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BIBLIOMETRIC ANALYSIS OF RESEARCH ON WHEAT LANDRACES: A WEB OF SCIENCE-BASED STUDY (2000–2025)

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Abstract: Wheat landraces are valuable genetic resources for improving crop adaptation, resilience, and sustainability under changing environmental conditions. However, despite the increasing number of studies, a systematic evaluation of global research trends in this field remains limited. A total of 1,774 publications indexed in the Web of Science Core Collection between 2000 and 2025 were analyzed using VOSviewer to assess publication trends, citation structures, keyword co-occurrence patterns, and international collaboration networks. The results showed a significant increase in research output, particularly after 2014, indicating growing scientific interest in wheat genetic resources. Keyword analysis revealed that studies are mainly concentrated on genetic diversity, genomics, and major wheat species such as *Triticum aestivum* and durum wheat. Citation and collaboration analyses identified the United States, China, and Israel as leading contributors, supported by strong international research networks. In conclusion, wheat landrace research has evolved into a rapidly expanding and collaborative scientific field. Strengthening the conservation of genetic resources and enhancing international collaboration will be critical for advancing sustainable agricultural development.

Keywords: Wheat landraces, Bibliometric analysis, Genetic diversity, Scientific collaboration, Sustainable agriculture

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1. Introduction

This article discusses the importance of wheat (*Triticum* spp.), a staple crop worldwide, and its relation to global food security. Wheat is one of the key crops in the world, providing much of the caloric and protein intake for a large proportion of the world's population. The Fertile Crescent region of Turkey is among several areas known to be the center of origin of wheat and has many wild relatives and traditional wheat varieties. Local or "landrace" wheat varieties have evolved over thousands of years through both natural processes of adaptation, and farmer-led selective processes. Landraces tend to be genetically variable and are well-suited to their local environment. As modern agriculture becomes increasingly homogenous, genetic diversity is being lost in wheat. Landraces, therefore, present opportunities for improving biodiversity and sustainability in agricultural production systems (Harlan, 1992; Brush, 2004; Dwivedi et al., 2016).

Landraces have been developed and maintained by farmers for centuries and now offer potentially valuable gene pools for developing new, more environmentally resilient wheat varieties. Modern wheat breeding programs have largely emphasized the development of high yield and highly uniform cultivars. While these traits will likely continue to be desirable, there may be limitations in how adaptable these cultivars are to changes in climate, or environmental stressors. Many local wheat genotypes have shown promise for adapting to low input agricultural systems, and marginal environmental conditions. Their ability to produce yields with limited water availability and poor soil fertility has been gaining increasing scientific attention (Mercer and Perales, 2010; Cavanagh et al., 2013). Other desirable traits associated with landraces include drought tolerance, disease and pest resistance, and their ability to utilize limited amounts of soil nutrients. Therefore, the genetic diversity contained in landrace populations presents unique advantages relative to adapting to the changing environmental conditions.

Wheat landraces are typically defined as genetically diverse populations that have developed over time through farmer selection and natural selection. As such, they are seen as a valuable genetic resource for modern plant breeding programs (Liu et al., 2024). Their inherent high genetic diversity and adaptability lend themselves well to supporting sustainable agriculture practices and long-term crop improvement strategies (Zeven, 1998; Newton et al., 2010).

Recently, numerous studies have investigated the genetic diversity, adaptations and agronomic value of wheat landraces. However, few comprehensive reviews exist to evaluate the total research output, trends, and network collaborations in the area.

Bibliometric analysis is a quantitative methodology used to assess the growth and knowledge structure of scientific research fields. It is a technique that enables researchers to analyze publication performance, citation relationships, keyword trends and international collaboration networks within a given research area (Haunschild et al., 2016; Nardi et al., 2016; Önder, 2025). Additionally, it can help identify the leading authors, institutions, countries and journals in a field, as well as emerging trends and developments in the body of scientific knowledge (Zhang et al., 2020; Çomaklı, 2021). Typically, bibliometric studies are performed using information obtained from large scientific databases including Scopus, ScienceDirect and Google Scholar. Of the available databases, the Web of Science (WoS) is frequently selected because it provides a broad scope of coverage, as well as a systematic citation index (Birkle et al., 2020; Pranckutė, 2021).

The purpose of this study was to examine research output in the form of scientific publications related to wheat landraces, using bibliometric methodologies. The study evaluated publication trends, citation patterns, keyword relationships, and international collaboration networks, in order to characterize the entire research landscape. The ultimate goal of the study was to generate an overview of the trajectory of research into wheat landraces, highlight the trends currently in place, and ultimately inform future research in this area.

2. Materials and Methods

2.1. Data Collection

The data used in this study were obtained from the Web of Science Core Collection, which is one of the most reliable and widely used databases for bibliometric research. A comprehensive literature search was conducted to identify scientific publications related to wheat landraces and traditional wheat varieties. The data retrieval process was carried out on 15 January 2026 using the Web of Science database.

The literature search was performed using the Topic (TS) field, which includes the title, abstract, author keywords, and Keywords Plus. To capture studies related to wheat landraces, the following search query was used: TS = ("wheat landrace*" OR "landrace wheat" OR "wheat landraces" OR "traditional wheat variet*" OR "heritage wheat" OR "ancient wheat" OR "primitive wheat" OR einkorn OR emmer OR "hulled wheat"). In order to include only peer-reviewed scientific studies, the analysis was limited to publications categorized as Article and Review. Furthermore, to focus on relevant research fields, the dataset was restricted to publications within the categories of Agronomy, Plant Sciences, and Genetics & Heredity. The selected publications covered the period between 2000 and 2025.

After applying the search query and filtering criteria, a total of 1774 publications were retrieved from the database. Prior to the bibliometric analysis, the dataset was subjected to a data cleaning process. During this stage, variations in author names, institutional affiliations, and keywords were standardized, and duplicate records were checked and removed where necessary. The research process was conducted following the five-stage framework commonly used in bibliometric studies (Figure 1; Putri et al., 2021).

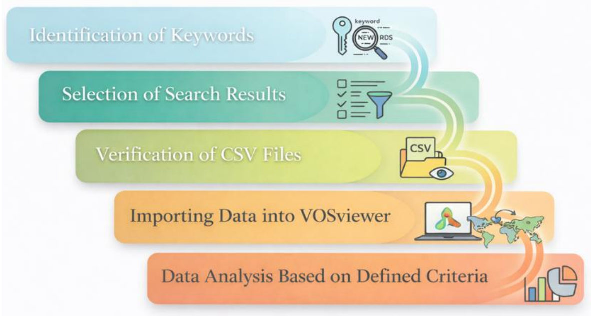

Figure 1. Workflow of the bibliometric analysis process for wheat landrace research.

2.2. Data Analysis

Bibliometrics of all the 1774 papers collected was performed with VOSviewer software (Version 1.6.20) (van Eck and Waltman, 2010). Using the same, the publications that have been cited the most times; the authors who have written the most publications; the countries where these authors are located; and the organizations that they belong to were identified and visualized using VOSviewer. Keyword co-occurrence network diagrams were also developed to define the primary thematic areas of study. In addition to developing keyword co-occurrence networks and country-collaboration maps that describe the pattern of global scientific collaboration and interaction among researchers. The results from the searches were retrieved from Web of Science in "Full Record and Cited References" format, exported as .csv file and then cleaned/standardized prior to importing into VOSViewer. Variance in author names, organizational affiliation and keywords were standardized to increase the accuracy of the analysis. For the author-level analysis, a manual thesaurus was applied to merge duplicate author records that referred to the same individual but appeared under different Web of Science name variants (for example, “Fahima, Tzion”/“Fahima, T” and “Nevo, Eviatar”/“Nevo, E”). After merging, each author’s publication and citation totals were recalculated as the sum of the corresponding records, and the most-cited authors were re-ranked accordingly. Lastly, the database has been examined for consistency errors and possible duplication to assure reliable and valid bibliography outputs.

3. Results and Discussion

3.1. Annual Patterns in Wheat Landrace Research and Language

The overall pattern of how many times wheat landraces have appeared as subjects in research articles each year has shown a general upward trend during the last two decades. In 2000, only four studies on wheat landraces were found. Although it did take some time for this type of research to begin to gain momentum, the numbers continued to grow. Specifically, there appears to be a sudden and large jump in the amount of research on wheat landraces since 2014. As illustrated in Figure 2, both publication output and citation counts have shown a consistent upward trend over time, with a particularly sharp increase observed after 2014. This post-2014 acceleration coincides with the sharp decline in next-generation sequencing (NGS) costs (Goodwin et al., 2016) and with international policy initiatives on the conservation of plant genetic resources (e.g., the International Treaty on PGRFA and the Nagoya Protocol), which together expanded genomics-based research on wheat landraces.

In 2021, 122 studies on wheat landraces were published which was by far the largest number of any single year during the study period. Since then, the number of new research articles has averaged about 100 per year. Therefore, the overall trend seems to be that researchers are finding wheat landraces and their genetic potential to be an increasingly popular and long-term subject in scientific literature.

Over the course of this study, researchers reviewed 1774 individual research studies. There were 49035 total citations associated with those research studies. Based upon those totals, we were able to determine that the average number of citations per research article was slightly greater than 27.6. Those numbers seem to suggest that wheat landraces and other forms of traditional wheat genetic resources have generated a lot of scientific interest (as evidenced by both a high volume of research being done on them and the relatively high number of citations received).

It also became apparent from our research that there has been an especially large increase in the past ten years in the types of studies being conducted related to the preservation of wheat genetic resources; assessing the levels of genetic diversity among wheat varieties; and adapting wheat varieties to be better suited to address future environmental changes (e.g., climate change). This may be due in part to the growing international interest in sustainable agriculture methods and preserving genetic resources. Overall, these data clearly illustrate that wheat landraces and traditional wheat genetic resources have garnered a tremendous amount of scientific focus especially over the past several years.

3.2. Most Frequently Occurring Keywords

To assess how often words appear together in articles referenced in this study, a co-occurrence analysis for the keywords found in these papers was performed by VOSViewer. The co-occurrence analysis produced a total of 234 keywords which could be linked by VOSViewer. A network map was then developed from the data created by VOSViewer to demonstrate the interlinkages among the keywords. The relative size of each node is proportional to the number of times each keyword appeared within all publications analyzed. The strength of connections between nodes demonstrates how closely each pair of keywords appears within the same publication.

As illustrated in Figure 3, the most common keywords used in this area of research relate to genetic diversity and genetic resource aspects of wheat including "wheat," "genetic diversity," "Triticum aestivum", "durum wheat" and "landraces." These findings illustrate the fact that a significant portion of the literature is focused upon evaluating wheat genetic diversity, identifying traits or features of local populations (i.e., landraces) and assessing wheat genetic resources.

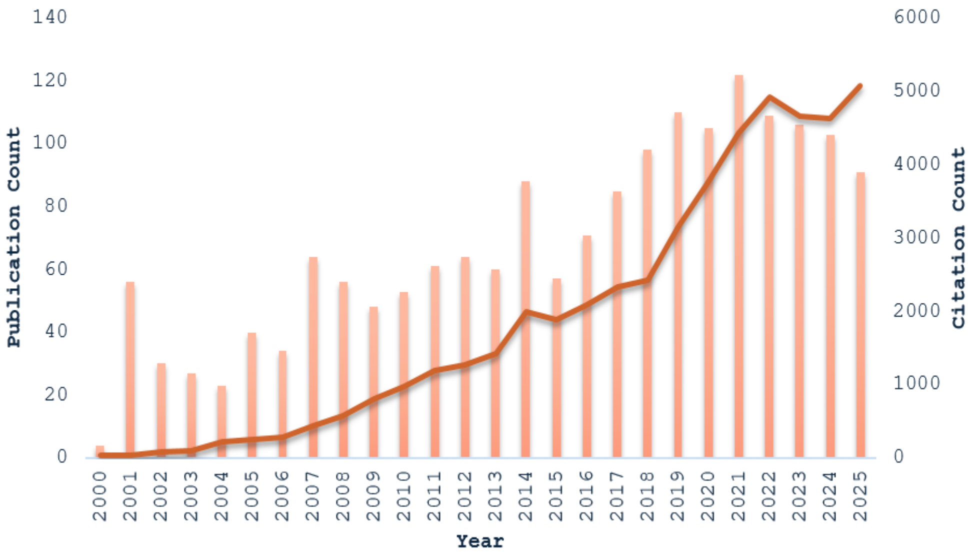

Figure 2. Annual distribution of publication and citation counts (2000–2025).

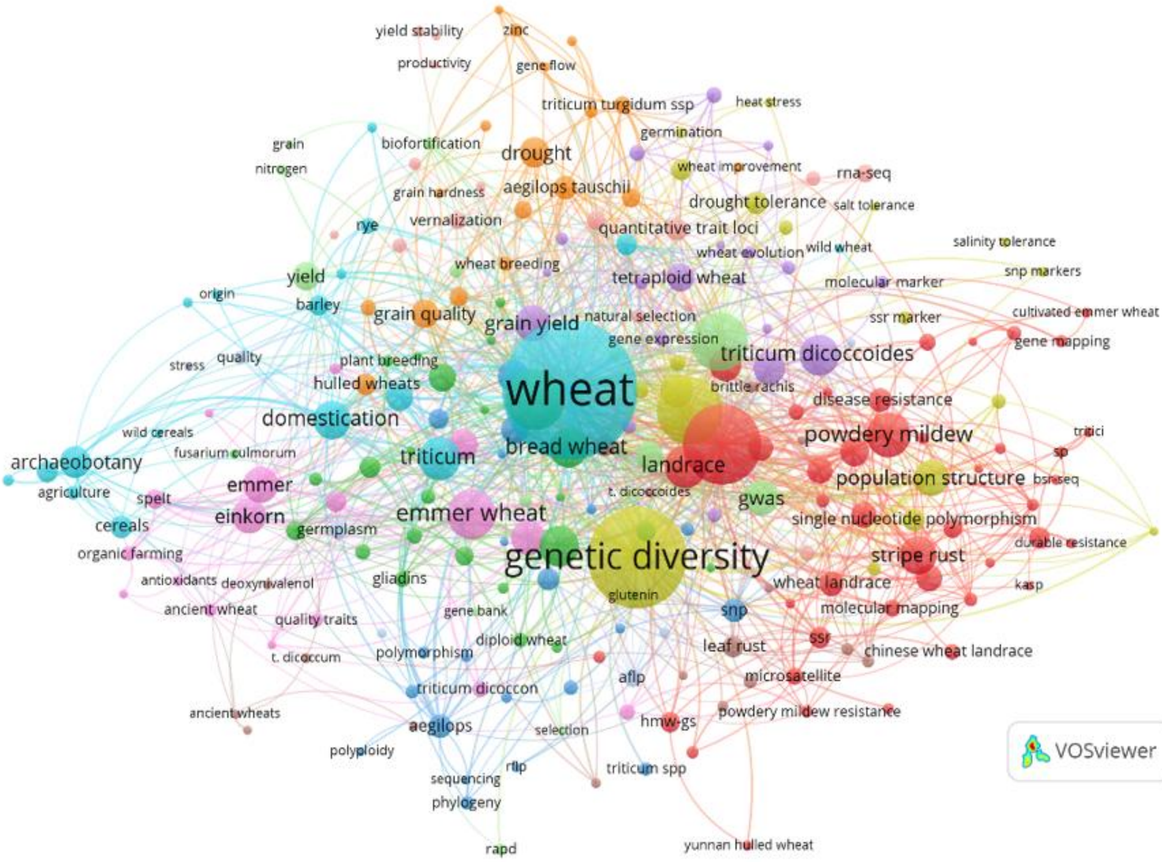

Figure 3. Network map of the most frequently used keywords.

The top 10 most frequently used keywords in the publications are presented in Table 1. As shown in the table, the keyword *"wheat"* has the highest frequency, with 225 occurrences. This is followed by *"genetic diversity"*. Other frequently used keywords include *"Triticum aestivum"*, *"landraces"*, and *"durum wheat"*. The high frequency of keywords such as *"landraces," "wild emmer wheat,"* and *"emmer wheat"* indicates that a significant proportion of studies focus on the genetic diversity of wheat and the evaluation of local genetic resources. In addition, the presence of disease-related keywords such as *"powdery mildew"* suggests that research on disease resistance in wheat landraces also constitutes an important component of the literature.

Table 1. Top 10 most frequently used keywords and their frequencies

Keyword	Frequency
Wheat	225
Genetic Diversity	145
Landraces	113
Triticum Aestivum	104
Durum Wheat	81
Wild Emmer Wheat	67
Emmer Wheat	52
Powdery Mildew	45
Triticum	42
Triticum dicoccoides	40

3.3. Most Frequently Cited Countries and Citation Analysis

The citation relationship between the countries were analyzed by means of bibliometric network analysis for this research. This has been made possible using the VOSviewer tool to evaluate the citation relationship (citation) between countries as well as the pattern of scientific collaboration between countries. A total of 98 countries participated in this research area. Node size is proportional to the sum of citations per country; while connection line thickness is representative of the degree of the relationship and cooperation between countries.

United States, China, Israel, Germany and Türkiye are placed in the middle of the network. They are central actors in the field of research owing to the combination of their high citation numbers and their wide range of cooperative relationships with other countries. Specifically, United States and China have very strong cooperative relations between themselves as well as with many countries.

Finally, countries from Europe and Asia actively participate in the structural formation of the network, therefore, they also play a major role in international scientific collaboration. As such, these results illustrate the collaborative nature of wheat landraces research at a global level.

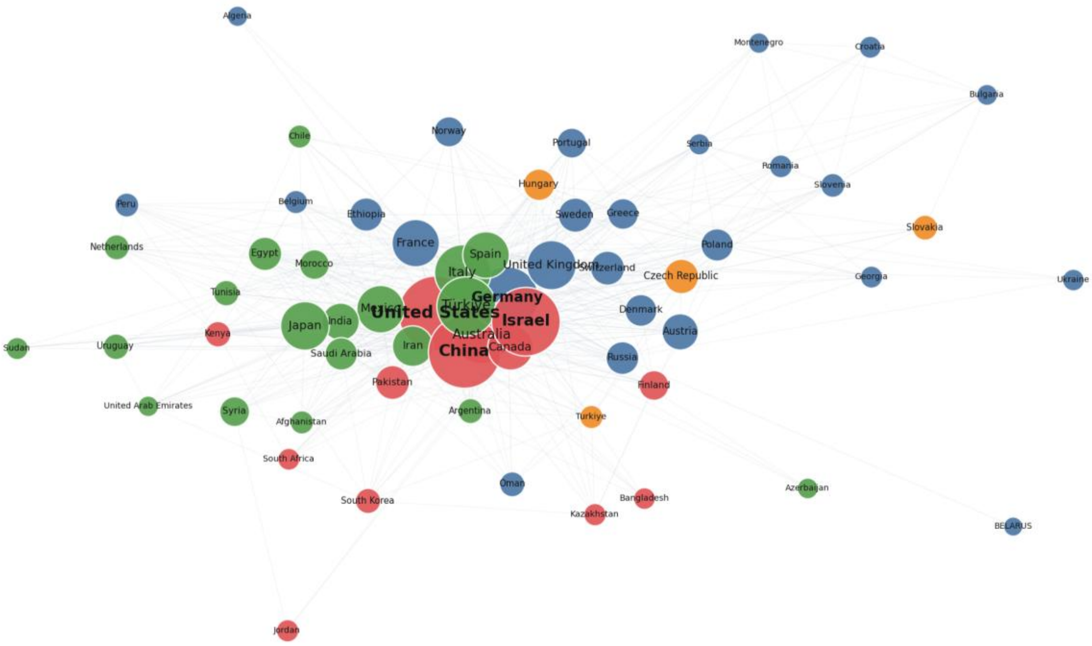

Figure 4. Network map of the most cited countries.

When the citation performance of countries is considered, the United States ranks first with a total of 12521 citations. This is followed by China (10746) and Israel (8939), respectively. In addition, countries such as Germany, Türkiye, and Australia also have high citation counts, indicating their significant contribution to the research field. The top 10 most cited countries, along with their publication and citation counts, are presented in Table 2.

Table 2. Top 10 most cited countries with publication and citation counts

Country	Publications	Citations
United States	308	12521
China	425	10746
Israel	199	8939
Germany	147	6945
Türkiye	116	5645
Australia	109	5226
Italy	158	5091
Mexico	77	3006
France	64	3073
Japan	95	2886

3.4. Most Productive Writers and Citation Study

A bibliometric network study was performed for the purpose of finding the authors who have made the greatest contributions within the field from the standpoint of citation. Using the VOSviewer tool, citation relations and the degree of collaboration among writers could be examined. In order to meet the criteria of being considered an "author" within the study, a writer had to publish at least 15 articles. Out of the 6613 writers found in the database, only 41 authors met this requirement. Each writer's total number of citations appears as a measure of node size within the graphical network created by the study. Each line between nodes indicates how many times one author has been cited by another.

Within the network graph created by this study, it can be seen that authors such as Fahima, Tzion;Nevo, Eviatar; Budak, Hikmet; Peleg, Zvi; Distelfeld, Assaf; and Saranga, Yehoshua appear to be among the most influential writers in the field. Additionally, these authors appear to be the ones with the highest numbers of citations. Within the overall design of the network, there appear to be multiple clusters of researchers, indicating that individual research teams have developed strong citation-based networks among themselves. Thus, it would appear that specific research teams are playing major roles in creating the body of knowledge within this subject area. Where the same author appeared under different database records (e.g., “Fahima, Tzion” and “Fahima, T”), these records were merged to avoid duplication and to represent author impact more accurately.

The results demonstrate that after merging duplicate author records, Fahima, Tzion is the most cited author with 4163 citations (69 publications); Nevo, Eviatar is second with 3,313 citations; Budak, Hikmet is third with 2467 citations; and Peleg, Zvi is fourth with 1927 citations. Table 3 contains the top ten most-cited authors along with their total number of citations.

These results indicate that a limited number of authors have a significant influence on the development of this research field.

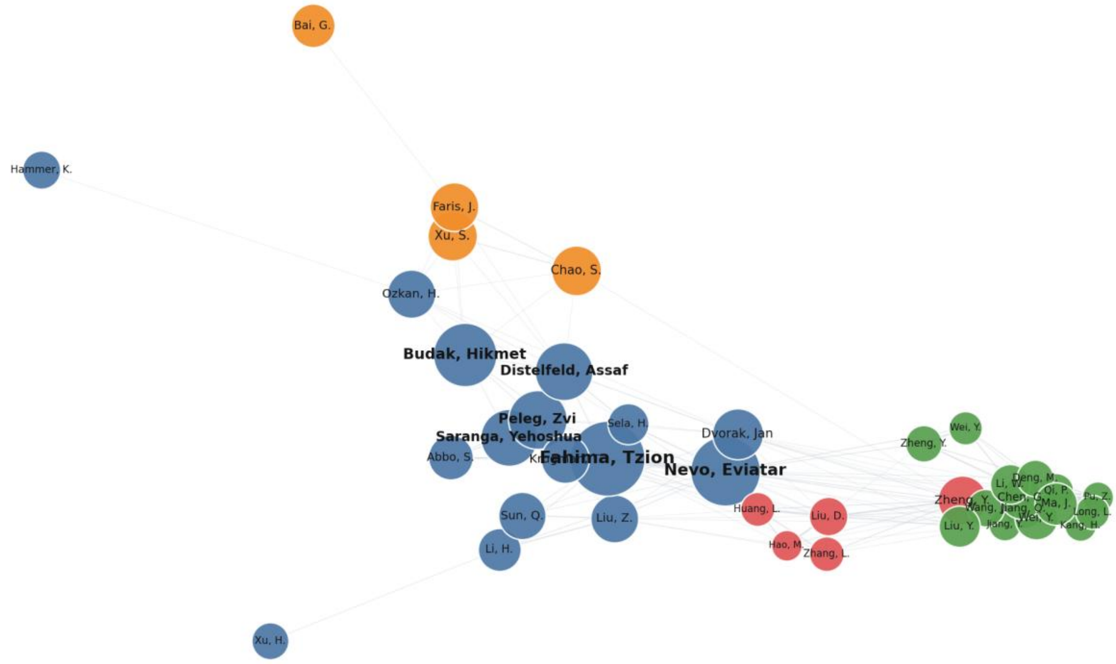

Figure 5. Network map of the most cited authors.

Table 3. Top 10 most cited authors with publication and citation counts (duplicate author records, e.g. “Fahima, Tzion” and “Fahima, T”, merged)

Author	Publications	Citations
Fahima, Tzion	69	4163
Nevo, Eviatar	64	3313
Budak, Hikmet	23	2467
Peleg, Zvi	30	1927
Distelfeld, Assaf	26	1838
Saranga, Yehoshua	27	1735
Dvorak, Jan	15	1204
Chao, Shiaoman	21	1114
Xu, Steven S.	23	1087
Zheng, Youliang	40	1052

3.5. Most Productive Institutions and Citation Analysis

In this study, a bibliometric network analysis was conducted to identify the leading institutions in the research field. VOSviewer software was used to examine collaboration patterns among institutions. A minimum threshold of five publications was applied, and out of a total of 1654 institutions, 195 institutions met the defined criteria. In the generated network map, node size represents the publication output and citation impact of institutions, while the connecting lines indicate the strength of scientific collaboration among them.

According to the analysis results, institutions such as the University of Haifa, USDA Agricultural Research Service (USDA-ARS), Chinese Academy of Sciences, University of California, Davis, and the Chinese Academy of Agricultural Sciences occupy prominent positions in the research field. An examination of the network structure shows that these institutions are actively involved in international collaborations and maintain strong connections with various research centers. In addition, institutions from the United States, China, and Europe play a central role in the overall network structure.

According to the analysis results, the University of Haifa is the most productive institution, with 133 publications and 6445 citations, making it the most influential institution in the research field. This is followed by Sichuan Agricultural University (118 publications, 1965 citations) and the USDA Agricultural Research Service (USDA-ARS) (90 publications, 3532 citations).

In addition, institutions such as the Chinese Academy of Sciences, University of California, Davis, Chinese Academy of Agricultural Sciences, Tel Aviv University, and Kansas State University also make significant contributions to the research field. These findings indicate that research on wheat landraces is concentrated within specific research centers and academic networks. In particular, institutions specializing in plant genetics and plant breeding play a key role in the development of this research area.Detailed information on the most productive institutions is presented in Table 4.

3.6 The distribution of the most productive journals

A bibliometric network analysis was performed to determine which journals had the most publications on the subject area. Using VOSViewer software, the citations made by one journal toward other journals were analyzed. Only journals that had at least 10 publications were included in the analysis; 39 journals from a total of 224 qualified.

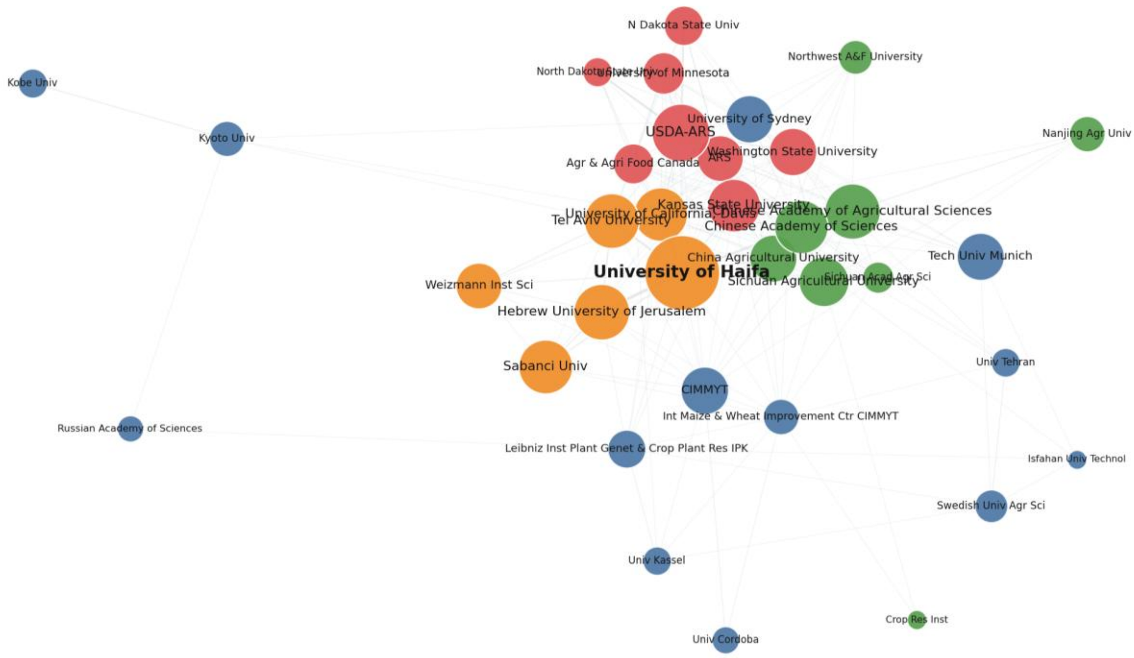

Figure 6. Network map of the most productive institutions.

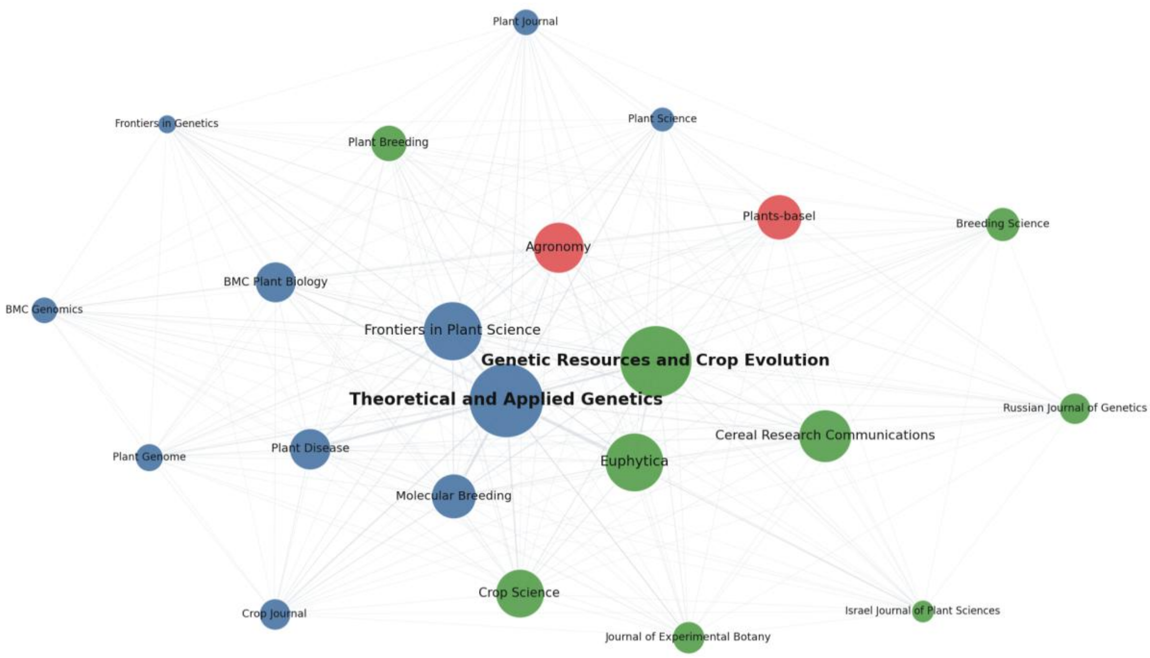

Figure 7. Top 20 journals with the highest total link strength.

The size of each journal's nodes represent both how many publications it has produced and its overall citation impact. The lines representing citation connections between the different journals indicate the degree to which they reference each other.

The leading publications (as indicated by the data) include Theoretical and Applied Genetics, Genetic Resources and Crop Evolution, Euphytica, and others. Publications such as Frontiers in Plant Science, Molecular Breeding, Crop Science, etc., provide an outlet for researchers to publish their work. Examination of the network demonstrates that these journals are strongly connected to each other through the literature, and that a high percentage of articles on topics such as plant genetics, plant breeding, and agricultural biotechnology appear in these journals.

According to the analysis results, Theoretical and Applied Genetics is the most productive journal, with 160 publications and 7261 citations, making it the most influential journal in the research field. This is followed by Genetic Resources and Crop Evolution (144 publications, 2661 citations) and Frontiers in Plant Science (91 publications, 2136 citations). In addition, journals such as Euphytica, Crop Science, Molecular Breeding, Agronomy, BMC Plant Biology, and Plant Disease also make significant contributions to the research field. Detailed information on the most productive journals is presented in Table 5.

Table 4. Top 10 most productive institutions with publication and citation counts

Institution	Publications	Citations
University Haifa	133	6445
USDA-ARS	90	3532
Chinese Academy of Sciences	78	2508
University Calif Davis	44	2620
Chinese Academy of Agriculture Sciences	69	2678
Tel Aviv University	49	2550
Kansas State University	52	2592
Sichuan Agricultural University	118	1965
University Minnesota	32	1571
Hebrew University Jerusalem	56	2674

Table 5. Top 10 most productive journals with publication and citation counts

Journal	Publications	Citations
Theoretical and Applied Genetics	160	7261
Genetic Resources and Crop Evolution	144	2661
Frontiers in Plant Science	91	2136
Euphytica	85	2424
Agronomy	61	841
Crop Science	55	1613
Molecular Breeding	43	1578
BMC Plant Biology	37	777
Plant Disease	34	523
Plant Breeding	26	846

3.7. Most Cited Publications, Authors, and Citation Counts

The list of publications was obtained from a search conducted on the Web of Science. All the retrieved publications are ordered by number of citation; therefore, it is possible to determine which studies have been considered as the most influential ones for this specific area of research. Based on the results of our analysis, we can find that "Durum wheat genome highlights past domestication signatures and future improvement targets" (Maccaferri et al., 2019), has had the highest number of citation with 571 citations. Second to Maccaferri et al. (2019) we can see "Genetics and geography of wild cereal domestication in the Near East" (Salamini et al., 2002) with 567 citations and thirdly "Contrasting patterns in crop domestication and domestication rates: Recent archaeobotanical insights from the old world" (Fuller, 2007) with 547 citations.

Also among the studies with high numbers of citation there are those by Zhu et al. (2021) and Chen et al. (2014). More detailed information about the first ten most cited publications is provided in Table 6.

Table 6. Top 10 most cited publications in the research field and their citation counts

Title	Author(s) and Year	Citations
Durum wheat genome highlights past domestication signatures and future improvement targets	Maccaferri et al., 2019	571
Genetics and geography of wild cereal domestication in the Near East	Salamini et al., 2002	567
Contrasting patterns in crop domestication and domestication rates: Recent archaeobotanical insights from the old world	Fuller, 2007	547
Optical maps refine the bread wheat *Triticum aestivum* cv. Chinese Spring genome assembly	Zhu et al., 2021	406
Wheat stripe (yellow) rust caused by *Puccinia striiformis* f. sp. *tritici*	Chen et al., 2014	374
A genetic framework for grain size and shape variation in wheat	Gegas et al., 2010	356
Wheat leaf rust caused by *Puccinia triticina*	Bolton et al., 2008	356
Exploiting genetic diversity from landraces in wheat breeding for adaptation to climate change	Lopes et al., 2015	350
Drought and salt tolerances in wild relatives for wheat and barley improvement	Nevo and Chen, 2010	331
Grinding up wheat: A massive loss of nucleotide diversity since domestication	Haudry et al., 2007	312

The analysis of the most cited publications indicates that studies focusing on wheat genomics, genetic diversity, disease resistance, and domestication processes have had a major impact on the scientific literature. This highlights that understanding the genetic structure of wheat genetic resources and landraces remains a key scientific priority in this research field.

4. Conclusion

In this study, scientific publications on wheat landraces were systematically analyzed using bibliometric methods. The results demonstrate a significant increase in the number of publications in recent years, indicating growing scientific interest in this topic. Keyword analysis revealed that research is largely concentrated on genetic diversity, wheat species, genomics, and molecular genetics.

The network analyses further showed that certain countries, institutions, and researchers occupy central positions in scientific production. In particular, the United States, China, and Israel were identified as leading contributors in terms of both publication output and citation impact. In addition, the findings indicate that scientific production in this field is concentrated around specific journals and research institutions. Journals such as Theoretical and Applied Genetics, Genetic Resources and Crop Evolution, and Frontiers in Plant Science serve as major publication platforms. Similarly, institutions such as the University of Haifa, USDA Agricultural Research Service (USDA-ARS), and the Chinese Academy of Sciences play a significant role in advancing research in this field. The prominence of certain authors with high citation counts further reflects the existence of influential scientific networks and collaborations.

Based on these findings, future research should focus on the conservation of wheat genetic resources, the development of sustainable agricultural practices, and the breeding of climate-resilient cultivars. Strengthening international research collaborations and integrating genetic resources from different regions will further contribute to the advancement of this field. Moreover, the application of advanced genomic technologies and molecular approaches will enhance our understanding of wheat genetic diversity and support improvements in agricultural productivity.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	B.Ö.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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