fresh in salads, cooked in stews, or preserved as brined products [11]. These plants possess significant nutritional value, containing high levels of vitamins A, C, and K, essential minerals, including calcium, magnesium, and iron, and bioactive compounds such as polyphenols and flavonoids that confer antioxidant and anti-inflammatory properties [12].

Historical documentation of *Sonchus* consumption dates to ancient Greek and Roman civilizations. The Greek physician Dioscorides recorded their medicinal applications in De Materia Medica [13], while contemporary traditional dishes such as Greek “horta” and Italian “pistic” demonstrate their enduring cultural relevance [14]. Beyond culinary applications, these species contribute to Mediterranean ecosystem stability by colonizing disturbed habitats and providing soil stabilization in challenging environmental conditions [15].

However, urbanization and evolving dietary patterns threaten the preservation of traditional knowledge surrounding *Sonchus* species, necessitating urgent documentation efforts to maintain Mediterranean cultural heritage and biodiversity [16,17].

Contemporary research has expanded understanding of the genus *Sonchus*, which comprises over 50 recognized species distributed across the Mediterranean and beyond, exhibiting considerable morphological and ecological diversity [5–10,18]. Phytochemical analyses have identified abundant bioactive compounds, including polyphenols, flavonoids, sesquiterpene lactones, and triterpenoids, which underpin their antioxidant, anti-inflammatory, and antimicrobial properties [19].

Recent studies have confirmed traditional medicinal applications for treating digestive disorders, liver conditions, and skin infections [20] while exploring their potential in functional foods and nutraceuticals due to exceptional nutritional profiles and health-promoting compounds [21]. Despite these advances, current reviews remain limited in scope, addressing either individual species or specific aspects rather than providing comprehensive analytical frameworks [21–23].

Experimental cultivation trials have investigated the agronomic requirements, yield potential, and environmental adaptability of *Sonchus* species [24]. These studies reveal promising prospects for integration into sustainable agricultural systems, particularly for diversified crop production. However, significant challenges persist, including the need for optimized cultivation protocols, enhanced understanding of genetic diversity, and development of strategies to control potential invasive behavior in certain environments [25,26].

A significant scientific gap persists in our understanding of Mediterranean species within the genus *Sonchus*. There is a pressing need for a comprehensive review that integrates detailed data on species taxonomy and distribution, ethnobotanical and ethnopharmacological knowledge, phytochemical composition, and nutritional and gastronomic value, as well as information on the natural habitats and ecosystems in which these species grow. Such ecological insights are essential for informing potential cultivation practices. This integrative approach would provide a clear synthesis of the current state of knowledge and highlight critical gaps that warrant further scientific investigation. Further research is essential to fully characterize the ecological, chemical, and pharmacological diversity within this genus and realize its potential for modern applications.

This review paper aims to critically synthesize the current body of knowledge on *Sonchus* species, with a particular focus on their horticultural development. The specific objectives are as follows:

- To provide a comprehensive overview of the taxonomy, distribution, and ecological adaptability of *Sonchus* species, highlighting their diversity and the environmental conditions under which they thrive.
- To review the traditional uses of *Sonchus* species as wild food plants but also as medicinal resources for humans and livestock, emphasizing their cultural significance and the ways in which they have been utilized by local communities.
- To analyze the phytochemical composition and nutritional value of *Sonchus* species, with a focus on their bioactive compounds and potential health benefits.
- To evaluate the results of experimental cultivation trials, assessing the agronomic potential of *Sonchus* species as novel crops and identifying key factors influencing their growth and yield.
- To discuss the prospects and challenges associated with the horticultural development of *Sonchus* species, including opportunities for their integration into sustainable agricultural systems and strategies to address potential limitations.
- To identify gaps in the current research and propose future directions, with the aim of advancing the understanding and utilization of *Sonchus* species in horticulture and beyond.

By addressing these objectives, this review seeks to provide a holistic perspective on the potential of *Sonchus* species as valuable resources for food, nutrition, and sustainable agriculture while also highlighting the need for further research to fully realize their benefits.

2. Materials and Methods

2.1. Research Design and Approach

To conduct a comprehensive review of the diversity, phytochemistry, historical context, and uses of *Sonchus* species, a systematic approach was employed to gather and analyze relevant data. We manually performed a systematic review complemented by bibliometric analysis. The methodology included the following steps:

Literature Search: A thorough search of scientific databases (e.g., PubMed, Scopus, Web of Science, and Google Scholar) was conducted using keywords such as "*Sonchus*", "sow thistle", "phytochemistry", "traditional uses", "ethnobotany", "horticulture", "nutritional value", and "bioactive compounds". The search was limited to peer-reviewed articles, books, and conference proceedings published in English, Spanish, French, Italian, and other languages, covering the period from 1980 to 2024.

A bibliometric analysis was performed by means of a search in Scopus [27] using "*Sonchus*" as a search term in the titles, and the 440 records were exported in a CSV file, which was processed using the tools of Bibliometrix 4.1 [28,29] and VOSviewer 1.6.20 [30]. VOSviewer is a software tool for creating maps based on network data and visualizing and exploring these maps [31,32].

The bibliometric analysis identified the most taxonomically relevant species and primary research domains, facilitating the selection of appropriate keywords for the systematic literature search. The comprehensive search encompassed all *Sonchus* taxa examined in this review, including recognized synonyms.

Figures were elaborated using different methods. In the case of Figure 1, Figure 4, Figure 7, and Figure 8, the images were obtained from nature using conventional digital photo cameras. Figure 2 was elaborated using the tools of VOSviewer for the construction and visualization of a co-occurrence network of terms extracted from the titles and abstracts of publications [30–32]. Figure 3 is elaborated using the Bibliometrix 4.1 R package [28,29] with Keywords Plus as the analytical parameter and employing six chronological demarcations (1992, 2009, 2013, 2018, 2020, 2022, 2025) to establish discrete temporal intervals [29]. In Figure 5, a heat map was created using Python 3.11.13 with the following libraries: Pandas 2.3.1 (used to structure the dataset into a DataFrame for easy handling before plotting), Matplotlib 3.10.3 (matplotlib.pyplot) (used for the overall plotting framework), Seaborn 0.13.2 (used for generating the heat map via seaborn.heatmap) and Color Map of Matplotlib 3.10.3. Figure 6 was manually elaborated using Excel 365.

Inclusion and Exclusion Criteria: Studies were included if they provided detailed information on the taxonomy, distribution, phytochemical composition, traditional uses, history, or pharmacological properties of *Sonchus* species present in the Mediterranean. Articles lacking proper identification of the material studied or referring to "Sonchus viruses" were excluded.

Data Extraction and Synthesis: Data from selected studies were systematically extracted, including species names, geographical distribution, phytochemical profiles, traditional uses, and biological activities. The information was organized into thematic categories (e.g., diversity, phytochemistry, traditional uses, and modern applications) to facilitate analysis.

2.2. Data Quality and Analysis

Quality Assessment: The methodological quality of included studies was evaluated using standardized tools, adapting the PRISMA guidelines for systematic reviews to ensure reliability and validity [33] to the peculiarities of the available literature. However, given the heterogeneity of fields and styles of publications, it was impossible to obtain a tool that was operative for the different subjects covered. We developed a comprehensive scoring rubric to systematically evaluate references in our *Sonchus* phytochemical literature review. Each reference was meticulously assessed using a standardized scoring system ranging from 0 to 5. The evaluation criteria were strategically designed to assess two primary dimensions of scholarly literature: botanical integrity and either ethnobotanical or chemical merit, depending on the references' specific focus. Detailed scoring criteria are elaborated in Supplementary Table S1, ensuring a rigorous and objective approach to literature evaluation. Given the heterogeneity in the analyzed fields, we have not systematically developed specific quality criteria for all fields. However, we have paid particular attention to the reliability of botanical identification, the clear definition of properties and uses, and the geographical area.

Data Analysis: Descriptive statistics and qualitative synthesis were used to summarize findings. Trends and gaps in the literature were identified, and the potential for future research was discussed.

Verification and Validation: To ensure accuracy, data were cross-referenced with authoritative botanical databases (e.g., Plants of the World Online) [4] and validated by consulting experts in ethnobotany and phytochemistry.

3. Sonchus Diversity and Research Fields

3.1. Sonchus Diversity

The genus *Sonchus* exhibits significant taxonomic diversity, encompassing ninety-eight species distributed across temperate and subtropical biomes. The distribution patterns reveal a pronounced Mediterranean–Irano–Turanian center of diversity, with several taxa demonstrating remarkable colonization capacity, as evidenced by *S. oleraceus* and *S. asper* (Table 1) [4–10]. Life-form diversity ranges from annual to perennial habits, including specialized adaptations such as tuberous and rhizomatous geophytes. *S. tenerrimus* presents notable infraspecific diversification in the western Mediterranean region, particularly along the Spanish Mediterranean coast and other Mediterranean regions (Table 1) [4–10]. The biogeographical pattern suggests an evolutionary radiation from ancestral Mediterranean elements, with subsequent adaptation to various ecological niches, reflected in the current distribution of endemic taxa such as *S. crassifolius* in central and eastern Spain, *S. erzincanicus* in eastern Turkey, *S. briquetianus, S. fragilis, S. maculigerus, S. masguindalii* in northern Morocco, *S. suberosus* in Israel and Jordan, and *S. macrocarpus* in Egypt.

Table 1. Mediterranean *Sonchus* taxa, distribution range, types, and biomes [1].

Species and Subspecies	Distribution Range	Types	Biomes
Sonchus arvensis L. [Sp. Pl.: 793 (1753)]	Temperate Eurasia, introduced in N. America. Naturalized in other regions [34]	Perennial	Temperate
Sonchus arvensis subsp. *uliginosus* (M.Bieb.) Nyman [Consp. Fl. Eur.: 433 (1879)]	Temperate Eurasia, introduced in N. America	Perennial	Temperate
Sonchus asper (L.) Hill [Herb. Brit. 1: 47 (1769)] (=*Sonchus oleraceus* var. *asper* L. [Sp. Pl.: 794 (1753)])	Temperate Eurasia, N. Africa, Sahel, Somalia. Naturalized in other regions [34]	Annual	Temperate
Sonchus asper subsp. *glaucescens* (Jord.) Ball [J. Linn. Soc., Bot. 16: 548 (1878)]	Europe to Medit. and Himalaya, Sri Lanka, New Guinea	Biennial	Temperate and Subtropical
Sonchus briquetianus Gand. [Bull. Soc. Bot. France 55: 657 (1909)]	Morocco	Perennial	Subtropical
Sonchus bulbosus (L.) N.Kilian & Greuter [Willdenowia 33: 237 (2003)] (=*Aetheorrhiza bulbosa* (L.) Cass. [G.-F. Cuvier, Dict. Sci. Nat., ed. 2. 48: 426 (1827)])	Mediterranean, Azores	Tuberous geophyte	Temperate

Table 1. *Cont.*

Species and Subspecies	Distribution Range	Types	Biomes
Sonchus bulbosus subsp. *microcephalus* (Rech.f.) N.Kilian & Greuter [Willdenowia 33: 237 (2003)]	E. Mediterranean	Tuberous geophyte	Temperate
Sonchus bulbosus subsp. *willkomii* (Burnat & Barbey) N.Kilian & Greuter [Willdenowia 33: 237 (2003)]	Baleares (Spain)	Tuberous geophyte	Temperate
Sonchus crassifolius Pourr. ex Willd. [Sp. Pl., ed. 4. 3: 1509 (1803)]	Central and E. Spain	Perennial	Temperate
Sonchus erzincanicus V.A.Matthews [Notes Roy. Bot. Gard. Edinburgh 33: 258 (1974)]	E. Turkey	ND	Temperate
Sonchus fragilis Ball [J. Bot. 11: 372 (1873)]	Morocco	Perennial	Subtropical
Sonchus macrocarpus Boulos & C.Jeffrey [Taxon 18: 349 (1969)]	Egypt	Perennial or rhizomatous geophyte	Subtropical
Sonchus maculigerus H.Lindb. [Acta Soc. Sci. Fenn., Ser. B, Opera Biol. 1(2): 169 (1932)]	Morocco	ND	Temperate
Sonchus maritimus L. [Syst. Nat., ed. 10. 2: 1192 (1759)]	Mediterranean to Central Asia, Pakistan, Chad. Naturalized in other regions [34]	Perennial or rhizomatous geophyte	Temperate
Sonchus maritimus subsp. *aquatilis* (Pourr.) Nyman [Consp. Fl. Eur.: 434 (1879)]	W. Mediterranean	Perennial or rhizomatous geophyte	Temperate and subtropical
Sonchus masguindalii Pau & Font Quer [Exsicc. (Iter Marocc.) 1927: nº 732 (1928)]	Morocco		
Sonchus mauritanicus Boiss. & Reut. [Pugill. Pl. Afr. Bor. Hispan.: 70 (1852)]	Morocco, Algeria, Tunisia	Perennial	Temperate and subtropical
Sonchus microcephalus Mejías [Lagascalia 16: 169 (1990)]	E. Mediterranean, Rift Valley, introduced in Spain	ND	Subtropical
Sonchus oleraceus L. [Sp. Pl.: 794 (1753)] (=*Sonchus oleraceus* var. *laevis* L. [Sp. Pl.: 794 (1753)])	Native in Europe, N. Africa Near East and introduced worldwide [8]	Annual or biennial	Temperate and subtropical
Sonchus pustulatus Willk. [M.Willkomm & J.M.C.Lange, Prodr. Fl. Hispan. 2: 242 (1865)]	SE. Spain, NW. Africa	Perennial	Subtropical
Sonchus suberosus Zohary & P.H.Davis [Kew Bull. 2: 87 (1947)]	Israel to Jordan	Perennial	Subtropical
Sonchus tenerrimus L. [Sp. Pl.: 794 (1753)] (=*Sonchus pectinatus* DC.)	Macaronesia, Mauritania, Medit. to Pakistan, Arabian Peninsula, NE. Tropical Africa. Naturalized in other regions [34]	Annual, biennial or perennial	Subtropical
Sonchus tenerrimus subsp. *amicus* (Faure, Maire & Wilczek) Véla [Islands and Pl.: 281 (2013)]	Algeria	Perennial	Subtropical

Table 1. *Cont.*

Species and Subspecies	Distribution Range	Types	Biomes
Sonchus tenerrimus subsp. *dianae* (Lacaita ex Willk.) Ballester, Figuerola, Peris & Stübing [Estud. Multidiscipl. Parque Nat. Montgo: 206 (1991)]	E. Spain	Perennial	Subtropical
Sonchus tenerrimus subsp. *halodianae* Mateo, P.P.Ferrer & R.Roselló [Fl. Montiber. 75: 26 (2019)]	E. Spain	Perennial	Subtropical
Sonchus tenerrimus subsp. *polypodioides* Mateo, P.P.Ferrer & R.Roselló [Fl. Montiber. 75: 26 (2019)]	E. Spain	Perennial	Subtropical

[1] Data according to POWO and Boulos [4–10].

The morphological analysis of Mediterranean *Sonchus* taxa reveals several diagnostic patterns. The genus *Sonchus* exhibits remarkable leaf morphological diversity across its constituent species and subspecies, demonstrating significant variation in shape, texture, margin characteristics, and anatomical features that reflect evolutionary adaptations to diverse ecological niches (Figure 1).

Sonchus species display a range of primary leaf shapes, with lanceolate representing the most prevalent form, occurring in approximately 70% of examined taxa. Oblong configurations are frequent in several species (*S. arvensis*, *S. asper*, *S. crassifolius*, *S. macrocarpus*, *S. maritimus*), while ellipsoid shapes characterize *S. arvensis* and *S. erzincanicus*. Obovate or obovoid forms occur in specialized taxa (*S. oleraceus*, *S. bulbosus*, *S. masguindalii*), representing adaptations to specific ecological niches.

The genus demonstrates a sophisticated gradient of leaf division complexity. Entire margins represent the simplest condition, observed in *S. bulbosus* and certain populations of *S. crassifolius* and *S. maritimus*. Pinnatifid architecture predominates across the genus, with variations including lyrate-pinnatifid (*S. asper*, *S. oleraceus*, *S. masguindalii*) and runcinate-pinnatilobed (*S. suberosus*) patterns.

Advanced division reaches pinnatisect levels in multiple lineages (*S. arvensis* subsp. *uliginosus*, *S. asper*, *S. erzincanicus*, *S. masguindalii*, *S. mauritanicus*, *S. microcephalus*, *S. tenerrimus*), with *S. tenerrimus* achieving the most complex bipinnate architecture, representing the pinnacle of leaf dissection within the genus.

Lobe characteristics exhibit remarkable diversity: linear lobes characterize highly dissected species (*S. briquetianus*, *S. microcephalus*, *S. tenerrimus*), while oblong lobes occur in *S. erzincanicus*. Ovate lobes distinguish *S. fragilis*, and rounded lobes are diagnostic for *S. masguindalii*. Lanceolate lobes appear in several taxa (*S. briquetianus*, *S. mauritanicus*, *S. tenerrimus*), demonstrating convergent morphological solutions.

Spiny margins constitute a major taxonomic character, occurring in the majority of species and representing a presumed ancestral condition. Notable spiny taxa include *S. arvensis*, *S. asper*, *S. crassifolius*, *S. erzincanicus*, *S. macrocarpus*, *S. maculigerus*, *S. maritimus*, and *S. mauritanicus*.

Non-spiny margins represent a derived condition in *S. oleraceus* and the *S. tenerrimus* complex, while reduced spinosity occurs in *S. asper* subsp. *glaucescens* and *S. maritimus* subsp. *aquatilis*. Slightly spiny conditions characterize *S. microcephalus*, suggesting intermediate evolutionary states.

Succulent or fleshy leaf texture represents a significant adaptive syndrome within *Sonchus*, occurring in multiple independent lineages: *S. briquetianus*, *S. crassifolius*, *S. erzincanicus*, *S. masguindalii*, *S. maritimus*, *S. pustulatus*, and *S. tenerrimus* subsp. *halodianae*. This convergent evolution toward succulence reflects adaptation to xeromorphic or halophytic conditions (Figure 1).

Figure 1. *Sonchus* leaf morphology. (**A**) Deeply pinnatisect, *S. microcephalus*; (**B**) entire, *S. maritimus* subsp. *aquatilis*, Arroyo Blanco, Murcia (Spain); (**C**) pinnatisect, spiny, *S. crassifolius*, El Romeral, Toledo (Spain); (**D**) pinnatisect, spiny, *S. crassifolius*, grown at Torretes, Alicante (Spain); (**E**) pinnatifid, *S. pustulatus*, San Telmo, Almería (Spain); (**F**) lyrate pinnatifid, spiny, *S. asper* Columbares, Murcia (Spain); (**G**) somewhat fleshy, adapted to saline environments, *S. tenerrimus* subsp. *halodianae,* San Antonio, Alicante (Spain); (**H**) glaucous, less spiny than *S. asper, S. asper* subsp. *glaucescens,* Santo Angel, Murcia (Spain); (**I**) lanceolate to obovoid, entire, *S. bulbosus*, El Saler, Valencia (Spain). Images: (**A**) Jose Luis Cánovas, with permission; (**B**,**F**,**H**) Antonio Robledo, with permission; (**C**,**D**) Segundo Ríos; (**E**) Estefania Mico, with permission; (**G**) Francisco Alcaraz; (**I**) Emilio Laguna, with permission.

Fragile texture characterizes *S. fragilis*, representing a unique mechanical property within the genus. Thick leaves occur in drought-adapted species (*S. crassifolius*, *S. erzincanicus*), while thin leaves distinguish the aquatic adaptation in *S. maritimus* subsp. *aquatilis*.

Glaucous coloration represents a widespread adaptive trait, occurring in approximately 45% of examined taxa (*S. asper* subsp. *glaucescens*, *S. briquetianus*, *S. erzincanicus*, *S. fragilis*, *S. macrocarpus*, *S. maritimus*, *S. masguindalii*, *S. mauritanicus*, *S. microcephalus*, *S. pustulatus*, *S. tenerrimus*). This blue-green pigmentation likely provides photoprotection and reduces water loss.

Green coloration characterizes several species (*S. arvensis*, *S. asper*, *S. crassifolius*, *S. maritimus* subsp. *aquatilis*, *S. oleraceus*, *S. suberosus*), while glossy green surfaces distinguish *S. asper*.

Auriculate leaf bases represent a distinctive character in three major species (*S. arvensis*, *S. asper*, *S. oleraceus*), suggesting possible systematic significance. Pustulate (tuberculate) surface ornamentation uniquely characterizes *S. pustulatus*, representing the most specialized textural modification within the genus.

Size variation ranges from small leaves (*S. briquetianus*, *S. bulbosus*, *S. fragilis*, *S. microcephalus*) to large configurations (*S. macrocarpus*), reflecting diverse resource allocation strategies.

Subspecific taxa demonstrate consistent differentiation through specific morphological parameters: degree of lobation (*S. arvensis* subsp. *uliginosus*, *S. tenerrimus* subsp. *dianae*), lobe width (*S. bulbosus* subsp. *willkomii*, *S. tenerrimus* subsp. *amicus*), division intensity (*S. tenerrimus* subsp. *polypodioides*), spinosity reduction (*S. asper* subsp. *glaucescens*, *S. maritimus* subsp. *aquatilis*), and ecological specialization (*S. tenerrimus* subsp. *halodianae*).

The remarkable morphological diversity in *Sonchus* leaf architecture reflects adaptive radiation responding to varied environmental pressures, including water availability, salinity stress, herbivory pressure, and light conditions. The prevalence of pinnatifid to pinnatisect forms suggests this architecture provides optimal photosynthetic efficiency while maintaining structural integrity across diverse habitats.

The convergent evolution of succulence, glaucescence, and spinosity reduction in multiple lineages indicates strong selective pressures shaping leaf morphology within the genus. The presence of highly specialized forms, such as the bipinnate architecture of *S. tenerrimus* and the pustulate surfaces of *S. pustulatus,* demonstrates the evolutionary potential for morphological innovation within *Sonchus*.

The achene, or cypsela, morphology presents two primary shapes: ellipsoid, predominant across the genus, and claviform, characteristic of *S. asper* and *S. oleraceus*. Achene dimensions exhibit limited variation, typically ranging from 2.5–4 mm, with *S. macrocarpus* displaying the largest fruits (4.5–5 mm) (Table 2). Leaf morphology demonstrates greater plasticity, ranging from soft, non-spiny margins in *S. oleraceus* and *S. tenerrimus* to distinctly spinose margins in *S. asper*. The pappus structure maintains relative uniformity across taxa (5–8 mm), with the presence or absence of an apical collar serving as a taxonomically significant character. Achene indument patterns show limited variation, with most taxa being glabrous or sparsely hairy, except for the distinctive retrorse spinulose hairs in *S. asper* and its subspecies.

Table 2. Mediterranean *Sonchus* leaf and cypsela (achene) characteristics [1].

Species and Subspecies	Leaves	Cypselae Shape	Superficial Processes	Apex Collar and Pappus Length
Sonchus arvensis L.	Lanceolate to oblong or ellipsoid, pinnatifid, green, spiny margins. Sheathing leaf base auriculate	Ellipsoid, 2.5–3.5 × 1–1.5 mm, brown, ribs 4–5(+) on each face	Faces transversely rugulose to tuberculate across and between ribs, glabrous or sparsely hairy	With a short collar. Pappus 8–12(14) mm
Sonchus arvensis subsp. *uliginosus* (M.Bieb.) Nyman	Similar to *S. arvensis* but often more deeply lobed to pinnatisect	Ellipsoid, 2.5–3.5 × 1–1.5 mm, brown, ribbed	Glabrous or sparsely hairy	With a short collar. Pappus 7–10 mm
Sonchus asper (L.) Hill	Oblong to lanceolate, lyrate pinnatifid to pinnatisect, spiny margins, glossy green. Sheathing leaf base auriculate	Claviform to ellipsoid, strongly compressed, 2.5–3 × 1–1.2 mm, whitish brown, each face 3-ribbed	Hairy at ribs and wings only, smooth among them. With minute retrorse spinulose hairs	Without a collar. Pappus (5)7–9 mm

Table 2. *Cont.*

Species and Subspecies	Leaves	Cypselae Shape	Superficial Processes	Apex Collar and Pappus Length
Sonchus asper subsp. *glaucescens* (Jord.) Ball	Glaucous, less spiny than *S. asper*	Claviform, 2.5–3 mm, whitish brown, hairy at ribs and wings	With retrorse spinulose hairs	Without a collar. Pappus 5–7 mm
Sonchus briquetianus Gand.	Leaves lanceolate, pinnatifid, small, with narrow lobes, lanceolate to linear, slightly fleshy, glaucous	Ellipsoid, 3–4 × 1 mm, brown-reddish, smooth	Glabrous	With a short collar. Pappus 6 mm
Sonchus bulbosus (L.) N.Kilian & Greuter	Relatively small leaves, lanceolate to obovoid, entire to slightly lobed	Ellipsoid, 3–4 mm, brown, smooth	Glabrous	With a short collar. Pappus 6–8 mm
Sonchus bulbosus subsp. *microcephalus* (Rech.f.) N.Kilian & Greuter	Similar to subsp. bulbosus but smaller leaves, lobed	Ellipsoid, 3–4 mm, brown, smooth	Glabrous	With a short collar. Pappus 6–8 mm
Sonchus bulbosus subsp. *willkomii* (Burnat & Barbey) N.Kilian & Greuter	Similar to *S. bulbosus* but with narrower lobes	Ellipsoid, 3–4 mm, brown, smooth	Glabrous	With a short collar. Pappus 6–8 mm
Sonchus crassifolius Pourr. ex Willd.	Oblong to lanceolate, entire to lobed or pinnatifid. Green. Thick, fleshy, spiny	Ellipsoid, 2–3.5 × 1–1.4 mm, brown, smooth	Glabrous	With a short collar. Pappus 7–10 mm
Sonchus erzincanicus V.A.Matthews	Widely lanceolate to the elliptic, pinnatisect, lobes oblong, glaucous, margin of leaf serrated, spiny, fleshy and thick	Ellipsoid, 3–4 mm, brown, ribbed	Glabrous or sparsely hairy	With a short collar. Pappus 6–8 mm
Sonchus fragilis Ball	Leaves small, lanceolate, deeply lobed, lobes ovate, fragile, glaucous	Ellipsoid, 3.5–4.25 × 1 mm, brown, smooth	Glabrous	With a short collar. Pappus 6 mm
Sonchus macrocarpus Boulos & C.Jeffrey	Large, oblong to lanceolate, lobate to lyrate pinnatifid, spiny margins, glaucous	Ellipsoid, 4–5.5 × 1.5–1.75 mm, brown to dark brown, smooth	Glabrous	Without a collar, or it is very short. Pappus 7– 8 mm
Sonchus maculigerus H.Lindb.	Lanceolate, pinnatifid, spiny margins	Ellipsoid, 3–4 mm, brown, ribbed	Glabrous or sparsely hairy	With a short collar. Pappus 6–8 mm
Sonchus maritimus L.	Oblong to lanceolate, entire to dentate, somewhat fleshy, spiny margins, glaucous	Ellipsoid, 2.25–3.5 × 1–1.6 mm, brown, smooth	Glabrous	With a short collar. Pappus 6–9 mm
Sonchus maritimus subsp. *aquatilis* (Pourr.) Nyman	Oblong to lanceolate, entire to dentate, rarely spiny, thin, green	Ellipsoid, 3–4 mm, brown, smooth	Glabrous	With a short collar. Pappus 6–8 mm
Sonchus masguindalii Pau & Font Quer	Leaves obovoid in outline, lyrate pinnatisect, with rounded lobes, slightly fleshy, glaucous	Ellipsoid, 2.25–3.25 × 0.6–0.8 mm, brown, smooth	Glabrous	With a short collar. Pappus 6–8 mm, white, bristly
Sonchus mauritanicus Boiss. & Reut.	Lanceolate in outline, pinnatifid to pinnatisect, lobes lanceolate with spiny margins, glaucous	Ellipsoid, 2.5–3 × 0.6–0.8 mm, brown, ribbed	Glabrous or sparsely hairy	With a short collar. Pappus 6–9 mm

Table 2. *Cont.*

Sonchus microcephalus Mejías	Widely lanceolate, small, deeply pinnatisect, lobes almost linear with slightly spiny margins. Somewhat glaucous	Ellipsoid, 2.5–3.5 mm, brown, ribbed	Glabrous or sparsely hairy	With a short collar. Pappus 6–8 mm
Sonchus oleraceus L.	Obovate, deeply lyrate pinnatifid, soft, and non-spiny. Green. Sheathing leaf base auriculate	Claviform, slightly compressed, (2)2.5–3(3.8) × 0.8–1 mm, bright brown, rugose especially at the ribs	Glabrous to minutely tuberculate between ribs	With a short collar. Pappus (5)6–7.5(10) mm
Sonchus pustulatus Willk.	Leaves lanceolate, pinnatifid, lobes fleshy, glaucous, with pustules (small bumps) on the surface	Cylindrical, 3.5–5 × 1.5 mm, brown, ribbed	Glabrous	With a short collar. Pappus 8 mm
Sonchus suberosus Zohary & P.H.Davis	Lanceolate in outline, runcinate-pinnatilobed to pinnatifid; green, lateral lobes irregularly dentate, rarely entire	Oblong, 3.5–4 × 0.8–1 mm, brown, tawny, nearly prismatic, 3–4-ribbed	Glabrous or sparsely hairy, striate between ribs	With a short collar. Pappus 4–5 mm
Sonchus tenerrimus L.	Widely lanceolate. Deeply divided, bipinnate. Lobes linear to lanceolate, glaucous, entire, pinnatifid to pinnatisect, soft and non-spiny	Ellipsoid, 2.5–3.5 × 1.2 mm, brown, ribbed	Glabrous or sparsely hairy	With a short collar. Pappus 6–8 mm
Sonchus tenerrimus subsp. *amicus* (Faure, Maire & Wilczek) Véla	Similar to *S. tenerrimus* but with narrower lobes	Ellipsoid, 2.5–3.5 mm, brown, ribbed	Glabrous or sparsely hairy	With a short collar. Pappus 6–8 mm
Sonchus tenerrimus subsp. *dianae* (Lacaita ex Willk.) Ballester, Figuerola, Peris & Stübing	Similar to *S. tenerrimus* but with more deeply lobed leaves	Ellipsoid, 2.5–3.5 mm, brown, ribbed	Glabrous or sparsely hairy	With a short collar. Pappus 6–8 mm
Sonchus tenerrimus subsp. *halodianae* Mateo, P.P.Ferrer & R.Roselló	Similar to *S. tenerrimus* but somewhat fleshy, adapted to saline environments	Ellipsoid, 2.5–3.5 mm, brown, ribbed	Glabrous or sparsely hairy	With a short collar. Pappus 6–8 mm
Sonchus tenerrimus subsp. *polypodioides* Mateo, P.P.Ferrer & R.Roselló	Similar to *S. tenerrimus* but with more finely divided leaves	Ellipsoid, 2.5–3.5 mm, brown, ribbed	Glabrous or sparsely hairy	With a short collar. Pappus 6–8 mm

[1] Data from [4–10,35–37].

3.2. Bibliometric Analysis of Sonchus Research Fields

The bibliometric network visualization map (Figure 2) presents a comprehensive overview of research centered on *Sonchus* species, particularly *Sonchus oleraceus* and *Sonchus asper*, revealing distinct but interconnected research domains. The network structure demonstrates several well-defined thematic clusters, each representing different research orientations and methodological approaches.

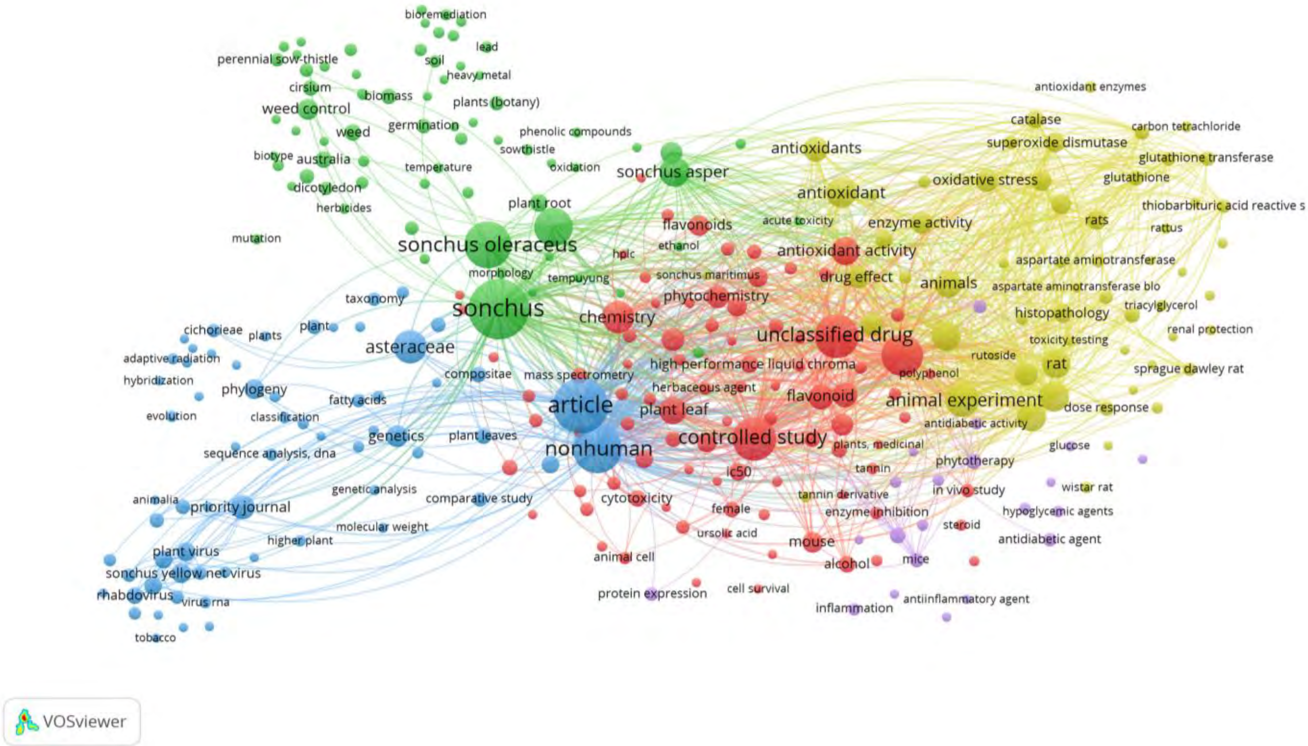

Figure 2. *Sonchus* research, bibliometric network (co-occurrence network of terms extracted from the titles and abstracts of publications) visualization map. Image elaborated by Diego Rivera with data from Scopus [27] processed using VOSviewer [30–32]. In the visualization presented, each circle represents a term. The size of a circle indicates the number of publications that have the corresponding term in their title or abstract. Terms that frequently co-occur tend to be located close to each other in the visualization. VOSviewer has grouped the terms into five clusters, of which four are of significant size. The red cluster, located in the lower central area in the visualization, consists of pharmacology terms. The green cluster, located in the upper left area, covers terms related to taxonomy, plant biology, and environmental factors. The blue cluster, located in the lower left area, consists of terms related to genetics but also to information science and information retrieval. In the right area in the visualization, the yellow cluster covers in vivo experiences in animal models and studies of activities. The small violet cluster, located in the lower central area, covers medicinal properties in terms of pharmacological activities and phytotherapy.

The agricultural and ecological research domain, displayed in green, emphasizes aspects such as weed control, bioremediation, and germination studies, reflecting the significance of these species in agricultural management and environmental applications. This connects naturally to the taxonomic and evolutionary studies shown in the blue cluster, which encompasses phylogenetic research, genetic studies, and viral interactions, providing fundamental understanding of these species within the Asteraceae family.

At the map's center, a prominent red cluster represents phytochemical and analytical research, featuring techniques such as mass spectrometry and HPLC, alongside studies of flavonoids and other chemical constituents. This central position suggests its role as a bridge between basic botanical research and applied studies.

The yellow/olive cluster reveals the significant attention paid to pharmacological and biochemical investigations, particularly focusing on antioxidant properties and oxidative stress studies. This research area demonstrates a substantial connection to experimental work involving animal models, suggesting active investigation of therapeutic potential.

The purple cluster, oriented toward medical applications, shows the translation of basic research into potential therapeutic uses, particularly in areas such as inflammation and diabetes management. This reflects the growing interest in developing plant-based therapeutic agents.

The visualization's structure, with its interconnected nodes of varying sizes, reveals both the breadth of *Sonchus* research and the complex relationships between different research approaches. The larger nodes, representing more frequently occurring terms, highlight the primary research foci, while the connecting lines demonstrate how these various research streams inform and influence each other, creating a rich tapestry of scientific investigation spanning basic science to applied research and potential therapeutic applications.

It can be deduced that the future cultivation and horticultural use of *Sonchus* should not forget its medicinal potential, which makes it a promising nutraceutical.

However, the bibliometric analysis yields ambiguous results in several aspects, which led us to conduct a manual review of the 440 publications selected by Scopus (Table 3). Following the application of exclusion criteria, 36 publications were discarded for referring to species missing in the Mediterranean region (species outside the geographical scope of the study), and 28 publications were excluded due to errors in species identification or, i.e., attribution of data to *Sonchus eruca*, an unknown taxon, or studies focusing specifically on "Sonchus viruses" not *Sonchus* species.

Table 3. Distribution of publications by subject area based on the results of the manual analysis of the *Sonchus* publications recovered by Scopus.

Subject Area	No. of Publications	Comments
Pharmacology	102	Multiple activity models
Phytochemistry	61	Flavonoids, sesquiterpene lactones
Weed Science	58	Weed control
Phytopathology	30	Fungal, viral, and insect-related studies
Ecology	23	Bioremediation
Horticulture	22	Optimal growing conditions
Microbiology	20	Bacteria and viruses
Genetics	17	Phylogenetic studies
Taxonomy	10	Nomenclatural, systematics, and morphological analyses
Nutrition	10	Nutritive properties of *Sonchus* and food processing
Plant Physiology	9	Responses to abiotic and biotic stress
Technology	8	Applications in biotechnology
Toxicology	4	Toxic and nocive substances
Ethnopharmacology	1	Traditional uses
Veterinary Medicine	1	Veterinary applications
Total	376	

Pharmacology, Phytochemistry, and Weed Science are the main research areas (Table 3). Additionally, it should be noted that a substantial portion of the 30 phytopathological studies focused on the development of biological control methods for *Sonchus* species as weeds.

Conversely, the numerous ethnobotanical and ethnopharmacological data documenting traditional uses of *Sonchus* species were excluded from the search results due to the search criteria based on "titles", "keywords", and "abstracts". These data typically appear in comprehensive studies of localities and regions that include dozens or hundreds of species, which authors cannot reflect in their abstracts. This limitation led us to develop specific targeted searches.

Figure 3 depicts a flow diagram representing the thematic evolution of *Sonchus* research from 1856 to 2025, based on 440 studies recorded in Scopus [27], with "*Sonchus*" in their titles and analyzed using Bibliometrix [28,29]. This temporal analysis reveals how research topics have evolved across different periods.

During the initial phase (1856–1992), research concentrated on fundamental aspects such as basic taxonomic studies of the *Sonchus* genus, electron microscopy, *Sonchus* yellow net virus, drug isolation from the Asteraceae family, and early extraction and purification studies.

The period from 1993 to 2009 witnessed an evolution toward specific studies in Cichorieae, research in Australasia, publications in priority journals, and initial work with *Sonchus oleraceus* extracts.

From 2010–2013, research became more specific, focusing on *Sonchus arvensis* (sow thistle), weed control reflecting its consideration as an invasive species, and the first systematic studies in China.

The 2014–2018 timeframe saw an expansion in research areas, including *Sonchus arvensis* extracts, medicinal herb properties, antioxidant studies, ethanol use for extraction, and a greater focus on plant extracts generally.

Between 2019 and 2020, there was notable diversification with studies on herbicides for agricultural control, genetic markers, glyphosate research, pharmacological investigations using rats, analyses of *Sonchus oleraceus* and *Sonchus asper*, and acute toxicity studies.

The 2021–2022 period focused on Asteraceae *Sonchus* taxonomic classification, ascorbic acid, mutation, *S. oleraceus* and *S. arvensis*, and biomass potential as a crop.

Most recent trends (2023–2025) include renewed general *Sonchus* studies, research in China, soil genetics, and pollution, as well as drought, biomass, and oxidative stress studies.

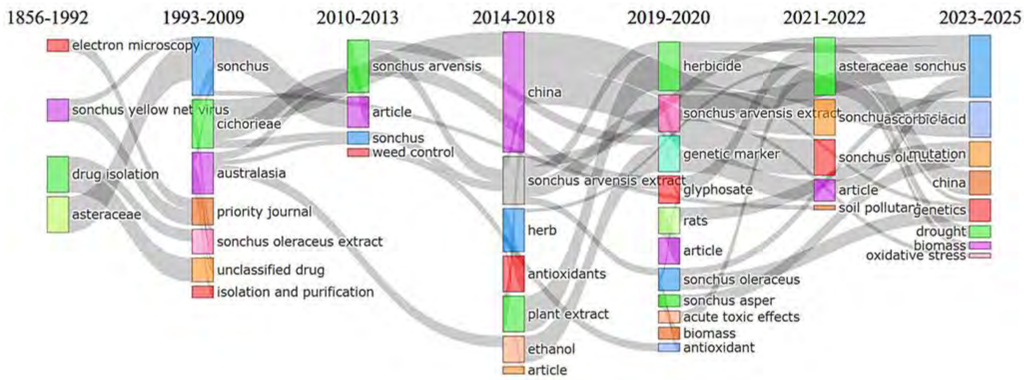

Figure 3. Comprehensive bibliometric analysis of 440 Scopus-indexed publications spanning 1856–2025 reveals the temporal evolution of research themes related to *Sonchus* species [27]. This longitudinal examination, visualized through alluvial flow mapping, demonstrates the shifting focus and emerging trends in *Sonchus* research over nearly two centuries of scientific investigation. The visualization was generated using the Bibliometrix R package [28,29] with Keywords Plus as the analytical parameter and employing six chronological demarcations (1992, 2009, 2013, 2018, 2020, 2022, 2025) to establish discrete temporal intervals [29]. The diagram illustrates significant thematic transitions across seven research periods, revealing the conceptual evolution from fundamental botanical characterization to applied horticultural and pharmacological investigations. Node size corresponds to keyword frequency, while flow width represents the strength of thematic connections between consecutive time periods. This visualization demonstrates the progressive diversification of *Sonchus* research, particularly the transition from taxonomic and ecological perspectives toward phytochemical, stress-response, and cultivation-oriented paradigms in recent years.

In the context of horticultural development, the data shows a clear evolution from purely botanical and taxonomic studies toward practical applications. There has been a gradual shift from considering *Sonchus* as a weed to valuing it as a potential crop, as evidenced by biomass studies in recent years. Relevant phytochemical advances, including the identification of specific compounds, like ascorbic acid, and antioxidant properties, suggest nutraceutical value.

Recent studies on environmental stresses, such as drought and oxidative stress, are particularly valuable for horticultural development under adverse conditions. The emergence of genetic marker research provides tools for improvement, while growing interest in China suggests an emerging potential market.

This thematic evolution supports the horticultural development of *Sonchus*, demonstrating a transition from basic research to more practical applications, with recent emphasis on characteristics relevant to sustainable cultivation and commercial uses.

4. Historical Context

4.1. Earliest Written Records and References to Sonchus Species in Historical Texts from Ancient Greece to Medieval Sources

The archaeological data includes the identification of cypselae from *Sonchus arvensis* L. in *Urartian* sites of the Caucasus, 1st mill BC. This is an example of the occasional presence of *Sonchus* remains in archaeological contexts of Europe, North Africa, and West Asia from Bronze Age levels of Baltic sites of Lithuania to Punic and Byzantine Carthage [38,39].

Campbell-Thompson's (posthumous edition in 1949) [40] interpretation of the Assyrian term $^{\text{šam}}$HA-HI-IN—rendered as $^{\text{(šam)(is)}}$GIR-HA-AH in logographic form and *puquttu* in syllabic Assyrian—remains contentious within scholarly discourse. This botanical term, referring to a thistle employed medicinally as both a diuretic and lithontriptic agent, was identified by Campbell-Thompson as potentially representing several taxa: *Carduus* sp., *Scolymus* sp., *Sonchus oleraceus* L., or *Silybum marianum* L. While this taxonomic attribution has generated considerable debate, the identification merits serious consideration, as it may constitute the earliest documented reference to a *Sonchus* species in the ancient Near Eastern pharmacological literature [41].

The earliest reliable references to *Sonchus* species can be traced back to ancient Greek and Roman texts. For instance, Dioscorides, in his seminal work De Materia Medica, documented the medicinal properties of *Sonchus*, emphasizing its use for digestive and liver ailments [13]. *Sonchus* species have been traditionally consumed as food and used medicinally across the Mediterranean. Historical accounts describe their incorporation into daily diets and healing practices, often linked to their perceived detoxifying and anti-inflammatory properties [13]. The earliest codices of Dioscorides' work with information on *Sonchus* are the Codex Anicia Juliana of the Wien Library, the Codex Neapolitanus, and the manuscript of the Pierpont Morgan Library.

The preservation of ancient botanical knowledge owes much to the meticulous work of Byzantine scribes who maintained and illustrated crucial medical texts. The most significant repository of early *Sonchus* documentation exists within the manuscript tradition of Dioscorides' De Materia Medica. The Codex Vindobonensis Med. Gr. 1, created circa 512 CE for the imperial princess Anicia Juliana in Constantinople, stands as the oldest and most valuable illustrated herbal manuscript in existence, housed today at the Austrian National Library in Vienna. This illuminated codex contains detailed illustrations of medicinal plants, including *Sonchus* species, representing an invaluable bridge between ancient knowledge and medieval practice.

Contemporary with this work, the Codex Neapolitanus, dating to the late sixth or early seventh century and preserved at the National Library of Naples, provides another crucial early illustrated copy of Dioscorides' botanical descriptions. The manuscript tradition continued through the tenth century with Morgan 652, a Byzantine manuscript held at the Morgan Library & Museum in New York, which contains significant portions of Dioscorides' text with accompanying botanical illustrations.

Dioscorides' systematic approach to botanical documentation established the foundation for understanding *Sonchus* species in medical contexts [13,41]. His De Materia Medica distinguished between two primary types of "*Sonchos*": "*Sonchos trachos*" and "*Sonchos trypheros*". Modern botanical scholarship generally interprets "*Sonchos trachos*", meaning "rough sow thistle", as corresponding to *Sonchus asper*, characterized by its spiny leaves and coarse texture. Conversely, "*Sonchos trypheros*", the "tender sow thistle", is commonly associated with *Sonchus oleraceus*, distinguished by its smoother, more palatable foliage.

Dioscorides' descriptions emphasize both morphological and therapeutic characteristics, noting that both species possessed angular stalks with reddish interiors surrounded by irregularly disposed leaves. Medicinally, he characterized these plants as cooling and moderately astringent, making them suitable for treating gastric inflammation, stomach ailments, and even conditions associated with venomous stings [13,41]. The versatility of these plants extended to gynecological applications, with their juice being employed to alleviate stomach pains, promote lactation, and address inflammatory conditions of the reproductive system.

The textual tradition of Dioscorides reveals interesting variations in interpretation and presentation. While Osbaldeston's modern academic translation emphasizes clarity and systematic organization, Gunther's interpretation preserves the archaic linguistic conventions that reflect the historical context of the original Greek formulations. These variations demonstrate the evolution of scholarly interpretation while maintaining core botanical and therapeutic knowledge.

Pliny the Elder's Natural History provides a complementary perspective on *Sonchus* species that both reinforces and expands upon Dioscoridean knowledge [42]. Writing in Book XXII, Chapter 44, Pliny distinguished between species based on color rather than texture, referring to "white" and "black" kinds of *Sonchus*. This classificatory difference suggests either regional variations in the plants themselves or alternative observational approaches to botanical categorization.

Both classical authors agreed on fundamental morphological characteristics, including angular stems and the presence of milky latex when stems were broken, suggesting consistent identification of *Sonchus oleraceus* and related species across different geographical contexts. Their shared emphasis on the cooling and emollient properties of these plants, particularly for gynecological and gastrointestinal applications, demonstrates remarkable consistency in therapeutic understanding.

Pliny's account distinguished itself through more elaborate pharmacological detail, including specific dosage instructions and preparation methods. His recommendations for combining *Sonchus* with wine, oil, or broth, along with precise measurements, such as "*three cyathi*", reflect a more systematized approach to medicinal preparation. The Roman author's therapeutic applications extended beyond Dioscoridean usage to include respiratory difficulties, urinary calculi, halitosis, and various dermatological conditions, suggesting an expansion of medicinal knowledge through practical experience.

The transition from classical to medieval medicine witnessed the continued recognition of *Sonchus* species across various European medical traditions. The Salernitan school, representing one of the most influential medieval medical centers, incorporated *Sonchus* into its systematic approach to health maintenance. The *Regimen Sanitatis Salernitanum* described "*sonco*" as a bitter herb with blood-cleansing properties that could "purify the vision" while treating fevers through its cooling effects [43].

The *Antidotarium Nicolai*, an early twelfth-century medical text from the School of Salerno, provided comprehensive therapeutic applications for sow thistle, emphasizing its cooling and binding properties [44]. This medieval compilation extended traditional uses to include digestive aid, sleep promotion, and treatment of urinary stones, migraines, and convulsions. The text's systematic organization reflects the growing sophistication of medieval pharmaceutical knowledge while maintaining continuity with classical sources.

Hildegard von Bingen's twelfth-century *Physica* represents a distinct Germanic approach to therapeutics, identifying the plant under "*distel*", notably "*carduus tam lenis quam hirsutus*" [45].

4.2. Uses of Sonchus in Traditional Medicine, Rituals, and as Food from the Renaissance to the 19th Century

The Renaissance marked a pivotal transition in botanical scholarship, characterized by the systematic reinterpretation of classical herbal knowledge. Herbalists of the period not only preserved ancient texts but also integrated contemporary observations, regional knowledge, and empirical findings into their treatises. The documentation of *Sonchus* species exemplifies this evolution, illustrating how Renaissance botanists expanded upon classical foundations with original insights derived from direct observation and cultural synthesis.

Pietro Andrea Mattioli's 1544 commentary on Dioscorides was foundational to Renaissance herbal literature, setting new standards by integrating classical sources with contemporary medical understanding. His treatment of *Sonchus* emphasized its therapeutic applications within the humoral framework, attributing cooling and moistening properties effective for inflammation [46].

Mattioli focused on medicinal uses relevant to physicians and apothecaries, particularly in women's health and lactation support. This practical orientation reflected a broader Renaissance trend of aligning medical utility with classical theory. His systematic categorization of therapeutic effects represented a shift from the descriptive style of ancient authors toward a more accessible clinical framework.

Andrés Laguna's 1555 Spanish translation and commentary on Dioscorides expanded upon Mattioli's work while introducing original content grounded in empirical observation and cultural context [47]. His documentation of *Sonchus* demonstrated a sophisticated synthesis of classical and contemporary scholarship, addressing both theoretical and practical dimensions.

Laguna identified three distinct *Sonchus* species—the wild and spiny *Sonchus asperus*, the tender *Sonchus laevis*, and a tree-like variety with broad, divided leaves—demonstrating detailed observational classification. His descriptions, consistent with classical sources, included angular, reddish stems and dissected leaves, while reaffirming traditional uses such as cooling, moderate astringency, and treatments for gastrointestinal discomfort, inflammation, lactation, and venomous stings.

Laguna's major contribution lay in his extensive cultural and linguistic contextualization. By documenting regional names across Romance and Germanic languages—such as *Cicerbita*, *Latucella*, *Latteron*, and *Gensz Distel*—he emphasized the widespread recognition of these plants, advancing botanical knowledge across linguistic boundaries.

His empirical observations further distinguished his work. Notably, he recorded that all *Sonchus* species are spineless in early growth, acquiring spines upon maturity—a developmental insight absent in classical texts. This phenological detail exemplifies the Renaissance shift from static to dynamic botanical descriptions.

Laguna also incorporated folk knowledge, referencing Apuleius' term "*lactuca leporina*" (hare's lettuce), tied to the belief that hares used the plant for cooling. His etymological explanation of *Latucella*, linked to its milky latex and lettuce-like appearance, demonstrated interpretive depth and alignment with vernacular associations.

He further contributed practical applications, including preparation methods like applying it with wool ("*puesto con un poco de lana*"), remedies for scorpion bites, and treatments mixing roots with pear juice for wounds, offering concrete therapeutic protocols largely absent from earlier sources.

Leonhart Fuchs' herbal observations [48], translated into Spanish by Jaraba in 1557 [49], also enriched *Sonchus* documentation by combining classical descriptions with folk knowledge. Drawing on Pliny, Fuchs identified two primary types: one more pungent and rustic and another milder and edible. His focus on morphological and sensory characteristics supported both medicinal and culinary uses.

Fuchs confirmed traditional cooling and constricting properties, with applications for inflammation, gastric heat, and lactation, aligning with classical therapeutics but in more accessible language. He preserved folklore around "hare's lettuce", underscoring his commitment to blending scholarly and popular botanical wisdom. His note on *Sonchus* juice for urinary issues suggested continued empirical refinement in therapeutic application.

Mattioli's 1557 edition, featuring *Soncho asper* and *Soncho liscio* with illustrations, epitomized Renaissance efforts to integrate visual and textual documentation [50]. These illustrations, alongside detailed descriptions, reflected the period's emphasis on precise identification and effective therapeutic use through multimodal representation.

Carolus Clusius in 1601 [51] continued the tradition of citing Dioscorides while adding his own observations on the plant's uses for stomach ailments, inflammations, and scorpion bites, demonstrating the persistence of classical medical knowledge through the Renaissance period.

By the seventeenth century, *Sonchus* had become so familiar across the Iberian Peninsula that it transcended medicinal contexts to enter popular language. Sebastián de Covarrubias' *Tesoro de la lengua castellana o española* (1674) captures this cultural integration, noting how the phrase "*agua de cerrajas*" (sow thistle water) became synonymous with weak or inconsequential arguments [52,53]. While acknowledging *Sonchus*' classical therapeutic value, particularly in Dioscorides, Covarrubias highlighted how the plant's perceived mildness led to its association with ineffectiveness in common discourse. His observation that people would dismiss feeble claims by saying "*todo es agua de cerrajas*" illustrates the integration of botanical references into colloquial speech, albeit with diminished regard for their medicinal efficacy.

This shift suggests that by the seventeenth century, *Sonchus* preparations were viewed more as gentle remedies for minor ailments than potent medicinal agents. The divergence between the medical literature, which upheld classical uses, and popular perception, which regarded the plant as ineffectual, reflects broader transformations in medical expectations and practice during the early modern era.

In the eighteenth century, *Sonchus* species saw a notable decline in pharmaceutical use. José Quer's extensive botanical survey noted that by the late 1700s, *cerraja* was seldom employed in Spanish apothecaries, indicating waning professional interest despite continued inclusion in materia medica literature [54].

Nonetheless, eighteenth-century authors largely upheld Dioscoridean assessments. *Sonchus oleraceus*, in particular, was consistently attributed cooling properties and mild astringency, aligning with classical humoral principles. Medicinal broths were still prepared to relieve heat and inflammation, while external applications treated skin conditions. The milky sap retained its use for gastric irritation and lactation support, underscoring the durability of classical concepts through the Enlightenment.

Quer also preserved traditional preparation methods, noting that crushing the plant with its root remained effective for treating scorpion stings in direct continuity with Dioscorides. Culinary uses persisted as well; young, tender leaves harvested before spine development continued to appear in salads, reflecting enduring knowledge about optimal harvesting and usage.

This eighteenth-century perspective reveals a complex relationship between evolving professional practice and persistent folk knowledge. Even as *Sonchus* lost favor in formal pharmacopoeias, traditional applications remained well-documented and widely understood, indicating that scholarly respect for classical therapeutic frameworks endured.

The nineteenth century brought a decisive transformation in the scientific treatment of *Sonchus* species, mirroring broader shifts in botanical science and medical research. Focus shifted from therapeutic descriptions to botanical classification and phytochemical analysis, as taxonomy and laboratory methods gained prominence [55].

This new scientific orientation enabled researchers to investigate the chemical constituents behind traditional effects, while systematic classification clarified interspecies relationships. Such developments marked a departure from earlier therapeutic models toward empirical frameworks rooted in analytical chemistry.

Despite this shift, ethnobotanical studies continued to document traditional uses across Europe. The persistence of local knowledge alongside scientific inquiry underscores the resilience of folk practices and the growing interest in validating them through modern research. This coexistence highlights a transitional phase in which traditional and scientific epistemologies were not mutually exclusive but mutually informative.

The documentation of continued ethnobotanical usage across Europe during this period provides important evidence for the enduring relevance of traditional knowledge systems. This parallel development of scientific investigation and traditional practice created opportunities for cross-validation between empirical folk knowledge and emerging scientific methodologies, laying the groundwork for modern approaches to natural product research and ethnopharmacology.

4.3. Cross-Cultural Adoption

The medicinal and culinary applications of *Sonchus* species eventually transcended their Mediterranean origins. Following European colonization of the Americas, Native American communities incorporated the plant into their pharmacopeia, employing it for diverse purposes, including as a vegetable, medicine, and notably as a treatment for opium addiction [56–58]. The *Biblioteca Digital de la Medicina Tradicional Mexicana* documents its integration into traditional Mexican healing practices, where *Sonchus oleraceus* was adopted alongside indigenous medicinal plants [58].

This cross-cultural adoption represents a significant example of medicinal plant knowledge exchange and adaptation, as *Sonchus* species introduced to the Americas were recognized for properties similar to those documented by ancient Mediterranean writers nearly two millennia earlier.

5. Ethnopharmacological Evidence

5.1. Medicinal Applications of Sonchus Species in the Mediterranean: A Quantitative and Qualitative Review

The traditional use of *Sonchus* species across Mediterranean cultures in late 20th and early 21st centuries (Table 4), through the analysis of references published from 1981 to 2024 [59–108], reflects a multifaceted medicinal profile, with evidence pointing to both high frequency and broad therapeutic scope (Supplementary Tables S2 and S3).

Quantitative analysis of ethnobotanical data reveals that the most common applications relate to the digestive system, accounting for approximately 28.8% of recorded uses. Treatments for injuries, including wounds, burns, and stings, follow at 16.8%, while respiratory disorders are addressed in 7.1% of cases. Uses pertaining to the circulatory system, skin diseases, and infectious or parasitic conditions each constitute around 3.3% of mentions. Less frequently, *Sonchus* is employed in the treatment of nervous system complaints (2.7%), as well as endocrine and nutritional disorders (1.6%). An additional 33.2% of uses pertain to various other conditions, including genitourinary issues, ear problems, and menstrual irregularities.

Table 4. Records for *Sonchus* ethnobotanical, ethnopharmacological, and ethnoveterinary uses by country.

Country	No. of Publications [1]	Records	% of Records	Average Records Per Publication	References
Spain	24(21)	463	65.8	19.3	[59–83]
Italy	15	169	23.0	11.3	[84–98]
France	3	27	3.8	9.0	[97,99,100]
Cyprus	1	13	1.8	13.0	[101]
Morocco	2	10	1.4	5.0	[102,103]
Greece	1	8	1.1	8.0	[104]
Turkey	3	7	1.0	2.3	[105–107]
Egypt	1	3	0.4	3.0	[108]
Libya	1	3	0.4	3.0	[109]
Croatia	2	3	0.4	1.5	[110,111]
Czechia	1	2	0.3	2.0	[112]
Pakistan	1	2	0.3	2.0	[113]
Algeria	1	1	0.1	1.0	[114]

[1] No. of publications: The number of publications in the consulted bibliography, including material from that particular country.

When examining specific medicinal functions, *Sonchus* emerges most prominently as a digestive aid, with 14 separate mentions supporting its role in facilitating gastrointestinal health (Supplementary Table S3). It is also frequently described as a depurative, used for systemic detoxification, and as a diuretic. Applications targeting liver ailments are similarly prevalent. The plant is repeatedly cited in wound healing contexts and is employed in the treatment of cutaneous abscesses, thermal injuries, and inflammatory skin conditions. Respiratory ailments such as upper tract infections, as well as anxiety and pain management, are also among its documented uses.

In terms of categorical emphasis, gastrointestinal support comprises roughly one-quarter of all recorded uses. Wound healing and injury-related applications follow at 17%, while detoxification and hepatoprotective treatments represent about 10%. Anti-inflammatory functions span approximately 8% of uses, and respiratory disorders account for 7%. These figures highlight the plant's predominant roles in digestive, dermatological, and anti-inflammatory therapeutic contexts.

Qualitative insights further underscore the versatility and cultural integration of *Sonchus* in traditional medicine. Its primary functions are centered around digestive regulation, hepatic support, and systemic detoxification. The plant is also widely recognized for its external applications in treating wounds, insect bites, scorpion stings, and burns. These practices are often grounded in their perceived anti-inflammatory and antimicrobial properties, which are reflected across multiple therapeutic categories.

Traditional methods of preparation vary depending on the intended use. Internal disorders are typically treated using decoctions and infusions, while external ailments are addressed through the application of poultices or direct topical treatments. In some cases, leaves are chewed for immediate relief of digestive discomfort, indicating a reliance on the plant's efficacy in both processed and raw forms.

From a phytochemical standpoint, the frequent use of *Sonchus* for hepatic conditions suggests the presence of hepatoprotective compounds. The consistency with which it is used for inflammatory and infectious conditions across body systems also indicates anti-inflammatory, antimicrobial, and potentially analgesic activities. These properties underscore the plant's pharmacological potential and warrant further biochemical investigation.

The medicinal use of *Sonchus* species within ethnobotanical contexts reveals a clear hierarchical pattern of utilization, with *Sonchus oleraceus* L. emerging as the primary species of therapeutic significance (Supplementary Table S4). Accounting for nearly half of all documented medicinal applications, *S. oleraceus* demonstrates exceptional versatility, followed by *S. asper* (L.) Hill subsp. *asper* and *S. tenerrimus* L. subsp. *tenerrimus*, which also contribute notably but on a reduced scale. In contrast, *S. arvensis* L., *S. maritimus* L., and *S. macrocarpus* exhibit limited-to-marginal medicinal relevance, either due to low intrinsic activity or underdocumentation.

Across the genus, medicinal applications are most concentrated in the treatment of digestive system disorders (Supplementary Table S3). This category alone encompasses over a third of all reported uses, with *S. oleraceus* showing particularly high frequency, suggesting a strong ethnopharmacological reputation for gastrointestinal relief. This widespread use across multiple species may reflect either shared phytochemical properties or convergent empirical validation across cultural groups. Injury treatment also emerges as a significant category, where *S. oleraceus*, *S. asper*, and *S. tenerrimus* are repeatedly employed. This suggests that certain *Sonchus* taxa may possess bioactive compounds with wound-healing potential, including anti-inflammatory, antimicrobial, or tissue-regenerative effects.

The application of *Sonchus* species to respiratory ailments appears more restricted and notably centered around *S. oleraceus*, implying a possible concentration of relevant phytoconstituents in this taxon not commonly present in its congeners. Similarly, the genus shows some involvement in treating infections, anxiety, and parasitic conditions. The presence of *Sonchus* species in contexts such as pyogenic infections and candidiasis supports the hypothesis of general antimicrobial potential across the genus. The use of *S. oleraceus* for anxiety introduces the possibility of neuroactive compounds, a hypothesis further supported by its unique presence in this therapeutic domain.

When examined through a species-specific lens, *S. oleraceus* possesses the most extensive medicinal profile, with documented use for eighteen distinct conditions spanning multiple physiological systems. It is especially prominent in the management of digestive and respiratory issues, circulatory concerns, and physical trauma, and is uniquely cited for treating anxiety and other specialized conditions. *S. asper* presents a moderately broad therapeutic scope, most strongly represented in digestive and genitourinary applications and distinguished as the only species employed in the treatment of candidiasis. *S. tenerrimus*, while comparable in breadth to *S. asper*, is especially relevant in wound care and is uniquely associated with the treatment of anorexia, nervous system disorders, and mite infestations such as sarcoptes. Meanwhile, *S. arvensis* shows modest medicinal engagement yet stands out for its association with anemia treatment, pointing to potential hematinic properties. *S. macrocarpus* and *S. maritimus* remain almost absent from the medicinal corpus, which may reflect either genuinely limited pharmacological utility or gaps in ethnomedical documentation.

The phytopharmacological implications of these patterns are significant. The multi-functionality of the more widely used species, particularly *S. oleraceus*, implies the presence of a suite of bioactive secondary metabolites with effects on diverse biological systems. This biochemical diversity may be underpinned by both common phytochemical frameworks shared across the genus and species-specific compounds that drive particular therapeutic uses. The consistent recurrence of certain uses—such as treatment of digestive ailments and injuries—across multiple species reinforces the credibility of these applications and suggests their entrenchment in traditional medical systems. Such patterns are likely the result of long-term empirical observation and cultural transmission rather than random or incidental use.

The widespread use of *Sonchus* in everyday contexts reflects its accessibility and cultural familiarity (Supplementary Tables S2–S4). Many of the conditions it addresses—such as indigestion, minor injuries, and respiratory discomfort—are common and recurrent, suggesting the plant played a regular role in household healthcare. Notably, its use in pediatric and maternal contexts (e.g., as a galactagogue or child sedative) points to its trusted status within the domestic sphere.

5.2. Veterinary Applications of Sonchus Species in the Mediterranean: A Quantitative and Qualitative Review

Although less documented than its use in human medicine, the ethnoveterinary application of *Sonchus* species offers valuable insights into traditional animal healthcare within the Mediterranean context (Supplementary Table S5). A notable feature is the clear parallel between human and veterinary uses—particularly in treating wounds, inflammation, and insect or scorpion stings—suggesting a shared recognition of the plant's therapeutic efficacy based on empirical observation [82,96,97].

Sonchus is especially prominent in livestock care, where it is employed to treat mastitis and promote lactation in dairy animals. These uses reflect its integration into traditional husbandry practices and its role in supporting agricultural productivity. Applications also extend to pigs, rabbits, and pigeons, animals of economic significance in rural Mediterranean settings, highlighting the plant's versatility in sustaining animal health.

Certain treatments appear unique to veterinary practice, such as remedies for pig rheumatism and rabbit dermatomycosis. These species-specific uses indicate a depth of traditional knowledge that goes beyond analogies with human medicine, reflecting a nuanced understanding of animal physiology and disease.

The practical focus of these applications is evident in their orientation toward conditions that directly impact productivity and welfare. The plant's use across both productive and companion animals illustrates its broad perceived value within traditional care systems. Viewed through a wider ethnomedical lens, this pattern aligns with a "One Health" perspective, wherein human, animal, and environmental health are interlinked. The shared use of *Sonchus* suggests an integrated knowledge system shaped by observation and transmitted across generations and domains.

Economically, the plant's role in treating animals is vital to household subsistence—particularly dairy livestock, pigs, and rabbits—and reinforces its significance in agromedicine. Its contribution extends beyond health to the resilience of rural livelihoods.

Finally, the recurrence of certain applications—especially for inflammation, infection, and lactation—supports phytopharmacological hypotheses. The evidence for galactagogue, antimicrobial, and anti-inflammatory effects across species strengthens the case for bioactive compounds within *Sonchus*.

6. Ethnobotanical Evidence for Sonchus Uses as Food

6.1. Documentation of Local Knowledge and Practices Surrounding Sonchus Gathering and Preparation by Rural Communities

Over time, the perception of *Sonchus* species has evolved from being a staple wild food to a plant of marginal economic importance. However, recent interest in wild edible plants has revived their cultural and culinary significance [24,60,115].

Rural communities have preserved extensive knowledge about gathering and preparing *Sonchus* species, often passed down through generations. These practices reflect a deep connection to local ecosystems and cultural heritage [115]. Contemporary ethnobotanical research has documented the ongoing use of *Sonchus* species in both rural and urban settings. While traditional practices persist in some areas, there are notable differences in consumption patterns between rural and urban populations [60,115]. The data highlights (Supplementary Table S2) the widespread consumption of *Sonchus* as food, its significant role in traditional medicine, and its value as livestock feed.

An examination of the geographic distribution of *Sonchus* ethnobotanical and ethnopharmacological data (Table 4) reveals a highly uneven landscape in both the quantity and quality of available records. Across twelve countries, a total of 714 use records were extracted from 55 academic references. However, this apparent breadth in geographic scope is deceptive, as a deeper statistical analysis underscores significant disparities in research intensity and documentation. The numerical distribution reveals a profound skew. While the mean number of records per country stands at approximately 55, the median is only 5.5, and the standard deviation is exceptionally high at 130.4. This statistical profile highlights a data landscape marked by concentration rather than balance. Indeed, Spain alone contributes 464 records, accounting for 65% of the entire dataset, followed by Italy with 169 records (23.7%) and France with 71 (9.9%). Together, these three Western European nations account for nearly 99% of all documented uses, while the remaining nine countries are responsible for just over 1%.

The geographic distribution further emphasizes this imbalance. The Mediterranean Basin dominates, with 84.3% of all records originating from this region, while the remainder is split between North Africa (2.4%) and a sparse collection of non-Mediterranean countries, accounting for 13.4% of the dataset. North Africa, a region historically rich in traditional medicinal and culinary practices, is severely underrepresented, with just 17 records across three countries and only four references. The Middle East is similarly marginal, with only a single reference from Pakistan. Other regions, such as Eastern Europe, Sub-Saharan Africa, the broader Asian continent, and the Americas, are either absent or nearly invisible in the corpus, despite the known presence or naturalization of *Sonchus* species in these areas.

The roots of this imbalance are multifaceted, beginning with the geographical limits of this review but also linked to academic infrastructure. Countries such as Spain and Italy benefit from robust ethnobotanical research programs, systematic regional surveys, and an institutional culture that values the documentation of traditional knowledge. Their high record counts are likely a result not only of cultural emphasis on traditional plant use but also of access to European Union research funding streams that prioritize biodiversity and heritage studies. In contrast, countries with less research infrastructure, lower publication output, or more fragmented knowledge transmission systems—particularly those that rely on oral traditions—are systematically underrepresented.

The complete absence of data from the Americas, much of Africa, and most of Asia—despite the presence of naturalized or historically used *Sonchus* species—is due to the geographical limitations defined for this review, but it does not mean true ethnobotanical insignificance in these areas.

Historically and culturally, the high concentration of records in Mediterranean countries aligns with longstanding traditions of *Sonchus* consumption and medicinal use (Table 4). These regions are deeply embedded in folk medicine practices and the broader framework of the Mediterranean diet, where wild greens, including *Sonchus*, play both nutritional and therapeutic roles.

In conclusion, the geographic patterns evident in the current *Sonchus* ethnobotanical literature underscore a critical need for more inclusive and globally representative research

(Table 4). Future studies should prioritize underrepresented regions—particularly the Middle East, Sub-Saharan Africa, Asia, and Latin America—where traditional plant knowledge exists but remains poorly documented. Collaborative research models that engage local scholars, community practitioners, and indigenous knowledge holders will be essential for addressing these gaps and constructing a more accurate global portrait of *Sonchus* uses.

6.2. Comparative Ethnobotanical Analysis Across Mediterranean Regions

Comparative ethnobotanical studies across Mediterranean regions have highlighted the diverse uses of *Sonchus* species in different cultures. These studies provide a comprehensive understanding of the plant's importance in traditional medicine and cuisine throughout the Mediterranean basin [115].

The analysis of total observations per country (Table 4 and Supplementary Table S2) demonstrates that Spain accounts for the highest number of *Sonchus* observations, with 463 records, representing approximately 65% of the total 704 observations. This substantial figure suggests that Spain may serve as a critical biodiversity hotspot for the genus, potentially due to its favorable Mediterranean climate, rich biodiversity, and extensive research endeavors. Italy follows with 169 observations, further reinforcing the notion of a strong *Sonchus* presence within Mediterranean regions. Countries such as France (27), Morocco (10), Greece (8), and Turkey (7) exhibit moderate observation numbers, while nations like Algeria (1), Pakistan (2), and Czechia (2) show very limited records, which could be attributed to either constrained research efforts or unsuitable ecological conditions.

Regarding species-specific distribution, *Sonchus oleraceus* emerges as the most widespread species, with 311 observations, being particularly prevalent in Spain (197) and Italy (74). Similarly, *S. tenerrimus* subsp. *tenerrimus* is also abundant, primarily observed in Spain (167) and Italy (20). *Sonchus asper* subsp. *asper* is frequently recorded in both Spain (72) and Italy (46). In contrast, several species exhibit highly restricted distributions. *Sonchus macrocarpus*, for instance, is exclusively found in Egypt (three observations), while *Sonchus crassifolius* (four observations) and *Sonchus maritimus* subsp. *aquatilis* (six observations) are confined to Spain. *Sonchus asper* subsp. *glaucescens* shows a scattered presence across Croatia (one), Turkey (two), and France (one). These patterns suggest a dichotomy between widespread generalist species and specialized species with narrow ecological niches or geographic ranges.

The favorable mild winters and hot summers characteristic of the Mediterranean climate appear to support a higher diversity and abundance of these species. Conversely, arid or African regions such as Morocco, Egypt, and Libya exhibit few observations (Table 4), likely due to less hospitable drier conditions. Similarly, the minimal presence in northern and central European countries like Czechia and Croatia suggests a preference for warmer climates.

The distinction between generalist and specialist species is evident. *Sonchus oleraceus* and *S. asper* are clear generalists, thriving across multiple countries, while species like *S. macrocarpus* and *S. crassifolius* are specialists, possibly adapted to unique local environmental conditions. Furthermore, the concentration of *Sonchus bulbosus* and *S. maritimus* observations predominantly within Spain and Italy hints at potential endemism or strong habitat preferences, such as coastal environments.

The high number of observations in Spain does not solely reflect actual abundance but could also be a consequence of more intensive botanical surveys in the region. Conversely, countries with limited records, such as Algeria, Libya, and Pakistan, may be considerably understudied. The influence of climate is also a significant factor, with *Sonchus* species generally thriving in temperate and Mediterranean zones but showing limited presence in deserts or colder climates.

In conclusion, Spain emerges as the predominant region for *Sonchus* diversity, closely followed by Italy, largely driven by the conducive Mediterranean climate. *Sonchus oleraceus* is identified as the most widespread species, contrasting with the localized distribution of species such as *S. macrocarpus* and *S. crassifolius*. The distribution patterns strongly suggest that Mediterranean climates favor *Sonchus* growth, while arid and colder regions present limitations. To obtain a more comprehensive understanding of *Sonchus* distribution, further research in currently underrepresented countries would be invaluable.

6.3. Food Applications Versus Other Traditional Uses: A Comparative Analysis of Contemporary Ethnobotanical Relevance in Sonchus Species

The analysis of total uses per category reveals that food is the most prevalent application of *Sonchus* species, accounting for 409 observations of traditional uses. This widespread consumption underscores the importance of *Sonchus* as a dietary component. Medicinal uses constitute the second most frequent category, with 158 observations, indicating the ethnobotanical significance of these plants in traditional remedies. Livestock feed also represents a substantial use, with 114 records, particularly for species such as *S. oleraceus* (54 observations) and *S. asper* (26 observations). In contrast, proverbs, sayings, and colloquial expressions (9 observations) and veterinary uses (12 observations) are less common but suggest a notable cultural integration of *Sonchus*. The use of *Sonchus* as an insecticide is negligible, with only a single record attributed to *S. oleraceus*.

Certain *Sonchus* species exhibit greater versatility in their applications. *Sonchus oleraceus* is identified as the most utilized species, demonstrating dominance across food (170 observations), medicinal (77 observations), and livestock feed (54 observations) categories. *S. tenerrimus* and *S. asper* subsp. *asper* follow, with strong applications in both food and medicinal contexts.

Niche uses are also observed. *Sonchus asper*, *S. bulbosus*, *S. oleraceus*, and *S. tenerrimus* are referenced in proverbs and sayings, suggesting their cultural recognition in folklore. Veterinary applications are predominantly associated with *S. oleraceus* (eight observations), with minor mentions for *S. asper* (one observation) and *S. tenerrimus* (three observations). The singular insecticide use is exclusively linked to *S. oleraceus*. Conversely, species such as *S. crassifolius* (four food uses only), *S. maritimus* subsp. *aquatilis* (six food uses only), and *S. macrocarpus* demonstrate minimal usage across food, feed, and medicinal categories.

The dominance of food uses suggests that *Sonchus* species are commonly consumed as leafy greens, akin to other wild edibles like dandelions or wild lettuce. The high value placed on *S. oleraceus* for food consumption may be due to its palatability and widespread availability. The significant number of medicinal uses indicates their integration into traditional remedies for various ailments, including inflammation, digestive issues, or wound healing (Supplementary Tables S3 and S4). Notably, *S. arvensis* has 12 recorded medicinal uses despite its less common application as food or livestock feed, warranting further investigation into its specific chemical properties. The presence of *Sonchus* in proverbs and sayings points to its symbolic significance within certain cultures, particularly in Mediterranean regions where it might be referenced in folk wisdom. The limited veterinary applications may relate to traditional animal health remedies, while the single insecticide use of *S. oleraceus* suggests experimental or highly localized pest control methods.

In summary, the primary uses of *Sonchus* species are for food, medicine, and livestock feed, with *Sonchus oleraceus* emerging as the most versatile species. While proverbs and veterinary applications are less common, they highlight noteworthy cultural and niche uses. Conversely, *S. crassifolius*, *S. macrocarpus*, and *S. maritimus* appear to be underutilized. Further ethnobotanical studies could explore the reasons behind the preference for certain species, and chemical analyses might elucidate the specific properties contributing to *S. arvensis*'s medicinal value. Additionally, the significant use of *Sonchus* as livestock feed suggests its potential for agricultural applications as a forage crop.

6.4. Traditional Agricultural Applications of Sonchus Species for Animal Feed

Analysis of *Sonchus* species utilization as animal fodder reveals their significant role in traditional small-scale and subsistence farming systems (Supplementary Table S2). A clear taxonomic hierarchy emerges in utilization frequency: *Sonchus oleraceus* dominates with 54 recorded uses, followed by *S. asper* subsp. *asper* (26 uses) and *S. tenerrimus* subsp. *tenerrimus* (21 uses). Other species (*S. maritimus*, *S. arvensis*, *S. bulbosus*, and *S. macrocarpus*) show minimal use, indicating marked variation in fodder relevance across the genus.

Animal-Specific Utilization Patterns: Feed applications demonstrate clear livestock preferences. Rabbits represent the most frequent recipients (31 instances), followed by general backyard animals (26 instances), partridges (16), and chickens (12). Goats, sheep, pigs, and various bird species appear less frequently (5–7 instances each), while waterfowl (geese and ducks) show a rare but notable association exclusively with *S. tenerrimus*.

Species-animal affinities reveal distinct utilization patterns. *S. oleraceus* exhibits the broadest utility across nine animal categories, serving primarily as general fodder (14 instances), rabbit feed (11), and partridge feed (9). *S. asper* shows specialized use in rabbit husbandry (13 instances), while *S. tenerrimus* functions primarily as general fodder (6 instances), occupying an intermediate position without dominating any single category.

Ecological and Agricultural Implications: The predominant use of *Sonchus* species as general fodder reflects their importance in small-scale agricultural systems where flexible, accessible feed resources are essential. The prominence of rabbit feeding suggests both physiological compatibility and farmer recognition of diverse dietary options for lagomorphs. Partridge utilization indicates a role in game bird management spanning both domesticated and wild contexts.

The specific association between *S. tenerrimus* and waterfowl may reflect unique palatability or digestibility characteristics. These patterns underscore the influence of animal preference, plant palatability, and regional ecological knowledge in shaping ethnoveterinary practices.

Taxonomic Hierarchy and Specialization: *S. oleraceus* emerges as the dominant multipurpose species, mirroring its prominence in culinary and medicinal applications and reinforcing its status as a cornerstone plant in Mediterranean ethnobotany. This broad applicability contrasts with the more specialized roles of other taxa: *S. asper* shows concentrated use in rabbit husbandry, suggesting specific biochemical properties favoring lagomorph consumption.

The focus on backyard and small-scale livestock operations highlights Sonchus species' particular value within traditional agricultural systems, supporting household food security through contributions to animal nutrition. The inclusion of wild and semi-domesticated species extends utility beyond conventional livestock to encompass broader wildlife management within traditional ecological systems.

Research Gaps and Future Potential: Limited documentation of several *Sonchus* species in livestock applications suggests significant unexplored potential within this genus. This gap presents opportunities for integrating these resources into sustainable livestock feeding strategies, particularly within contemporary ecological farming and agroforestry systems that combine traditional knowledge with modern sustainable practices.

The livestock applications of *Sonchus* species complement their established culinary and medicinal roles, demonstrating fundamental multifunctionality. This convergent utilization pattern establishes these species as integral components of the ecological and economic systems sustaining traditional Mediterranean communities, where their value transcends individual use categories to encompass comprehensive resource utilization strategies.

7. Gastronomical Value

7.1. Plant Parts

Our findings reveal a selective preference for young plants and tender plant parts for culinary consumption, attributed to their enhanced palatability and reduced bitterness. However, this pattern does not extend to medicinal applications, as active compounds typically accumulate throughout the plant's developmental stages, as discussed subsequently. For gastronomic purposes, young leaves, shoots, and bulbs are consistently favored due to their superior organoleptic properties (Figure 4).

Figure 4. Relevant edible and/or medicinal *Sonchus* plant parts. (**A**) Young leaves along the stem but also in a basal rosette *Sonchus aquatilis*. (**B**) Inmature capitulum, *S. oleraceus*. (**C**) Underground stem and rhizome, *S. crassifolius*. (**D**) "Bulbs"—root tubers, *S. bulbosus*. Images: (**A**,**B**) Antonio Robledo, with permission. (**C**) Javier Tardío, with permission. (**D**) S. Ríos.

The analysis of plant part utilization in *Sonchus* species reveals distinct patterns of exploitation for food and medicinal purposes. Aerial parts demonstrate the highest overall usage (338 records) (Table 5), with leaves representing the most frequently utilized component (233 records), followed by whole plant preparations (72 records). This pattern reflects the practical accessibility and abundance of above-ground tissues, particularly the tender foliage that constitutes the primary edible portion of these species. The preference for aerial parts aligns with traditional harvesting practices that prioritize easily accessible plant materials while allowing for sustainable collection without destroying the entire plant.

The distribution between food and medicinal applications shows notable differences in plant part selection. While aerial parts and leaves dominate both categories, medicinal uses show greater diversity in plant-part exploitation, incorporating specialized tissues such as latex (seven records), flowers (six records), and cypselae (two records) that are absent or minimal in food applications. Roots, including both standard and tuberous forms, contribute modestly to both categories but show relatively higher representation in medicinal uses (18 total records) compared to their food applications. This pattern suggests that medicinal preparations often target specific bioactive compounds concentrated in particular plant tissues, whereas culinary uses focus primarily on palatability and nutritional content found in commonly consumed aerial parts.

Table 5. Relevance of the different *Sonchus* plant parts in terms of frequency among the analyzed records.

Plant Part	Records of *Sonchus* Traditional Uses	Food	Medicinal Plants
Aerial parts	338	190	85
Leaf	233	173	40
Whole plant	72	15	11
Root	18	11	7
Stem	15	14	1
Flower	9	0	6
Latex	7	0	7
Tuberous root	6	3	0
Cypselae	3	0	2

7.2. Traditional Culinary Uses

Sonchus species have been incorporated into various culinary traditions, particularly in Mediterranean cuisine. These plants are often used in salads, stews, and as brined products, contributing to the diverse gastronomic landscape of the region [22,24] (Table 6). Regional recipes, such as Greek "horta" variants, including *Bombotópita* or *Plastós* [98,104] and Italian "pistic" [11,96], highlight the adaptability of *Sonchus* species to local culinary traditions [12,24].

Table 6. Records of traditional food uses and *Sonchus* species.

N° Food Uses	*S. arv*	*S. aspasp*	*S. aspgla*	*S. bul*	*S. cras*	*S. mac*	*S. mar*	*S. maqu*	*S. ole*	*S. ten*
Boiled	4	22	2	1	1	1	0	2	63	43
Salads	1	34	2	4	3	0	0	4	68	81
Bombotópita, is a traditional Greek cornbread pie or cornmeal cake	0	1	0	0	0	0	0	0	1	0
"Braised" refers to a cooking method where food, typically meat or vegetables, is first seared at a high temperature and then slowly cooked in a covered pot with a small amount of liquid, such as broth or wine	0	0	0	0	0	0	0	0	1	0
Cooked in a variety of preparations, including soupy rice dishes	0	0	0	0	0	0	0	0	1	0
Cooked in a variety of preparations, including soupy rice dishes or pan-fried with garlic	0	1	0	0	0	0	0	0	9	2
Lake fish-based soups	0	0	0	0	0	0	1	0	0	0
Pistic refers to a traditional dish from Western Friuli, Italy, made from a collection of over 50 wild herbaceous meadow and wood plants that are boiled and then sautéed together	0	1	0	0	0	0	0	0	1	0
Plastós is a traditional pie from various regions of Greece, particularly Thessaly and parts of central Greece	0	1	0	0	0	0	0	0	1	0
Regional Greek wild green sauté	0	1	0	0	0	0	0	0	1	0
Seasoning or sauce suitable for all varieties of pasta	0	2	0	0	0	0	0	0	1	1
Tender spring leaves blanched and subsequently sautéed, finished with smoked ricotta cheese for added depth and aroma	0	0	0	0	0	0	0	0	1	0
The plants are initially boiled and subsequently sautéed	2	5	0	0	0	0	0	0	3	1

Table 6. *Cont.*

Nº Food Uses	*S. arv*	*S. aspasp*	*S. aspgla*	*S. bul*	*S. cras*	*S. mac*	*S. mar*	*S. maqu*	*S. ole*	*S. ten*
The plants are initially boiled and subsequently sautéed with garlic and green peppers to enhance flavor and aroma	0	0	0	0	0	0	0	0	4	0
The plants are initially boiled and subsequently sautéed with garlic to enhance flavor and aroma	0	0	0	0	0	0	0	0	1	2
The plants are initially boiled and subsequently sautéed with ñora peppers and salted sardines to enhance flavor and aroma	0	1	0	0	0	0	0	0	1	0
The plants are initially boiled with Swiss chard and subsequently sautéed with blood sausages to enhance flavor and aroma	0	0	0	0	0	0	0	0	1	0
The plants are initially boiled with Swiss chard and subsequently sautéed with garlic to enhance flavor and aroma	0	0	0	0	0	0	0	0	2	0
The root undergoes roasting and grinding processes to be served as a coffee surrogate	0	1	0	0	0	0	0	0	1	0
The roots are incised to extract latex, which is subsequently chewed	0	0	0	0	0	0	0	0	1	0
These are prepared as Italian vegetable frittata, in which diced seasonal vegetables are incorporated into an egg matrix and cooked until set	0	1	0	0	0	0	0	0	2	0
These are prepared as Spanish vegetable omelets, in which diced seasonal vegetables are incorporated into an egg matrix and cooked until set	0	1	0	0	0	0	0	0	3	8
These leafy greens are commonly employed as substitutes for spinach in culinary preparations such as pizzas and soups	0	0	0	0	0	0	0	0	1	1
Typically roasted and then cooked with rice to enhance flavor and texture	0	0	0	0	0	0	0	0	1	0
Used as a coffee substitute	0	0	0	0	0	0	0	0	1	0
	7	72	4	5	4	1	1	6	170	139

Abbreviations: S. arv, Sonchus arvensis L.; S. aspasp, S. asper (L.) Hill subsp. asper; S. aspgla, S. asper subsp. glaucescens (Jord.) Ball; S. bul, S. bulbosus (L.) N.Kilian & Greuter; S. cras, S. crassifolius Pourr. ex Willd.; S. mac, S. macrocarpus Boulos & C.Jeffrey; S. mar, S. maritimus L.; S. maqu, S. maritimus subsp. aquatilis (Pourr.) Nyman; S. ole, S. oleraceus L.; S. ten, S. tenerrimus L. subsp. tenerrimus. Data from Supplementary Table S2.

An analysis of culinary applications of *Sonchus* species in Mediterranean ethnobotany reveals a strong preference for certain taxa and preparation methods, underscoring their cultural and gastronomic importance (Table 6). Among the documented species, *Sonchus oleraceus* and *Sonchus tenerrimus* subsp. *tenerrimus* emerge as the most frequently utilized, accounting for 170 and 139 recorded uses, respectively. These species dominate the culinary landscape, far surpassing others in frequency of use. In contrast, *Sonchus asper* subsp. *asper* appears significantly less often, with 72 recorded uses, while all remaining taxa exhibit markedly limited culinary relevance. Species such as *S. maritimus* subsp. *aquatilis*, *S. bulbosus*, *S. arvensis*, *S. crassifolius*, *S. asper* subsp. *glaucescens*, *S. maritimus*, and *S. macrocarpus* collectively account for only a handful of instances, reflecting their marginal presence in traditional foodways.

In terms of preparation methods, raw consumption in salads constitutes the predominant mode of culinary use, with 197 instances recorded (Table 6). Boiling, either on its own or mixed with other wild greens, is the second most common preparation technique, cited 139 times. These two methods together represent the vast majority of culinary applications, while other techniques—such as sautéing or frying—appear only sporadically, typically with fewer than ten mentions. This pattern suggests a culinary preference for simplicity, likely intended to preserve or subtly enhance the natural characteristics of the plant.

A closer examination of species-specific culinary combinations reinforces the centrality of *S. oleraceus*, *S. tenerrimus*, and *S. asper*. The most frequently recorded preparations include *S. tenerrimus* consumed in salads (81 instances) and *S. oleraceus* similarly used (68 instances), followed by their respective boiled preparations. *S. asper* is also present in both categories, though with a significantly lower frequency. The high rate of repetition across these core preparations highlights their integration into daily food practices and suggests they are the most palatable or culturally valued members of the genus.

Qualitative data provides further insight into the culinary versatility of *Sonchus* species. Their frequent raw consumption, particularly in salads, indicates that certain species are palatable without the need for cooking, a trait not universally common among wild leafy greens. Where cooking is involved, boiling dominates, potentially serving to reduce bitterness or soften fibrous textures. In some regional traditions, additional techniques such as sautéing follow boiling, suggesting layered preparation methods aimed at refining flavor or texture.

Distinct regional cuisines further reflect the depth of culinary integration. In the western Mediterranean, *Sonchus* is incorporated into Spanish omelets [62,67,73,75,81,82] and traditional Catalan or Valencian dishes. Greek gastronomy includes preparations such as *plastós* and *bombotópita* [104], while in Italy, *Sonchus* is used in frittatas and pasta-based dishes [96]. These examples suggest that the plant is not only accepted but embedded within long-standing culinary repertoires.

Flavor enhancement is a notable theme across these preparations. Garlic is the most consistently cited additive [52,67,82,83], followed by regionally specific ingredients such as *ñora* peppers [67], salted sardines [67], blood sausages [67], and smoked ricotta [96]. These accompaniments imply that *Sonchus* is frequently paired with strong or savory elements, perhaps to balance bitterness or augment its earthy flavors.

Beyond their role in primary dishes, *Sonchus* species also serve alternative culinary and quasi-culinary functions. In some traditions, the roots are roasted and used as a coffee substitute [88], while its latex has been noted for both medicinal [83,93,97] and recreational purposes [107], suggesting a broader spectrum of plant utility within local knowledge systems.

Certain species exhibit unique or highly specialized culinary applications. *S. maritimus* subsp. *maritimus*, for instance, is exclusively associated with fish-based lake soups, potentially indicating a specific flavor compatibility [86]. While *S. asper* is employed across several methods, it appears less frequently in complex or culturally specific recipes compared to *S. oleraceus* and *S. tenerrimus*, reinforcing the latter's greater culinary status.

Overall, the data affirms the significant cultural embeddedness of *Sonchus* species within traditional Mediterranean cuisine. The specificity of dishes and preparation techniques points to a deep-rooted culinary heritage rather than opportunistic or incidental use. Moreover, the predominance of just a few species suggests that palatability, availability, or cultural preference has historically shaped selection practices (Table 6).

8. Phytochemical and Nutritional Evidence

8.1. Phytochemical Composition

8.1.1. Overview of Phytochemical Evidence

Sonchus species contain a diverse array of bioactive compounds, including polyphenols, flavonoids, and sesquiterpene lactones. These phytochemicals contribute to the plant's medicinal properties and potential health benefits [22,24]. In the review (Table 7) of the 25 publications selected, *S. oleraceus* exhibited the highest value with 302 chemical records distributed across 11 publications, followed by *S. maritimus* (293 records primarily from 2 publications) and *S. arvensis* (210 records across 8 publications). Less studied species include

S. crassifolius, *S. macrocarpus*, and *S. erzincanicus*, with only 5–7 records each from single publications. These data highlight significant research concentration on select *Sonchus* species while revealing substantial knowledge gaps for the less-studied taxa.

Table 7. Distribution of chemical compounds in *Sonchus* species across the published literature. This table presents the frequency of chemical compound records across 25 representative publications (columns 1–25) for 11 *Sonchus* taxa. Numbers within cells indicate the quantity of distinct chemical compounds reported in each publication for the corresponding taxon.

Taxa/Publication [1]	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	Nº Records
S. oleraceus L.	39	25	0	23	0	9	4	64	32	69 *	0	0	0	13	0	0	0	16	0	8	0	0	0	0	0	302
S. maritimus L.	0	0	288 *	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	293
S. arvensis L.	0	0	0	0	0	0	0	0	0	0	0	0	108	0	12	9	3	0	10	0	0	0	25	17	26	210
S. tenerrimus L.	0	25	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	5	0	50	0	0	0	84
S. asper (L.) Hill	0	0	0	0	5	9	0	0	0	0	0	35	0	0	0	0	0	0	0	9	10	0	0	0	0	68
S. asper subsp. *glaucescens* (Jord.) Ball	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	14
S. maritimus subsp. *aquatilis* (Pourr.) Nyman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	10
S. erzincanicus V.A.Matthews	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
S. arvensis subsp. *uliginosus* (M.Bieb.) Nyman	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
S. macrocarpus Boulos & C.Jeffrey	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
S. crassifolius Pourr. ex Willd.	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Total Chemicals	39	50	288	23	5	18	34	64	32	69	7	35	108	13	12	9	3	16	10	41	10	50	25	17	26	1004
Botanical score	5	2.7	4	5	1.8	1.6	1.5	2	2.4	3.7	3.3	3.5	0	2.5	3.2	3.4	1.4	0	2.7	1.3	2.7	2.7	3	1.2	0.1	-
Chemical score	4.9	4.2	2.5	4.1	4	1	1.2	4.2	3.7	1.9	4.5	4.2	4.5	3	4.4	4.4	3	0	4.2	3.6	3.1	2.2	2.5	2.6	0.8	-

[1] References and countries: a [116] Algeria; b [24] Spain; c [117] Algeria; d [118] Egypt; e [119] Egypt; f [120] Pakistan; g [121] Egypt and other countries; h [122] Egypt; i [123] South Africa; j [124] Tunisia; k [125] Turkey; l [126] Italy; m [127] Indonesia; n [128] India; o [129] China; p [130] China; q [131] India; r [132] Kazakhstan; s [133] China; t [134] Spain; u [135] Pakistan; v [136] Libya; w [137] Indonesia; x [138] Indonesia; y [139] Ukraine. (*) Caution: Some of the reported compounds potentially represent analytical artifacts or possess marginal evidential support for their structural identification.

Table 7 reveals a striking shift in the geographical focus of *Sonchus* chemical research, expanding far beyond the traditional Mediterranean centers that historically dominated ethnobotanical documentation. The data encompasses 1004 distinct chemical compound records across 11 *Sonchus* taxa from 25 publications spanning 15 countries, representing a significant diversification from the previously Spain-, Italy-, and France-centric research landscape.

The distribution of research effort shows pronounced taxonomic bias, with *Sonchus oleraceus* dominating the literature, with 302 compound records (30.1% of all records), followed by *S. maritimus* with 293 records (29.2%) and *S. arvensis* with 210 records (20.9%). These three species account for approximately 80% of all documented chemical compounds, while the remaining eight taxa collectively contribute only 199 records. This concentration suggests either greater chemical diversity in the dominant species or research preference for more widely distributed taxa.

Geographically, the research landscape has undergone a remarkable transformation. North African countries now contribute substantially, with Algeria [116,117] providing the highest single-study chemical diversity (288 compounds) [117] and Egypt contributing across multiple studies [118,119,121,122]. Asian representation has expanded significantly, including contributions from China [129,130,133], Indonesia [127,137,138], India [128,131], Pakistan [120], and Kazakhstan [132]. African research extends beyond the Mediterranean to include South Africa, while the traditional European strongholds are represented by only two Spanish studies [24,134] and one Italian study [126] among the 25 references.

The temporal analysis reveals interesting patterns in research intensity. Recent publications (2020–2025) account for 12 of the 25 references, indicating accelerated research activity. The chemical scores, ranging from 0.8 to 4.9, suggest varying analytical rigor or scope across studies, with several African studies achieving high scores despite being geographically distant from traditional research centers.

The geographical redistribution of *Sonchus* research reflects broader trends in global scientific capacity building and the recognition of traditional knowledge systems outside Europe. The emergence of substantial research contributions from Algeria, Egypt, Indonesia, and other developing nations suggests successful technology transfer and local expertise development in phytochemical analysis. This shift is particularly significant given that these regions often harbor greater plant biodiversity and traditional medicinal knowledge than the historically dominant research centers.

The taxonomic focus reveals potential biases in species selection that may not reflect actual chemical diversity. *S. oleraceus* and *S. maritimus* show remarkably high compound counts in individual studies, with some studies reporting over 60 compounds from a single species. This could indicate either exceptional chemical richness or methodological differences in compound identification and reporting standards. The cautionary note in Table 7 regarding potential analytical artifacts in some highly prolific studies suggests that quantity may not always correlate with quality in phytochemical research.

The emergence of specialized regional research programs is evident from the data. Indonesian researchers appear to be developing systematic approaches to *Sonchus* chemistry, with multiple recent publications focusing on *S. arvensis*. Similarly, North African research centers have demonstrated sophisticated analytical capabilities, particularly in Algeria, where a single study [117] identified 288 compounds from *S. maritimus*.

The botanical and chemical scoring systems reveal interesting disparities between traditional botanical knowledge and modern chemical analysis capabilities. Some studies with lower botanical scores achieve high chemical scores, suggesting that chemical analysis expertise may now exist independently of classical taxonomic expertise in some regions. However, this casts doubt on the reliability of botanical identification of such analyses.

This geographical diversification represents a democratization of phytochemical research that contrasts sharply with the historical concentration in Mediterranean Europe. The data suggests that the center of *Sonchus* chemical research has effectively shifted toward regions where these plants may have greater ethnobotanical significance and where modern analytical techniques are being applied to traditional knowledge systems. However, the wide variation in compound numbers per study and the cautionary notes about analytical artifacts highlight the need for standardized methodologies and quality control measures as this research field continues to expand globally.

The evaluation of the 25 papers on *Sonchus* phytochemistry (Table 7), based on botanical and chemical scoring criteria (Supplementary Table S1), reveals notable disparities in methodological rigor. The botanical scores, which assess critical aspects of plant identification, taxonomy, and documentation, exhibit significant variability, ranging from 0 to 5, with a mean of approximately 2.3. This indicates that a substantial proportion of studies lack thorough botanical validation, as nearly 28% of papers scored below 1.5, while only a minority (28%) achieved scores above 3. In contrast, chemical scores—reflecting the robustness of extraction, analytical procedures, and compound identification—demonstrate comparatively stronger performance, with a mean of 3.2 and 32% of studies scoring above 4. However, this relative strength in chemical methodology is undermined by inconsistencies, as 20% of papers received chemical scores below 2, suggesting deficiencies in experimental reproducibility or analytical precision.

A striking observation is the frequent dissociation between botanical and chemical rigor. Several studies (e.g., with botanical scores of 0 paired with chemical scores of 4.5) [127] exhibit advanced laboratory techniques but neglect fundamental botanical documentation, potentially compromising the reproducibility and ecological relevance of their findings. Conversely, a subset of papers with high botanical scores (e.g., 5) but moderate chemical scores (e.g., 2.5) suggests rigorous plant science that is undermined by less stringent analytical protocols. Only a single study [116] achieved high marks in both domains (botanical = 5, chemical = 4.9), serving as a benchmark for comprehensive phytochemical research. These disparities highlight an urgent need for more balanced methodologies, integrating meticulous botanical practices—such as voucher specimen deposition and precise taxonomic identification—with standardized chemical analyses to ensure both accuracy and ecological validity.

The findings underscore a broader trend in phytochemical research, where technical advancements in chemical analysis often outpace foundational botanical rigor. To address this, future studies should prioritize harmonizing these dimensions, adopting established guidelines for plant collection and identification alongside validated analytical techniques. Such an approach would enhance the reliability, reproducibility, and applicability of phytochemical data, particularly in understudied genera like *Sonchus*. Further statistical exploration, including correlation analyses between botanical and chemical scores, could yield additional insights into the interdependence of these research domains.

8.1.2. Comparative Analysis of Significant Compounds Across Different Sonchus Species

Comparative studies reveal significant variations in the phytochemical profiles of different *Sonchus* species, influenced by environmental and genetic factors [121,122].

The phytochemical profile, organized by main chemical classes, presents significant chemical distribution patterns within the genus while also acknowledging the influence of research intensity disparities across species (Figure 5).

Volatile organic compounds (VOCs) emerge as the most abundantly documented chemical class in *Sonchus*, with 224 total records. Their distribution is notably uneven, with *S. maritimus* containing the highest concentration (165 records), followed by *S. tenerrimus* (24), *S. arvensis* (21), and *S. oleraceus* (14). The overwhelming concentration of VOCs in *S. maritimus* (Figure 5) represents a striking chemotaxonomic feature, suggesting specialized ecological adaptations possibly related to its coastal habitat but also differential intensity in the analyses among species.

Flavonoids constitute the second most prevalent class with 172 records (Figure 5), showing a markedly different distribution pattern. *S. arvensis* demonstrates exceptional flavonoid diversity (61 records), followed by *S. oleraceus* (52), with substantially lower but still significant numbers in *S. asper* (17), *S. tenerrimus* (6), *S. maritimus* subsp. *aquatilis* (6), and *S. asper* subsp. *glaucescens* (5). This distribution points to *S. arvensis* as being particularly rich in flavonoids but also establishes *S. oleraceus* as another major flavonoid-containing species.

Phenolic compounds (142 records) display an even more pronounced concentration in *S. oleraceus* (87 records) (Figure 5), distantly followed by *S. arvensis* (29) and *S. asper* (*11*). This dramatic predominance in *S. oleraceus,* in parallel with the minimal phenolic presence in other species, underscores *S. oleraceus'* distinctive phenolic profile.

Terpenoids, comprising 100 records, show a relatively balanced distribution across *S. oleraceus* (28), *S. arvensis* (25), *S. maritimus* (24), and *S. tenerrimus* (13), with *S. asper* (10) containing a moderate number. This substantial terpenoid presence is relevant, particularly given the ecological and pharmacological importance of terpenoids in the Asteraceae family.

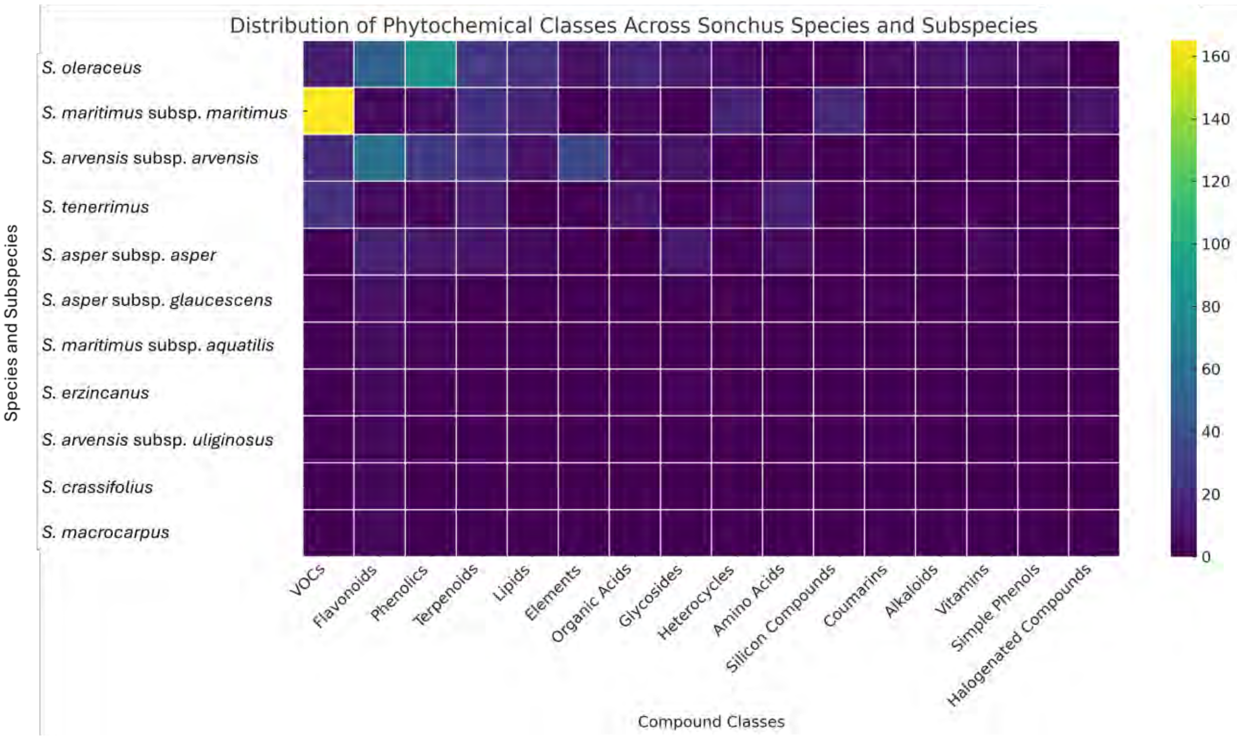

Figure 5. Heatmap displaying the distribution of 16 major phytochemical compound classes across selected *Sonchus* species and subspecies. The data represent the presence and relative abundance (as count of reported compounds) for each class, including volatile organic compounds (VOCs), flavonoids, phenolics, terpenoids, lipids, glycosides, alkaloids, and others. Notably, species such as *S. oleraceus* and *S. maritimus* exhibit high phytochemical diversity, while other taxa show limited chemical representation based on the published literature. Data from Supplementary Table S6.

The lipid profile (56 records) reveals concentrations in *S. oleraceus* (24) and *S. maritimus* (18), with modest representation in *S. arvensis* (9) and *S. asper* (5). Elements (44 records) demonstrate an overwhelming concentration in *S. arvensis* (36), with the remainder found in *S. oleraceus* (8), highlighting the lack of a systematic analysis of elements along the entire genus.

Organic acids (40 records) and glycosides (40 records) show distinctive distribution patterns. Organic acids appear predominantly in *S. oleraceus* (18) and *S. tenerrimus* (10), with modest presence in *S. arvensis* (7) and *S. maritimus* (5). Glycosides concentrate in *S. oleraceus* (13), *S. asper* (12), and *S. arvensis* (10), with minimal representation elsewhere.

Several additional chemical classes reveal species-specific accumulation patterns. Heterocycles (29 records) appear concentrated in *S. maritimus* (18). Amino acids (27 records) show their highest concentration in *S. tenerrimus* (16). Silicon compounds (22 records) demonstrate a striking concentration in *S. maritimus* (20) and are most likely artifacts of the analysis. Coumarins (16 records) appear most abundant in *S. oleraceus* (6). Alkaloids (14 records) and vitamins (13 records) both concentrate in *S. oleraceus* (10 and 8, respectively). Simple phenols (11 records), likewise, demonstrate the highest representation in *S. oleraceus* (7).

The comprehensive dataset reveals distinct chemotaxonomic patterns that substantially revise previous interpretations.

S. maritimus emerges as remarkably VOC-rich and the primary reservoir within the genus, suggesting specialized adaptations possibly related to its wetland/coastal habitat, but this requires further confirmation.

S. arvensis maintains its status as flavonoid-rich but also demonstrates exceptional elemental accumulation capacity, suggesting distinctive nutritional strategies.

S. oleraceus reinforces its phenomenal phenolic diversity while additionally revealing substantial flavonoid, terpenoid, lipid, organic acid, alkaloid, and vitamin content, establishing it as perhaps the most phytochemically diverse but also the most widely analyzed (Figures 5 and 6) *Sonchus* species.

S. tenerrimus demonstrates a distinctive amino acid profile alongside significant terpenoid and organic acid content, suggesting unique biosynthetic pathways.

S. asper exhibits moderate diversity across flavonoids, phenolics, terpenoids, and glycosides but lacks the pronounced chemical specialization observed in other species.

The subspecies, including *S. arvensis* subsp. *uliginosus*, *S. maritimus* subsp. *aquatilis*, and *S. asper* subsp. *glaucescens*, show markedly reduced chemical diversity compared to their parent species, though this may partially reflect research bias rather than biological reality.

Figure 6 addresses compounds reported in at least five samples within the genus, representing only a fraction of the approximately 580 different compounds identified across all samples. The chemical constituents can be categorized into seven primary classes: flavonoids, phenolic acids, coumarins, simple phenolics, other organic acids, carbohydrates, and minerals or elements.

The notable absence of volatile organic compound (VOC) representatives in Figure 6 appears inconsistent with their apparent significance in *Sonchus*, as indicated in Figure 5. Analysis of Supplementary Table S6 reveals that while VOCs are reported with high frequency, they occur in fewer than five individual cases. This discrepancy necessitates consideration of two critical factors in future investigations: first, whether the observed high diversity of VOCs reflects genuine genetic and environmental variability within the genus, or second, whether this diversity may be partially attributable to methodological artifacts inherent in the analytical approaches employed.

Flavonoids that constitute a predominant class within *Sonchus* species (Figure 5) are represented by compounds such as luteolin derivatives, apigenin derivatives, quercetin, and rutin, differentially distributed across taxa. Notably, *Sonchus arvensis* demonstrates exceptional flavonoid diversity, particularly with respect to luteolin (seven refs), apigenin (five refs), and is the sole species with significant quercetin and rutin presence in this high-frequency dataset (Figure 6). This distinctive flavonoid profile suggests potential species-specific biosynthetic pathways or ecological adaptations. *Sonchus oleraceus* similarly exhibits substantial flavonoid diversity, though with a different compositional pattern than *S. arvensis*.

Phenolic acids represent another significant chemical class in *Sonchus* (Figure 5), with caffeic acid, chlorogenic acid, gallic acid, chicoric acid, and ferulic acid being the most frequently detected compounds (Figure 6). *S. oleraceus* demonstrates remarkable accumulation of these compounds, containing the highest observed frequencies of caffeic acid (five), chlorogenic acid (six), and gallic acid (six). This extraordinary phenolic acid frequency in *S. oleraceus* suggests enhanced antioxidant defense mechanisms, potentially reflecting evolutionary adaptations to specific environmental stressors or herbivory pressures. The absence or minimal presence of these compounds in species such as *S. erzincanicus*, *S. crassifolius*, and *S. macrocarpus* could further highlight the taxonomic significance of phenolic acid distribution patterns or the lack of exhaustive analysis for these species.

Compound and Chemical Class / Taxa	*S. arvensis* subsp. *arvensis*	*S. arvensis* subsp. *uliginosus*	*S. asper* subsp. *asper*	*S. asper* subsp. *glaucescens*	*S. crassifolius*	*S. erzincanicus*	*S. macrocarpus*	*S. maritimus* subsp. *maritimus*	*S. oleraceus*	*S. tenerrimus*	*S. maritimus* subsp. *aquatilis*
Flavonoids											
Luteolin 7-O-glucoside	2	1	2	1	1	0	1	1	2	2	1
Apigenin 7-O-glucuronide	3	1	0	1	1	1	1	1	2	1	0
Luteolin	7	0	0	0	0	0	0	0	1	1	1
Luteolin 7-O-glucuronide	2	1	0	1	1	1	1	1	2	1	0
Apigenin	5	0	1	0	0	0	0	0	2	0	1
Luteolin 7-O-glucosylglucuronide	0	1	0	1	1	0	1	1	1	1	0
Apigenin 7-O-glucoside	1	0	2	1	0	0	0	0	1	0	1
Quercetin	4	0	0	0	0	0	0	0	0	0	1
Rutin	4	0	0	0	0	0	0	0	1	0	0
Phenolic Acids											
Caffeic acid	3	0	1	1	0	0	0	0	5	1	1
Chlorogenic acid	1	0	2	1	0	0	0	0	6	1	1
Gallic acid	0	0	0	0	0	0	0	0	6	0	0
Chicoric acid	2	0	1	0	0	0	0	0	2	0	0
Ferulic acid	1	0	0	0	0	0	0	0	4	0	0
Coumarins											
Esculetin	2	1	1	2	1	0	1	1	0	0	0
Simple Phenolics											
Catechol	0	0	0	0	0	0	0	0	5	0	0
Pyrogallol	0	0	0	0	0	0	0	0	5	0	0
Other Organic Acids											
Quinic acid	1	0	0	0	0	0	0	0	5	1	0
Azelaic acid	4	0	0	0	0	0	0	0	1	0	0
L-Ascorbic acid	0	0	1	0	0	0	0	0	3	1	0
Carbohydrates											
1-Butyl β-D-glucopyranoside	5	0	0	0	0	0	0	0	1	0	0
Minerals											
Calcium	4	0	0	0	0	0	0	0	1	0	0
Magnesium	4	0	0	0	0	0	0	0	1	0	0
Manganese	4	0	0	0	0	0	0	0	1	0	0
Phosphorus	4	0	0	0	0	0	0	0	1	0	0
Potassium	4	0	0	0	0	0	0	0	1	0	0
Sodium	4	0	0	0	0	0	0	0	1	0	0
Publications	8	1	5	2	1	1	1	2	11	4	1

Figure 6. Heatmap showing the frequency of the more commonly reported chemical compounds in different *Sonchus* taxa species. Numbers represent the frequency of reports in the scientific literature. Publications row (green) shows the total number of papers analyzed for each taxon. Low presence (1), medium presence (3–4), high presence (6+). It is important to note that among the 580 chemicals recorded in the revised literature from *Sonchus*, only those recorded 5 times or more are included. Generated using Excel.

The coumarin esculetin displays an interesting distribution pattern across the genus, being present in multiple species but conspicuously absent in *S. erzincanicus*, *S. oleraceus*, and *S. tenerrimus*. This differential distribution may serve as a valuable taxonomic marker and warrants further investigation regarding its ecological significance. Simple phenolics, specifically catechol and pyrogallol, appear exclusively concentrated in *S. oleraceus* (frequency of five for both compounds), further distinguishing this species' chemical profile.

Regarding other organic acids, quinic acid shows notable frequency in *S. oleraceus* (five), while azelaic acid appears predominantly in *S. arvensis* (four). L-ascorbic acid (vitamin C) demonstrates a more restricted distribution, with the highest frequencies in *S. oleraceus* (three). The carbohydrate 1-butyl β-D-glucopyranoside appears concentrated in *S. arvensis* (five), with limited presence elsewhere in the genus.

Mineral accumulation patterns reveal another dimension of chemotaxonomic differentiation, with calcium, magnesium, manganese, phosphorus, potassium, and sodium all showing significantly higher frequencies in *S. arvensis* (four for each) and modest presence in *S. oleraceus* (one for each). This mineral distribution pattern may reflect differential soil adaptation strategies or nutrient uptake mechanisms between species but also deficiencies in the systematic study of minerals along the different *Sonchus* species.

The sampling bias inherent in examining only compounds detected in five or more samples necessitates acknowledging significant limitations in this analysis. The complete phytochemical diversity of *Sonchus*, comprising approximately 580 compounds, likely includes numerous species-specific or rare compounds that could serve as important biomarkers or possess unique biological activities. Notably absent from this high-frequency dataset are compound classes typically abundant in Asteraceae, including terpenoids, sesquiterpene lactones, alkaloids, saponins, and essential oils, which might be represented in the broader dataset.

The chemical profiles observed provide valuable insights into taxonomic relationships within *Sonchus*. Subspecies, such as *S. arvensis* subsp. *uliginosus*, exhibit distinct chemical signatures from their parent species, lending phytochemical support to their taxonomic differentiation. Furthermore, the distribution of defensive compounds, particularly flavonoids and phenolics, likely reflects adaptation to varying ecological pressures across species' native ranges.

From an applied perspective, the distinctive phytochemical profiles suggest potential applications in natural product research. *S. oleraceus* demonstrates considerable promise for antioxidant applications due to its exceptional phenolic frequencies, while *S. arvensis* could be explored for flavonoid-related bioactivities. These unique chemical signatures could guide the strategic selection of Sonchus species for further phytopharmaceutical investigation.

This analysis, while necessarily constrained by the limited dataset of high-frequency compounds, provides valuable chemotaxonomic insights into *Sonchus*. A comprehensive analysis incorporating the full complement of 580 identified compounds would likely reveal additional species-specific patterns and potentially discover bioactive compounds of significant pharmacological interest. The current findings nonetheless establish a foundation for understanding the chemical ecology and potential applications of this diverse plant genus. The substantial discrepancies in compound numbers across species likely reflect, in great part, differences in research intensity rather than solely biological differences (Table 7, Figures 5 and 6). *S. oleraceus*, *S. arvensis*, *S. maritimus*, and *S. asper* appear to be most extensively investigated, while subspecies and less common species have received comparatively minimal phytochemical attention. This research bias must temper interpretations of apparent chemical absence in less-studied taxa.

8.1.3. Ecological and Pharmacological Implications

The revised chemical patterns suggest distinct ecological adaptations. *S. maritimus*' VOC and silicon-rich profile likely reflects adaptations to coastal/wetland environments, potentially functioning in salt tolerance or herbivore deterrence. *S. oleraceus*' exceptional phenolic and alkaloid diversity suggests strong selection for chemical defense against herbivores and pathogens, while *S. arvensis*' mineral accumulation capacity may represent an adaptation to nutrient-poor soils, but this could be expected in other *Sonchus* species.

From a pharmacological perspective, this comprehensive analysis highlights *S. oleraceus* as an outstanding candidate for broad-spectrum bioactivity investigation, with exceptional diversity across multiple bioactive compound classes. *S. maritimus* emerges as a potentially valuable source of novel VOC compounds, with possible applications in agricultural chemistry and materials science. *S. arvensis*, with its unique flavonoid and elemental profile, warrants investigation for nutritional applications.

8.2. Nutritional Value and Health Benefits

8.2.1. Macronutrient and Micronutrient Composition

Sonchus species are a good source of fiber, vitamins (A, C, and K), and minerals (calcium, magnesium, and iron), making them a nutrient-dense food [23].

The genus *Sonchus* comprises several species of unconventional food plants that have garnered attention for their potential nutritional value. Multiple studies have investigated the chemical composition of these species, particularly focusing on their application as alternative food sources for rural populations and their contribution to food security.

Nutritional analyses of *Sonchus* species employed standardized methodologies to ensure reliable and comparable results. Proximate composition analyses followed the protocols established by the Association of Official Analytical Chemists (AOAC), while mineral content determination utilized atomic emission spectrometry with inductively coupled plasma. High-Performance Liquid Chromatography (HPLC) has been the preferred method for quantifying carotenoids and vitamins, providing accurate measurements of these bioactive compounds [23,24,140].

The four primary *Sonchus* species studied (*S. oleraceus*, *S. asper*, *S. tenerrimus*, and *S. arvensis*) exhibit distinct macronutrient profiles. *S. asper* demonstrates superior lipid content (1.32 g/100 g) and available carbohydrate concentrations (0.34 g/100 g) compared to its congeners. Notably, all species maintain characteristically low proportions of available carbohydrates, a feature that may contribute to their potential dietary applications. Fiber content consistently exceeds 30 g/kg across all species, indicating substantial dietary fiber availability [23,140].

Vitamin C emerges as the most extensively studied and abundant vitamin component across *Sonchus* species. Concentrations range from 457 mg/kg in *S. tenerrimus* to 779 mg/kg in *S. oleraceus*, representing a 2-3-fold increase compared to conventional leafy vegetables such as lettuce [140]. These concentrations are nutritionally significant, as consumption of 142 g of *S. oleraceus* or 172 g of *S. tenerrimus* would satisfy the average daily recommended vitamin C requirements for women (75 mg). *S. arvensis* exhibits the highest vitamin E content (72.98 μg/100 g) and exceptional vitamin K concentrations (604.85 mg/100 g), distinguishing it from other species in the genus [24,140].

Carotenoid concentrations vary substantially among species, with *S. oleraceus* demonstrating the highest levels at 158 mg/kg fresh weight, while *S. asper* contains 5.58 mg/100 g total carotenoids. These compounds contribute to the antioxidant capacity of the plants and represent important provitamin A sources [140].

The mineral profiles of *Sonchus* species align with those of conventional green leafy vegetables, though specific concentrations vary among species. *S. asper* exhibits superior calcium content (96.25 mg/100 g), while *S. oleraceus* contains the highest iron concentrations (23.74 mg/100 g). Essential minerals, including sodium, potassium, magnesium, phosphorus, copper, zinc, and manganese, are present in nutritionally relevant quantities across all species [23,140].

The fatty acid composition of *Sonchus* species reveals notable concentrations of essential omega-3 fatty acids, with *S. oleraceus* containing the highest proportion (44.97%) of ω-3 series fatty acids. This characteristic enhances the nutritional value of these species, particularly considering the limited availability of plant-based omega-3 sources [140].

Studies conducted in different geographic regions, including southeastern Spain and the Brazilian Atlantic Forest, demonstrate the adaptability of *Sonchus* species to various environmental conditions while maintaining their nutritional integrity. This geographic distribution supports their potential as accessible food resources for diverse rural populations.

The comprehensive nutritional profile of *Sonchus* species, characterized by high concentrations of essential vitamins, minerals, fiber, and beneficial fatty acids, positions these plants as valuable contributors to dietary diversity and food security. Their widespread availability in rural environments, combined with their superior nutritional density compared to conventional vegetables, makes them particularly relevant for populations with limited access to commercial food sources.

The collective evidence supports the classification of *Sonchus* species as nutritionally valuable unconventional food plants. Their exceptional vitamin C content, substantial fiber levels, balanced mineral profiles, and presence of essential fatty acids demonstrate their potential for integration into human diets. The species-specific variations in nutritional composition suggest that different *Sonchus* species may serve complementary roles in addressing various nutritional requirements, thereby contributing to enhanced food security and dietary quality in rural communities.

8.2.2. Health Benefits Associated with Consumption of Sonchus

The *Sonchus* genus, comprising species such as *S. arvensis*, *S. oleraceus*, and *S. asper*, has been extensively studied for its diverse pharmacological properties. These plants are rich in bioactive compounds, including polyphenols, flavonoids, and terpenoids, which contribute to their antioxidant, anti-inflammatory, antidiabetic, hepatoprotective, and hypolipidemic effects [141,142]. These findings support the traditional use of these plants in folk medicine and highlight the potential of *Sonchus* species in preventing chronic diseases due to their bioactive compounds [59].

The antioxidant capacity of *Sonchus* species is primarily attributed to their high phenolic and flavonoid content, including kaempferol, quercetin, and rutin. Methanolic extracts of *S. arvensis* demonstrated potent free radical scavenging activity (420 $\pm$ 6.9 mg GAE/g total phenolics), with significant correlations between flavonoid content and antioxidant efficacy [141]. Similarly, *S. oleraceus* ethanolic extracts exhibited 43.46% DPPH radical inhibition, while *S. asper* extracts from discarded leaves showed stronger antioxidant activity than edible parts, suggesting potential applications in nutraceutical formulations [121,137]. These properties mitigate oxidative stress, reducing cellular damage linked to chronic diseases such as diabetes, cancer, and atherosclerosis [143].

Anti-Inflammatory Effects: *Sonchus oleraceus* aqueous extract has been shown to suppress pro-inflammatory cytokines (TNF-α, IL-6) by inhibiting TLR-4, NF-κB, and COX-2 pathways in LPS-stimulated macrophages [61,144]. In vivo studies confirmed its efficacy, with doses of 125–250 mg/kg significantly reducing ear edema in mice without adverse effects. HPLC-MS analysis identified villosol, ferulic acid, and ursolic acid as key anti-inflammatory constituents [61,144]. These findings suggest therapeutic potential for inflammatory conditions such as arthritis and inflammatory bowel disease.

Antidiabetic and Antiglycation Activity: *Sonchus* extracts exhibit notable α-glucosidase and α-amylase inhibitory effects, modulating postprandial glucose absorption [143]. In diabetic rats, *S. oleraceus* extract (200–300 mg/kg) reduced blood glucose, LDL cholesterol, and improved pancreatic histology, comparable to glibenclamide [142]. Additionally, antiglycation properties were observed, with extracts preventing advanced glycation end-products (AGEs) and preserving protein thiols, indicating protective effects against diabetic complications [143].

Hepatoprotective and Hypolipidemic Effects: *S. asper* has traditionally been used for liver detoxification, with studies demonstrating its ability to reduce hepatotoxicity markers (AST, ALT) and lipid peroxidation in CCl4-induced liver injury models [145]. Furthermore, *S. oleraceus* extract significantly lowered total cholesterol and LDL while increasing HDL in hyperlipidemic rats, supporting its role in managing metabolic disorders [142].

Anti-Inflammatory and Gastroprotective Effects: Preclinical studies confirm the anti-inflammatory and gastroprotective properties of *Sonchus oleraceus* hydroalcoholic extracts (SoHE). In rat models, oral SoHE (100–300 mg/kg) reduced carrageenan-induced paw edema, inhibited leukocyte migration, and attenuated lipopolysaccharide-induced fever [146]. SoHE also suppressed cotton pellet-induced granuloma formation, confirming chronic anti-inflammatory activity.

Gastroprotective mechanisms involve multiple pathways. SoHE (30–300 mg/kg) reduced ethanol-induced gastric ulceration by 71.5–76.2% while increasing mucin production up to 477.5% [147]. These effects resulted from enhanced antioxidant defenses (elevated glutathione, superoxide dismutase, catalase, and glutathione-S-transferase), reduced myeloperoxidase activity and TNF levels, and inhibited gastric acid secretion and pepsin activity. Phytochemical analysis identified luteolin-7-O-β-D-glucoside as a key bioactive constituent with notable free radical scavenging capacity (IC_{50} = 15.41 μg/mL against DPPH). These findings support *S. oleraceus* as a therapeutic candidate for inflammatory and gastrointestinal disorders.

The pharmacological potential of *Sonchus* species is well-supported by in vitro and in vivo evidence, highlighting their antioxidant, anti-inflammatory, antidiabetic, and hepatoprotective properties. Their rich phytochemical profile and nutritional value position them as promising candidates for functional foods and therapeutic applications.

9. Ecological and Habitat Analysis

9.1. Habitat Preferences of Sonchus Species

9.1.1. Natural Habitats: Rocky Outcrops, Wetlands, Springs, etc.

Sonchus species exhibit diverse habitat preferences, including rocky outcrops, wetlands, and springs (Table 8). Understanding these natural habitats is crucial for conservation efforts and potential cultivation strategies [25].

Table 8. Habitat types and ecological distribution of *Sonchus* species across Mediterranean environments.

Taxa	Habitat	Ref.
	Rocky habitat	
S. briquetianus	Coastal rocks and cliffs	[8]
S. bulbosus subsp. *microcephalus*	Rocky habitats	[8]
S. fragilis	Rocky, sometimes nitrified walls	[8,148,149]
S. masguindalii	Coastal calcareous rocks	[8,148,149]
S. pustulatus	Cliffs with a steep slope	[8,148,149]
S. suberosus	Limestone rocky slopes	[150]
S. tenerrimus subsp. *amicus*	Rheolitic volcanic rocks	[151]
S. tenerrimus subsp. *dianae*	Cliffs near the sea	[151]
S. tenerrimus subsp. *halodianae*	Coastal cliffs and coastal sands	[151]
S. tenerrimus subsp. *polypodioides*	Steep limestone rocks	[151]
	Scree slopes	
S. bulbosus subsp. *willkomii*	Carbonate screes and scrub on stony soils	[152]
	Wet soils and wetlands	
S. macrocarpus	Moist ground, Nile, and canal banks	[8]
S. maculigerus	Meadows on wet soils	
S. maritimus subsp. *aquatilis*	Wet grasslands on the banks of freshwater streams	[8]
S. mauritanicus	Natural and artificial wetlands	[8]
	Sandy soils	
S. bulbosus subsp. *bulbosus*	Sandy shores, occasionally on roadsides and embankments	[152]
	Salinized habitats	

Table 8. *Cont.*

Taxa	Habitat	Ref.
S. crassifolius	Salt marshes and grasslands on saline soils, as well as the margins of brackish streams and lagoons	[8]
S. erzincanicus	Halophytic grasslands and reedbeds	[37,153]
S. maritimus subsp. *maritimus*	Salt steppes and reed beds	[8]
	Anthropized habitats	
S. arvensis subsp. *arvensis*	Crops, gardens, parks, roadsides, and other anthropized areas	[8]
S. arvensis subsp. *uliginosus*	Crops, gardens, parks, roadsides, and other anthropized areas	[8]
S. asper	Crops, gardens, parks, roadsides, and other anthropized areas	[8]
S. microcephalus	Crops, gardens, parks, roadsides, and other anthropized areas	[154]
S. oleraceus	Crops, gardens, parks, roadsides, and other anthropized areas	[8]
S. tenerrimus subsp. *tenerrimus*	Crops, roadsides, walls, palm trunks, and other anthropized areas	[8]

Abbreviations: Ref., references.

The *Sonchus* taxa exhibits a clear dichotomy in habitat preference, with distinct ecological niches separating natural and anthropic environments (Table 8, Figure 7). A quantitative assessment reveals that out of the 21 entries, 15 taxa (approximately 71%) are associated with natural habitats, while 6 taxa (29%) predominantly occupy anthropized areas. This distribution underscores the genus's ecological versatility, with a majority of species adapted to undisturbed ecosystems, while a smaller subset thrives in human-modified landscapes.

Figure 7. *Sonchus* habitats. (**A**) Sand dunes, *S. bulbosus*, Mar Menor, Murcia (Spain); (**B**) anthropized, *S. tenerrimus* subsp. *tenerrimus*, Saccargia, Sardinia (Italy); (**C**) coastal cliff, *S. tenerrimus* subsp. *halodianae*, San Antonio, Alicante (Spain); (**D**) grassland in the park La Benamá, *S. tenerrimus*, Albalat de la Ribera, Valencia (Spain); (**E**) anthropized, crack at the edge of an asphalt parking lot, next to a wall, *S. asper,* Saccargia, Sardinia (Italy); (**F**) coastal cliff, *S. pustulatus*, San Telmo, Almería (Spain); (**G**) anthropized wet habitats of Albufera, *S. oleraceus*, Catarroja, Valencia (Spain); (**H**) anthropized, *S. tenerrimus* subsp. *tenerrimus*, in a street of Cagliari, Sardinia (Spain); (**I**) grassland on saline soil, *S. oleraceus*, Nora archeological park, Sardinia (Italy). Images: (**A**) Antonio Robledo, with permission; (**B**,**E**,**H**,**I**) Diego Rivera; (**C**) Francisco Alcaraz; (**F**) Estefania Mico, with permission; (**D**,**G**) Emilio Laguna, with permission.

Natural habitats are further divisible into three primary categories: rocky or coastal environments (Figure 7), wetlands, and saline or halophytic ecosystems. Rocky and coastal habitats are the most prevalent, hosting nine taxa, including *Sonchus briquetianus*, *S. bulbosus* subsp. *microcephalus*, and *S. tenerrimus* subsp. *dianae*. These species demonstrate adaptations to xeric conditions, steep slopes, and mineral-rich substrates, suggesting a specialization in low-competition, high-stress environments. Wetland-affiliated taxa, such as *Sonchus macrocarpus*, *S. maritimus* subsp. *aquatilis*, and *S. mauritanicus*, occupy hydric soils along riverbanks, canals, and marshes, indicating a tolerance for waterlogged conditions. Halophytic species, including *Sonchus crassifolius* and *S. maritimus* subsp. *maritimus*, are restricted to saline grasslands and brackish wetlands, reflecting niche specialization in high-salinity environments.

9.1.2. Anthropized Environments: Cultivated Fields, Roadside Verges, Urban Landscapes

Anthropic habitats are dominated by ruderal species such as *Sonchus asper*, *S. oleraceus*, and *S. arvensis* subsp. *arvensis*, which colonize disturbed areas, including croplands, roadsides, and urban spaces. These taxa exhibit broad ecological amplitudes, enabling them to exploit nutrient-rich, frequently disturbed soils [25,26]. The presence of multiple subspecies in both natural and anthropized settings (e.g., *Sonchus tenerrimus* subsp. *tenerrimus* in anthropogenic areas versus subsp. *amicus* in volcanic rocks) suggests that certain lineages within the genus have diverged to occupy contrasting ecological niches [151].

9.2. Role in Ecosystem Services

Sonchus species play important roles in ecosystem services, contributing to biodiversity, soil health, and pollinator support. Their presence in various habitats underscores their ecological significance (Table 8 and Figure 7).

The *Sonchus* genus contributes variably to ecosystem services depending on habitat specialization. Species occupying natural habitats play critical roles in erosion control, particularly those colonizing rocky slopes and coastal cliffs, where root systems stabilize loose substrates. Wetland-associated taxa contribute to water filtration and flood mitigation by reinforcing riparian vegetation structure. Halophytic species, such as *Sonchus crassifolius*, enhance soil formation in saline environments while providing forage for specialized fauna.

Anthropic-adapted *Sonchus* species, though often regarded as weeds, contribute to provisional and regulatory services. Their rapid colonization of disturbed soils aids in early succession, preventing further degradation. Some, like *Sonchus oleraceus*, serve as food sources for pollinators, while others may contribute to nutrient cycling in agroecosystems. However, their presence in cultivated areas may also entail disservices, such as competition with crops. Overall, the genus demonstrates a dual role across ecosystems, with natural-habitat species supporting stability and resilience, while anthropic taxa influence urban and agricultural ecological dynamics. The potential contributions of *Sonchus* species to food security and sustainable agriculture warrant further investigation. Their adaptability to various environments and nutritional value makes them promising candidates for addressing global food challenges. Furthermore, *Sonchus* species that have adapted to anthropogenic habitats may be incorporated into seed mixtures of wild greens sown in organically cultivated Mediterranean systems, such as olive and almond orchards, vineyards, and other agroforestry settings. When young, these plants provide a valuable yield of tender, edible leaves, serve as fodder for livestock, and later contribute to soil fertility as green manure. These were named “crypto crops” [155].

10. Cultivation and Commercialization

10.1. Agronomic Performance and Cultivation Requirements

Sonchus plants have shown remarkable adaptability to anthropized environments, often thriving in cultivated fields, along roadside verges, and in urban landscapes. This adaptability contributes to their widespread distribution and potential for sustainable harvesting [156,157].

Scientific research on cultivating *Sonchus* species has generated substantial insights into their agronomic potential, nutritional characteristics, and commercial viability as domesticated crops. These investigations have established a foundation for understanding both the opportunities and challenges associated with transitioning these wild edible plants into cultivated food systems [14,24,158].

Recent studies have demonstrated that *Sonchus* species, particularly *S. oleraceus* and *S. arvensis*, exhibit considerable adaptability to various cultivation conditions. Research conducted in Greece revealed that *S. oleraceus* displays moderate tolerance to salinity stress, maintaining growth performance under irrigation water containing 40–60 mM NaCl concentrations [159]. While high salinity levels adversely affected plant growth, the species showed promise for cultivation in regions where irrigation water quality is compromised, though the health implications of consuming salt-stressed plants require further investigation.

Fertilization studies have indicated that organic fertilization approaches, particularly those utilizing vinasse-based fertilizers, can achieve comparable results to conventional fertilization methods in promoting growth characteristics and nutrient accumulation [160]. Organic fertilization treatments produced the highest plant height in common sow thistle, while combination treatments of conventional fertilizers with side-dressing applications resulted in leaf number increases of up to 41.6% compared to conventional fertilization alone. Notably, organic fertilization enhanced dry matter content by up to 20.9% relative to other treatments, suggesting potential benefits for crop quality.

Hydroponic cultivation systems have shown particular promise for *Sonchus* production. Research by [161] demonstrated that sow thistle can be successfully cultivated in soilless systems, with optimal nitrogen supply concentrations of 100–200 mg L^{-1} promoting both plant growth and nutritional quality. These intermediate nitrogen concentrations enhanced plant defense mechanisms against oxidative stress while achieving high agronomic efficiency and irrigation water productivity.

10.2. Challenges and Solutions in Domesticating Wild Sonchus Species

Cultivation significantly influences the nutritional profile of *Sonchus* species compared to their wild counterparts. Botella et al. [24] found that cultivated *S. oleraceus* exhibited reduced phenolic compound concentrations but increased vitamin C content relative to wild-harvested plants. Similarly, cultivation of *S. tenerrimus* enhanced concentrations of sugars, organic acids, and β-carotene, which are compounds with important nutritional and health-promoting properties. These compositional changes suggest that cultivation practices can be optimized to enhance specific nutritional attributes depending on intended applications.

Domestication efforts face challenges, such as variability in seed germination and susceptibility to pests [24,25].

The transition from wild harvesting to controlled cultivation presents several technical challenges that require systematic solutions. Seed germination represents a primary obstacle, with field germination rates significantly lower than those in laboratory conditions. Botella et al. [24] reported field germination rates of 49.9% for *S. oleraceus* and only 17.8% for *S. tenerrimus*, compared to laboratory rates of 75.8% and 82.1%, respectively. To address this inconsistency, researchers have developed pre-germination protocols using Petri dishes, followed by seedbed transplantation during autumn–winter cycles to achieve greater uniformity in cultivation trials.

Comparative germination studies have revealed species-specific adaptations that influence cultivation success. Lee et al. [25]. demonstrated that *S. asper* exhibits superior tolerance to environmental stresses compared to *S. oleraceus*, including better performance under low temperatures, drought conditions, and soil burial. These findings have important implications for species selection and cultivation system design.

The rapid maturation characteristics of *Sonchus* species present both opportunities and challenges for sustained production. While quick growth cycles enable multiple harvests, they also limit the collection period for optimal young leaves and aerial parts [162]. Additionally, the weedy nature of these species and their potential for developing herbicide resistance, as documented in glyphosate-resistant populations of *S. oleraceus* in New South Wales [163], requires careful management strategies to prevent unwanted spread.

10.3. Commercial Cultivation

Although large-scale commercial cultivation of *Sonchus* species remains limited, growing interest in functional foods and sustainable agriculture has created market opportunities for these nutrient-dense plants [24,164].

Small-scale cultivation trials across various regions, including Cyprus and other Mediterranean regions and Brazil, have demonstrated the feasibility of incorporating *Sonchus* species into organic farming systems [160]. These initiatives suggest that with appropriate cultivation protocols, *Sonchus* species can be successfully integrated into commercial agricultural operations.

The market appeal of *Sonchus* species stems from their exceptional nutritional profile, including high concentrations of carotenoids, phenolic compounds, and antioxidants, which align with consumer demand for functional foods [24]. Their culinary versatility and sensory acceptability further enhance their commercial potential, particularly in haute cuisine and health-focused market segments.

Sustainability considerations provide additional market advantages, as organic cultivation methods have proven effective for *Sonchus* production, aligning with eco-conscious consumer preferences [161]. However, achieving commercial scalability requires addressing challenges related to germination consistency and yield stability across diverse growing conditions.

Beyond food applications, *Sonchus masguindalii* has been identified as a candidate for ornamental use in Morocco, reflecting broader biodiversity valorization efforts [165]. However, economic feasibility hinges on addressing gaps in supply chain development and consumer awareness.

11. Future Prospects and Research Directions

11.1. Opportunities for Horticultural Development

Scientific research has established that *Sonchus* species (e.g., *S. oleraceus, S. asper, S. arvensis*) possess significant potential as cultivated crops due to their adaptability to diverse agricultural systems and high nutritional value. Studies demonstrate their resilience in varied climates, from Mediterranean regions to subtropical zones, with *S. asper* showing superior drought tolerance and *S. oleraceus* thriving in disturbed soils. Their nutritional profiles—rich in vitamins (A, C, E, K), minerals (iron, calcium), and antioxidants—position them as functional foods, with *S. arvensis* containing notably high vitamin K (604.85 mg/100 g) and *S. oleraceus* providing iron (23.74 mg/100 g) [23–25].

While challenges such as rapid maturation, seed germination variability (e.g., light-dependent germination in *S. oleraceus*), and compositional fluctuations under cultivation persist, targeted agronomic strategies can mitigate these issues. For instance, cultivation trials of *S. oleraceus* and *S. tenerrimus* in Mediterranean climates revealed that controlled environments enhance vitamin C content, though phenolic compounds may decrease. Future research should prioritize standardized cultivation protocols, nutritional optimization, and sustainability assessments.

11.2. Areas for Further Research

Standardized cultivation protocols should focus on optimizing planting density, irrigation, and soil management to balance yield and nutrient retention [24,162]. Nutritional optimization should investigate fertilization regimes to enhance bioactive compounds (e.g., carotenoids, polyphenols) [23,126]. Sustainability assessments should evaluate long-term impacts on soil health and ecosystem biodiversity in agroecological systems [156].

Breeding programs could further enhance commercial viability by selecting traits like delayed bolting (*S. oleraceus* matures in 60–90 days), improved pest resistance, and uniformity in leaf morphology [25]. Integration into agroecological systems—such as intercropping with grains—could reduce herbicide reliance, as *Sonchus* competes effectively with weeds but is suppressed by competitive crops like barley [156].

Despite growing interest, critical knowledge gaps remain. Phytochemical variability, including compositional differences between wild and cultivated populations, is poorly documented. For example, cultivated *S. oleraceus* shows reduced phenolics but higher sugars compared to wild counterparts [21,120]. Germination ecology studies indicate that *S. asper* outperforms *S. oleraceus* under stress (e.g., salinity up to 40 mM NaCl, osmotic potential of -0.4 MPa), suggesting species-specific cultivation niches [25].

Socioeconomic barriers, such as farmer adoption and consumer acceptance, require study, particularly in regions where *Sonchus* is traditionally foraged (e.g., Mediterranean, Brazil). Pilot projects could test marketability, as seen with *S. asper*'s use in gourmet dishes in Italy [23,126,166,167].

Digital ethnobotanical platforms such as CONECT-e represent a transformative advancement in the preservation and democratization of traditional ecological knowledge (TEK) [168]. These platforms function as vital repositories, safeguarding ancestral wisdom from irreversible erosion while fostering cross-cultural knowledge dissemination and scientific inquiry. The establishment of analogous collaborative databases in other regions would substantially bolster global initiatives aimed at documenting endangered traditional practices, particularly as elder knowledge custodians pass away and rural communities experience accelerated modernization.

Although several international efforts exist—including the traditional knowledge section of the Encyclopedia of Life and various regional databases across Europe and Latin America—few adopt CONECT-e's integrative wiki-based framework, which enables direct community contributions. EOL does not have a dedicated "Traditional Knowledge section" as a centralized feature, but it systematically incorporates TK where data exists, particularly through trait annotations and partnerships [169]. The extensive documentation of *Sonchus* species within CONECT-e, notably the 402 records for *S. oleraceus* [170] and 159 for *S. tenerrimus* [171], underscores the platform's efficacy in elucidating the depth of traditional use associated with even ostensibly common flora. Such data provide researchers with unparalleled access to geographically and culturally varied applications, offering valuable insights for ethnobotanical research and potential bioprospecting endeavors.

This robust corpus of crowdsourced information not only reaffirms the cultural importance of *Sonchus* species across Mediterranean societies but also establishes a foundation for systematic comparative analyses of traditional uses. Such analyses may reveal previously unrecorded applications while supporting evidence-based strategies for integrating TEK into contemporary sustainable agriculture and healthcare systems.

11.3. Broader Applications

Sonchus species have ethnomedicinal applications, including anti-inflammatory and antimicrobial properties attributed to sesquiterpene lactones and flavonoids [126,172]. Nanoformulations of *S. asper* extracts (e.g., liposome encapsulation) are being explored for enhanced bioavailability in nutraceuticals [126]. Industrial uses could include latex-derived biopolymers, though toxicity to livestock (e.g., lambs) necessitates caution [173].

Their adaptability to marginal lands and climate resilience make *Sonchus* species candidates for addressing food insecurity. In Brazil's Atlantic Forest, rural communities rely on wild *Sonchus* for nutrition, highlighting its role in food sovereignty [23].

High antioxidant levels (4× red wine) and essential fatty acids support *Sonchus*' use in health-promoting products. Clinical studies on hypoglycemic effects (e.g., GLP-1 modulation by *S. asper*) are nascent but promising.

11.4. Culinary Innovation

Chefs and food innovators are increasingly incorporating *Sonchus* into haute cuisine, experimenting with its flavors and textures in creative dishes. Chefs in avant-garde restaurants incorporate *Sonchus* into salads, soups, and functional foods (e.g., *S. oleraceus* as a bitter green in Mediterranean cuisine). Traditional dishes like *zuppa delle streghe* (Italy) and *Māori puha* (New Zealand) exemplify cultural integration [24].

The unique nutritional profile and flavor characteristics of *Sonchus* species present opportunities for their use in functional and gourmet foods. Ongoing research and culinary experimentation are exploring the potential of these plants as novel ingredients in the food industry. The nutritional profile of *Sonchus* species makes them a promising ingredient for functional foods aimed at promoting health and wellness [24,126].

The incorporation of various species from the genus *Sonchus* in modern cuisine in southern and southeastern Spain originates from traditional cooking, featuring dishes such as dry or brothy rice (typically using short-grain rice varieties like "Bomba" or "Bahía", *Oryza sativa* var. *japonica*, known for their high broth absorption capacity), omelets, *cocas*, and *minchos* (Spanish-style flatbreads with wild greens and herbs, similar to Italian pizza but without cheese).

Today, numerous restaurants utilize different species of sow thistles (e.g., *Sonchus oleraceus, S. tenerrimus, S. asper*) in these traditional recipes with varying degrees of innovation. Many of these dishes are documented by Ruiz in 2022 [174]. Additionally, new culinary creations can be found in the work of the amateur cook Orengo [175], such as the "*Quitxe de Llicsons amb alls tendres i anacardos*" (*Sonchus* tart with tender garlic and cashews) described by the author.

However, one of the most prolific chefs and educators in the use of wild plants is David Ariza, who currently manages Restaurante Rices & Bones in Alicante [176] (Figure 8). His culinary creations frequently incorporate *Sonchus* species in three main preparations.

Vegetable Broth: Ingredients include dried tomato (*Solanum lycopersicum* L.), wild rocket leaves (*Diplotaxis erucoides* (L.) DC.), dandelion (*Taraxacum* sect. *Taraxacum* F.H.Wigg.), sow thistles (*Sonchus oleraceus, S. tenerrimus*, and/or *S. asper*), hedge mustard (*Sisymbrium officinale* (L.) Scop. and related species), saffron (*Crocus sativus* L.), onions (*Allium cepa* L.), garlic (*Allium sativum* L.), carrot (*Daucus carota* L.), ginger (*Zingiber officinale* Roscoe), honey, and salt.

Figure 8. Creative modern recipes made with wild *Sonchus* and other wild greens as main ingredients: (**A**) Spanish rice with marinated weeds ("escabeche"); (**B**) marinated eggplant and weeds ("escabeche"); (**C**) marinated mullet fish with weeds ("escabeche"); (**D**) Spanish rice with fresh weeds. Images by David Ariza, Rest. Rices & Bones Alicante, with permission.

Fermented Weeds: A blend of wild rocket (*Diplotaxis erucoides*), hedge mustard (*Sisymbrium officinale* and related species), dandelion (*Taraxacum* sect. *Taraxacum* F.H.Wigg.), and sow thistles (*Sonchus oleraceus, S. tenerrimus*, and/or *S. asper*).

Stir-Fry: Comprising onion (*Allium cepa*), garlic (*Allium sativum*), saffron (*Crocus sativus*), dandelion (*Taraxacum* gr. *officinale*), tomato (*Solanum lycopersicum*), and sow thistles (*Sonchus oleraceus*, *S. tenerrimus*, and/or *S. asper*).

12. Conclusions

The comprehensive examination of *Sonchus* species across botanical, phytochemical, and agricultural dimensions reveals both significant potential and critical research needs. The key findings from each section demonstrate that while these species possess notable nutritional and bioactive properties, substantial gaps remain in our understanding of their phytochemical composition, optimal cultivation methods, and commercial viability. By bridging the gap between botanical and chemical rigor, future studies can not only elevate the quality of *Sonchus* phytochemical research but also serve as a model for interdisciplinary standardization in ethnopharmacology and natural product chemistry.

The potential of *Sonchus* species as novel crops extends beyond traditional food applications, encompassing medicinal and industrial uses that could unlock new economic opportunities. Future research directions should prioritize breeding programs aimed at optimizing yield, enhancing pest resistance, and improving nutritional value to develop cultivars better suited for commercial production. The integration of these species into agroecological systems presents particularly promising opportunities for sustainable agriculture and biodiversity conservation, potentially contributing to more resilient and diverse farming practices that align with contemporary environmental priorities.

However, realizing this potential requires addressing several critical knowledge gaps and inherent challenges. Despite growing scientific interest, our understanding of optimal cultivation methods remains limited, hindering the transition from wild harvesting to systematic agricultural production. The weedy nature of many *Sonchus* species presents a particular challenge for domestication efforts, as their aggressive growth habits and dispersal mechanisms could pose risks in agricultural settings if not properly managed through careful breeding and cultivation protocols. Moreover, the variability in phytochemical profiles across different *Sonchus* species and growing conditions necessitates standardized analytical approaches to ensure consistent quality and efficacy of derived products. Socioeconomic research examining farmer adoption patterns and consumer acceptance is equally essential for assessing commercial viability and informing market development strategies.

The path forward demands multidisciplinary collaboration that combines expertise from agronomy, ethnobotany, food science, and policy development. Such interdisciplinary approaches should focus on optimizing cultivation practices while exploring diverse applications across food, pharmaceutical, and industrial sectors. Policy support mechanisms that incentivize *Sonchus* cultivation within broader agroecological programs, similar to existing EU wild plant initiatives, could provide the institutional framework necessary for scaling research efforts and commercial implementation. Only through this coordinated, multifaceted approach can the scientific community fully unlock the potential of *Sonchus* species as valuable contributors to sustainable agriculture and human nutrition.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/horticulturae11080893/s1, Table S1: Scoring rubric for *Sonchus* phytochemical literature review. Table S2: Ethnopharmacological and ethnobotanical *Sonchus* data in the Mediterranean. Table S3: Synthesis of traditional medicinal uses of *Sonchus* in the Mediterranean. Table S4: Synthesis of traditional medicinal uses of the different *Sonchus* species. Table S5: Traditional veterinary uses of *Sonchus*. Table S6: Phytochemical *Sonchus* data.

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