






Review article

Global Landscape of Sunflower–Broomrape Interaction Research: a Scopus-Based Bibliometric Study

Liana Relina ^{a,*}, Kateryna Makliak ^a, Valeriia Kolomatska ^a,
Dmytro Kurylych ^a & Oleksandr Syvenko ^a

^aLaboratory of Sunflower Breeding and Genetic, Yuriev Plant Production Institute of The National Academy of Agrarian Sciences of Ukraine, Ukraine

Abstract

Common sunflower (*Helianthus annuus* L.) is a pivotal oilseed crop for global food security, yet sunflower broomrape (*Orobancha cumana*) poses a major threat to its yields. This study presents a bibliometric analysis of 337 publications from the Scopus database (1960–2025) using Biblioshiny and VOSviewer. The temporal evolution of publishing activity follows an atypical 4th-degree polynomial model, with a general decline in mean total citations per article. Key contributors were identified: Spain is the leading country; CSIC - Instituto de Agricultura Sostenible (IAS) (Spain), the Institute of Field and Vegetable Crops (Serbia), and Northwest A&F University (China) are the most productive institutions. *Helia* is the core journal, while Pérez-Vich B., Velasco L., and Fernández-Martínez J.M. are the most prolific authors. Collaboration networks are described based on connection maps. Analysis of keywords identified research priorities: “plant breeding”, “physiology”, and “genetics” emerged as Motor Themes; “sunflower” and “broomrape” as Basic Themes; and chemistry or “sesquiterpene” and “lactones” as Niche Themes. “Combining ability”, “mutant line”, and “new breeding material” represent Emerging or Declining Themes. Furthermore, the five most influential publications were distinguished and discussed. These findings provide insights into the current research status and outline emergent trends in addressing the broomrape challenge in sunflower cultivation.

Keywords: *Helianthus*, *Orobancha*, Scientometric Parameters

Received: 07 February 2026 * **Accepted:** 10 April 2026 * **Published:** 12 June 2026

* Corresponding author:

Liana Relina, Assoc. Prof. Dr., Laboratory of Sunflower Breeding and Genetic, Yuriev Plant Production Institute of The National Academy of Agrarian Sciences of Ukraine, Ukraine.
Email: lianaisaakovna@gmail.com

INTRODUCTION

Once being one of several plants cultivated by Native Americans in prehistoric North America (Britannica, 2026), nowadays common sunflower (*Helianthus annuus*) is cultivated throughout the world. Due to the continuous growth of the human population, the demand for sunflower oil, edible seeds, and by-products has also increased; hence, to meet the demand, there is a need to intensify efforts to raise sunflower output (Taher et al., 2017). There are several threats that sunflowers face today. Sunflower broomrape (*Orobancha cumana*) is a parasitic plant and one of the major threats to sunflower crops in countries around the Black Sea and across Europe. *O. cumana* was first identified as a problem in Russia soon after sunflowers started to be commercially grown in mid-19th century (Škorić et al., 2021). Later the world sunflower acreage has more than quadrupled in the last 60 years (1961-2024), rising from 6,667,130 to 28,728,506 hectares (FAOSTAT, 2026) and the spread of *O. cumana* followed the expansion of sunflower production from Russia, across Ukraine, Moldova, Romania, Bulgaria, Hungary and sunflower broomrape is now present in all sunflower-growing countries (Kaya, 2014), especially where farmers do not adhere to recommended crop rotations (Kurylych & Makliak, 2022). Broomrape-inflicted damage to sunflower crops and yield losses can be as high as 100% under heavy infestation (Encheva et al., 2008; Fernández-Martínez et al., 2015).

Current research in this field encompasses studies of parasite biology (Delavault, 2015; Duca et al., 2013), broomrape races and populations (Duca et al., 2022; Fernández-Melero et al., 2023; Hu et al., 2019; Makliak et al., 2018; Martin-Sanz et al., 2016;), criteria of broomrape resistance (Labrousse et al., 2004), physiological and biochemical mechanisms of broomrape resistance in sunflower (Labrousse et al., 2001; Sakhno et al., 2018), inheritance of broomrape resistance in sunflower (Kurylych & Makliak, 2024; Kurylych & Makliak, 2025; Velasco et al., 2006), parasite-host interactions and co-evolution (Cochavi, 2025; Echevarría-Zomeño et al., 2006; Rotarenco, 2010), management strategies for broomrape, including trap crops (Su et al., 2022; Ye et al., 2020), mechanical control (Pilorgé et al., 2020), crop rotation (Shevchenko et al., 2024), tillage (Shevchenko et al., 2024), chemical control (Fernández-Martínez, et al., 2015; Mitkov et al., 2019), biological control (Masliiov et al., 2018), host resistance, i.e. breeding of broomrape-resistant varieties and hybrids (Burlov & Burlov, 2010; Florin Gabriel et al., 2024; Khablak et al., 2025; Kurylych & Makliak, 2023; Makliak & Kyrychenko, 2012; Shcherban et al., 2023), and Clearfield® Production Systems (Kysylchuk et al., 2025), search for sources of resistance (Christov et al., 2014; Velasco et al., 2006) as well as estimation of economic implications of infestation (Kebede & Ayana, 2018). Each of these directions can be discussed in traditional reviews; however, it is difficult to cover the entire scope of sunflower broomrape research in one article. For such analyses, bibliometric approach is applied. Unlike traditional literature reviews, which synthesize qualitative information from existing research to provide a cohesive summary of knowledge, identify themes and gaps, bibliometric approach utilizes quantitative data and statistical methods to analyze characteristics of published documents, dealing with diverse large datasets and revealing temporal

trends, regional patterns, networks, and the intellectual structure of a research field (Passas, 2024). A bibliometric analysis of research into another *Orobanchae* species, which parasites on legumes, has been published recently (El Amri et al., 2023); a comprehensive traditional review on *O. cumana* races and sunflower breeding for resistance to broomrape is also available (Molinero-Ruiz et al., 2015), so is an in-depth review on *Orobanchae* weeds discussing mechanisms underlying parasitism and control strategies (Fernández-Aparicio et al., 2016). However, to our knowledge, sunflower broomrape research has not yet been addressed through the lens of bibliometrics. Thus, we set a goal to conduct a bibliometric analysis of scientific literature on sunflower broomrape and resistance of sunflower to this parasitic plant to facilitate choosing topics for future studies and establishing collaborations links for sunflower/broomrape scientists.

MATERIALS AND METHODS

On September 28, 2025, we used specific keywords to retrieve literature from the Scopus database at the Library of the Yuriev Plant Production Institute of the National Academy of Agrarian Sciences of Ukraine. The search terms “*Orobanchae*”, “broomrape”, “*Helianthus*”, and “sunflower” were employed in different combinations. Then we set the following filters: document types were limited to articles, data papers, conference papers, books, book chapters, reviews, conference reviews, and short surveys; publication stage was limited to final; and languages were limited to English. For data export, we used the CSV format, selecting all available information fields. There were 4 files; they were merged and the resulting file contained a total of 961 documents covering the period from 1960 to 2025. After removing duplicates, 337 documents were left. The final file was uploaded to the web-interface Biblioshiny of the Bibliometrix package in the free software RStudio (version 2025.09.0; Posit Software, PBC) for analyses of bibliometric parameters and constructing charts (Aria & Cuccurullo, 2017) or to VOSviewer (version 1.6.20) (van Eck & Waltman, 2010) for mapping connections. To enhance the accuracy of analysis of keywords, a CSV file was created and uploaded to Biblioshiny to omit irrelevant keywords and to consolidate synonyms. For the same purpose, TXT files were compiled for clustering of keywords in VOSviewer. For mapping in VOSviewer, the default option “Full Counting” was used (in an article with 10 coauthors, each coauthor got 1 point in the total number of documents); for normalization, Association Strength was used (this method calculates the ratio between the actual observed number of shared publications and the expected number of shared publications derived from the total output (Weight) of both organizations in the dataset). To construct Figure 2 and Table 1 in Excel, we used data sheets processed in Biblioshiny and downloaded from Biblioshiny as XLSX files. Figures 3-6 were downloaded from Biblioshiny as PNG files. Figures 7-11 were downloaded from VOSviewer as PNG files. The design and flow of this study are depicted in Figure 1. The flowchart in Fig. 1 was built in the free online diagram software diagrams.net (formerly draw.io; JGraph Ltd., 2026).

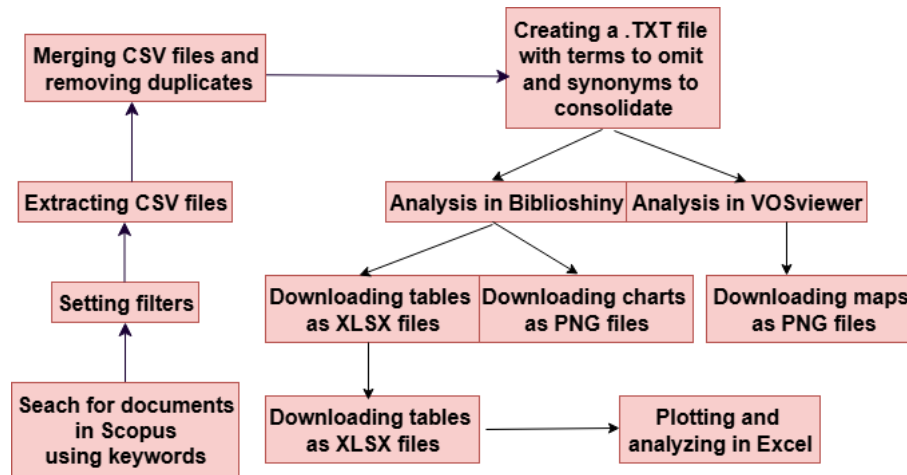


Figure 1. Algorithm of the study

RESULTS AND DISCUSSION

Temporal patterns

Fig. 2 demonstrates the temporal evolution of the publishing activities related to sunflower and broomrape. With the first articles published in 1960, 1977, and 1982 and long intervals in the publishing activities, this topic attracted little attention from scholars until the early 1990s. Afterwards they intensified publication of research results, but, unlike other fields of research, where the volumes of publications grew significantly and consistently and could be described by an exponential model (Zhou et al., 2024) or by linear regression (Cai et al., 2025), the blue line in this chart demonstrates that the growth in the ‘sunflower and broomrape’ research was clearly neither stable (not linear) nor constantly proportional (not purely exponential). It is best described by a 4th-degree polynomial model. Coefficient of determination (R^2) is a statistical measure that indicates the proportion of the variance (variability) in the dependent variable (Y, number of publications) that is explained by the model (equation). In our case, R^2 is 0.847. This means that approximately 84.7% of the variability in the number of publications over the years is explained by this 4th-degree polynomial model. The remaining (about 15.3%) is accounted for by other factors or random noise. At the moment, we have no fully convincing explanation for the atypical temporal profile of publication volume related to sunflower and broomrape. We can hypothesize that the observed sharp peaks and the S-shaped trend line may reflect the historical 'arms race' between sunflower breeders and the rapidly evolving broomrape parasite, as research output may surge following significant infestation outbreaks. For example, a highly aggressive race of *O. Cumana*, race F, was first detected in Spain in 1995 (Alonso et al., 1996) and quickly spread to most areas of Eastern Europe by the early 2000s (Fernández-Escobar et al., 2008; Škorić et al., 2010). This could explain the first peak in 1996 and a large number of publications between 2000 and 2004. In 2008, a highly virulent broomrape infection was detected in a traditionally non broomrape infested area in Spain.

Racial determination identified that broomrape inoculum as race F (Fernández-Escobar et al., 2009). A year later, in 2009, there was another spike in the number of publications. In 2014, race G was detected in Spain (Martín-Sanz et al., 2016). Another source attests that it was first found even earlier (2013) in China and Mongolia (Shi et al., 2015). It might contribute to the spike in 2014. However, this assumption requires further empirical verification. Timepoints of the development of anti-broomrape chemicals could be another factor explaining such an unusual temporal profile. Al-Khatib et al. (1998) reported about a natural mutation in acetolactate synthase that made wild sunflower is less sensitive to an imidazolinone herbicide (imazethapyr) and, four year later, Miller and Al-Khatib (2002) described imidazolinone herbicide-resistant sunflower lines carrying the altered acetolactate synthase gene. These discoveries could at least partially explain the 2000 and 2004 peaks, as this was the onset of the Clearfield® technology development. Another natural mutation in the acetolactate synthase enzyme conferring resistance to a sulfonylurea herbicide, tribenuron, was discovered in wild sunflower, with registering its carriers in 2004 (Miller & Al-Khatib, 2004). This became the basis for the ExpressSun® sunflower technology, which was officially released for the 2007 growing season (Jursík et al., 2014). These events could contribute to the 2004 and 2009 peaks. In 2008, the Argentinean scientists described an ethyl methanesulfonate-induced mutation that confer even greater resistance to imazapyr (Sala et al., 2008) and, in 2010, the Clearfield® Plus technology was first commercialized (Weston et al., 2012). In the graph, we observe peaks in 2009, 2012, and 2014, which can reflect development and testing of Clearfield® Plus lines and hybrids. These considerations cannot fully explain all spikes and troughs in the sunflower broomrape-related scientific production, as a lot of other factors may affect this parameter. The general rise in the number of publications is attributed to the development of state-of-the art techniques of molecular genetics, as we can observe in many other research areas. Furthermore, a potential source of data volatility is the exclusion of regional or national journals not indexed in Scopus. Many researchers in major sunflower-producing countries publish in local venues, which may account for the 'troughs' in our temporal graph. While Scopus-based analyses are inherently limited in their coverage of non-indexed literature, we prioritized this database due to its high concentration of peer-reviewed, high-impact sources. Additionally, the standardized metadata provided by Scopus facilitates robust multi-parameter evaluations using specialized bibliometric software.

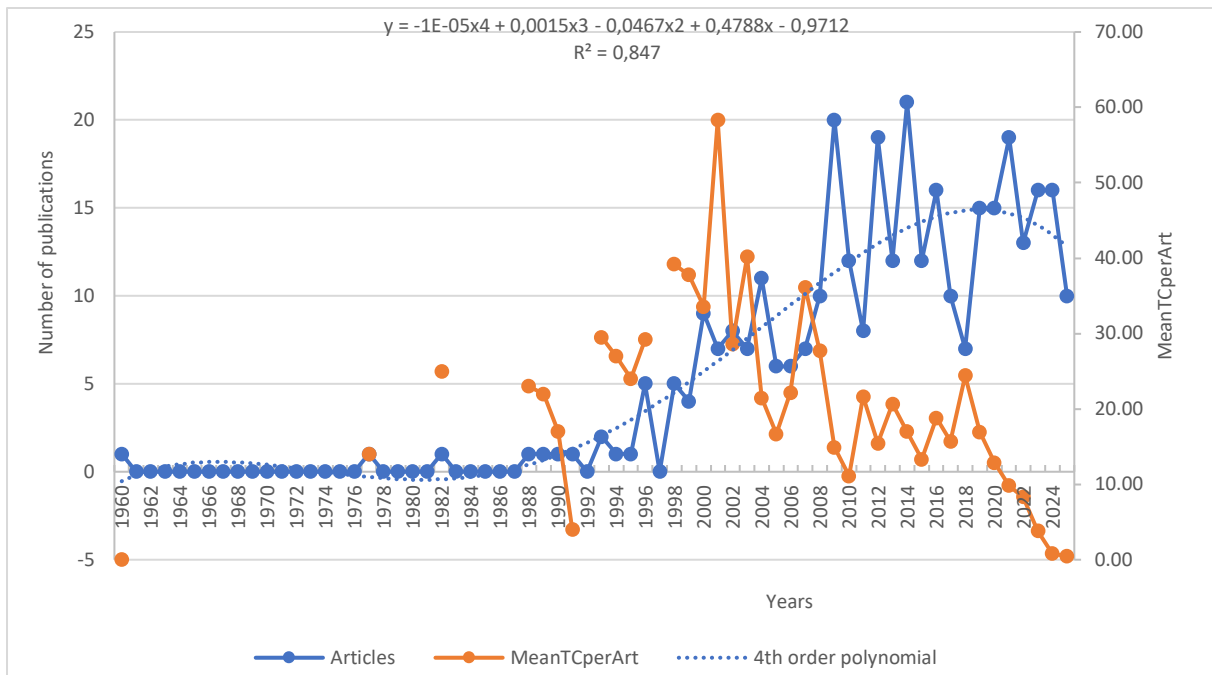


Figure 2. Temporal evolution of the publishing activities in the research related to sunflower and broomrape

The red line in Fig. 2 shows a general decline in the mean total citations per article. A decrease in the total citations per article is often observed in different areas of knowledge (Javed et al., 2024; Pranajaya et al., 2024). As a rule, this is explained by shorter citation lifespans, as more recent papers naturally had shorter periods to accumulate citations, and quality of publications. The latter consideration is contradictory. It was reported about moderate positive correlations, but there were great inter-study variations in the comparison results (Teplitkiy et al., 2022).

The data summarized in Table 1 (the early period with few publications and “empty years” is not presented) show that *Helia* is the journal No.1 in the research field under investigation for the entire analyzed period. Among countries, Spain has been the undeniable leader since the very beginning of research into sunflower and broomrape. Since 2017, Chinese authors have drastically enhanced their publishing activities. One can notice that Argentina is not on the list of the 10 top counties despite being the motherland of the Clearfield® Plus technology. The apparent discrepancy between Argentina’s pivotal technological contribution and its bibliometric representation in this study can be attributed to a thematic divergence in research objectives. In Argentina, the development of the CLHA-Plus mutation was primarily driven by the need to manage common weeds rather than *O. cumana*, which was not a critical pathogen in South America until 2023 (Barea et al., 2025). Consequently, the core Argentinian research outputs are indexed under keywords such as “herbicide tolerance”, “induced mutagenesis”, and “AHAS/ALS enzymatic activity.” Since our search keywords were specifically centered on sunflower broomrape, these foundational studies remain on the periphery of the retrieved dataset. Once the mutations in acetolactate synthase became objects of commercial interest, the published information on them was frequently restricted by proprietary protections. Consequently, the countries primarily

involved in the commercialization of these technologies (the USA and Germany) have a less prominent presence on the bibliometric top-country list. Among institutions, CSIC - Instituto de Agricultura Sostenible (IAS) has been the leading institution since 1998, followed by Institute of Field and Vegetable Crops (Serbia) and Northwest A&F University. However, these rankings have certain Scopus-imposed limitations, as a lot of regional/local journals in sunflower growing countries are not Scopus-indexed and were not included in the analyzed dataset; hence, the scientific outputs of these countries and their institutions are less visible (see also the discussions of Figs. 7 and 8).

Table 1. Cumulative scientific production of the leading journals, countries, and institutions in sunflower and broomrape research over time (values represent total publications by year-end).

Year	HELIA	WEED RESEARCH	FRONTIERS IN PLANT SCIENCE	BULGARIAN JOURNAL OF AGRICULTURAL SCIENCE	PLANT BREEDING	PLANT DISEASE	ROMANIAN AGRICULTURAL RESEARCH	THEORETICAL AND APPLIED GENETICS	AGRONOMY	WEED SCIENCE
2025	74	17	13	12	8	7	7	7	6	6
2024	74	17	13	11	8	7	7	7	5	6
2023	74	17	12	11	8	7	7	5	4	5
2022	71	17	10	11	8	7	7	5	4	5
2021	70	17	9	11	8	7	6	4	3	5
2020	68	17	8	11	8	7	6	4	2	5
2019	68	17	8	10	8	7	5	4	0	4
2018	66	17	7	10	8	6	4	4	0	4
2017	65	17	6	10	8	5	3	4	0	4
2016	65	17	4	10	8	5	3	4	0	4
2015	64	17	0	10	8	4	3	4	0	4
2014	61	17	0	7	8	3	3	4	0	4
2013	52	15	0	6	8	3	3	4	0	4
2012	49	13	0	5	7	3	3	4	0	4

Year	ROMANIA	TURKEY	USA	SERBIA	GERMANY	BULGARIA	CHINA	ISRAEL	FRANCE	SPAIN
2025	51	50	49	106	68	86	256	104	129	311
2024	51	50	47	106	68	85	230	98	124	311
2023	50	50	47	105	67	85	197	94	109	297
2022	50	50	47	97	67	82	174	94	105	287
2021	49	49	47	90	67	82	125	89	96	278
2020	48	44	47	81	59	82	100	83	90	271
2019	41	43	45	75	59	78	69	77	90	266
2018	39	38	43	70	56	74	65	73	76	258
2017	36	34	43	69	55	74	65	66	76	257
2016	36	34	43	69	55	74	44	59	73	247
2015	28	34	43	62	55	74	27	55	68	230
2014	27	34	38	58	51	66	17	55	67	224
2013	27	29	33	55	49	59	12	49	67	192
2012	27	28	33	48	47	54	2	49	67	173

Year	CSIC - INSTITUTO DE AGRICULTURA SOSTENIBLE (IAS)	DOBRODZHA AGRICULTURAL INSTITUTE	INNER MONGOLIA UNIVERSITY CHINA	INSTITUTE OF CROP SCIENCE	INSTITUTE OF FIELD AND VEGETABLE CROPS SERBIA	NORTHWEST AANDF UNIVERSITY	UNIVERSIDAD DE CÓRDOBA	UNIVERSITÄT HOHENHEIM	UNIVERSITÉ DE TOULOUSE	V.S. PUSTOVOIT ALL-RUSSIAN RESEARCH INSTITUTE OF OIL CROPS
2025	187	64	25	30	77	69	31	44	35	50
2024	187	63	20	30	77	60	31	44	35	50
2023	179	63	20	18	76	53	27	44	25	50
2022	174	63	10	14	71	52	27	44	21	43
2021	167	63	10	14	64	38	26	44	15	43
2020	167	63	0	14	62	38	26	41	15	37
2019	164	62	0	6	56	31	26	41	15	33
2018	162	62	0	5	52	31	26	41	9	33
2017	161	62	0	5	51	31	26	41	9	33
2016	154	62	0	5	51	21	26	41	9	33
2015	141	62	0	0	45	16	26	41	4	33
2014	136	54	0	0	44	12	26	37	4	33
2013	113	49	0	0	43	10	24	37	4	29
2012	98	44	0	0	38	0	24	35	4	29

2011	40	12	0	3	6	3	2	4	0	4
2010	36	11	0	2	6	3	1	4	0	4
2009	29	9	0	2	6	3	1	4	0	4
2008	15	6	0	1	6	3	1	4	0	4
2007	12	5	0	0	6	3	0	4	0	4
2006	11	4	0	0	5	3	0	4	0	4
2005	10	3	0	0	5	3	0	4	0	4
2004	10	3	0	0	5	3	0	4	0	4
2003	7	3	0	0	5	2	0	3	0	3
2002	6	3	0	0	5	2	0	3	0	1
2001	3	3	0	0	4	2	0	3	0	1
2000	3	3	0	0	4	1	0	3	0	1
1999	0	3	0	0	4	1	0	2	0	1
1998	0	3	0	0	4	1	0	2	0	1
1997	0	3	0	0	3	1	0	0	0	1
1996	0	3	0	0	3	1	0	0	0	1
1995	0	2	0	0	1	0	0	0	0	0
1994	0	2	0	0	1	0	0	0	0	0
1993	0	1	0	0	1	0	0	0	0	0
1992	0	0	0	0	1	0	0	0	0	0
1991	0	0	0	0	1	0	0	0	0	0
1990	0	0	0	0	1	0	0	0	0	0

2011	27	26	32	25	47	40	2	45	58	166
2010	22	21	30	25	47	38	2	42	58	164
2009	22	16	29	15	45	38	2	40	52	156
2008	8	5	29	3	45	33	2	36	50	132
2007	0	3	20	3	41	27	2	36	50	124
2006	0	3	19	0	34	27	2	36	34	116
2005	0	3	19	0	34	22	2	36	34	102
2004	0	3	19	0	26	22	2	32	29	102
2003	0	3	13	0	22	11	2	27	24	91
2002	0	2	6	0	20	4	2	18	24	84
2001	0	2	4	0	12	4	2	18	24	66
2000	0	0	4	0	10	3	2	9	19	58
1999	0	0	4	0	10	0	2	9	12	40
1998	0	0	2	0	6	0	2	9	8	34
1997	0	0	0	0	0	0	0	0	0	0
1996	0	0	1	0	0	0	2	3	1	31
1995	0	0	0	0	0	0	2	3	1	17
1994	0	0	0	0	0	0	2	3	1	15
1993	0	0	0	0	0	0	2	3	1	12
1992	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	2	0	1	9
1990	0	0	0	0	0	0	2	0	1	9

2011	91	30	0	0	21	0	24	35	0	23
2010	89	28	0	0	21	0	24	35	0	14
2009	85	28	0	0	12	0	24	34	0	14
2008	73	24	0	0	3	0	22	34	0	8
2007	66	18	0	0	3	0	22	31	0	8
2006	63	18	0	0	0	0	21	24	0	8
2005	61	13	0	0	0	0	15	24	0	8
2004	61	13	0	0	0	0	15	16	0	8
2003	53	10	0	0	0	0	15	13	0	5
2002	49	3	0	0	0	0	13	11	0	5
2001	37	3	0	0	0	0	11	8	0	5
2000	32	3	0	0	0	0	8	7	0	5
1999	24	0	0	0	0	0	3	7	0	1
1998	18	0	0	0	0	0	3	3	0	1
1997	0	0	0	0	0	0	0	0	0	0
1996	15	0	0	0	0	0	3	0	0	1
1995	5	0	0	0	0	0	3	0	0	0
1994	3	0	0	0	0	0	3	0	0	0
1993	0	0	0	0	0	0	3	0	0	0
1992	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	3	0	0	0
1990	0	0	0	0	0	0	3	0	0	0

In total, 774 authors contributed to this research area. The plot in Fig. 3 provides a visual representation of the publishing history of the 10 key authors in this specific field. The blue bubble size indicates the number of publications in a given year, and the color intensity represents the total citations per year. The horizontal red lines show the span of the authors' publishing activities. This analysis in Biblioshiny indicates that Pérez-Vich, Begoña exhibited consistent publishing activity starting in 2002 to 2024, which was especially intense between 2012-2017, when both the article number (5 articles in 2014) and total citations per year (12.6 in 2016) were the highest. Velasco, L. mirrors Pérez-Vich's pattern closely, suggesting collaboration and co-authorship (see Figure 7 below). Fernández-Martínez, José María shows an early start date (in 1989), with a peak in his publishing history between 2013 and 2016 (3-4 articles per year and the maximum total citations per year of 7.1 in 2016). Meléro-Vara, José María started his publishing activities even earlier, in 1982 (one of the first articles on this topic), reached the peak in 2000 (3 articles; 6.58), and then his publishing activities gradually were reduced to zero by 2014. Encheva, Julia had a shorter period of activities between 2003 and 2015 and her publication count and citation impact appear to be the lowest among the listed authors. Domínguez, Juan was active from 1989 to 2015. Eizenberg, Hanan shows more recent activities, starting from 2003 and continuing to 2025. He has published not so many articles (1-2 articles per year), but with relatively high citation counts (4.25 in 2022). Ma, Yongqing started publishing in 2013 and is still active, with the maximum citation count (6.75) also in 2022. Shindrova, Pepa S has been active since 2013 until now, with moderate citation counts (below 2). Jocić, Siniša B. is a recent but impactful contributor, with publishing activities started between 2007 and 2023 and the maximum citation count of 6.67 in 2020.

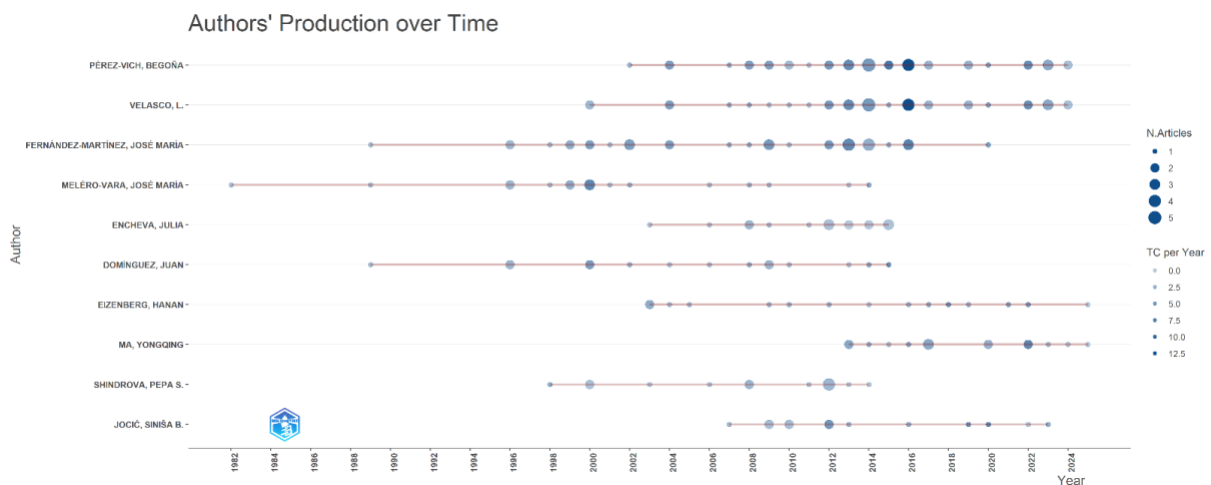


Figure 3. Temporal patterns of 10 top authors' publishing activities in the sunflower and broomrape research

The plot in Fig. 4 visualizes the evolution of research topics related to sunflower and broomrape. The plot allows us to identify emerging, sustained, and declining areas of interest within the field. The start and end of the line are the years of the first and third quartiles of the term frequency, and the median is denoted by the circle. Terms like “genetics” (median 19 in 2021), “gene expression” (25 in 2021),

“plant protein” (23 in 2021), “genomics” (10 in 2022), and “gene” (16 in 2020) appear relatively late in the timeline, indicating the growing importance of genetic and biochemical approaches in this research field. This recent burst in genetic terms can be attributed to the development of numerous molecular markers as well as of state-of-the-art genomic and proteomic techniques applied to analyze the genetic diversity of *O. cumana* (Cvejić et al., 2020; Duca et al., 2024; Pineda-Martos et al., 2013), to monitor virulence patterns (Dedić et al., 2026), to search for wild germplasm as a reservoir of adaptivity (Sisou et al., 2026), to investigate the gene-for-gene interaction (Velasco et al., 2016), parasitism (Calderón-González et al., 2019) and resistance mechanisms (Calderón-González et al., 2023) as well as host-parasite interactions (Sisou et al., 2026), and to foster marker-assisted/genomic selection (Dimitrijevic & Horn, 2018; Lu et al., 2000; Miladinović et al., 2012). Terms, such as “disease resistance”, “parasite”, “host-parasite interaction”, “plant breeding”, “physiology”, “herbicide”, “crop yield”, emerge and gain traction, suggesting sustainable interest in these issues. For instance, the consistent presence of the term “herbicide” after 2002 may reflect the rapid expansion of herbicide-resistant sunflower lines and hybrids. This trend correlates with the commercial introduction of Clearfield® technology, followed by the subsequent development and global adoption of the more advanced Clearfield® Plus and ExpressSun® systems. The consistent prevalence of the terms “plant breeding” and “host-parasite interaction” reflects an ongoing co-evolutionary arms race, in which breeders have continuously to outpace the evolution of the parasite and the emergence of increasingly virulent races. Being the definitive metric of breeding success, the term “crop yield” maintains its status as a top topic even in the era of advanced technologies. At the same time terms like “fungus” (median 14 in 2005), “*Fusarium oxysporum*” (14 in 2002), “*Orobanche aegyptiaca*” (12 in 2003), “*Orobanche cernua*” (38 in 2000) point to declining/disappearing themes. This trend is likely to mean that fungal pathogens and *Orobanche* species, other than *Orobanche cumana*, are much less frequently discussed in the context of sunflower broomrape.

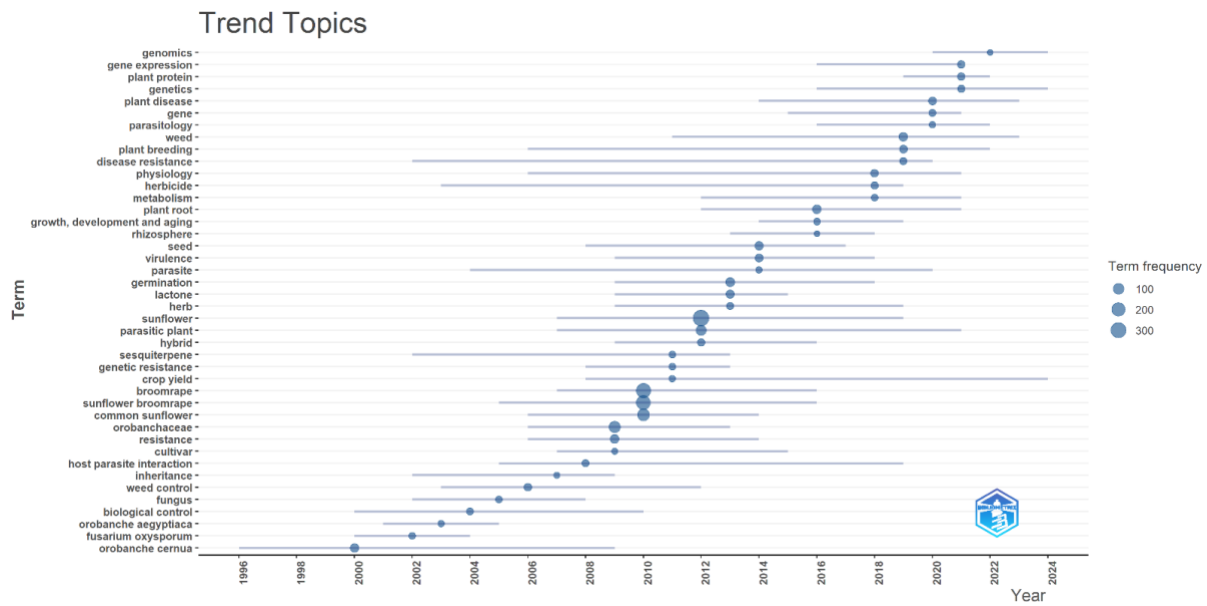


Figure 4. Temporal evolution of themes in the sunflower and broomrape research based on authors' keywords (minimum word frequency 10; number of words per year 3)

Connections and associations

Fig. 5 visualizes the flow of connections between the three fields. The thicker the gray band connecting two elements, the stronger the relationship (i.e., more publications linking them). This helps identify the dominant collaborations and affiliations. The left field (AU_CO - Author Country) represents the countries of the authors. The height of each bar indicates the overall representation from each country within this dataset. The center field (AU_UN - Author Affiliation) lists the authors' affiliations. The height indicates the number of publications associated with each institution. The right field (AU - Author) lists authors (10 most relevant based on results from Biblioshiny), with the height indicating their publication number. Spain and China appear to be the dominant countries (which agrees with the data in Table 1). For example, "CSIC - Instituto de Agricultura Sostenible (IAS)" is a Spanish institution collaborating with France, USA, Israel, Romania, and Bulgaria. Probably, it is this institution that promotes Spain to the first position in the sunflower broomrape research. Institute of Field and Vegetable Crops (Serbia) collaborates with the US and Turkey. However, Northwest A&F University (a Chinese university, which is likely to have made a significant contribution to bringing China to the top list in the sunflower and broomrape research, although only one scientist, Ma, Yongqing, is affiliated with this organization), another prominent institution in the Scopus dataset, has no international connections in this specific field. The plot reveals which authors are most active within these institutions and countries. For example, the most influential authors, Pérez-Vich, Begoña, Fernández-Martínez, José María, and Velasco, L., are associated with the CSIC - Instituto de Agricultura Sostenible (IAS). Pérez-Vich, Begoña and Velasco, L. also collaborate with Universidad de Córdoba (Spain) and Université de Toulouse (France). Fernández-Martínez, José María collaborates with Universidad de Córdoba too.

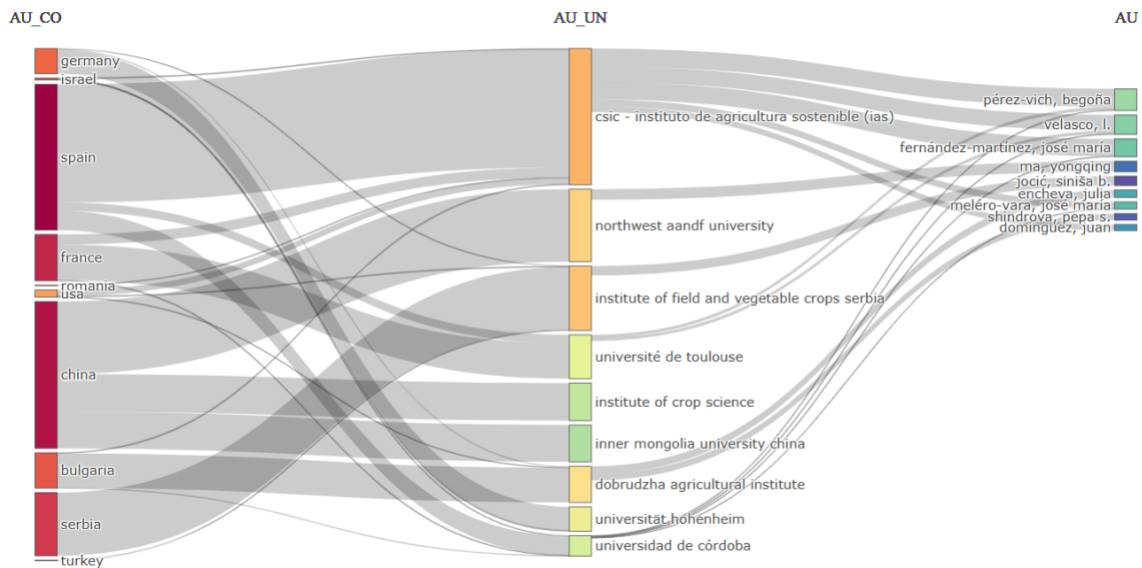


Figure 5. Three-field plot: country-affiliation-author associations in the sunflower and broomrape research (10 top items)

Strategic maps are tools used in bibliometrics to visualize the thematic structure of a research field. They are typically divided into four quadrants. Motor Themes (Upper Right) are both highly central (influential) and highly dense (developed). They represent the core, well-established areas of research. Niche Themes (Upper Left) are highly developed but not very central. They are specialized areas that might be isolated from the main research streams. Emerging or Declining Themes (Lower Left) are neither very central nor very developed. They could be new areas gaining attraction or older areas losing relevance. Basic Themes (Lower Right) are central but not very well developed. They represent fundamental concepts or areas that are crucial to the field but might not be experiencing rapid growth. The map in Fig. 6 reveals four distinct clusters. The big red bubble ("plant breeding, physiology, genetics") located in the 'Motor Theme' quadrant suggests that plant breeding-related topics are both central to the field of study and well-developed. This indicates a strong, ongoing research focus. The biggest blue bubble ("sunflower", "broomrape", "sunflower broomrape") located in the 'Basic Theme' quadrant suggests that sunflower-broomrape issues *per se*, while fundamental to understanding sunflower agriculture, might not be as actively developed as other areas. This could indicate a relatively stable, but important, area of research. The lilac "chemical" bubble positioned in the 'Niche Theme' quadrant includes such terms as "chemistry", "lactone", "sesquiterpene", implying that this area is well-developed but not a primary driver of the broader field. The classification of "sesquiterpene" and "lactone" as niche themes (despite the prospect of causing suicide germination of the parasitic weed seeds (Pérez de Luque et al., 2000) in our mapping reflects the high-tech specialization required for research into sesquiterpene lactone secretion. The technical exactingness of stable root exudate

collection and the requirement for integrated LC-MS/MS workflows naturally restrict this research to few specialized physiological laboratories. This creates a bibliometric signal lag compared to frequently mentioned terms like “genes” or “plant breeding”. The small green bubble comprises such keywords as “combining ability”, “mutant line”, “new breeding material” and is located in the 'Emerging or Declining Theme' quadrant. This position, characterized by low centrality and density, typically suggests a research area that is either nascent or fading. However, we propose a more nuanced interpretation of these themes. In the case of “mutant line,” the low bibliometric visibility likely reflects a declining interest, as classical mutagenesis for developing broomrape resistance may have reached its practical limits with currently available mutagens. Conversely, we argue that assessments of “combining ability” and “new breeding material” remain indispensable in breeding practice. Their presence in this quadrant does not signify a loss of relevance, but rather their transition into routine methodological steps. Unlike state-of-the-art genomic or biotechnological techniques, these fundamental breeding procedures are less frequently the primary focus of contemporary Scopus-indexed publications. However, it should be noted that a lot of studies using these indispensable steps of breeding practice can be documented in local/regional journals that remain outside the scope of the Scopus database, potentially affecting the perceived frequency of specific terms.

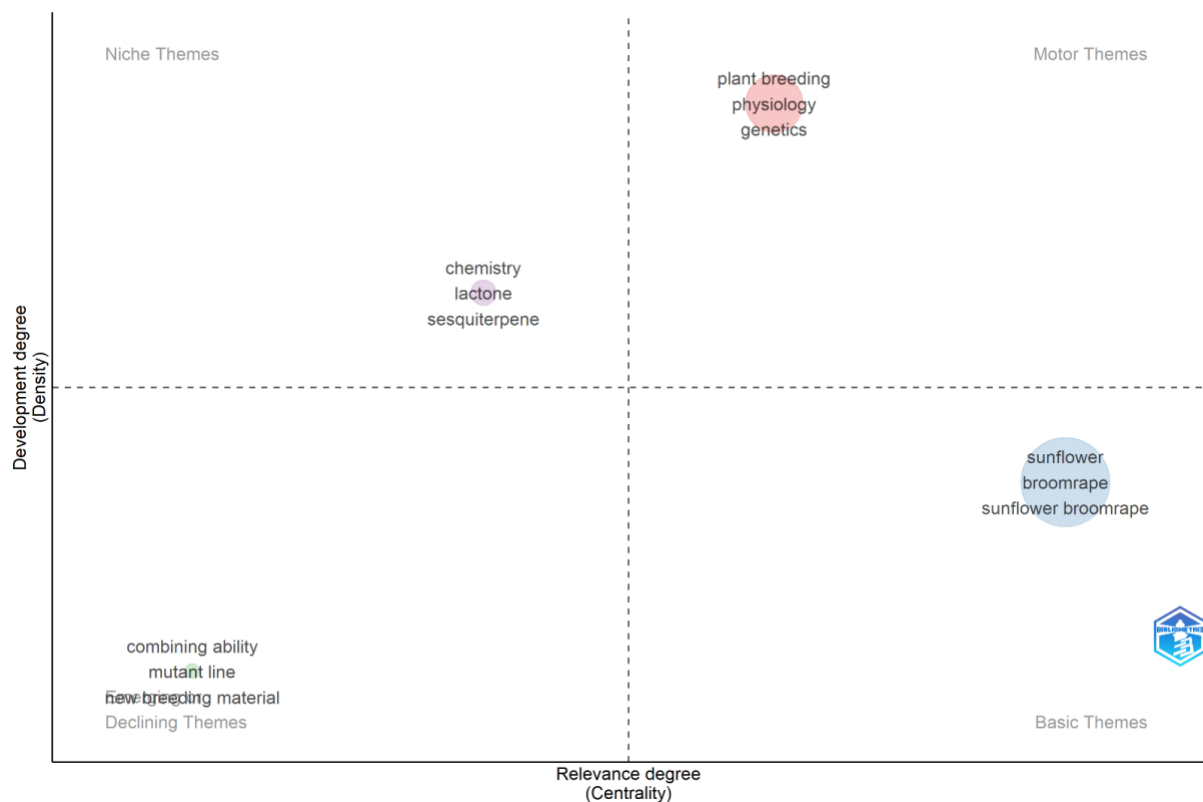


Figure 6. Thematic map of the sunflower and broomrape research

The co-authorship in Fig. 7 shows connections established by researchers in the sunflower broomrape research. This VOSviewer analysis resulted in 13 clusters. The presence of 6 isolated clusters, which are not connected with others, stands out. This may reflect the fact that broomrape spread always has local peculiarities; therefore, regional teams of researchers may work independently, investigating broomrape races and sunflower lines and hybrids that are crucial for their areas. Three clusters (green, red and brown) have numerous connections. The violet cluster has few connections with the red and green ones. The yellow cluster is also connected with the red and green ones. The orange and lilac clusters are only connected with each other. The most prolific authors are in the green and red clusters (Pérez-Vich Begoña and Velasco L.- green cluster; Fernández-Martínez José María - red cluster). Pérez-Vich Begoña has established 20 connections with other researchers, with the total link strength of 119, and published 39 papers. The corresponding figures for Velasco L and Fernández-Martínez José María are as follows: 15, 104, 36 and 16, 103, 35, respectively. The link strength between Pérez-Vich, Begoña and Velasco, L. is 34, confirming their close co-authorship, which we assumed from Fig. 3. We should emphasize that the co-authorship map would likely exhibit additional clusters from broomrape-affected regions in Eastern and Southeastern Europe, if databases indexing local journals provided sufficient metadata for comprehensive bibliometric analysis or if the levels of these journals met the Scopus criteria. The current mapping reflects the scientific landscape as provided by Scopus metadata, which does not account for the extensive volume of research published in local journals.

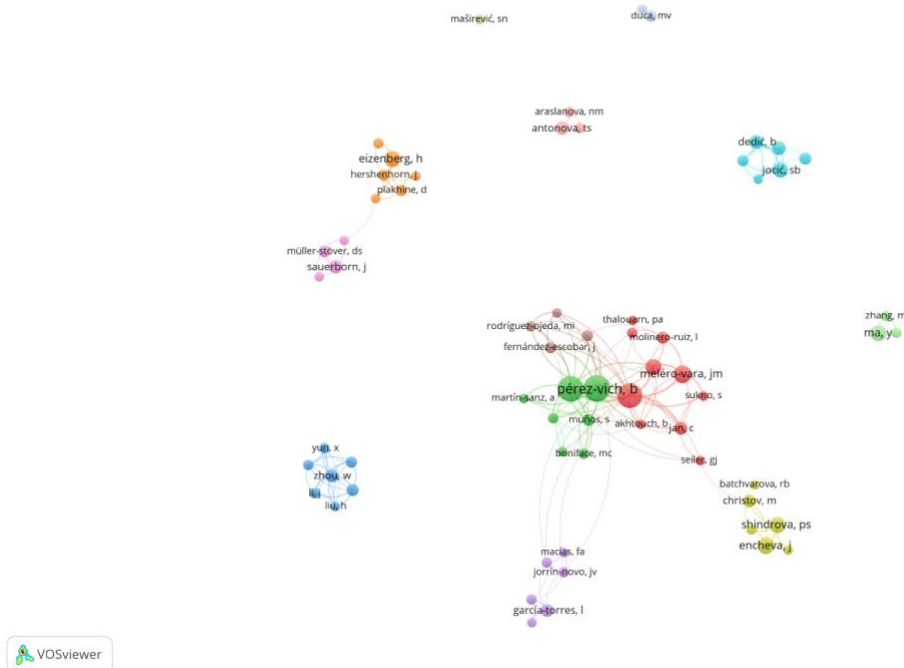


Figure 7. Co-authorship map for authors in the sunflower and broomrape research

Clustering of the countries by co-authorship resulted in 6 clusters (Fig. 8; one-country clusters of India and Ukraine are not presented in the map because of too big distances between them and the major clusters). The red cluster comprises Germany, Israel, Italy, Serbia, Turkey, and the US. The green cluster contains 4 countries: Bulgaria, Moldova, Romania, and Russia. The green cluster could be significantly larger as it encompasses countries with extensive sunflower acreages. The current clustering reflects the volume of research represented within the Scopus database rather than the absolute scientific output of the regions. The yellow cluster has 2 countries: Spain and France. The blue cluster also has 2 countries: China and Australia. At first, we assumed that clustering of countries would reflect broomrape spread or regional peculiarities of broomrape infestation. However, this map, with Israel and the US in one cluster or with China and Australia in the same cluster, etc., refutes this assumption. Thus, this map attests that inter-country collaboration is not driven by geographical spread of broomrape races.

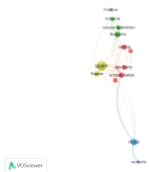


Figure 8. Co-authorship map for the countries in the sunflower and broomrape research

Bibliographic Coupling measures the degree to which two newer documents share a common reference list, i.e. documents A and B are coupled if they both cite one or more of the same older documents (C). This analysis reflects a shared knowledge base. Fig. 9 illustrated bibliographic coupling between scientists in the sunflower broomrape research. This VOSviewer analysis grouped the researchers in 5 clusters closely connected with one another. Here Pérez-Vich Begoña, Velasco L., and Fernández-Martínez José María are assigned to the same cluster, meaning they very frequently rely on the same references. For example, the link strength between Pérez-Vich Begoña and Velasco L. is 1290,

between Pérez-Vich Begoña and Fernández-Martínez José María – 1187 and between Velasco L. and Fernández-Martínez José María - 1032.

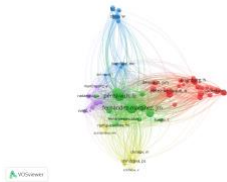


Figure 9. Bibliographic coupling between the authors in the sunflower and broomrape research

There are 4 clusters in Fig. 10 that shows bibliographic coupling of the countries. The red cluster comprises Moldova, Romania, Russia, Serbia, Spain, Turkey, and Ukraine. The green cluster consists of 4 countries: France, Germany, Israel, and Italy. The blue cluster has 3 countries: Australia, China, and India. The yellow cluster has 2 countries: the US and Bulgaria. Bibliographic coupling of the countries in Fig. 10 demonstrates that Spanish and American scientists often cite the same references, as the Spain-US link strength is 785. The Spain-China link strength is 268. For comparison, the Spain-Ukraine link strength is 38.



Figure 10. Bibliographic coupling between the countries in the sunflower and broomrape research

We also analyzed bibliographic coupling for journals (Fig. 11). This analysis produced 3 clusters. The red cluster contains the following journals: *Agronomy*, *Bulgarian Journal of Agricultural Science*, *Crop Science*, *Frontiers in Plant Science*, *Helia*, and *Theoretical and Applied Genetics*. The green cluster comprises of *Biotechnology and Biotechnological Equipment*, *Plant Disease*, *Weed Research*, and *Weed Science*. The blue cluster only has 2 journals: *Plant Breeding* and *Romanian Agricultural Research*. Here we can see that *Helia*, the most influential journal in this area of knowledge, besides its own red cluster, often has reference lists similar to those of *Plant Breeding* (link strength 199) and *Weed Research* (240).

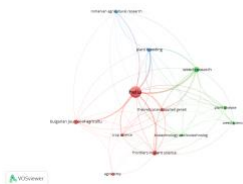


Figure 11. Bibliographic coupling between the journals in the sunflower and broomrape research

Keyword mapping produced 6 clusters (Fig. 12). The red cluster is broad-scoped: it encompasses terms of genetics and breeding, parasitology, plant biochemistry, physiology, and immunology. The green cluster contains such diverse terms as “enzyme activity”, “hybridization”, “host-parasite interaction”, “morphology”, “polymerase chain reaction”, “weeds”, etc. The dark-blue cluster is focused on pest control, *Orobanchaceae* species, fungal pathogens, and parasitism. The yellow cluster concerns such issues as germination, growth, development, and aging, sesquiterpenes, lactones, roots and rhizosphere, and allelopathy. The lilac cluster contains the “main characters” of this study: common sunflower and sunflower broomrape; in addition, it has terms concerning breeding and sunflower pathogens. The light-blue cluster contains such terms as “randomly amplified polymorphic DNA”, “races”, “virulence”, “genetic flow”, “inheritance”, “genetic resistance”, and “genetic diversity”. This clustering generally corroborates the thematic mapping in Fig. 6.

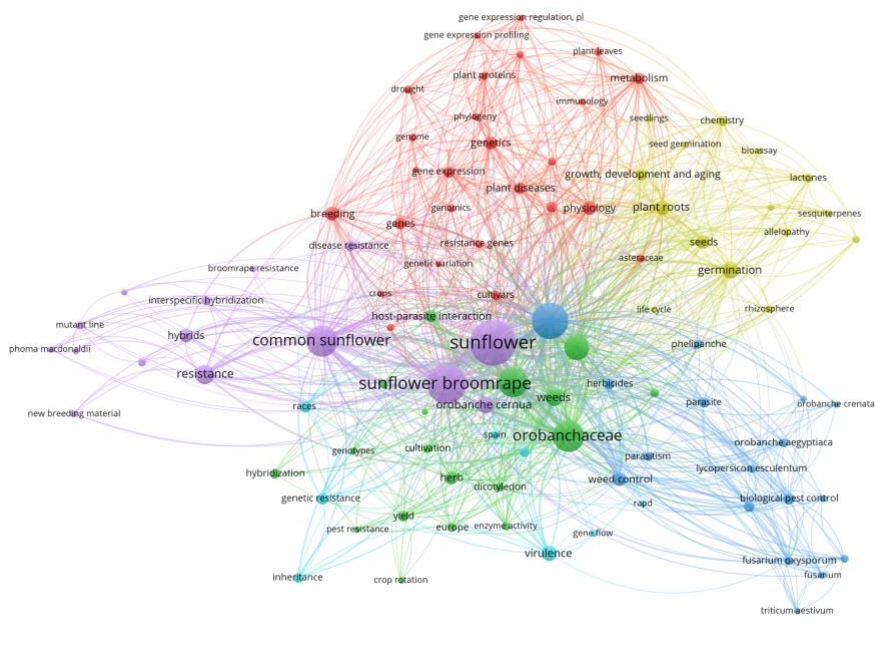


Figure 12. Co-occurrence of authors' keywords in the sunflower and broomrape research

Analysis in Biblioshiny allowed to identify the most cited articles, with the total citation count of over 100. The most cited article (the total citation count was 147), Labrousse et al. (2001) reported about several mechanisms of resistance of *Helianthus* to *O. cumana*, which included cell wall deposition, vessel occlusion, and broomrape cellular disorganization and were detected in a resistant sunflower genotype by histological assay of the host-parasite interface. This article is most likely to have contributed the peak in the total citations per article in 2001 (Figure 2). The next 3 most cited papers (the total citation count was 144, 128, and 122, respectively) were devoted to chemical response of sunflower to broomrape infestation (Joel et al., 2011; Serghini et al., 2001; Ueno et al., 2014). It is evident that the article by Serghini et al. (2001) also contributed to the 2001 peak. Despite the highly-cited article by Joel et al. (2011), the spike in the total citations per article in 2011 was relatively low. The highly-cited article by Ueno et al. (2014) did not result in a spike at all; this point on the 'total citations per article' line is on the slope. The last article on the top list (the total citation count was 102) is rather more broad-scoped than concentrated on broomrape-sunflower interaction only, describing nucleotide binding site leucine-rich repeat sequences, which were tightly linked to previously mapped downy mildew, rust, and broomrape resistance genes (Radwan et al., 2008). The article by Radwan et al. (2008) is not associated with any of the spikes either.

CONCLUSION

This study offers extensive comprehension of Scopus-based bibliometric variables related to sunflower-broomrape interactions. Using analyses in Biblioshiny and VOSviewer, the greatest contributors among countries, institutions, journals, and authors were identified, with Spain

distinguished as the undeniable leader (311 publications) among countries in the research related to broomrape and sunflower, CSIC - Instituto de Agricultura Sostenible (IAS) as the most publishing organization (187 publications), *Helia* as the most important journal (74 papers), and Pérez-Vich B. (20 connections with other researchers, with the total link strength of 119 and 39 papers), Velasco L. (15, 104, and 36, respectively) and Fernández-Martínez J.M. (16, 103, and 35, respectively) as the most prolific authors in this field. The temporal patterns in the publishing activities revealed that the publishing volume was described by an atypical 4th-degree polynomial model, while the profile of mean total citations per article showed a typical decline. Terms like "genetics", "gene expression", "plant protein", "genomics", and "gene" indicate the growing importance of genetic and biochemical approaches in this research field. The most influential papers were devoted to mechanisms of resistance of *Helianthus* to *O. cumana*, chemical response of sunflower to broomrape infestation, and genes encoding disease resistance proteins. The bibliometric findings may help researchers to evaluate the current status and outline emergent trends related to the challenge posed by broomrape to sunflower cultivation.

Acknowledgements

The authors express their gratitude to the Ministry of Education and Science of Ukraine and the State Scientific and Technical Library of Ukraine for providing the Yuriev Plant Production Institute with free access to the Scopus database used in this study.

Funding

The study was supported by the National Academy of Agrarian Sciences of Ukraine within the project "Development of Theoretical Principles for Using the Heterosis Effect in F1 Sunflower Hybrids Adapted to Climatic Changes and Based on Different Germplasms, with Improved Combinations of Valuable Economic Features" (State Registration No 0121U100556).

Declaration of AI And AI-assisted Technologies in the Writing Process

During the preparation of this work, we used AI tools (Gemini) for technical assistance. Specifically, these tools were employed to improve our English and to format the bibliographic references according to the journal's style. Following the use of these tools, we all reviewed and edited the manuscript, taking full responsibility for the final scientific content and the accuracy of the reference list.

Conflicts of Interest

The authors declare no conflicts of interest.

REFERENCES

- Al-Khatib, K., Baumgartner, J. R., Peterson, D. E., & Currie, R. S. (1998). Imazethapyr resistance in common sunflower (*Helianthus annuus*). *Weed Science*, 46(4), 403–407. <https://doi.org/10.1017/S0043174500090809>
- Alonso, L. C., Fernández-Escobar, J., López, G., Rodríguez-Ojeda, M. I., & Sallago, F. (1996). New highly virulent sunflower broomrape (*O. cernua* Loefl.) pathotypes in Spain. In *Advances in parasitic plant research* (pp. 639–644). Sevilla, Spain: Junta de Andalucía.
- Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959–975. <https://doi.org/10.1016/j.joi.2017.08.007>
- Barea, G., García-Carneros, A. B., Baltazar, L., Coimbra-Melgar, D. C., Zankiz-Salvatierra, M., Zomeño, P., & Molinero-Ruiz, L. (2025). First report of *Orobanche cumana* Wallr. (sunflower broomrape) in South America. *Plant Disease*, 109(11), 3245. <https://doi.org/10.1094/PDIS-05-25-1014-PDN>
- Britannica. (2026, January 23). *Native American: Prehistoric farmers*. Retrieved January 26, 2026, from <https://www.britannica.com/topic/Native-American/Prehistoric-farmers>
- Burlov, V., & Burlov, V. (2010). Breeding of sunflower resistant to new races of broomrape *Orobanche cumana* Wallr. *Helia*, 33(53), 165–172. <https://doi.org/10.2298/hel1053165b>
- Cai, Y., Liu, J., Zhang, M., Qin, N., Liao, M., Gao, F., Zhao, Z., & Sha, O. (2025). Trends and hotspots in research of virus and gastrointestinal mucosal immunity: A bibliometric analysis of four decades. *Virology Journal*, 22, Article 29. <https://doi.org/10.1186/s12985-025-02929-x>
- Calderón-González, Á., Pérez-Vich, B., Pouilly, N., Boniface, M. C., Louarn, J., Velasco, L., & Muñoz, S. (2023). Association mapping for broomrape resistance in sunflower. *Frontiers in Plant Science*, 13, 1056231. <https://doi.org/10.3389/fpls.2022.1056231>
- Calderón-González, Á., Pouilly, N., Muñoz, S., Grand, X., Coque, M., Velasco, L., & Pérez-Vich, B. (2019). An SSR-SNP linkage map of the parasitic weed *Orobanche cumana* Wallr. including a gene for plant pigmentation. *Frontiers in Plant Science*, 10, 797. <https://doi.org/10.3389/fpls.2019.00797>
- Christov, M., Batchvarova, R., & Hristova-Cherbadzhi, M. (2014). Wild species of *Helianthus* L.: Sources of resistance to the parasite *Orobanche cumana* Wallr. *Helia*, 32(51), 65–73. <https://doi.org/10.2298/HEL0951065C>
- Cochavi, A. (2025). Broomrape–host interaction: Host morphology and physiology as metrics for infestation. *Planta*, 261(4), Article 45. <https://doi.org/10.1007/s00425-024-04581-1>
- Cvejić, S., Radanović, A., Dedić, B., Jocković, M., Jocić, S., & Miladinović, D. (2020). Genetic and genomic tools in sunflower breeding for broomrape resistance. *Genes*, 11(2), 152. <https://doi.org/10.3390/genes11020152>
- Dedić, B., Martin-Sanz, A., Sayago, A., Perez-Vich, B., Velasco, L., & Cvejić, S. (2026). Population genetics and virulence patterns of sunflower broomrape populations from Serbia. *Weed Research*, 66(1), e70072. <https://doi.org/10.1111/wre.70072>
- Delavault, P. (2015). Knowing the parasite: Biology and genetics of *Orobanche*. *Helia*, 38(62), 15–29. <https://doi.org/10.1515/helia-2014-0030>
- Dimitrijević, A., & Horn, R. (2018). Sunflower hybrid breeding: from markers to genomic selection. *Frontiers in Plant Science*, 8, 2238. <https://doi.org/10.3389/fpls.2017.02238>

- Duca, M., Bivol, I., Mutu, A., Port, A., & Clapco, S. (2024). Analysis of genetic relationships between broomrape populations from different countries using ISSR markers. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 52(1), 13590. <https://doi.org/10.15835/nbha52113590>
- Duca, M., Clapco, S., & Joita-Pacureanu, M. (2022). Racial status of *Orobanche cumana* Wallr. in some countries around the world. *Helia*, 45(76), 1–22. <https://doi.org/10.1515/helia-2022-0002>
- Duca, M., Glijin, Aliona., & Acciu, Adriana. (2013). The biological cycle of sunflower broomrape. *Journal of Plant Development*, 20, 71–78.
- Echevarría-Zomeño, S., Pérez-de-Luque, A., Jorriñ-Novó, J., & Maldonado-Alconada, A. (2006). Pre-haustorial resistance to broomrape (*Orobanche cumana*) in sunflower (*Helianthus annuus*): Cytochemical studies. *Journal of Experimental Botany*, 57(15), 4189–4200. <https://doi.org/10.1093/jxb/erl195>
- El Amri, M., Khayi, S., Triqui, Z. E. A., Amri, M., & Mentag, R. (2023). *Orobanche crenata*: A bibliometric analysis of a noxious parasitic plant. *Plant Disease*, 107(11), 3332–3343. <https://doi.org/10.1094/PDIS-10-22-2478-SR>
- Encheva, J., Christov, M., & Shindrova, P. (2008). Developing mutant sunflower line (*Helianthus annuus* L.) by combined use of classical method with induced mutagenesis and embryo culture method. *Bulgarian Journal of Agricultural Science*, 14(4), 397–404.
- FAOSTAT. (2026). *Crops and livestock products*. Retrieved January 26, 2026, from <https://www.fao.org/faostat/en/#data/QCL>
- Fernández-Aparicio, M., Reboud, X., & Gibot-Leclerc, S. (2016). Broomrape weeds. Underground mechanisms of parasitism and associated strategies for their control: A review. *Frontiers in Plant Science*, 7, Article 135. <https://doi.org/10.3389/fpls.2016.00135>
- Fernández-Escobar, J., Rodríguez-Ojeda, M. I., & Alonso, L. C. (2008, June). Distribution and dissemination of sunflower broomrape (*Orobanche cumana* Wallr.) race F in Southern Spain [Conference presentation]. *Proceedings of the 17th International Sunflower Conference* (Vol. 1, pp. 231–236). Córdoba, Spain. https://www.juntadeandalucia.es/export/drupaljda/133716107917x_International_Sunflower_Conference_x_2_volumenesx.pdf
- Fernández-Escobar, J., Rodríguez-Ojeda, M. I., Fernández-Martínez, J. M., & Alonso, L. C. (2009). Sunflower broomrape (*Orobanche cumana* Wallr.) in Castilla-León, a traditionally nonbroomrape infested area in Northern Spain. *Helia*, 32(51), 57–64. <https://doi.org/10.2298/hel0951057f>
- Fernández-Martínez, J. M., Pérez-Vich, B., & Velasco, L. (2015). Sunflower broomrape (*Orobanche cumana* Wallr.). In E. Martínez-Force, N. T. Dunford, & J. J. Salas (Eds.), *Sunflower* (pp. 129–155). AOCS Press. <https://doi.org/10.1016/B978-1-893997-94-3.50011-8>
- Fernández-Melero, B., Martín-Sanz, A., del Moral, L., Pérez-Vich, B., & Velasco, L. (2023). A novel sunflower broomrape race with unusual virulence potentially caused by a mutation. *Frontiers in Plant Science*, 14, Article 1236511. <https://doi.org/10.3389/fpls.2023.1236511>
- Florin Gabriel, A., Joita, P., & Luxita, R. (2024, September 14–15). *Sunflower breeding for broomrape resistance* [Conference presentation]. National Conference: Natural Sciences in the Dialogue of Generations, Chisinau, Republic of Moldova. <https://doi.org/10.13140/RG.2.2.23667.34087>
- Hu, L., Louarn, J., Archipiano, M., Bazerque, J., Lopez-Sendon, M., Tardin, M.-C., Jestin, C., Pouilly, N., Chabaud, M., Rolland, M., Zhang, Z., Zhao, J., Yang, C., Zhou, W., & Muñoz, S. (2019, June). *Genetic diversity of Orobanche cumana (sunflower broomrape) populations at the world level revealed by SSR*

- markers [Conference presentation]. 15th World Congress on Parasitic Plants, Amsterdam, The Netherlands.
- Javed, F., Ahmad, S., Issrani, R., Zeeshan, H. M., Iqbal, A., Syed, E., Alam, M. K., & Prabhu, N. (2024). Relevance of the human microbiome in breast cancer: A global bibliometric and visual analysis. *Scientifica*, 2024, Article 5518835. <https://doi.org/10.1155/2024/5518835>
- JGraph Ltd. (2026). *diagrams.net* (Version 26.0.9) [Computer software]. <https://app.diagrams.net/>
- Joel, D. M., Chaudhuri, S. K., Plakhine, D., Ziadna, H., & Steffens, J. C. (2011). Dehydrocostus lactone is exuded from sunflower roots and stimulates germination of the root parasite *Orobanche cumana*. *Phytochemistry*, 72(7), 624–634. <https://doi.org/10.1016/j.phytochem.2011.01.037>
- Jursík, M., Hamouzová, K., Soukup, J., Andr, J., & Holec, J. (2014). Differences in sensitivity of F1 and F2 generations of herbicide tolerant sunflower volunteers to selected acetolactate synthase inhibiting herbicides. *Plant, Soil and Environment*, 60(10), 446–451. <https://doi.org/10.17221/185/2014-PSE>
- Kaya, Y. (2014, June 3–6). *Current situation of sunflower broomrape around the world* [Conference presentation]. 3rd International Symposium on Broomrape (*Orobanche* spp.) in Sunflower, Cordoba, Spain.
- Kebede, M., & Ayana, B. (2018). Economically important parasitic weeds and their management practices in crops. *Journal of Environment and Earth Science*, 8(1), 104–115. https://www.researchgate.net/publication/350687353_Economically_Important_Parasitic_Weeds_and_Their_Management_Practices_in_Crops
- Khablak, S. H., Bondareva, L. M., Dolia, M. M., Blume, Y. B., Tymoshchuk, T. M., Mrynskyi, I. M., Hrytsiuk, N. V., & Sychak, V. M. (2025). Resistance of new sunflower hybrids to sunflower broomrape (*Orobanche cumana*) and the possibility of their use in the strategy of protection against the parasite. *Regulatory Mechanisms in Biosystems*, 16(2), e25063. <https://doi.org/10.15421/0225063>
- Kurylych, D. V., & Makliak, K. M. (2022). Peculiarities of the sunflower breeding for resistance to broomrape (*Orobanche cumana* Wallr.). *Plant Breeding and Seed Production*, 122, 19–39. <https://doi.org/10.30835/2413-7510.2022.271748> (<https://selektsiia-nasinytstvo.com.ua/pbsd/uk/article/view/2022-122-02/631>)
- Kurylych, D. V., & Makliak, K. M. (2024). Genetic analysis of the inheritance of sunflower resistance to broomrape by diallel method. *Plant Breeding and Seed Production*, (126), 6–20. <https://doi.org/10.30835/2413-7510.2024.318739> (<https://selektsiia-nasinytstvo.com.ua/pbsd/en/article/view/2024-126-01/664>)
- Kurylych, D., & Makliak, K. (2025). Inheritance of resistance of annual sunflower (*Helianthus annuus* L.) to race F of broomrape (*Orobanche cumana* Wallr.). *Bulletin of Sumy National Agrarian University. The series: Agronomy and Biology*, (58), 57–63. <https://doi.org/10.32782/agrobio.2024.4.9> (<https://snaubulletin.com.ua/index.php/ab/article/view/1273>)
- Kysylchuk, A., Zakharchenko, E., Turchina, S., Dashutina, L., Bolshakov, Y., Lemishko, S., Chernykh, S., Azarov, V., Berdin, S., Vereshchahin, I., & Tkachenko, R. (2025). Management of cultivation, market analyses, diversification, and changes in herbicide groups of sunflowers in the northeastern region of Ukraine. *Modern Phytomorphology*, 19, 178–182. <https://doi.org/10.5281/zenodo.15302209>
- Labrousse, P., Arnaud, M. C., Griveau, Y., Fer, A., & Thalouarn, P. (2004). Analysis of resistance criteria of sunflower recombined inbred lines against *Orobanche cumana* Wallr. *Crop Protection*, 23(5), 407–413. <https://doi.org/10.1016/j.cropro.2003.09.013>

- Labrousse, P., Arnaud, M. C., Serieys, H., Bervillé, A., & Thalouarn, P. (2001). Several mechanisms are involved in resistance of *Helianthus* to *Orobanche cumana* Wallr. *Annals of Botany*, 88(5), 859–868. <https://doi.org/10.1006/anbo.2001.1520>
- Lu, Y., Melero-Vara, J., García-Tejada, J. A., & Blanchard, P. (2000). Development of SCAR markers linked to the gene *Or5* conferring resistance to broomrape (*Orobanche cumana* Wallr.) in sunflower. *Theoretical and Applied Genetics*, 100(3), 625–632. <https://doi.org/10.1007/s001220050083>
- Makliak, K. M., & Kyrychenko, V. V. (2012). Resistance of sunflower starting material to new races of broomrape (*Orobanche cumana* Wallr.). *Seleksiia i nasinnytstvo*, (102), 16–21. (in Ukrainian)
- Makliak, E., Kyrychenko, V., & Joița-Păcureanu, M. (2018, July 2–4). *Race composition and phenology of sunflower broomrape (Orobanche cumana Wallr.) in Ukraine* [Paper presentation]. 4th International Symposium on Broomrape in Sunflower, Bucharest, Romania. https://www.isasunflower.org/fileadmin/documents/Symposia/4th_Symposium_broomrape_Bucharest_2018/BIOLOGY_AND_GENETICS_OF_THE_PARASITE_OROBANCHE_CUMANA/makliak.pdf
- Martin-Sanz, A., Malek, J., Fernandez-Martinez, J. M., Perez-Vich, B., & Velasco, L. (2016). Increased virulence in sunflower broomrape (*Orobanche cumana* Wallr.) populations from Southern Spain is associated with greater genetic diversity. *Frontiers in Plant Science*, 7, Article 589. <https://doi.org/10.3389/fpls.2016.00589>
- Masliiov, S. V., Macai, N. J., Beseda, O. O., & Stepanov, V. V. (2018). Control of broomrape *Orobanche cumana* Wallr. *Ukrainian Journal of Ecology*, 8(2), 74–80. https://doi.org/10.15421/2018_312
- Miladinović, D., Imerovski, I., Dimitrijević, A., Jocić, S., Cvejić, S., Dedić, B., & Miklič, V. (2012, June). Conventional and molecular breeding for broomrape resistance in sunflower [Conference presentation]. *International Conference on BioScience: Biotechnology and Biodiversity*. Novi Sad, Serbia. <https://www.cabidigitallibrary.org/doi/pdf/10.5555/20143243698>
- Miller, J. F., & Al-Khatib, K. (2002). Registration of imidazolinone herbicide-resistant sunflower maintainer (HA 425) and fertility restorer (RHA 426 and RHA 427) germplasms. *Crop Science*, 42(3), 988–989. <https://doi.org/10.2135/cropsci2002.988a>
- Miller, J. F., & Al-Khatib, K. (2004). Registration of two oilseed sunflower genetic stocks, SURES-1 and SURES-2 resistant to tribenuron herbicide. *Crop Science*, 44(3), 1037–1038. <https://doi.org/10.2135/cropsci2004.1037>
- Mitkov, A., Yanev, M., Neshev, N., Tonev, T., Pacureanu-Joita, M., & Cojocar, F. (2019). Efficacy against broomrape and selectivity of imazamox-containing herbicides in sunflower. *Romanian Agricultural Research*, 36, 327–334. <https://doi.org/10.59665/rar3623>
- Molinero-Ruiz, L., Delavault, P., Pérez-Vich, B., Pacureanu-Joita, M., Bulos, M., Altieri, E., & Domínguez, J. (2015). History of the race structure of *Orobanche cumana* and the breeding of sunflower for resistance to this parasitic weed: A review. *Spanish Journal of Agricultural Research*, 13(4), Article e10R01. <https://doi.org/10.5424/sjar/2015134-8080>
- Passas, I. (2024). Bibliometric analysis: The main steps. *Encyclopedia*, 4(2), 1014–1025. <https://doi.org/10.3390/encyclopedia4020065>
- Pérez de Luque, A., Galindo, J. C., Macías, F. A., & Jorrín, J. (2000). Sunflower sesquiterpene lactone models induce *Orobanche cumana* seed germination. *Phytochemistry*, 53(1), 45–50. [https://doi.org/10.1016/s0031-9422\(99\)00485-9](https://doi.org/10.1016/s0031-9422(99)00485-9)

- Pilorgé, E., Dauguet, S., Jestin, C., & Mestries, E. (2020). The main dynamics of sunflower research presented at the 19th International Sunflower Conference in 2016. *OCL*, 27, Article 21. <https://doi.org/10.1051/ocl/2020011>
- Pineda-Martos, R., Velasco, L., Fernández-Escobar, J., Fernández-Martínez, J. M., & Pérez-Vich, B. (2013). Genetic diversity of *Orobanche cumana* populations from Spain assessed using SSR markers. *Weed Research*, 53(4), 279–289. <https://doi.org/10.1111/wre.12022>
- Pranajaya, E., Alexandri, M. B., Chan, A., & Hermanto, B. (2024). Examining the influence of financial inclusion on investment decision: A bibliometric review. *Heliyon*, 10(3), Article e25779. <https://doi.org/10.1016/j.heliyon.2024.e25779>
- Radwan, O., Gandhi, S., Heesacker, A., Whitaker, B., Taylor, C., Plocik, A., Kesseli, R., Kozik, A., Michelmore, R. W., & Knapp, S. J. (2008). Genetic diversity and genomic distribution of homologs encoding NBS-LRR disease resistance proteins in sunflower. *Molecular Genetics and Genomics*, 280(2), 111–125. <https://doi.org/10.1007/s00438-008-0346-1>
- Rotarenco, V. (2010). *Morpho-physiological and genetic aspects of parasitic host interaction (Helianthus annuus L. – Orobanche cumana Wallr.)* [Doctoral dissertation, Moldova State University].
- Sakhno, T., Petrenkova, V., Sharypina, Y., Borovskaya, I., & Makliak, E. (2018, July 2–4). *Physiological particularities of sunflower lines and hybrids resistance to broomrape* [Paper presentation]. 4th International Symposium on Broomrape in Sunflower, Bucharest, Romania. https://www.isasunflower.org/fileadmin/documents/Symposia/4th_Symposium_broomrape_Bucharest_2018/RESISTANCE_MECHANISMS_TO_OROBANCHE_CUMANA_IN_SUNFLOWER/tamara.pdf
- Sala, C. A., Bulos, M., & Echarte, A. M. (2008). Genetic analysis of an induced mutation conferring imidazolinone resistance in sunflower. *Crop Science*, 48(5), 1817–1822. <https://doi.org/10.2135/cropsci2007.11.0625>
- Serghini, K., Pérez de Luque, A., Castejón-Muñoz, M., García-Torres, L., & Jorrín, J. V. (2001). Sunflower (*Helianthus annuus* L.) response to broomrape (*Orobanche cernua* Loefl.) parasitism: Induced synthesis and excretion of 7-hydroxylated simple coumarins. *Journal of Experimental Botany*, 52(364), 2227–2234. <https://doi.org/10.1093/jexbot/52.364.2227>
- Shcherban, S., Shcherban, N., Abitayev, F., Hryhorchuk, N., & Sotsioner, A. (2023). Evaluation of sunflower breeding material for resistance to broomrape (*Orobanche cumana* Wallr.) and herbicides under artificial climate conditions to accelerate the breeding process. *Scientific Horizons*, 26(11), 111–122. <https://doi.org/10.48077/scihor11.2023.111>
- Shevchenko, S., Derevenets-Shevchenko, K., Shevchenko, M., & Shevchenko, O. (2024). Sunflower broomrape (*Orobanche cumana* Wallr.) and weeds in sunflower crops with minimized tillage in a steppe ecotype crop rotation. *Ekológia (Bratislava)*, 43(1), 34–42. <https://doi.org/10.2478/eko-2024-0004>
- Shevchenko, S., Desyatnyk, L., Shevchenko, M., Kolesnykova, K., & Derevenets-Shevchenko, K. (2024). Control of weeds and sunflower broomrape (*Orobanche cumana* Wallr.) in sunflower crops by crop rotation and tillage. *International Journal of Environmental Studies*, 81(1), 382–392. <https://doi.org/10.1080/00207233.2024.2320031>
- Shi, B. X., Chen, G. H., Zhang, Z. J., Hao, J. J., Jing, L., Zhou, H. Y., & Zhao, J. (2015). First report of race composition and distribution of sunflower broomrape, *Orobanche cumana*, in China. *Plant Disease*, 99(2), 291. <https://doi.org/10.1094/PDIS-07-14-0721-PDN>

- Sisou, D., Ziadna, H., Eizenberg-Weiss, M., Eizenberg, H., & Hübner, S. (2026). Wild genes to the rescue: High-throughput genomics reveals the wild source of broomrape resistance in sunflower. *Journal of Experimental Botany*, 77, erag141. <https://doi.org/10.1093/jxb/erag141>
- Škorić, D., Joița-Păcureanu, M., Gorbachenko, F., Gorbachenko, O., & Maširević, S. (2021). Dynamics of change in broomrape populations (*Orobanche cumana* Wallr.) in Romania and Russia (Black Sea area). *Helia*, 44(74), 1–14. <https://doi.org/10.1515/helia-2020-0025>
- Škorić, D., Pacureanu-Joita, M., & Sava, E. (2010). Sunflower breeding for resistance to broomrape (*Orobanche cumana* Wallr.). *Analele I.N.C.D.A. Fundulea*, 78, 63–79.
- Su, Y., Tian, X., Du, L., Bai, Q., Liu, Z., Zhao, J., Xu, J., Duan, X., Wu, Z., & Yun, X. (2022). Screening trap crops of sunflower broomrape (*Orobanche cumana* Wallr.) in Bayannur. *Journal of Northern Agriculture*, 50(2), 103–109. <https://doi.org/10.12190/j.issn.2096-1197.2022.02.13>
- Taher, M., Javani, M., Beyaz, R., & Yildiz, M. (2017). A new environmental friendly production method in sunflower for high seed and crude oil yields. *Fresenius Environmental Bulletin*, 26(6), 4004–4010.
- Teplitskiy, M., Duede, E., Menietti, M., & Lakhani, K. R. (2022). How status of research papers affects the way they are read and cited. *Research Policy*, 51(4), Article 104484. <https://doi.org/10.1016/j.respol.2022.104484>
- Ueno, K., Furumoto, T., Umeda, S., Mizutani, M., Takikawa, H., Batchvarova, R., & Sugimoto, Y. (2014). Heliolactone, a non-sesquiterpene lactone germination stimulant for root parasitic weeds from sunflower. *Phytochemistry*, 108, 122–128. <https://doi.org/10.1016/j.phytochem.2014.09.018>
- Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 84(2), 523–538. <https://doi.org/10.1007/s11192-009-0146-3>
- Velasco, L., Pérez-Vich, B., & Fernández-Martínez, J. M. (2016). Research on resistance to sunflower broomrape: an integrated vision. *Oilseeds and fats, Crops and Lipids*, 23(2), D203. <https://doi.org/10.1051/ocl/2016002>
- Velasco, L., Pérez-Vich, B., Jan, C. C., & Fernández-Martínez, J. M. (2006). Inheritance of resistance to broomrape (*Orobanche cumana* Wallr.) race F in a sunflower line derived from wild sunflower species. *Plant Breeding*, 125(1), 67–71. <https://doi.org/10.1111/j.1439-0523.2006.01278.x>
- Weston, B., Pfenning, M., Perez-Brea, J., Tan, S., McNevin, G., Carlson, D., Bertero de Romano, A., Romano, C., Bulos, M., & Sala, C. (2012, February). Yield and oil improvements in Clearfield® Plus sunflowers [Conference presentation]. *18th International Sunflower Conference*. Mar del Plata & Balcarce, Argentina. https://www.isasunflower.org/fileadmin/documents/aaProceedings/18thISAArgentina-vol1/Herbicide_Resistance/Yield_and_Oil_Improvements_in_Clearfield_Plus_Sunflowers.pdf
- Ye, X., Zhang, M., Zhang, M., & Ma, Y. (2020). Assessing the performance of maize (*Zea mays* L.) as trap crops for the management of sunflower broomrape (*Orobanche cumana* Wallr.). *Agronomy*, 10(1), Article 100. <https://doi.org/10.3390/agronomy10010100>
- Zhou, Z., Li, J., Gao, Y., Wang, X., Wang, R., Huang, H., Zhang, Y., Zhao, L., & Wang, P. (2024). Research on drought stress in *Medicago sativa* L. from 1998 to 2023: A bibliometric analysis. *Frontiers in Plant Science*, 15, Article 1406256. <https://doi.org/10.3389/fpls.2024.1406256>