

Trends in scientific research in *Yucca* spp.

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ABSTRACT

Objective: To analyze the performance and trends of research on *Yucca* spp. at the international level through a bibliometric approach.

Design/methodology/approach: Publications indexed in SCIE, SSCI, and ESCI (1904-2024) were analyzed using unidimensional and multidimensional bibliometric indicators, as well as network visualization tools to evaluate literature growth, author collaboration, and thematic evolution.

Results: A total of 1,266 documents were retrieved, showing sustained growth with a significant increase in the last five years. Collaboration networks with influential authors were identified, along with five main research lines: ecology and evolution, ruminal fermentation, steroidal saponins, metabolite biosynthesis, and applications in sustainable materials.

Limitations on study/implications: The analysis was limited to documents indexed in SCIE, SSCI, and ESCI, which may exclude relevant research published in other databases or non-indexed sources.

Findings/conclusions: The study reveals a transition from taxonomic and ecological research toward applications in biotechnology and materials science. Bibliometric analysis proves useful for identifying emerging trends and priority areas, contributing to the sustainable use of *Yucca* spp.

Keywords: *Yucca* sp., bibliometrics, scientific production, collaboration networks.

Citation: Martínez-Betancourt, S. R., Cadena-Iñiguez, J., Bravo-Vinaja, Á., Loera-Alvarado, G., Soto-Hernández, R. M., Ruiz-Vera, V. M., & López-Padilla, C. (2026). Trends in scientific research in *Yucca* spp. *Agro Productividad*. <https://doi.org/10.32854/v6ar8h59>

Editor: Jorge Cadena Iñiguez

Associate Editor: Dra. Lucero del Mar Ruiz Posadas

Guest Editor: Juan Francisco Aguirre Medina

Received: January 26, 2026.

Accepted: March 5, 2026.

Published on-line: April XX, 2026.

Agro Productividad, 19(3). March. 2026. pp: 303-XXX.

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INTRODUCTION

Low-income populations are concentrated primarily in rural areas, where they depend on activities related to agriculture, livestock farming, and the harvesting of non-timber forest resources (FAO, 2010). Although these resources constitute an important source of income, they are often marginalized in public policies and development strategies (Shackleton *et al.*, 2015), and the limited information on their chemical composition and biological assessment restricts their comprehensive use.



Non-timber forest resources have played a fundamental role in traditional medicine, food, and crafts, representing a significant source of economic sustenance in rural areas (Meinhold and Darr, 2019). In Mexico, semi-arid ecosystems cover 70.79 million hectares (Villavicencio-Gutiérrez *et al.*, 2020) and harbor species of high value, including the genus *Yucca* L., comprised of 40-50 species native to North and Central America (Hochstätter, 2004). Around 30 species are recorded in the country, of which 53% are endemic (García-Mendoza, 2004).

Yucca species have been historically used in the production of food, fibers, cosmetics, and medicines (Patel, 2012). Archaeological evidence documents their use in rope and textile making for over two thousand years (Pearlstein, 2008), as well as medicinal applications (Efferth, 2007). They are also recognized as sources of saponins and polyphenols with bioactive properties (Jiménez *et al.*, 2021). However, research has focused on a limited number of species and metabolites, leaving gaps in the comprehensive knowledge of the genus.

In this context, a bibliometric analysis of the scientific output on *Yucca* spp. indexed in SCIE, SSCI, and ESCI of the WoS Core Collection was conducted for the period 1904-2024, with the purpose of evaluating its growth, identifying the main institutions and thematic areas, and characterizing the documentary dynamics of the field.

MATERIALS AND METHODS

Data Collection

To compile the scientific literature on *Yucca* spp., the SCIE, SSCI, and ESCI databases of the WoS Core Collection were consulted, selected for their coverage of high-impact scientific journals and their usefulness in bibliometric studies. The search was conducted in July 2024, considering the title, abstract, and keyword fields, using the term “*Yucca*” and applying exclusion criteria to remove records not directly related to the genus. The document types selected were: Article, Letter, Note, and Early Access.

Initially, 809 documents were retrieved using the title search (TI=“*Yucca*”), which were then subjected to a manual cleaning process, excluding records associated with terms such as “*Yucca Mountain*,” “*Manihot esculenta*,” and “*Arabidopsis*,” among others. After this review, 652 relevant documents were obtained. Subsequently, a thematic search was conducted (TS=“*Yucca*”), yielding 627 records which, after cleaning, were reduced to 614 relevant documents.

This strategy allowed for the differentiation of documents that directly address the topic in the title from those where it appears secondarily in the abstract or keywords. The final records were reclassified by year of publication (1904-2024) and document type for the development of bibliometric indicators.

Statistical Processing

1,266 bibliographic records were retrieved from the Web of Science database (accessed July 31, 2024). The records were exported in RIS format and processed in Zotero for preliminary cleaning and organization, as well as in Microsoft Excel[®] 2010 for the calculation of initial descriptive indicators.

Subsequently, the complete records, including cited references, were exported in plain text format and analyzed using the Bibliometrix package to generate unidimensional and multidimensional bibliometric indicators. The unidimensional indicators evaluated included: growth in scientific output, document type, language of publication, most productive authors, and countries with the highest number of publications.

Regarding multidimensional indicators, the concentration and dispersion of the literature were analyzed by applying Bradford's Law proposed by Samuel C. Bradford (1934), as well as the productivity of authors by country, the thematic evolution and the relationship between authors and lines of research based on Keyword Plus.

The construction of collaborative networks between authors and countries, citation analysis between journals, co-citation, and keyword co-occurrence were performed using VOSviewer (v.1.6.18), generating bibliometric maps and clusters to visualize structural patterns and thematic trends.

The variables analyzed included number of articles, year of publication, authors per document, citations per article and per author, document type, and collaborative networks. Finally, abstracts and, when necessary, full texts were reviewed to validate the thematic relevance of the 1,266 documents included in the study.

RESULTS AND DISCUSSION

Growth of the literature (1904-2024)

The analysis of the period 1904-2024 (120 years) showed sustained growth in scientific production on *Yucca* spp., with a positive trend supported by a coefficient of determination $R^2=0.6964$. During the first third of the period (1904-1944), production was incipient, with fewer than five documents per year. Between 1945 and 1984, a period of moderate expansion was observed, with averages of between 5 and 15 publications per year. From 1985 onward, growth accelerated, with between 15 and 55 documents per year recorded in most years (Figure 1).

Similar to what Urbizagástegui Alvarado (2016) noted in his analysis of Bradford's Law, the sustained growth of scientific production has also been documented in *Dactylopius coccus* (Bravo-Vinaja and Méndez-Gallegos, 2022). As with *Yucca* spp., research on this species has

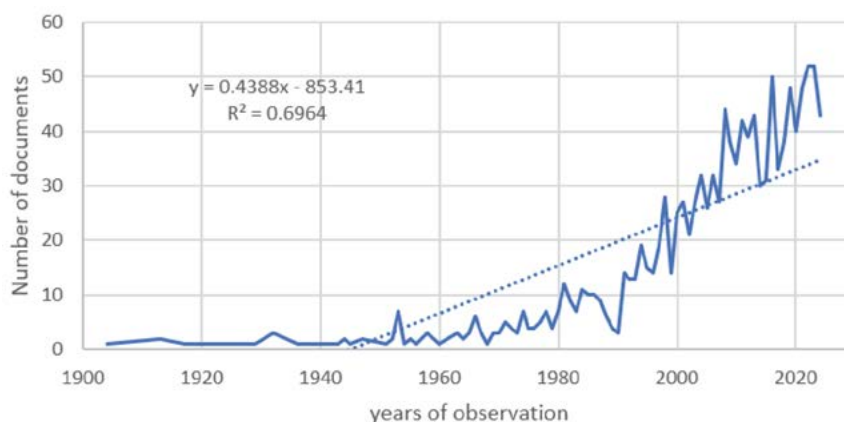


Figure 1. Growth of literature (1904-2024) on *Yucca* spp.

experienced progressive expansion in recent decades, associated with the growing interest in sustainability, agro-industry, and the biology of organisms with economic and ecological relevance. This trend confirms the growth patterns described in bibliometric studies applied to plant resources and species of productive interest. Regarding document type, research articles constitute the predominant form of scientific communication (94.3%), while early access documents represent only 0.23% of the total (Table 1).

Documents in which the search term appeared in the title represented 51.5% of the total, while the remaining 48.5% were located in the abstract and keywords. This distribution indicates that more than half of the publications explicitly address *Yucca* spp. as the central focus of the study, suggesting a high degree of thematic specificity.

Regarding document type, the results show a trend consistent with previous bibliometric studies. Urbizagástegui Alvarado (2016) reports that scientific articles constitute 86% of the publications analyzed under Bradford's Law, while Bravo-Vinaja and Méndez-Gallegos (2022) identify a proportion of 95.3% in the literature on *Dactylopius coccus*. Similarly, in the case of *Yucca* spp., journal articles emerge as the predominant format. This pattern confirms the central role of the scientific article as the main vehicle for communicating peer-validated knowledge, favoring its visibility, circulation, and impact in the academic community.

Publication language

Regarding the language of publication, English was the predominant language in the scientific production on *Yucca* spp., representing 95.5% of the total documents analyzed. In contrast, publications in German, Hungarian, Turkish, Czech, Indonesian, Lithuanian, and Polish each accounted for less than 2% (Table 2).

This marked hegemony of English demonstrates its consolidation as the lingua franca of international scientific communication, even in a field of study primarily associated with Latin American regions. The predominance of this language favors the global visibility of the results, but also reflects the editorial dynamics of journals indexed in international databases.

The analysis of scientific production on *Yucca* spp. reveals a pattern consistent with previous studies regarding the language of publication. Similar to the findings reported by Urbizagástegui Alvarado (2016), who identified that 86% of documents related to Bradford's Law are published in English, and to those noted by Bravo-Vinaja and Méndez-Gallegos

Table 1. Types of documents obtained from SCIE, SSCI and ESCI (first 20) with the most published documents (1904-2024) on *Yucca* spp.

Types of documents	Total	%
Scientific article	1195	94.39
Note	29	2.29
Letter	20	1.58
Brief article	19	1.50
Early access	3	0.23
Total	1266	100

Table 2. Publication languages of documents on *Yucca* spp., published (1904-2024) in journals.

Languages	Documents	%
English	1209	95.50
Spanish	21	1.66
Russian	14	1.11
Japanese	5	0.40
Portuguese	4	0.31
French	3	0.23
7 languages with fewer than 3 publications	10	0.78
Total	1266	100

(2022), who found that 92.7% of the literature on *Dactylopius coccus* is in English, the present study shows that 95.5% of articles on *Yucca* spp. are also published in English. This high proportion confirms the consolidation of English as the lingua franca of international scientific communication. Its predominance not only facilitates the dissemination and visibility of findings within the global academic community but also reflects the editorial dynamics of journals indexed in international databases.

Distribution of Publications by Journal: concentration and dispersion of scientific literature

The results show a high concentration of scientific output in a small number of journals. In total, 88 journals (15.60%) account for 50.07% of the analyzed documents, while the remaining 49.03% are distributed among 476 journals (84.39%). Furthermore, 61.52% (347 journals) published only one document on *Yucca* spp., reflecting a marked dispersion on the periphery of the field.

Table 3 shows the 20 most productive journals, representing 3.54% of the 564 registered titles and accounting for 24.48% of the publications. Among those with more than 15 documents, *Animal Feed Science and Technology*, *American Journal of Botany*, *Oecologia*, *Journal of Animal Science*, *Phytochemistry*, and *Asian-Australasian Journal of Animal Sciences* stand out. This behavior is consistent with the core-periphery structure described by Bradford's Law.

The JCR category indicated in the table corresponds to the one in which the journal achieves its highest position according to the impact factor (IF). *IF 2021, the most recent available; **IF 2000 and IF 1999, the latest reported values for the corresponding journals. Among the leading journals that have published research on the genus *Yucca* are *Animal Feed Science and Technology*, *American Journal of Botany*, and *Ecology*, which together account for approximately 8% of all articles in the field. These journals are indexed in the *Journal Citation Reports (JCR)* and are located in categories related to ecology, biology, and food science, which reinforces their relevance as established channels for disseminating scientific information on *Yucca* spp. Their ranking enhances the visibility, editorial rigor, and international reach of the research published in this area.

Table 3. Journals indexed in SCIE, SSCI, and ESCI (top 20) with the most published documents (1904-2024) on *Yucca* spp.

Journal	Documents number	Documents (%)	Impact factor (2023)	Category Journal of Citation Reports	Position in the JCR category/ Quartile in the Category
Animal feed science and technology	41	3.24	2.5	Agriculture, Animal and Dairy Science	13/80, 1
American journal of botany	33	2.61	2.4	Plant Science	96/265, 2
Oecology	27	2.13	2.3	Ecology	87/195, 2
Journal of animal science	21	1.66	2.7	Agriculture, Animal and Dairy Science	10/80, 1
Phytochemistry	21	1.66	3.2	Plant Science	68/265, 2
Asian-australasian journal of animal sciences	17	1.34	2.7 *	Agriculture, Animal and Dairy Science	17/62, 2
Journal of dairy science	15	1.18	3.7	Agriculture, Animal and Dairy Science	7/80, 1
animals	13	1.03	2.7	Veterinary Science	16/167, 1
Oikos	12	0.95	3.1	Ecology	56/195, 2
Southwestern naturalist	12	0.95	0.2	Biodiversity Conservation	64/65, 4
Journal of arid environments	11	0.87	2.6	Ecology	73/195, 2
Livestock science	11	0.87	1.8	Agriculture, Animal and Dairy Science	25/80, 2
Poultry science	11	0.87	3.8	Agriculture, Animal and Dairy Science	6/80, 1
Dutch Botanical Act	10	0.79	1.3**	Plant Science	39/137, 2
Plant	10	0.79	3.6	Plant Science	56/265, 1
Industrial crops and products	9	0.71	5.6	Agronomy	8/125, 1
Journal of agricultural and food chemistry	9	0.71	5.7	Multidisciplinary Agriculture	7/89, 1
Journal of the science of food and agriculture	9	0.71	3.3	Multidisciplinary Agriculture	16/89, 1
Khimiya prirodnikh soedinenii	9	0.71	0.2***	Organic Chemistry	46/48, 4
Nature	9	0.71	50.5	Multidisciplinary Sciences	1/134, 1
544 journals with less than 9 publications	956	75.51	Not applicable	Not applicable	NA
Total	1266	100			

Prolific Authors

The most prolific authors on *Yucca* spp. are Olle Pellmyr (University of Idaho), David M. Althoff (Syracuse University), and Tim A. McAllister (University of Manitoba). Pellmyr has focused his research on ecology and evolutionary biology, particularly on the coevolution between *Yucca* and pollinating moths of the genus *Tegeticula*. Althoff has explored insect-plant interactions from an ecological and evolutionary perspective, examining the role of competition, plant chemistry, genetics, and global change in mutualisms. McAllister, for his part, has conducted research focused on sustainability and livestock production, addressing feeding strategies, the rumen microbiome, and greenhouse gas mitigation.

Taken together, the most influential publications on *Yucca* spp. It reveals two predominant thematic axes: on the one hand, coevolution and ecological interactions with pollinating moths; and on the other, productive applications linked to animal nutrition and sustainability. These approaches demonstrate the convergence between basic research focused on mutualism and reciprocal adaptation and applied studies oriented toward agricultural systems. Details of authors with 20 or more documents, as well as the classification of their output according to the presence of search terms in the title, abstract, or keywords, are presented in Table 4.

It was observed that seven of the eight most productive authors published papers addressing *Yucca* spp., treating the topic as their main focus, since the search terms for information included it in the title of most of their studies. These studies centered on *Yucca* spp. research in environmental science and ecology, focusing on its adaptation and role in arid ecosystems. In agriculture, its applications in crops and sustainability were explored. In microbiology, its interactions with soil microorganisms were analyzed. In plant science, its physiology and adaptations were investigated.

Finally, in chemistry, the composition of its bioactive compounds was studied. Among these authors, Olle P., David M. Althoff, and Tim A. McAllister from the USA stood out. Conversely, only one author included the topic in the abstract and keywords of their papers, specifically the search terms for the topic under study. This means that *Yucca* represents the main theme addressed in these documents, which include environmental science and ecology, agriculture, microbiology, chemistry, cultivation and production,

Table 4. Authors with 20 or more documents (1904-2024) related to *Yucca* spp.

Author	Documents	H-index	Citations	documents with search concepts found in the title	documents with search concepts found in the abstract and keywords	Institution	Research topics
Olle Pellmyr	51	38	2479	45	6	University of Idaho	Environmental Sciences and Ecology
David M. Althoff	29	22	667	25	4	Syracuse University	Environmental Sciences and Ecology
Tim A. McAllister.	25	67	1376	8	17	University of Manitoba	Agriculture and Microbiology
Jim Leebens-Mack	22	68	1080	16	6	University of Georgia	Plant Sciences
Seagraves, K. A.	22	24	575	20	2	Archbold Biology Station	Environmental Sciences and Ecology
Wieslaw Oleszek	21	49	772	17	4	Institute of Soil Science and Plant Cultivation	Chemistry
Ether Kemertelidze	20	19	239	18	2	Tbilisi State Medical University	Chemistry
Smith, C. I. Edvard	20	15	536	13	7	University of Liverpool	Chemistry

as well as physiological aspects. On the other hand, the three authors with the highest H-index in the SCIE were: Jim Leebens-Mack, from the University of Georgia (68 in the WoS Core Collection), Tim A. McAllister, from the University of Manitoba (SCI 67), and Wieslaw O., from the Institute of Soil Science and Plant Cultivation (SCI 49). In general, studies on cassava focus on coevolution and ecological interactions with their pollinating moths, evaluating how reciprocal adaptations and environmental factors influence these mutualistic relationships.

The “Docs. title” and “Docs. keywords” columns in Table 4 indicate the number of documents in which the search terms appear in the title, abstract, and keywords, or in the abstract and keywords. The colors indicate whether the author’s work addressed the topic as a primary or secondary focus, according to the strategy applied for the period 1904-2024 (Table 4).

Cooperation between authors

Thirty-two research clusters with no interaction between them were identified, highlighting a fragmented structure in the field. However, two main clusters focused on studies of *Yucca* spp. stand out (Figure 2).

The first cluster is comprised of David M. Althoff, Olle Pellmyr, Robert A. Raguso, Kari A. Segraves, Göran P. Svensson, M. Balcázar-Lara, and C. J. Huth, affiliated with institutions such as Syracuse University, the University of Colima, Vanderbilt University, the University of Idaho, Cornell University, and Lund University in the United States, Mexico, and Sweden. This group focuses primarily on studies of evolutionary ecology and plant-insect mutualism.

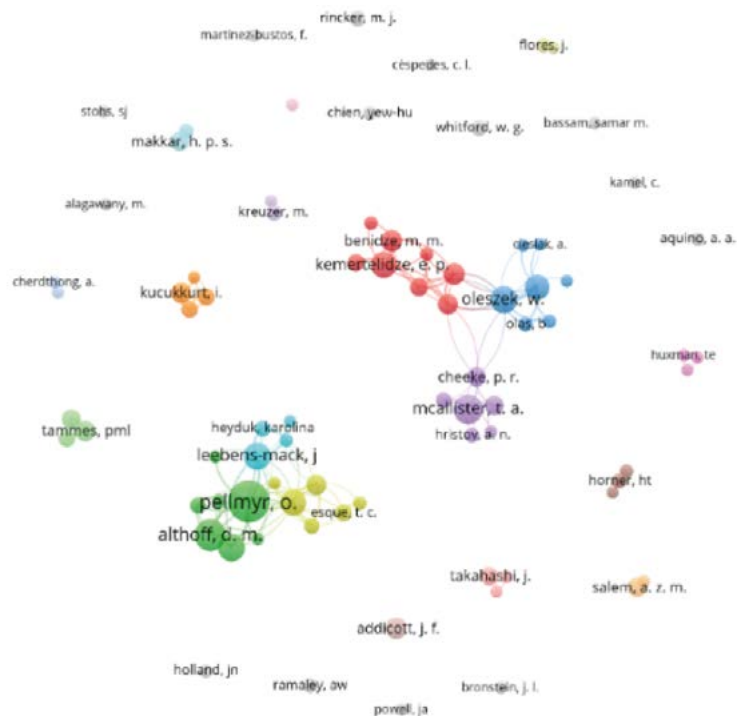


Figure 2. Visualization of research clusters on *Yucca* spp. using VOSviewer software.

The second cluster includes Benidze, M. M., Kemertelidze, E. P., Montoro, P., Piacente, S., Pizza, C., Pkheidze, T. A., and Skhirtladze, A. V., affiliated with Tbilisi State Medical University, the University of Salerno, the TSMU I. Kutateladze Institute of Pharmacochimistry, and Ivane Javakishvili State University of Tbilisi, in Georgia and Italy. This cluster focuses on research related to chemical properties and secondary metabolites.

Although no interaction was observed between clusters, a consolidated collaboration exists within each one. Three subgroups were identified in Cluster 1, notably including Jim Leebens-Mack and Smith, C. I., along with Althoff, whose research is linked to Environmental Science and Ecology. Cluster 2 also includes three subgroups, led by Tim A. McAllister, Wiesław Oleszek, and Kemertelidze, focused on plant chemistry and production applications. Together, these two clusters comprised six of the eight most prolific authors, confirming the existence of specialized groups that structure the development of the field.

Co-authorship Index

During the analyzed period (1904-2024), the overall average was 4.13 authors per document, reflecting a high level of collaboration in scientific production on *Yucca* spp. However, this indicator has varied significantly over time. Between 1904 and 1980, the co-authorship index was lower, averaging 1.96 (Table 5).

For the period 2001-2010, the co-authorship index was 3.94, a value comparable to that reported by Bravo-Vinaja and Méndez-Gallegos (2023), who recorded indices of 3.59 and 3.75 for the decades 1990-1999 and 2000-2009, respectively, in research on *Dactylopius coccus* Costa (Hemiptera: Dactylopiidae), carminic acid, and its derivatives. Likewise, these results are consistent with those documented in Mexico by the Scientific and Technological Advisory Forum (2006), which reported an average of 3.96 in agricultural sciences for the period 1990-2004. Taken together, these comparisons demonstrate a sustained trend toward increased scientific collaboration, suggesting a progressive transition toward more integrated and multidisciplinary research approaches.

Countries with the Most Publications

The country-by-country analysis revealed that the United States leads scientific production with 31.75% of the total documents, followed by Mexico with 9.00%. The People's Republic of China and India also had a significant share within the analyzed

Table 5. Co-authorship Index for documents related to *Yucca* spp. (1904-2024).

Time (years)	Co-authorship index
1904 to 1980	1.96
1981 to 1990	2.20
1991 to 2000	2.90
2001 to 2010	3.94
2011 to 2020	4.86
2021 to 2024	5.30

set. The “Other” category grouped 372 documents distributed across 75 countries, with fewer than 34 publications each, representing 29.38% of the total (Table 6). Overall, these results show a structure characterized by a strong concentration in a small number of countries, accompanied by a broad international base with smaller contributions. This pattern demonstrates both the leadership of certain nations in the field and the increasing internationalization of research on *Yucca* spp.

The concentration of publications in countries such as the United States, Mexico, and the People’s Republic of China suggests greater institutional capacity, funding, and consolidation of research lines focused on *Yucca* spp. In contrast, the dispersion of production among the remaining 75 countries, with small individual contributions, demonstrates broad but asymmetrical international participation. This pattern reflects a global structure characterized by centers of scientific leadership and a periphery with emerging contributions, highlighting the need to strengthen international cooperation networks that foster a more balanced integration of knowledge in the field of *Yucca* spp.

Publishing Institutions

The ten institutions with more than 15 documents accounted for 16.43% of all publications on *Yucca* spp. Among them, the University of Idaho stands out with 2.92% of the registered documents. Of the top ten institutions, seven are located in the United States, one in Canada, one in Mexico, and one in Saudi Arabia. This distribution confirms the predominance of North American institutions in the scientific output of this field and is linked to the leadership of English-speaking countries, which helps explain the high proportion of publications in English (Table 7).

Research topics

The joint keyword analysis performed in VOSviewer using bibliographic records and the LingLog normalization method, visualized according to the number of occurrences

Table 6. Countries with the Most Publications (1904-2024) on documents related to *Yucca* spp.

Country	Documents	%
USA	402	31.75
Mexico	114	9.00
People’s Republic of China	86	6.79
Egypt	48	3.79
Canada	46	3.63
Poland	43	3.40
Japan	42	3.32
Turkey	40	3.16
Italy	38	3.00
India	35	2.76
Other	372	29.38
Total	1266	100.00

Table 7. Institutions publishing documents on *Yucca* spp., published (1904-2024).

Institution	Country	Number of citations	Documents	%
University of Idaho	USA	1168	37.00	2.92
Agriculture and Agri-Food Canada	CANADA	1751	27.00	2.13
National Autonomous University of Mexico	MEXICO	581	23.00	1.82
Syracuse University	USA	389	21.00	1.66
University of Georgia	USA	616	21.00	1.66
U.S. Geological Survey	USA	320	17.00	1.34
Vanderbilt University	USA	750	17.00	1.34
King Saud University	Saudi Arabia	353	15.00	1.18
University of California, Riverside	USA	368	15.00	1.18
Willamette University	USA	314	15.00	1.18
1101 institutions			1,058.00	83.57

(considering five or more per author keyword) in the SCIE, SSCI, and ESCI (Keyword Plus) databases, revealed that the research focused on the topics covered by the five clusters related to *Yucca* (Figure 3). These clusters range from the evolution and pollination of the Agavaceae family, through the impact of *Yucca schidigera* on growth performance and digestibility in animals, to ruminal fermentation and methane production. Studies on the chemical properties of *Yucca*, such as steroidal saponins, and the biosynthesis of compounds in *Yucca* plants were also included. The studies applied various techniques to delve deeper into these aspects and contribute to the knowledge of *Yucca* and its importance in animal nutrition, ecology, and plant chemistry. Among the most relevant topics is the red cluster, focused on the Agavaceae family, which addresses the evolution, diversity, and pollination of plants such as *Yucca*, as well as their ecological interactions and coevolutionary processes with pollinators (Kato *et al.*, 2003; Pellmyr & Augenstein, 1997). The green cluster analyzes the effects of *Yucca schidigera* on growth performance and animal digestibility, including ruminal fermentation and ammonia reduction in feed (San Martín & Briones, 2000; Wallace, 2004). Closely related, the blue cluster delves into ruminal fermentation and methane production, highlighting the influence of *Yucca schidigera* and other additives on methanogenesis and emissions mitigation (Busquet *et al.*, 2005; Wallace, 2004).

The yellow cluster focuses on steroidal saponins present in *Yucca*, especially their antimicrobial activity and their application in animal feed and health (Wallace, 2004; Wallace *et al.*, 2002). Finally, the purple cluster addresses the biosynthesis of plant compounds, such as auxins and other metabolites, and their influence on plant growth and development (Patra *et al.*, 2006; Youle & Huang, 1981). Together, these clusters demonstrate the multidisciplinary nature of *Yucca* research, integrating evolutionary ecology, animal nutrition, and plant chemistry.

Research trends over the years

Keyword analysis allows us to identify the main lines of research developed in this field. To examine thematic evolution, 413 keywords present in 1266 articles were analyzed.

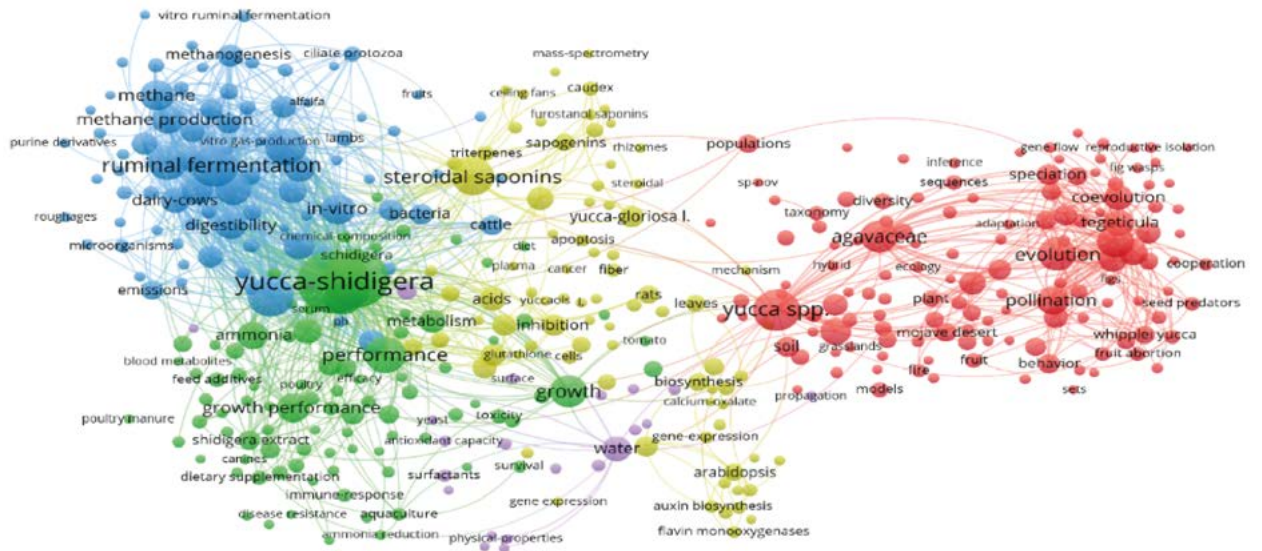


Figure 3. Joint word analysis by author and database keywords with five or more occurrences, in publications (1904-2024) on *Yucca* spp.

Figure 4 shows the network map organized by year of publication, where the size of the nodes indicates the frequency of occurrence of each keyword and the colors represent the groups according to their co-occurrence.

Five main clusters were identified that reflect the evolution of knowledge about *Yucca*: Cluster 5 (royal blue, 1904-2000): Brings together the oldest studies, focused on taxonomy, diversity, traditional uses and early applications in food and biomaterials.

Cluster 2 (blue, 2000-2009): Focused on evolution, pollination, and coevolution within the Agavaceae family, highlighting ecological and genetic interactions. Cluster

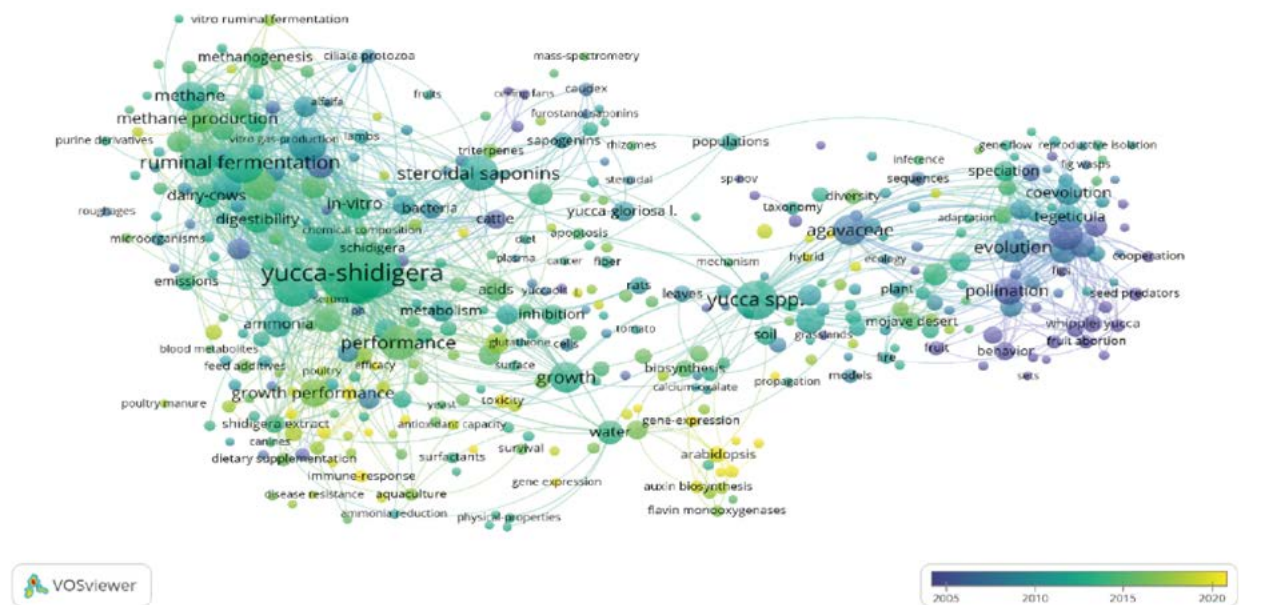


Figure 4. Evolution of Research Topics in *Yucca* (1904-2024): Analysis of Keywords and Co-occurrence in Academic Publications.

1 (aqua green, 2010-2015): Focused on *Yucca schidigera*, extracts, ruminal fermentation, and steroidal saponins, with an emphasis on digestibility and methane reduction in animal feed.

Cluster 4 (lime green, 2015-2019): Focused on the biosynthesis of compounds in *Yucca* and their relationship to plant growth and development, as well as applications in improving crop yields. Cluster 3 (yellow, 2019-2024): Represents the most recent research, focused on the characterization of *Yucca schidigera*, ruminal fermentation, and the mitigation of greenhouse gas emissions through the regulation of methanogenesis. Together, these clusters demonstrate a transition from taxonomic and descriptive studies toward applied and environmental approaches with greater productive and ecological impact.

Over time, research lines have evolved toward the development of value-added applications for the use of wild plants as biomaterials and in food. Likewise, production and utilization strategies for *Yucca* species have been strengthened, aimed at optimizing the sustainable use of these natural resources. In parallel, scientific activity has addressed its management from multiple perspectives, integrating its role in animal feed, ecology, and plant chemistry.

Recent advances in yucca research: analysis of the most cited articles in the last five years

The citation structure of articles published between 2019 and 2021 included five studies with an average of 64 citations (Table 8). The most cited article was “Experimental and computational investigation of sound absorption performance of sustainable porous material: *Yucca gloriosa* fiber” by Soltani *et al.* (2020) with 80 citations, which evaluated the acoustic properties of its fiber as a sustainable porous material for sound absorption.

With the same number of citations (80), the study “Saponin-Induced Shifts in the Rumen Microbiome and Metabolome of Young Cattle” by Wang *et al.* (2019) stood out. This study analyzed the effect of saponins on rumen microbiota and the metabolome in calves, providing relevant evidence in animal microbiology and nutrition.

The most cited study was “The regulatory roles of *Yucca* extract on the growth rate, hepatorenal function, histopathological alterations, and immune-related genes in common

Table 8. The five most cited articles on *Yucca* in the last five years. Abbreviated title TD Journal Category.

Author	Year	Citations (number)	Abbreviated title	Documnt type	Journal	Category
Soltani <i>et al.</i>	2020	80	Sound absorption of <i>Yucca gloriosa</i> fiber	Art.	Applied Acoustics	Sustainable Materials
Wang <i>et al.</i>	2019	80	Saponin shifts in rumen microbiome of cattle	Art.	Frontiers in Microbiology	Microbiology
Dawood <i>et al.</i>	2021	55	<i>Yucca</i> extract under ammonia stress in carp	Art.	Aquaculture	Aquaculture
Grodsky & Hernandez	2020	54	Solar development effects on desert plants	Art.	Nature Sustainability	Ecology and Sustainability
Zazharskyi <i>et al.</i>	2019	53	Antimicrobial activity of plant extracts	Art.	Biosystems Diversity	Biotechnology and Pharmacognosy

carp exposed with acute ammonia stress” by Dawood *et al.* (2021), with 55 citations. This study evaluated the impact of yucca extract on the growth and health of common carp under ammonia stress, highlighting its application in aquaculture. The text abruptly shifts to a different topic: Taken together, these studies demonstrate the relevance of the genus *Yucca* in areas ranging from applied acoustics to biotechnology and aquaculture, highlighting its potential as a natural resource in research focused on sustainability and efficient resource management.

Main Contributions to *Yucca* Stability: Analysis of Highly Cited Articles

The most cited articles from the period 1904-2024 demonstrate key advances in understanding mutualism and its stability, as well as in biotechnological applications for agriculture and livestock.

The most cited work was that of Bull and Rice (1991) (378 citations), which analyzes the mate choice model in the relationship between moths and yuccas, demonstrating how this mechanism promotes cooperation and penalizes non-cooperative individuals. Similarly, Pellmyr and Huth (1994) (334 citations) explain the stability of mutualism through the selective abort of flowers with a high egg load, which promotes efficient pollination.

In the field of biotechnology, Krishnamurthy *et al.* (2014) (216 citations) stand out for the synthesis of nanomaterials derived from *Yucca* with catalytic potential, demonstrating the use of natural compounds in new technologies. Furthermore, several studies cited in Table 9, such as Wallace *et al.* (2002) (211 citations), analyze the use of plant extracts to

Table 9. Most cited articles on *Yucca* (1904-2024).

Author	Year	Citations (number)	Abbreviated title	Documnt type	Journal	Category
Benchaar <i>et al.</i>	2007	221	Essential oils and rumen fermentation in dairy cows	Article	J. Dairy Sci.	Veterinary Medicine and Animal Nutrition
Bodas <i>et al.</i>	2012	270	Plant metabolites and methane reduction	Article	Anim. Feed Sci. Technol.	Veterinary Medicine and Metabolism
Bull & Rice	1991	378	Evolution of cooperation mechanisms	Article	J. Theor. Biol.	Evolutionary Biology
Busquet <i>et al.</i>	2006	323	Plant extracts and rumen fermentation	Article	J. Dairy Sci.	Veterinary Medicine and Metabolism
Hu <i>et al.</i>	2005	202	Tea saponin and rumen fermentation	Article	Anim. Feed Sci. Technol.	Veterinary Medicine and Metabolism
Krishnamurthy <i>et al.</i>	2014	216	<i>Yucca</i> -mediated gold nanomaterials	Article	Nano Res. Lett.	Nanotechnology
Patra <i>et al.</i>	2006	206	Plant extracts and in vitro methanogenesis	Article	Anim. Feed Sci. Technol.	Veterinary Medicine and Metabolism
Pellmyr & Huth	1994	334	Stability of yucca–moth mutualism	Article	Nature	Evolutionary Ecology
Wallace	2004	311	Antimicrobial plant metabolites	Article	Proc. Nutr. Soc.	Pharmacognosy
Wallace <i>et al.</i>	2002	211	Natural products and rumen manipulation	Article	Asian-Australas. J. Anim. Sci.	Veterinary Medicine and Metabolism

modify ruminal fermentation and reduce methane production, contributing to improved feed efficiency and a decreased environmental impact of livestock production.

CONCLUSIONS

During the period 1904-2024, research on *Yucca* spp. showed sustained growth, with a notable increase in the last five years, which accounted for 22.35% of publications. In 2023-2024, 95 articles (7.50%) were published in 13 languages, predominantly English (95.49%). The United States leads in scientific production, followed by Mexico, China, Japan, and Canada, and also consolidates the main international collaboration networks. Among the most prominent institutions are the University of Idaho and Agriculture and Agri-Food Canada, while Olle Pellmyr and David M. Althoff are the most prolific authors. The most frequently used keywords were *Yucca schidigera*, saponins, *Yucca* spp., ruminal fermentation, and evolution, identifying five main lines of research: saponins and extracts, mutualism, rumen, pollination, and evolutionary studies. The thematic evolution reveals a transition from taxonomic and ecological approaches toward applications in animal nutrition, sustainability, biotechnology, and methane emission mitigation. Although the study is limited to the exclusive use of Web of Science and a predominantly quantitative approach, the results allow for the identification of trends, collaborative dynamics, and emerging areas, contributing to guiding future research and scientific cooperation strategies.

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