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Review

Structure and Trends of Worldwide Research on Durum Wheat by Bibliographic Mapping

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Abstract: The bibliometric mapping approach is a quantitative methodology to analyze the structure and evolution of research activities in a scientific area or a discipline. The objective of the current study was to perform a bibliometric analysis of the worldwide durum wheat literature published from 1961 to 2022 to identify topics and trends and their evolution over time. A total of 7512 documents were analyzed to generate bibliometric maps illustrating the main research topics. Most of the articles (91.6%) were published in indexed journals, with a low percentage (3.4%) in conference proceedings. The most active journals were the *Journal of Cereal Science*, *Euphytica*, *Theoretical and Applied Genetics*, *Cereal Research Communications*, and *Cereal Chemistry.* Italy, the USA, Canada, Spain, and France were the countries publishing the most documents. Research interests were focused on mutagenesis, interspecific hybridization, and technological quality in 1961–1980 and moved to conservation farming, molecular genetics, and nutritional quality in the last two decades. Future durum wheat production is facing challenges from climate change, water scarcity, and rising demand for sustainable food production. Advancements in molecular breeding techniques, genome editing, precision agriculture, and conservation farming can expedite wheat improvement and pave the way toward a healthier environment. The analysis of a large amount of bibliographic data provides useful information for researchers and policymakers and represents a starting point for a comprehensive discussion for future research.

Keywords: durum wheat; *Triticum turgidum*; cereal crops; durum breeding; wheat review; durum wheat research; wheat improvement; science mapping; bibliometrics; VOSviewer

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1. Introduction

Durum wheat (*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.) is an ancient crop domesticated about 10,000 years ago in the Near Fertile Crescent regions, including the historic areas of Lebanon, Jordan, Palestine, Israel, and Syria. Its wild progenitor, the wild emmer (*T. turgidum* subsp. *dicoccoides* (Körn. ex-Asch. and Graebn.) Thell), is an allotetraploid species (2n = 4x = 28, genome AABB) that originated through spontaneous hybridization between the wild diploid wheat *Triticum urartu* (2n = 2x = 14, genome AA) and a species related to *Aegilops speltoides* (2n = 2x = 14, genome BB) around 0.8 million years ago [1]. The domestication of the wild emmer started about 10,000 years BP by a subconscious selection of genotypes with non-brittle rachis and non-latent seeds, giving rise to the cultivated emmer (*T. turgidum* subsp. *dicoccum*). The free-threshing durum wheat (*T. turgidum* subsp. *durum*) originated from the selection of naked seeds from hulled tetraploid wheat genotypes [2]. Cultivated durum populations slowly spread into the Middle East regions and remained confined to the Fertile Crescent regions for a long period. Subsequently, the Romans, Phoenicians, and Greeks expanded durum cultivation in all Mediterranean regions, while the early Arab empire expanded cultivation in northern Africa [3].

The first durum wheat breeding programs began in the early 1900s with the genealogical selection of homozygous lines within the several genetically highly variable landraces cultivated in southern Italy, the Near East, and North African countries. Special mentions deserve the first breeding programs by N. Strampelli, which, with its Cappelli variety, replaced a large part of cultivated landraces in Italy and, for several decades, occupied more than 60% of the Italian durum wheat area [4]. However, specific durum wheat breeding programs were initiated in the 1950s at the Laboratory of Plant Genetics and Mutagenesis at the Research Centre of Rome in Italy, as well as at two international research centers: CIMMYT (International Maize and Wheat Improvement Center) in Mexico and ICARDA (International Center for Agricultural Research in the Dry Areas), originally located in Syria and now in Morocco. The semi-dwarf, high-yielding cultivars obtained with the introduction of the Norin 10 dwarfing genes (*Rht*) very soon replaced the tall old landraces. The success of the durum breeding programs in releasing high-yield cultivars able to compete with common wheat and the high world demand for pasta in the last decades of the 20th century contributed significantly to the diffusion of durum cultivation in many other regions of the world.

Durum wheat is grown on about 13.7 million ha worldwide, which produces 34.3 million tons of grain (average of 2018–2022) [5], with wide variation from 30 to 39 million tons caused mainly by abiotic (i.e., drought, high temperatures, low temperatures, or pre-sprouting) and biotic (i.e., fungal and viral diseases, weeds, or insect pests) stresses (Figure 1). Although the durum wheat area is relatively small on a global basis, accounting for about 6.2% of the total cultivated wheat area and 4.5% of the total wheat grain production, it represents a main crop and staple food for some Mediterranean regions and is the essential raw material of typical end-products (e.g., pasta, couscous, bulgur, several types of bread, etc.) consumed worldwide.

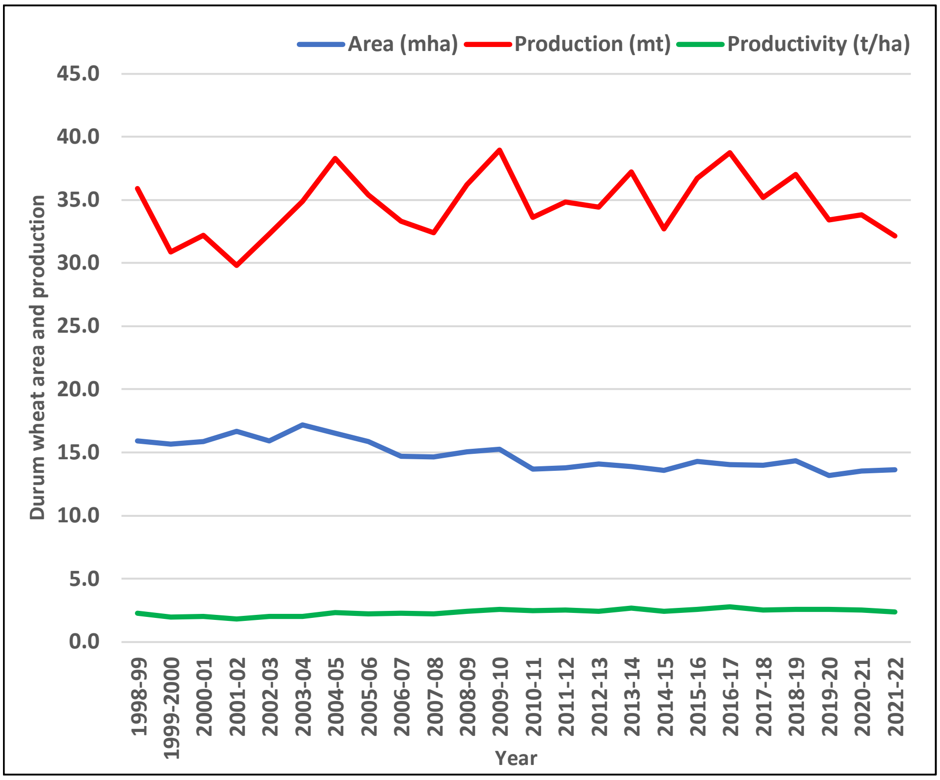

Figure 1. Durum wheat area, grain production, and productivity from 1998 to 2022 in the world [5].

Durum wheat is grown in all the Mediterranean countries, the USA (Northern Plains of North Dakota and Montana, southeast of Arizona and southern California), Canada (Saskatchewan and Alberta), and Mexico (Baja California and Sonora). Smaller areas of cultivation are also found in Russia, Kazakhstan, Australia, India, and Argentina. The major durum-producing countries are the European Union, Canada, Turkey, Algeria, Morocco, the USA, Mexico, China, and India (Figure 2). The European Union is the first producer of durum wheat, with more than 8.0 million tons of grain, with Italy playing a leading role. Canada is the most important player in the world durum market, as it exports most of its production. The European Union is not only among the major producers and exporters, but it is also the most important consumer, and since the middle of the 1990s, it has become a net importer to offset the pasta export. Other durum wheat exporters are the USA, Russia, Mexico, and Australia.

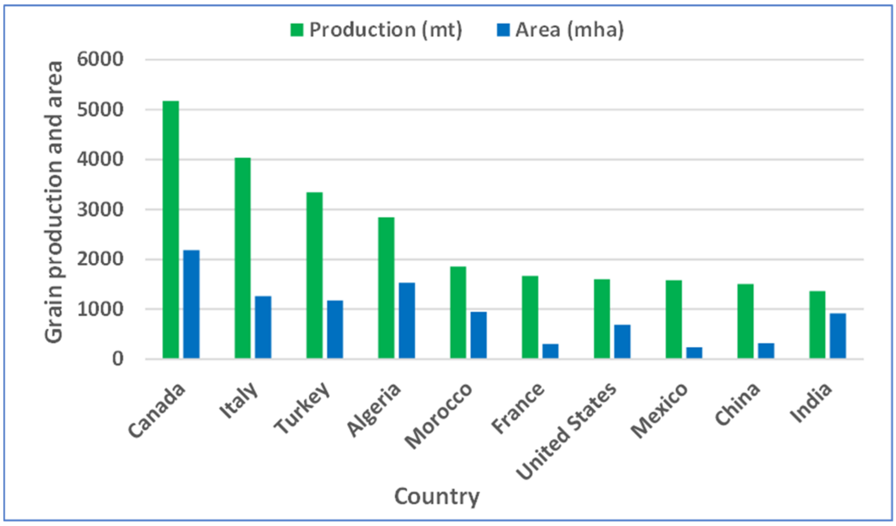

Figure 2. Top ten countries with the largest durum wheat grain production and related growing area (means of the five years 2018–2022) [5].

Classical bibliometric methods have been applied to analyze durum wheat research worldwide. The recent literature concerning durum wheat and related end-products includes several traditional reviews focusing on agronomic aspects: tillage, crop rotation, and soil [6], production systems by exploring genotype, environment, and management [7], and the influence of drought and salt stress on grain quality and composition [8]. Other reviews address the genetic diversity of wild gene pools to enhance wheat crop production, grain quality, and sustainability [9], the durum grain composition and the effects of modifications of protein and starch on the end-product quality [10,11], QTL and genes for grain yield components and carotenoid pigments [12–14], the disease resistance, mainly fusarium head blight [15,16] and rusts [17], metabolomics and transcriptomics [18,19], and durum breeding [20,21]. Some reviews focused on semolina and pasta quality, such as the rheological properties of semolina [22], phenolic compounds and strategies to formulate functional pasta [23], nutritional value, and the technological and sensory properties of durum pasta enriched with dietary compounds [24–26]. Other reviews concern different cereal crops, including durum wheat, i.e., they focus on wheat evolution [27,28], heat and drought resilience [29], wheat breeding [30], the influence of climate on agricultural decisions [31], and pesticide risk assessment [32].

Bibliometric mapping approaches have been successfully applied to analyze the structure and evolution of research activities in a scientific area or a specific discipline [33]. These quantitative methodologies, which combine mathematical tools, statistics, and visualization technology, can be considered an alternative and innovative way to complement classical bibliometric analyses. Particularly, the bibliometric mapping approaches are useful for obtaining insights into sectors of knowledge where there is a wide and complex amount of information contained in bibliographic databases [34]. In the past two decades, bibliometric mapping analysis has been applied to analyze several research areas [34]. This methodology has also been used for mapping research developments and trends in individual crop species such as sugarcane [35], maize [36], wheat and barley [37], and hazelnut [38].

Considering that durum wheat research has received much attention in the last decades and that several studies have been published on a wide range of scientific areas, the science mapping approach could be an effective approach to analyzing the durum literature and provide a useful contribution to revealing the structure and evolution of the worldwide research activity targeting tetraploid wheat. The objective of the current study was a historical overview of the structure and evolution of worldwide research on durum wheat. More specifically, the aims were (a) to perform a bibliometric analysis and mapping of the durum wheat literature published from 1961 to 2022; (b) to quantify the documents published by journals, countries, and research institutions; (c) to report the most cited publications and research topics; and (d) to identify topics and trends and their interaction and evolution over time in the durum scientific research. A review of the structure and evolution of the scientific literature on a crop may help to detect and visualize the main research topics investigated in the past, detect research gaps and current trends, and hence provide a landmark for future research development [39].

2. Materials and Methods

2.1. Data Collection

The most frequently used databases for bibliometric analyses, Web of Science (VOS), Scopus, and Dimensions, significantly differ in their coverage of journals and subject areas [40]. In the current study, the literature search on durum wheat was conducted using the Elsevier Scopus database for its high number of indexed journals and its outperforming multidisciplinary databases [41]; almost all journals indexed in the Web of Science are also covered by Scopus [40]. Moreover, abstracts and keywords for papers published from 1965 and up to 1990 are not reported and are not available for analysis by WOS. Bibliographic data were retrieved on March 18, 2023, by using the string TITLE-ABS-KEY ((“durum wheat” OR “*Triticum durum*” OR “*Triticum turgidum* var. *durum*” OR “*Triticum turgidum* subsp. *durum*” OR “*Triticum turgidum* ssp. durum”)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (EXCLUDE (PUBYEAR, 2023)), i.e., by using the search parameters “durum wheat” and the different scientific names of the species used by authors in the combined fields of title, abstract, and keywords. The document search was limited to 2022 to have complete year intervals, while no starting date was imposed to find and retrieve all the earliest documents in the durum wheat bibliography. The search was limited to documents written in English to consider the literature visible to the whole scientific community; research publications in other languages were therefore not included in the current bibliometric analysis. No limitations about source type, data, or subject were used. The Scopus function “export refine” was used to retrieve data organized by country, subject, document type, affiliation, author, source, and year. Information on the number of citations, not excluding self-citations and top-cited articles, was also obtained from Scopus.

2.2. Bibliometric Analysis and Clustering

The VOSviewer software version 1.6.5.0, available at www.vosviewer.com (accessed on 21 April 2021) [42], was used to generate and visualize bibliometric maps. The term map, which is a two-dimensional representation of a research field and visualizes clusters of related terms in different colors, provides an overview to identify the number and structure of research topics and themes. The term map was created using the co-occurrence of terms present in the title, abstract, and keywords of documents, including journal articles and conference papers, and excluding reviews, book chapters, errata corrige, notes, and editorials. To analyze the evolution of durum wheat research activities, the retrieved bibliographic data were split into three different periods (two decades): 1961–1980, 1981–2000, and 2001–2022. The period before 1960 was not considered due to the low number of published documents. A thesaurus file was created and used before mapping to consider different spellings, synonyms, singular/plural terms, common names/scientific names of plant species, etc. (example: color and colour, quantitative trait loci and QTL, flour and flours). In addition, some terms not relevant to the analysis (country names, city names, time, article, case study, comparative study, controlled study, priority, journal, review, surveys, publishers' names, etc.) were omitted by the appropriate function of the VOSviewer software before creating maps. Considering the different number of documents and the frequency of extracted terms by the software in the three considered time slices, terms co-occurring at least three times were taken into consideration for obtaining the term maps. More detailed cluster analysis and graphical map representation explanations are available in the VOSviewer manual [43].

3. Results and Discussion

3.1. Annual Evolution of Published Documents

The development of scientific literature on durum wheat in the period 1961–2022 is shown in Figure 3, taking the number of documents per year into account. Eleven papers were present before 1961, with the first two articles published in 1905. Out of a total of 7512 documents retrieved until 31 December 2022, and used to analyze publication performance and science mapping, 6877 (91.6%) articles were published in journals and 256 (3.4%) in conference proceedings; the reviews were 174 (2.2%) and 132 (1.7%) book chapters or books; the other 73 (0.9%) documents were notes, short surveys, data papers, editorials, and errata corrige.

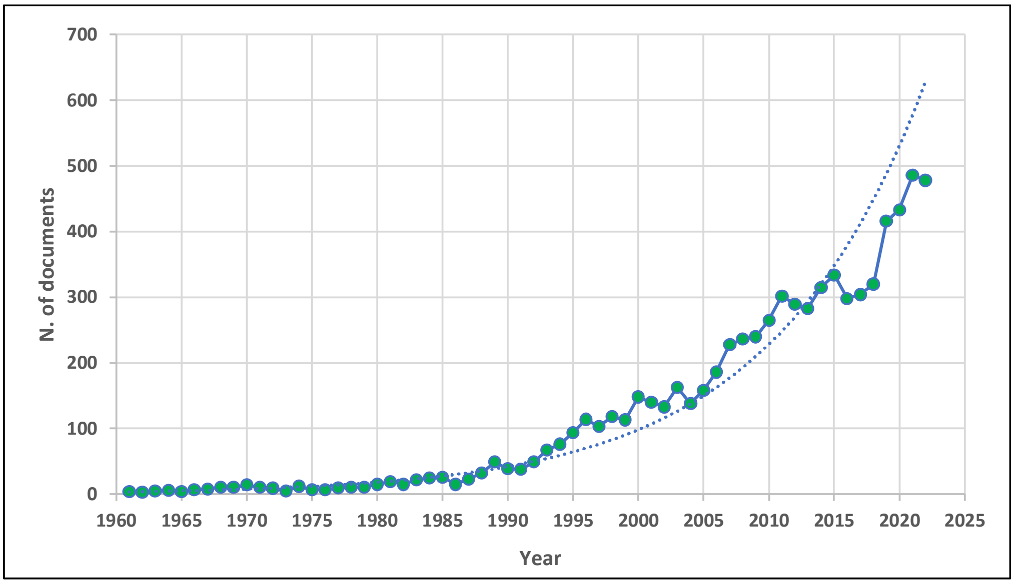

Figure 3. Documents per year on world durum wheat research from 1961 to 2022.

During the first three decades (1961–1990), there was low interest in durum wheat issues, with an average of 14.5 publications per year. The number of documents exponentially increased in the last three decades, with an average of 92.0 documents per year in 1991–2000, 188.7 documents per year in 2001–2010, and 329.4 documents per year in 2011–2020. A total of 486 and 478 documents were published in 2021 and 2022, respectively. This shows an increased interest in worldwide durum wheat research.

3.2. Journal of Publication

Most of the documents (96%) were published in several international indexed journals; a total of 149 sources published at least 10 articles. Table 1 lists the 25 journals publishing a minimum of 50 documents and shows their main metric characteristics (CiteScore, SJR, SNIP, and highest percentile within the Scopus categories). The five most active journals publishing at least 150 papers were the *Journal of Cereal Science* (212 articles), *Euphytica* (210 articles), *Theoretical and Applied Genetics* (178 articles), *Cereal Research Communications*

(167 articles), and *Cereal Chemistry* (154 articles). Three journals primarily publish original research on cereal crops and cereal grains, covering all aspects of cereal science related to the functional and nutritional quality of cereal grains (*Journal of Cereal Science*), breeding, genetics, physiology, pathology, and production of wheat, rye, barley, oats, and maize (*Cereal Research Communications*), and genetics, biotechnology, composition, processing, and utilization of cereal grains, pulses, oil seeds, and specialty crops (*Cereal Chemistry*). *Theoretical and Applied Genetics* publishes original research and review articles in all key areas of plant genetics, plant genomics, and plant biotechnology, while *Euphytica* covers the theoretical and applied aspects of plant breeding. The top six journals with higher SJR were the *Journal of Experimental Botany* (1.913), *Field Crops Research* (1.571), *Food Chemistry* (1.489), *European Journal of Agronomy* (1.426), *Frontiers in Plant Science* (1.359), and *Theoretical and Applied Genetics* (1.350). These six journals, along with the *Journal of Agricultural and Food Chemistry* and *Plant and Soil*, showed the highest CiteScore (>7.3) and ranked in the 91st–97th percentile in the Scimago Journal Ranking.

Table 1. Journals of publication, publisher, number of documents, Scopus CiteScore, Scimago Journal Rank (SJR), Source-normalized Impact per Paper (SNIP), and highest percentile.

Journal [a]	Publisher	No. of Articles	CiteScore	SJR	SNIP	Highest Percentile
Journal of Cereal Science	Elsevier	212	6.4	0.807	1.404	85
Euphytica	Springer Nature	210	3.4	0.546	0.981	77
Theoretical And Applied Genetics	Springer Nature	178	9.1	1.350	1.711	95
Cereal Research Communications	Springer Nature	167	1.9	0.329	0.63	47
Cereal Chemistry	Wiley-Blackwell	154	3.5	0.488	0.919	60
Crop Science	Wiley-Blackwell	139	3.8	0.649	1.177	73
Plant Breeding	Wiley-Blackwell	111	3.5	0.582	0.974	70
J. of Agricultural and Food Chemistry	American Chemical Society	110	8.6	1.018	1.404	94
Frontiers in Plant Science	Frontiers Media S.A.	109	8	1.359	1.827	93
Agronomy	MDPI	104	3.9	0.654	1.284	73
Canadian Journal of Plant Science	Agricultural Institute Canada	101	1.6	0.33	0.658	47
Field Crops Research	Elsevier	101	10.5	1.571	2.384	97
Food Chemistry	Elsevier	95	13.1	1.489	2.268	97
Genetic Resources and Crop Evolution	Springer Nature	88	2.8	0.433	1.119	62
J. of the Science of Food and Agriculture	Wiley-Blackwell	83	6.9	0.705	1.285	89
Plant and Soil	Springer Nature	81	7.3	1.123	1.388	91
Foods	MDPI	75	4.1	0.726	1.428	95
European Journal of Agronomy	Elsevier	72	9.1	1.426	2.128	95
PLoS ONE	Public Library of Science	70	5.6	0.852	1.368	87
Molecular Breeding	Springer Nature	67	5.4	0.762	1.081	85
Int. Journal of Molecular Sciences	MDPI	61	6.9	1.176	1.401	85
Italian Journal of Agronomy	PagePress	59	3.7	0.368	0.877	72
Plants	MDPI	59	3.6	0.765	1.347	71
Journal of Experimental Botany	Oxford University Press	57	10.9	1.913	1.82	96
Journal of Plant Nutrition	Taylor and Francis	51	3.4	0.51	0.928	69

[a] Journals with at least 50 articles. CiteScore, SJR, SNIP, and highest percentile refer to 2021 [44].

3.3. Subject Area

The main subject areas of the journals that published durum wheat documents are *Agricultural and Biological Sciences* (47%) and *Biochemistry, Genetics, and Molecular Biology* (22%); other subject areas are involved to a minor extent, such as *Chemistry* (5%), *Environmental Science* (5%), *Engineering* (3%), *Immunology and Microbiology* (2%), *Medicine* (2%), and *Earth and Planetary Sciences* (2%) (Figure 4). However, note that multidisciplinary papers dealing with different aspects of durum wheat can be classified at the same time in more subject areas.

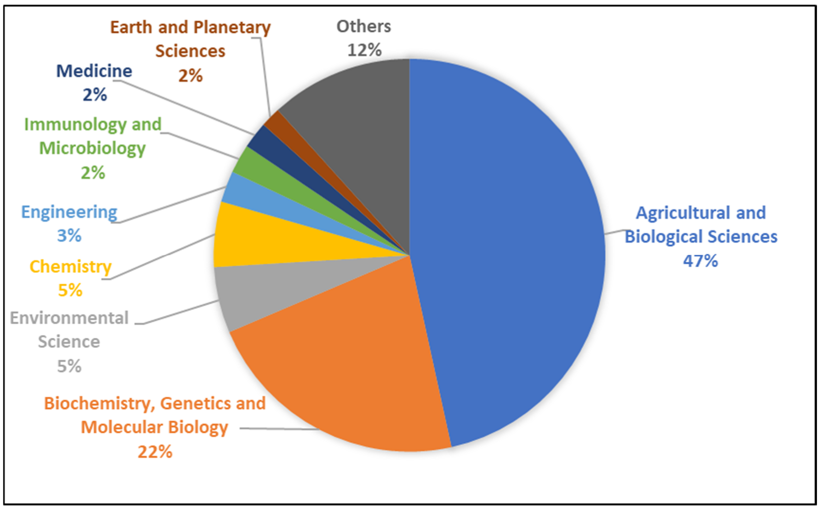

Figure 4. Subject area of publications on durum wheat. Numbers following the subject area name refer to the percentage of articles that fall into the subject area.

3.4. Most Relevant Countries

One hundred and ten countries (by author affiliation) published at least one document related to durum wheat research, but only 57 countries published at least 10 papers. Table 2 shows the list of the top 20 countries with more than 200 documents ranked by the number of total publications; the number of total citations, the average number of citations per article, and the H-index are also reported for the total documents. The most active durum-wheat-contributing country was Italy, with 2065 (27.5%) documents out of a total of 7512. The USA was in second place (n = 897, 11.9%), followed by Canada (n = 589, 7.8%), Spain (n = 545, 7.3%), and France (n = 489, 6.5%). Other countries with a significant number of papers are Australia, Turkey, India, Tunisia, and Mexico. Notably, the most productive countries are in the Mediterranean basin and North America, and to some extent, this can be related to the importance of durum wheat cultivation and grain production in those areas. The lack of other significant durum wheat-producing countries in North Africa and the Near East may be attributed to the limited research funding usually available to national institutions and to low motivation for academics to publish in indexed journals. Considering the average citations per paper, the four countries—Australia, the United Kingdom, the USA, and Mexico—show the highest number of citations per document with 54.8, 46.9, 37.8, and 36.9 citations, respectively.

Table 2. The most productive countries that published at least 200 documents on durum wheat from 1961 to 2022.

Country	No. of Documents						Total Number of Citations	Average Number of Citations *	H-Index
	Total	Journal	Conference Paper	Review	Book Chapter	Others			
Italy	2065	1885	79	40	39	22	56,284	27.3	98
USA	897	814	22	32	22	7	33,917	37.8	79
Canada	589	545	15	16	11	2	17,473	29.7	68
Spain	545	512	18	9	3	3	18,388	33.7	72
France	489	448	16	9	11	5	16,682	34.1	69
Australia	401	354	9	18	14	6	21,993	54.8	72
Turkey	385	367	9	6	3	0	9921	25.8	48
India	330	315	3	4	4	4	4518	13.7	35
Tunisia	320	302	4	6	6	2	5315	16.6	38
Mexico	286	264	7	6	5	4	10,566	36.9	54
United Kingdom	271	246	6	8	7	4	12,697	46.9	63
Germany	270	255	5	3	4	3	9153	33.9	50
Iran	268	260	3	2	3	0	5498	20.5	37
China	235	215	3	7	7	3	6165	26.2	39
Algeria	229	211	10	0	6	2	2651	11.6	25
Syria	203	183	11	3	5	1	6760	33.3	45
Morocco	200	188	6	0	6	0	3457	17.3	31

* Number of citations divided by the number of documents.

3.5. Research Institutions and Co-Operative Network of Authors

A total of 124 institutions have published at least 30 documents on durum wheat. The main characteristics (number and type of documents, total number and average number of citations, h index) of the most active institutions with more than 150 published documents are reported in Table 3.

The most active institutions are national research centers characterized by a network of branches/offices distributed throughout the national territory (Consiglio Nazionale delle Ricerche, Italy; Agriculture and Agri-Food, Canada; USDA, Agriculture Research Service, USA; Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement, INRAE, France; Swift Current Research and Development Center, Canada; CREA, Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Italy), or international research centers with branches in various countries (CIMMYT, Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico; ICARDA, International Center for Agricultural Research in the Dry Areas, Syria). Active institutions are also individual universities, such as the Università degli Studi di Bari Aldo Moro, Italy; the North Dakota State University, USA; and the Università degli Studi della Tuscia, Viterbo, Italy. Three institutions—Universitat de Barcelona, Spain; INRAE, France; and Alma Mater Studiorum, Università di Bologna, Italy—show the highest average citations per paper, with more than 40 citations.

Figure 5 shows a graphic representation of the cooperative network of authors who participated in publishing a minimum of 12 documents on durum wheat. The map shows how closely the authors' cooperation was related to the number of publications they co-authored. The number of articles published is indicated by the node size. The co-authorship between a specific author and other researchers is indicated by the connecting links, and the strength of a link shows the level of cooperation. Different colors are used to symbolize the collaboration clusters.

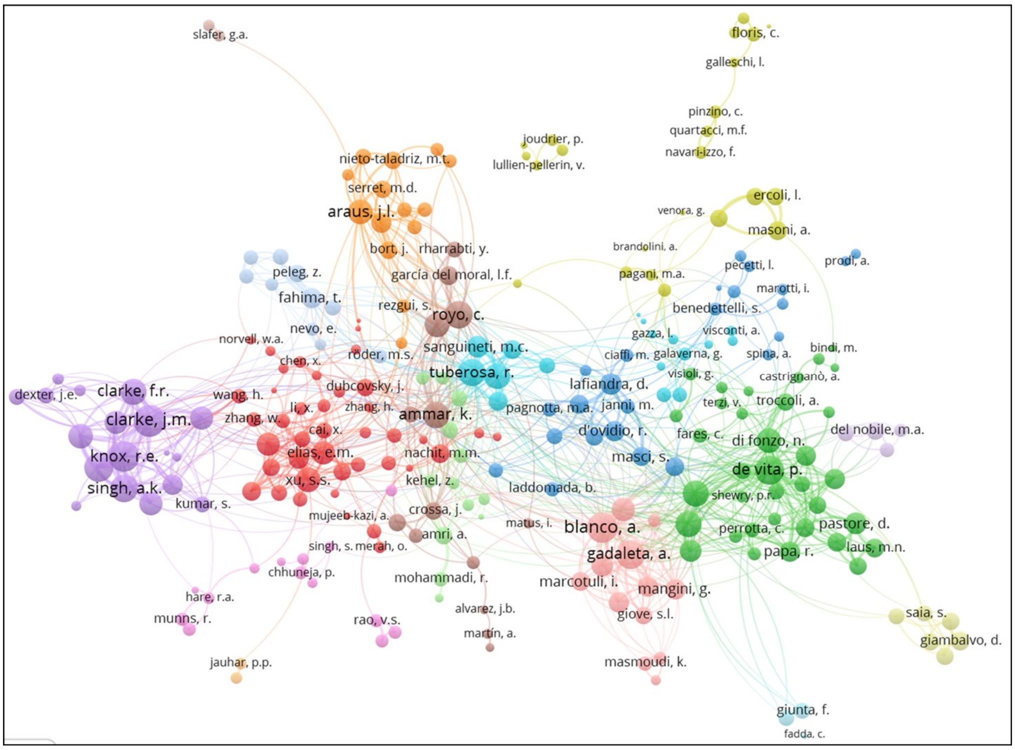

Figure 5. Cooperative network of key authors.

Table 3. The most productive institutions (by author affiliation) publishing at least 100 articles on durum wheat from 1961 to 2022.

Institution	Country	No. of Publications						Total Number of Citations	Average Number of Citations *	H-Index
		Total	Journal	Conference Paper	Review	Book Chapter	Others			
Consiglio Nazionale delle Ricerche	Italy	330	301	18	2	5	4	8909	27.0	46
Agriculture and Agri-Food	Canada	321	298	10	9	4	0	9776	30.5	53
Università degli Studi di Bari Aldo Moro	Italy	273	244	7	8	6	8	8452	31.0	49
USDA, Agriculture Research Service	USA	271	245	8	7	9	2	9508	35.1	50
CIMMYT, Centro Internacional de Mejoramiento de Maiz y Trigo	Mexico	226	209	6	5	3	3	8639	38.2	49
North Dakota State University	USA	216	203	3	5	4	1	6221	28.8	46
ICARDA, International Center for Agricultural Research in the Dry Areas	Syria	210	189	9	2	8	2	6643	31.6	44
INRAE's Occitanie-Montpelier Centre	France	185	169	9	1	5	1	7996	43.2	51
Università degli Studi della Tuscia	Italy	177	160	7	4	6	0	5218	29.5	39
Swift Current Research and Development Center	Canada	159	148	5	4	2	0	5134	32.3	40
CREA, Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria	Italy	153	139	7	2	3	2	4560	29.8	36
United States Department of Agriculture	USA	147	132	4	6	5	0	5488	37.3	36
University of Saskatchewan	Canada	139	131	1	5	0	2	4246	30.5	34
Alma Mater Studiorum Università di Bologna	Italy	136	123	6	3	0	4	5521	40.6	40
Università degli Studi Pisa	Italy	136	132	3	0	0	1	3312	24.4	29
Università degli Studi di Foggia	Italy	119	104	5	4	3	3	3145	26.4	31
Universitat de Barcelona	Spain	100	89	8	1	0	2	5158	51.6	41

* Number of citations divided by the number of articles.

The eight largest clusters reveal extensive collaboration among researchers working in the same research group or the same institution. As a result of this, the organizations to which they are affiliated are among the most significant in terms of the number of articles. The violet and red clusters are located particularly close together, which indicates strong collaboration among research groups from Canada (University of Saskatchewan, Saskatoon) and the United States (North Dakota State University). The green, pink, blue, and pale blue clusters are interconnected and located close together, revealing collaboration among researchers from different Italian institutions (Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Università degli Studi di Bari Aldo Moro, Università degli Studi della Tuscia, Alma Mater Studiorum, Università di Bologna). The orange and brown clusters indicate collaboration among researchers from two Spanish institutions (Universitat de Barcelona, Institute for Food and Agricultural Research and Technology, Lleida).

3.6. Main Topics and Trends of Durum Wheat Research

To better detect the research topics and their temporal evolution, the study period 1961–2022 was divided into three time slices (20 years each) in such a way as to detect research topics in the different 20-year periods and, from the comparison of the term maps over the three-time slices, obtain important information on the structural and dynamic aspects of the durum wheat research topics. The Scopus database reports 11 papers published before 1961, including three published in 1905–1907 and eight from 1943 to 1957. Most papers (seven) concerned studies on the adaptability, grain yield, and quality components of durum wheat, whereas two papers concerned cytological aspects of interspecific hybrids, one with the description of a chlorophyll mutant and one with the description of four fungal species of *Lophodermium*.

3.7. Research Topics during the Period 1961–1980

A total of 169 documents were present in the Scopus database in the time slice 1961–1980. Several documents did not report the keywords for which it was necessary to analyze several documents and insert 3–5 keywords based on the title and abstract. Due to the limited number of documents published in these two decades and the relatively low number of total keywords (n = 423), the term map was determined by a minimum number of occurrences of three terms (n = 87). The obtained clusters are illustrated in Figure 6, where the different colors represent the terms belonging to the different clusters, the circle size is related to the number of occurrences, and the links between the nodes indicate the co-occurrence between terms. The 87 terms are grouped into six clusters referring to different research topics, each representing a group of research themes: mutagenesis (yellow cluster), interspecific hybridization and polyploidy (red cluster), grain yield (violet cluster), grain composition (green cluster), plant viruses (blue cluster), and fungal diseases (pale blue cluster). The following is a summary of the contributions to these key topics:

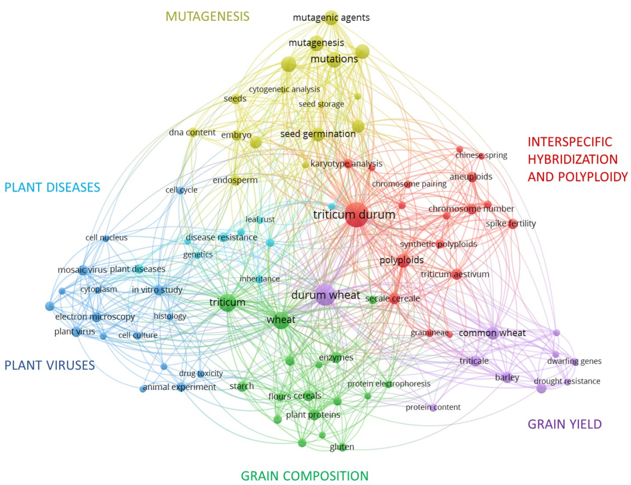

Figure 6. The term map based on durum wheat publications from 1961 to 1980.

3.7.1. Mutagenesis

The yellow cluster includes 16 terms with the high-frequency keywords "mutagenesis", "mutations", "mutagenic treatments", and "seed germination". This cluster mainly includes the early studies on mutagenesis research programs started in 1959 at the Laboratory of Plant Genetics and Mutagenesis at the Research Center (CNEN) of Rome, Italy, aimed at understanding the mutation mechanism, increasing the frequency of induced mutations, and selecting mutants useful for genetic and biochemical analyses and for breeding programs. Mutations induced by physical agents and chemical mutagens were compared as to their effects on the frequency of chlorophyll and morphological mutations, as well as for their effectiveness in inducing genetic variability in quantitative traits. Some studies reported mutations affecting gametogenesis, such as chromosome stickiness, asynapsis and desynapsis, pollen sterility, and low seed setting. Increasing consideration was given to some mutations (short straw, lodging resistance, yellow berry, response to nitrogen fertilization) for their breeding value and for isolating mutant lines with higher grain yield than the parental cultivars; indeed, some mutant lines were released as new cultivars or intercrossed with commercial varieties to transfer the mutations into a superior background [45,46]. Some investigations concerned the effects of seed dormancy and seed aging on the onset of spontaneous chromosome aberrations, seed germination, length of the mitotic cycle, and polyamine levels in embryos and endosperms of aged seeds.

3.7.2. Interspecific Hybridization and Polyploidy

The red cluster includes 18 terms with the high-frequency keywords "karyotype analysis", "aneuploids", "chromosome pairing", and "synthetic amphidiploid". Studies on chromosome morphology received special attention to achieve a greater knowledge of wheat speciation and evolution. The durum wheat karyotype was found to be similar to that of the A and B genomes of bread wheat, and the investigations on the homoeologous relationships led to the same classification and designation of durum chromosomes as that used for common wheat [47]. To make genetic analysis by durum aneuploids possible, as in common wheat, numerous attempts were made to produce nullisomic or monosomic lines that showed high sterility or low viability, or null-disomic lines in which the negative effects of the missing chromosome were compensated by the addition of the D genome homoeologous chromosome. Other studies focused on the development of trisomics by isolating trisomic plants in varieties treated with radiation or by the "conversion technique" using the tetrasomic or null-tetrasomic lines of Chinese Spring [48]. Several investigations focused on the interspecific hybridization of durum wheat with wild *Aegilops* species, but the transfer of useful genes did not take place because of the inability of durum chromosomes to pair with those of the wild relatives. The deletion of the *Ph* gene on chromosome 5B, which suppresses the pairing between homoeologous chromosomes, was obtained by the isolation of a mutant line of Cappelli treated with radiation [49] and by the production of a durum nullisomic 5B—disomic 5D line [50]. The meiotic studies of F_1 hybrids between durum wheat and some *Aegilops* species and rye revealed a high amount of homoeologous pairing and supported the possibility of transferring useful genes from related species to durum wheat. Expression of parental histone genes, alpha-amylase, soluble-sugar content, and amino acid composition of protein fractions were made in various alien genome combinations of natural and synthetic polyploids, including the new synthetic cereal crop triticale. Wheat evolution and species relationships in diploid, tetraploid, and hexaploid *Triticum* species and some related *Aegilops* species were studied by immunochemical approaches, physiological traits, chromosome pairing in pentaploid hybrids involving different species, and the extraction of ancestral constituents of natural polyploids.

3.7.3. Grain Yield

The violet cluster corresponds to an important research area for durum wheat production: agronomical management and grain yield increase. The cluster includes the high-frequency terms "yield components", "grain yield", "dwarfing genes", and "drought resistance". The terms "barley", "triticale", and "common wheat" are also included, as the field trials had the objective of comparing the yielding capacity of different cereal crops. Researchers focused on diverse themes, such as drought resistance and nitrogen and phosphorous fertilizers. A wide range of cultivars of cereal crops (durum wheat, common wheat, barley, and triticale) were investigated in field experiments to understand the genetic basis of grain yield under drought conditions. The relationships of morpho-physiological traits, plant water status, and canopy temperature with yield responses suggested that the selection of high-yielding lines in drought conditions can increase drought susceptibility and may increase or decrease yield under drought as a function of the drought level [51]. The effects of osmotic stress on coleoptiles and primary leaves and the significance of seed germination and seedling growth in osmotic media were evaluated as screening methods for drought tolerance [52]. Many studies addressed the early generation selection of dwarf genotypes and the effects of the introduction of the Norin 10 genes in durum wheat cultivated germplasm. The improvement of durum wheat plant type, yield potential and adaptation, genotype–environment interaction, and nitrogen and phosphorus fertilizers in semi-arid regions were also important research themes.

3.7.4. Plant Viruses

The blue cluster includes 16 terms with the recurrent keywords "virus isolation", "mosaic virus", "plant virus", and "electron microscopy", referring to investigations on viral infection and isolation. Some studies focused on the isolation and morphology of the wheat striate mosaic virus examined in the electron microscope by the negative staining technique and its localization in both parenchyma and phloem companion cells determined by thin sections taken from plants at various intervals after infection. Serological analysis of antigens related to the striate mosaic virus and its relative concentration in a leafhopper vector, *Endria inimica* (Say), at various times after the insects had acquired the virus by feeding on infected plants was the focus of other investigations.

3.7.5. Plant Diseases

The pale blue cluster encompasses nine terms with recurring keywords such as "plant diseases", "disease resistance", "genetics", and "rusts", reflecting the research theme of fungal diseases. Most investigations centered on stem rust (*Puccinia graminis* f. sp. *tritici*), aiming to elucidate disease inheritance, the interaction of pathogenicity and resistance genes, and the responses of specific cultivars to evolving rust races. Several studies explored the transfer of stem rust resistance from the diploid wild einkorn wheat (*Triticum boeoticum*) to susceptible durum varieties, while others delved into the inheritance of stripe rust resistance (*Puccinia striiformis*) in crosses between wild emmer wheat (*Triticum dicoccoides*) and durum wheat. Investigations also focused on evaluating panels of durum wheat and other cereal crops for resistance to speckled leaf blotch (*Septoria tritici*), black point (*Alternaria alternata*), and ergot (*Claviceps purpurea*). Additional studies examined the plant tissues and grains of durum wheat and other cultivated cereals in the context of flour and food safety. Some aspects of cereal pests were also considered, including the ability of red flour beetle (*Tribolium castaneum*) larvae to thrive on different wheat varieties and the reactions of various genotypes to the *Tetranychus sinhai* mite.

3.7.6. Grain Composition

The green cluster grouped terms ("plant proteins", "protein electrophoresis", "gluten", "flour", "enzyme activity", "lipids", and "starch") related to grain and flour composition and quality. From 1961 to 1980, the chemical composition of flour in relation to pasta and bread quality was a primary research theme, focusing mainly on specific components such as proteins, lipids, and starch. Water-soluble gliadin fractions and HMW-glutenins from the endosperm of several genotypes were compared in terms of electrophoretic mobility and components, gliadin-glutenin ratios, and varieties were classified for their quality in making bread or pasta products. Some studies compared different cereal species for their hypersensitivity to inhaled flour allergens. The distribution of acyl lipids in the germ, aleurone, starch, and non-starch endosperm of different durum and bread wheat varieties was investigated for their bread-making potentialities. Some studies specifically focused on the differences between hard red spring and durum wheat in terms of biochemical constituents, the role of the pentosan fraction, and the relationship between durum protein properties and pasta dough rheology and spaghetti cooking. Starch and endosperm in the durum kernels were examined to solve the problem of the origin and nature of the vitreous or starchy texture in the ripe seeds, while other studies showed the effect of genotype, nitrogen fertilization, and location on the vitreousness of durum varieties under rainfed conditions. The microwave conditioning of durum grain was studied to optimize and increase semolina yield and spaghetti quality.

3.8. Research Topics during the Period 1981–2000

The term map for the two decades 1981–2000 was constructed based on 209 terms with a minimum number of co-occurrences of 6 (Figure 7). This map was characterized by five clusters related to (a) interspecific hybridization and genomics; (b) plant diseases; (c) water stress and grain yield; (d) technological and nutritional quality; and (e) grain protein and health.

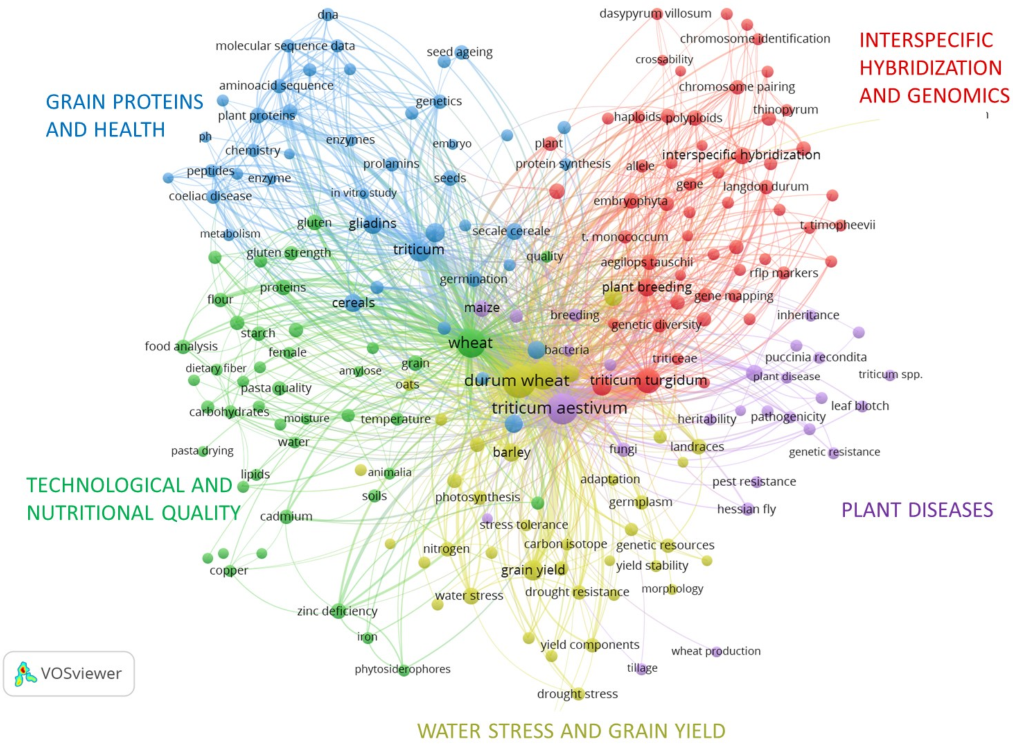

Figure 7. The term map based on durum wheat publications from 1981 to 2000.

3.8.1. Interspecific Hybridization and Genomics

The red cluster corresponds to the various aspects of interspecific hybridization and to the emerging research area of biodiversity and genomics. The cluster includes the high-frequency keywords "interspecific hybridization", "chromosome pairing", "genetic diversity", "RFLP markers", and "gene mapping". Several studies were devoted to the interspecific and intergeneric hybridization of durum wheat with different *Triticinae* species for deepening knowledge of the structure and evolution of the A and B genomes and for achieving improvement in desirable traits. Meiotic pairing observations in triticale × rye hybrids (ABRR) using the C-banding technique to identify the durum chromosome arm homoeology confirmed the presence of translocations involving chromosome arms 4AL, 5AL, and 7BS as in *T. aestivum* [53]. Numerous studies concerned chromosome engineering methodologies based on inducing targeted homoeologous chromosome recombination by manipulating the pairing control mechanisms (*ph1* gene and null-5B tetra-5D substitution lines) to introgress desirable genes from wild species into cultivated durum germplasm. In situ hybridization techniques (Giemsa C-banding, fluorescent FISH hybridization, and GISH hybridization) and the use of DNA markers (RAPDs and RFLPs) were employed to monitor and facilitate the introgression of alien genes in the durum genome [54]. The durum wheat was also utilized in intergeneric hybridizations with *Hordeum chilense* and *Thinopyrum bessarabicum* to produce the hexaploid amphiploids called Tritordeum and Tritipyrum, respectively, which were evaluated for agronomic and quality traits and proposed as potential new crops [55,56]. Different approaches for obtaining double haploids (anther culture, hybridization with *Hordeum bulbosum,* pollination with maize), largely unsuccessful, were attempted with the goal of accelerating the production of homozygous lines.

The structure and distribution of genetic variability were analyzed in different world collections by morpho-physiological traits and by deploying the first generation of molecular markers (Restriction Fragment Length Polymorphisms, RFLPs, and Random Amplified Polymorphic DNA, RAPDs). To enhance the use of plant genetic resources contained in large collections, different strategies were assessed for selecting "core samples" representative of the whole collection. The development of RFLP and SSR markers in common wheat facilitated the production of the first molecular genetic maps in durum wheat [57] and the marker application in QTL detection for bio-agronomic traits, marker-assisted selection, and tracking common wheat adulteration of durum wheat and pasta. Several studies addressed the genetic basis of the main grain quality components (grain protein content, grain protein quality, and color) as directly correlated with pasta cooking quality. The quantitative polygenic control of GPC, the environmental influence, the heritability, and the correlation of GPC with grain yield and yield components were investigated in different durum production areas.

3.8.2. Plant Diseases

The high-frequency terms "leaf rust", "disease resistance", "pest resistance", "pathogenicity", and "inheritance" are grouped into the violet cluster, thus representing the research topic of plant diseases. Some studies were carried out on the major fungal disease Fusarium head blight (FHB), focusing on its complex quantitative control by multiple interacting genes and environmental factors and on the toxicity and effects of FHB grain infection on semolina milling, gluten strength, and pasta color. Wild and cultivated durum collections were evaluated for the worldwide diseases leaf rust, stripe rust, and powdery mildew, together with race identification, population structure, and virulence variability of the pathogens. Studies on the inheritance of disease resistances and the chromosomal location of resistance loci by aneuploid lines and molecular markers were carried out to identify associated markers to be used for marker-assisted selection (MAS) in breeding programs. Race differentiation, genetic variation for virulence and resistance in the durum wheat-fungi pathosystems, and interactions between pathogen isolates and hosts were also analyzed for other fungal pathogens, such as *Pyrenophora tritici* causing the tan spot disease and *Mycosphaerella graminicola* causing the septoria leaf blotch disease. Cultivar susceptibility to some pests, such as the hessian fly (*Mayetiola destructor*) and root-lesion nematode (*Pratylenchus thornei*), and implications for yield and grain quality were the research topics of some papers.

3.8.3. Water Stress and Grain Yield

The yellow cluster grouped terms related to two relevant topics for the durum wheat crop: adaptation to abiotic stress conditions (i.e., "drought stress", "water stress", "osmotic adjustment", and "adaptation") and agronomical management (i.e., "grain yield", "yield components", "nitrogen", and "cultivars"). The response of durum landraces and cultivars to abiotic stresses (salt, heat, and water) from an agronomical, physiological, and biochemical point of view was the focus of many investigations. The effects of drought on grain yield and yield components under different drought-stress conditions in greenhouse and field experiments were studied to understand the relationships among yield components and their compensatory changes under low water availability and to identify drought-tolerant genotypes to be used in breeding programs. Salinity stress was addressed in terms of its effects on plant growth inhibition, mechanisms of cellular toxicity of NaCl, seedling ability to induce antioxidant defenses, the physiological strategy of some genotypes resistant to salinity, and the enhancement of salt tolerance by the *Kna1* locus [58]. Some studies reported and discussed the application of morphological, physiological, and biochemical traits as selection criteria in breeding programs for improving drought and salt tolerance.

Several other studies focused on agronomic techniques related to the application of nitrogen fertilizers, the adoption of reduced tillage practices, irrigation, crop rotation, and arbuscular mycorrhizal fungi. Responses of durum wheat to the application of nitrogen fertilizers were analyzed regarding the N use efficiency (accumulation, distribution, and utilization of absorbed N) to minimize leaching and denitrification losses and the potential contamination of groundwater supplies. The effects of fallow frequency, reduced tillage, and no-till farming were investigated in productive, environmental, and economic terms [59]. The benefits of arbuscular mycorrhizal fungi in durum wheat grown under drought stress were studied in terms of the acquisition of mineral nutrients, water use efficiency, soil aggregation, plant growth, cultivar genotypes, and yield potential.

3.8.4. Technological and Nutritional Quality

The green cluster includes the high-frequency terms "semolina", "starch", "proteins", "gluten", "pasta quality", and "pasta drying", which mainly refer to the relationships between grain and semolina composition and pasta quality. The major topics concerned the characterization and quantification of grain storage proteins (gliadins, HMW-glutenins, and LMW-glutenins), amino acid composition, the association between specific prolamin subunits and gluten strength and pasta cooking quality, and the effects of environment and genotype on gluten strength, viscoelasticity, and pasta quality. Special attention was devoted to the effects of temperature drying on the technological properties of pasta and to the relative importance of protein content and gluten quality at low and high drying temperatures, the formation of colored compounds by the Maillard reaction in a gluten-glucose system, and structural changes of starch during industrial pasta processing and pasta cooking.

Some investigations examined the Cd binding, uptake, and translocation in seedlings, the relationship of root morphology on Cd accumulation, the effects of soil composition, and the nitrogen, phosphorous, and zinc fertilization on the availability and uptake of Cd. Other studies focused on the inheritance of Cd concentration and the identification of molecular markers associated with loci controlling Cd uptake. The role and effects of zinc on plant growth, yield components, and uptake and translocation of Fe, the enhanced capability of some genotypes to take up Zn from soils, the physiological mechanisms conferring Zn efficiency, and the search for genotypes with high Fe and Zn concentrations in durum grain were the focus of other studies aiming to improve the micronutrient composition of durum end-products.

3.8.5. Grain Proteins and Health

The blue cluster comprises studies addressed to semolina and pasta structure and composition in relation to gluten intolerance (i.e., "gliadins", "coeliac disease", "peptides", and "amino acid sequence"). The availability of starch in durum wheat finished products, the mechanisms affecting starch digestion and absorption, and the importance of processing conditions for glycemic and hormonal responses to pasta were investigated in healthy subjects, whereas protein structure and composition were studied in relation to gluten intolerance and coeliac disease. The agglutinating activity and the effects of specific gliadin-derived peptides on small intestine cultures were studied for their implications for coeliac disease pathogenesis. Studies on functional pasta rich in dietary fiber were conducted through the utilization of β-glucan-enriched barley flour fractions or other by-products.

3.9. Research Topics during the Period 2001–2022

The more recent time slice 2001–2022 includes five clusters with intense investigations on (a) biodiversity and genomics; (b) molecular genetics; (c) plant diseases; (d) agronomical management; and (e) nutritional quality and health (Figure 8). The term map developed for this most recent period deserves special attention since it represents the current state of durum wheat research.

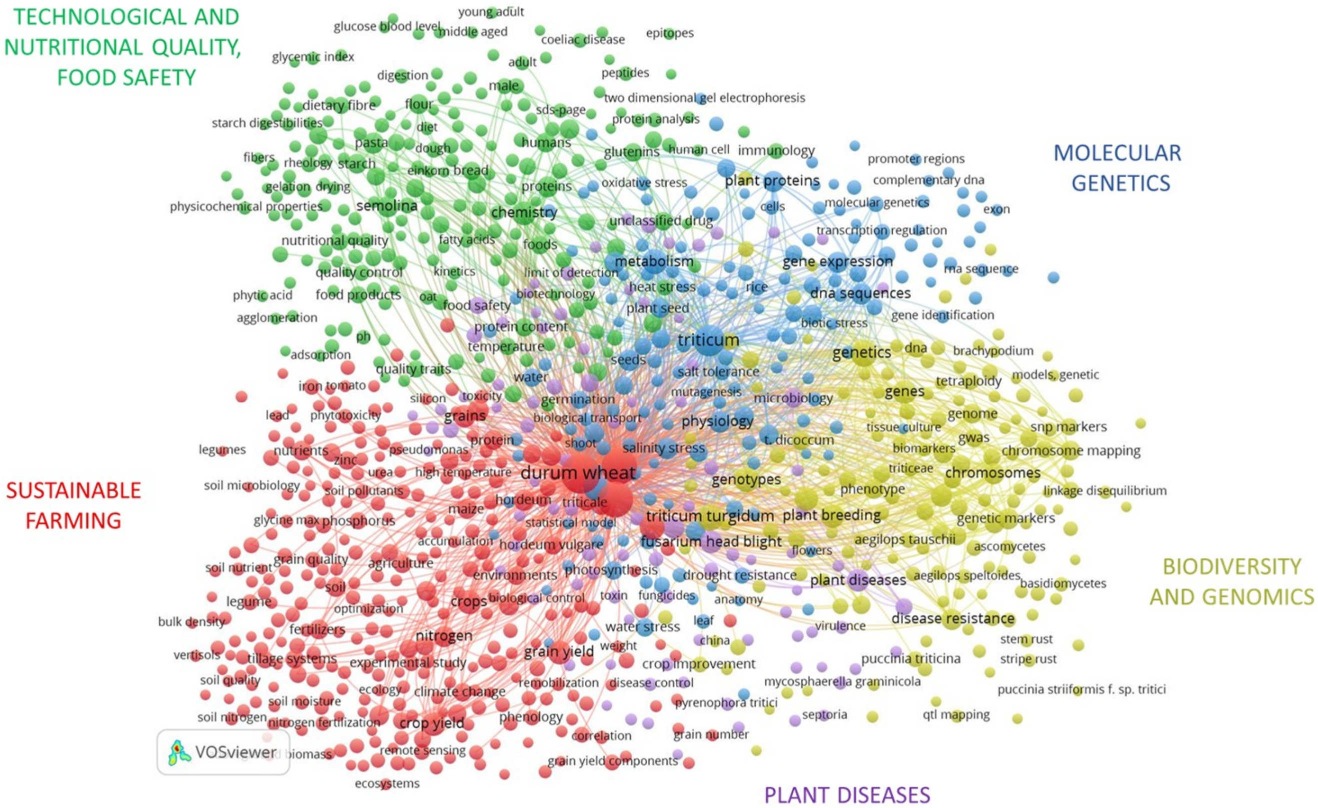

Figure 8. The term map based on durum wheat publications from 2001 to 2022.

3.9.1. Biodiversity and Genomics

The yellow cluster includes the high-frequency keywords "genetic maps", "genetic markers", "QTL", "GWAS", "genetic variation", "genetic resources", "plant breeding", and "disease resistance" and is focused on genomics, genetic resources, and plant breeding. The great scientific and breeding interest in biodiversity and the fact that durum wheat can act as a bridge between tetraploid wild relatives and bread wheat have prompted an expert working group endorsed by the Wheat Initiative to assemble two collaborative germplasm collections publicly available: the Tetraploid Wheat Global Collection consisting of 1856 accessions representing four main germplasm pools (wild emmer wheat, domesticated emmer wheat, durum wheat landraces, and durum wheat modern cultivars) [60] and the Global Durum Wheat Panel (GDP) including 1011 accessions representing modern durum germplasm and landraces [61]. These collaborative tetraploid collections, individual durum collections, and wild-related species of the tribe *Triticeae* were largely investigated to identify valuable genes for yield components, grain quality, biotic and abiotic stress resistance, photosystem efficiency, and nutrition utilization efficiency, thus enriching the gene pool available for durum and common wheat improvement. The complex physiological and molecular mechanisms underlying quantitative traits were studied to provide suitable information for more practical and efficient procedures for germplasm screening and effective selection strategies through conventional breeding, molecular breeding, and genetic engineering. Major elite genes were characterized and fine-mapped to provide tightly linked markers for MAS programs.

Recent progress in high-throughput next-generation sequencing (NGS) has made it possible to produce many high-density SNP-based maps. As consensus maps are essential tools in crop genomics, a durum SNP-based consensus map has been assembled, integrating data sets from 13 different biparental populations. It comprises more than 30 thousand SNP markers and several hundred microsatellite markers useful for comparisons with previously developed maps [62]. The availability of wheat genome sequences and molecular markers (mainly Simple Sequence Repeats (SSR) and Single Nucleotide Polymorphisms (SNP)) greatly promoted studies on the mapping of major genes and quantitative trait loci, hence QTLome dissection, for agronomically important traits by linkage analysis in biparental populations and by genome-wide association study (GWAS) in wild and cultivated wheat collections [63]. Many studies addressed the efficient detection of natural variation and isolation of novel genes/haplotypes, genotype analysis and its relationship with the phenotype, the rapid use and pyramiding of allelic variants in classical breeding procedures such as marker-assisted selection (MAS) and marker-assisted backcrossing (MABC), and integrated genomic selection (GS) strategies for faster and more effective breeding. Numerous studies concerned the cloning of resistant genes to fungal pathogens, such as rusts and powdery mildew, to understand the molecular mechanisms underlying disease resistance and to functionally characterize the wheat–pathogen interaction as a first step for allele mining and genome editing.

3.9.2. Molecular Genetics

During the last two decades, the molecular genetics issue related to durum wheat has evolved into a distinct research area, including topics of genome sequencing, transcriptomics, metabolomics, and proteomics. The blue cluster (Figure 8) includes keywords such as “molecular genetics”, “DNA sequences”, “transcriptomics”, “plant proteins”, “promoter regions”, “metabolism”, and “abiotic stress”, which relate to the more recent aspects of molecular biology. The strong advancement of next-generation high-throughput DNA sequencing technologies has given a strong impetus to studies on the system biology of durum wheat and to the release of the high-quality reference genome sequences of emmer wheat and durum wheat published in 2017 and 2019, respectively [60,64]. The availability of these reference genomes allowed several investigations on the development of genomic tools and bioinformatic resources and on the molecular biology of durum wheat by the so-called multi-omics approaches (genomics, transcriptomics, metabolomics, proteomics, ionomics, etc.), with the aim of accurately identifying candidate genes/haplotypes, hence overcoming existing bottlenecks in gene transfer and conventional phenotypic and molecular breeding methodologies.

Massive RNA sequencing (RNA-seq) of cDNA libraries was carried out for studies on expression analysis and the detection of polymorphisms among samples. Transcriptome sequencing was used in regulatory network studies as an efficient tool for gene and eQTL discovery and post-transcriptional regulation mediated by miRNAs [65]. Several studies concerned the RNA-seq methodology for discovering the different mechanisms of abiotic and biotic stress responses and for the detection of related genes and transcription factors. Proteomic studies focused on the stress response of durum wheat and other cereal crops grown in temperate climates by examining the changes in structural proteins and protein functional groups, paying specific attention to the differences between differentially tolerant genotypes and to the possibilities of identifying protein markers to be used in breeding programs. The metabolomic approach was addressed to studies on different durum aspects and problems, such as abiotic and biotic stresses, control of pests and disease, nutrient management, genotype–environment interactions, root–nitrogen-fixing bacteria interactions, analysis of food safety, and human nutrition. The physiological, biochemical, and molecular responses to abiotic stresses (drought, salt, heat, and cold) of wild and cultivated wheat were analyzed to identify new genetic tolerance sources and more practical and efficient procedures for germplasm screening and breeding. Drought- and salt-related candidate genes/QTL were identified and characterized at the molecular level, coupled with morphological and physiological trait analysis of tolerant genotypes.

Some studies concerned strategies for generating marker-free transgenic plants and for intragenesis and cisgenesis modifications as alternatives to transgenic crop development [66]. The TILLING and EcoTILLING reverse genetic approaches and the novel genome editing techniques as more efficient mutagenesis tools were the focus of some studies to elucidate the function of genes and for the targeted manipulation of single genes. Noteworthy, a paper reported 1535 mutant lines of the durum variety Knonos and developed a public database including some million mutations obtained by combining traditional mutagenesis, high-throughput sequencing, and genome editing [67].

3.9.3. Plant Diseases

The violet cluster relates to plant diseases and includes specific related keywords such as "plant diseases", "fusarium head blight", "mycotoxins", "food safety", "virulence", "*Mycosphaerella tritici*", "*Pyrenophora tritici*", "tan spot", "microbiology", "bacteria", and "insect resistance". Numerous studies concerned fungal diseases with emphasis on the population biology of the different species and races of parasites, the evolution of new virulence, the infection process, the pathogen–wheat interaction, the physiological and molecular aspects of pathogenicity, the mechanisms of host hypersusceptibility, tolerance, or resistance, and pathogen spread in relation to durum production systems. Studies on resistance genes to the globally widespread diseases leaf rust, stem rust, yellow rust, and powdery mildew and their introduction in cultivated germplasm are grouped in the interconnected yellow cluster related to biodiversity and genomics. Other studies focused on the facultative parasites Fusarium head blight (FHB), Septoria leaf blotch (*Mycosphaerella graminicola*), spot blotch, and tan spot (*Pyrenophora tritici repentis*). Among the major fungal diseases, FHB resistance was a major research topic, including the identification of the predominant *Fusarium* species in the different durum cultivation areas, infection mechanisms and pathogenesis, the evaluation of cultivated and wild germplasm collections to identify efficient sources of resistance, and the identification and characterization of pathways and candidate resistance genes. Large research efforts were directed to QTL mapping of FHB resistance by linkage analysis and genome-wide association study (GWAS), genomic prediction, and identifying closely associated markers to FHB resistance loci to be used in MAS programs [68]. Due to the difficulty of finding efficient FHB resistance sources, some studies are concerned with the potential role of morphological and physiological traits, such as plant height, heading time, spike compactness, and cell wall polymers, in enhancing FHB resistance.

Some studies were conducted on some important wheat pests, such as the Russian wheat aphid *Diuraphis noxia*, the cecidomyid hessian fly *Mayetiola destructor*, the nematode *Heterodera avenae*, and the curl mite *Aceria tosichella*.

3.9.4. Sustainable Farming

The red cluster includes the high-frequency keywords "crop yield", "tillage systems", "fertilizer", "nutrients", "precision agriculture", "carbon isotope", and "physiological response" and represents the farming systems of sustainable and conservation agriculture. Strategies for conservation practices in rainfed durum wheat cultivation areas have been proposed and studied in terms of crop yield, grain quality, and environmental safeguarding. No-tillage, minimum tillage, the influence of conservation practices on the physical, chemical, and biological properties of soil, maintenance of soil cover, intercropping and cover crops, drip irrigation and fertigation, energy consumption, greenhouse gas emissions and carbon footprint, and organic agriculture were investigated with the aim of overcoming the various problems of intensive agriculture, increasing the efficiency of agricultural systems, and enhancing long-term sustainability. The introduction of nitrogen-fixing grain legumes into crop rotations was proposed and investigated for their positive environmental impact and crop productivity.

Research efforts were devoted to reducing the use of N fertilizers to avoid unfavorable environmental effects without affecting crop productivity and to estimating the direct nitrogen effects on wheat yield and/or quality. The N nutritional status of plants was considered for its positive impact on root uptake and the accumulation of micronutrients (particularly Zn and Fe) in the grain. The ability of plant growth-promoting rhizobacteria (PGPR) to provide nutrients for plant growth and crop yield improvement was examined with the potential possibility of substituting chemical fertilizers. The application of remote sensing in precision agriculture (PA) was addressed for the possibility of optimizing crop management, such as the use of fertilizers and herbicides as a function of climate conditions and vegetation index, minimizing negative environmental impacts, and predicting crop yield and quality before harvest. Sustainable durum production and biotic and abiotic threat mitigation were the focus of numerous studies concerning the need to consider the interactions and synergies between the availability of high-yielding cultivars, the high variability of cultivation environments, climate change, and unique agro-technical management.

3.9.5. Nutritional Quality and Health

The green cluster is focused on different aspects of grain and semolina quality and the nutritional properties of end-products in relation to human health; it includes numerous keywords such as "quality control", "nutritional quality", "dietary fiber", "starch digestibility", "bioactive compounds", "coeliac disease", "gluten", "peptides", "glycemic index", and "gluten-free diet". The quality of raw materials and processing conditions were largely studied for their direct relationship to pasta cooking quality. Due to the importance of the grain's physical properties in determining its commercial value, many studies explored the relationships between kernel characteristics (test weight, thousand-kernel weight, kernel size, physical defects, vitreousness, and grain protein content) and milling performance, semolina composition, color, and processing quality of end-products (pasta, couscous, bulgur, and local bread). Many studies paid attention to the different steps of the pasta-making process (hydration of semolina, shaping of the dough, and drying) and their impacts on pasta quality characteristics (cooking, firmness, stickiness, bulkiness, sensory, and nutritional). Greater interest was paid to the protein and starch property modifications induced by the drying temperatures above 60 °C and their impact on pasta quality. Numerous research efforts were made by researchers and pasta companies to propose rapid and reliable tests for the semolina's technological quality to predict pasta-making potential and cooking quality. Many investigations focused on assessing the gluten rheological properties (strength, tenacity, extensibility, viscoelasticity, and elasticity) by different approaches (extracted gluten, dough systems, and slurry systems), their relationship with the quantity and quality of gliadins, HMW- and LMW-glutenins, and their relevance for pasta quality.

To improve the transformation processes and nutritional characteristics of traditional durum end-products and develop new end-products with improved healthy characteristics, some investigations focused on the modification of starch composition by silencing the genes involved in amylose and amylopectin synthesis and thus modifying the amylose/amylopectin ratio [11]. Other studies concerned the introduction of some favorable *Glu-D1* subunits from common wheat to improve the durum bread-baking performance and the introgression of the wild-type *Pina-D1a* and *Pinb-D1a* genes to produce soft-textured kernels, leading to large changes in the milling characteristics of the grain and the gluten rheological properties. Some papers report the utilization of milling by-products for the extraction of healthful compounds such as high-quality oil rich in unsaturated fatty acids, vitamin E, and carotenoids, potentially usable in food, cosmetics, and drugs.

Due to the low content of phytochemicals, micronutrients, and fiber in durum wheat pasta and the increased interest of consumers in healthy foods, several studies have focused on product innovations such as "functional pasta" and gluten-free products. The impact of additional flours derived from legumes, roots, vegetables, herbs, soluble dietary fiber, and polyphenol-rich products was investigated concerning the nutritional and health values of fortified durum end-products. Several studies delved into the role and influence of carbohydrate quality and quantity, processing parameters, cooking degree, starch and protein digestibility, and glycemic and hormonal responses to pasta consumption on wheat-associated human pathologies, including allergy, wheat-dependent anaphylaxis, and coeliac disease. Other studies focused on the amino acid sequence and tri-dimensional structure of the gluten peptides of wheat gliadin, rye secalin, and hordein barley responsible for the inflammatory immune response and causing coeliac disease in susceptible individuals. Emphasis was given to developing high-quality gluten-free pasta based on the utilization of various additives or technological processes to improve some quality properties and consumer acceptability.

3.10. Research Topics in the Top Publishing Countries

Figures S1–S6 show the term maps of the top six publishing countries on durum wheat research for the period 2001–2022. As expected, the individual term maps exhibit a high degree of overlap with the global term map constructed for the same period (Figure 8). This overlap in keywords suggests that durum wheat research across the world focuses on similar thematic areas, with an emphasis on improving grain yield and quality in the face of changing climatic conditions and increased sustainability demands. Common research topics include agronomical management, technological quality, biodiversity and genomics, plant diseases, and pests. Nevertheless, a deep analysis of Figures S1–S6 indicates that some research priorities exist in some countries to address specific environmental conditions and/or local population needs concerning the end-product quality characteristics.

Current priority research topics in Italy concern agronomical practices for sustainable grain production and soil health improvement, integrated disease and pest management, identifying key genes and QTL for breeding for sustainable production using traditional methods and cutting-edge technologies, and the grain and end-product quality characteristics for the reduction of wheat-related disorders in humans.

Important durum research in the USA focuses on interspecific hybridization and biodiversity, plant diseases and pests, disease resistance and developing alternative control strategies, sustainable production practices to minimize nutrient losses, and genetics and breeding of drought-tolerant varieties using molecular tools.

In Spain, specific research efforts are devoted to the physiology of plant abiotic stress, genetics and breeding for drought and heat tolerance, precision farming, and food safety related to mycotoxins and gluten intolerance.

Sustainability is a major focus in Canadian durum research, including developing practices that minimize environmental impact, improve soil health, improve water use efficiency, use precision farming to optimize grain production, and integrate pest management strategies.

France shares similar research interests with Italy and Canada but also has its own unique focus areas, such as increasing grain yields while minimizing environmental impact, improving organic farming to ensure profitability and sustainability, and precision agriculture with a focus on understanding how specific terroirs (soil, climate, etc.) influence wheat quality and developing tailored management practices for each region.

Australia has active research initiatives focused on addressing challenges and opportunities specific to its climate, soil, and market demands. Currently, some key topics include research on identifying key genes for salinity tolerance and heat and drought tolerance, optimizing agronomic practices for minimizing soil erosion, promoting natural pest control methods, and minimizing reliance on pesticides. Specific investigations on grain quality improvement include exploring biofortification, improving protein digestibility, and gluten-free products.

3.11. Evolution of Research Trends

3.11.1. The Most Cited Articles

Although a high number of documents (n = 7512) have been published on durum wheat until 2022, a relatively small number of articles (n = 392, 5.2%) received 100 or more citations. Table 4 shows the top 17 original research articles (not including reviews or state-of-the-art papers) that have received more than 300 citations and at least an average of 20 citations per year. These top articles allow for the identification of the research themes that most attract the scientific interest of researchers: drought resistance and water-use efficiency and grain yield responses [51,69], cell membrane stability, photosynthetic efficiency and miRNA expression of genotypes subjected to drought [70,71], the effect of salt and osmotic stresses and screening methods for salinity tolerance, major Na^+ genes and grain yield on saline soils [72–75], QTL for grain yield and adaptation across a wide range of water availability [76], genome sequencing [60,64], genome editing through transient expression of CRISPR/Cas9 DNA or RNA [77], the effect of fertilizer application on soil heavy metal concentration [78], variation of mineral micronutrient concentrations in wheat grain [79], speed breeding by multiple generations per year [80], no-tillage and conventional tillage effects on yield and grain quality [81], biochar as a strategy to sequester carbon and increase yield [82].

Table 4. Published papers that received more than a total of 300 citations and at least an average value of 20 citations per year (20 March 2023).

Authors	Title	Year	Journal	Total Citations	Citations per Year
Fischer R.A., Maurer R. [51]	Drought resistance in spring wheat cultivars. I. Grain yield responses	1978	*Aust. J. Agric. Res.*, 29(5), 897–912.	1382	31.4
Munns R., James R.A. [75]	Screening methods for salinity tolerance: A case study with tetraploid wheat	2003	*Plant Soil*, 253(1), 201–218.	599	31.5
Condon A.G., Richards R.A., Rebetzke G.J., Farquhar G.D. [69]	Improving intrinsic water-use efficiency and crop yield	2002	*Crop Sci.*, 42(1), 122–131.	542	27.1
Zhang Y., Liang Z., Zong Y., Wang Y., . . . , Gao C. [76]	Efficient and transgene-free genome editing in wheat through transient expression of CRISPR/Cas9 DNA or RNA	2016	*Nat. Commun.*, 7(12617).	531	88.5
Bajji M., Kinet J.-M., Lutts S. [71]	The use of the electrolyte leakage method for assessing cell membrane stability as a water stress tolerance test in durum wheat	2002	*Plant Growth Regul.*, 36(1), 61–70.	531	26.6
Munns R., James R.A., Xu B., Athman A., . . . , Gilliham M. [73]	Wheat grain yield on saline soils is improved by an ancestral Na + transporter gene	2012	*Nat. Biotechnol.*, 30(4), 360–364.	529	52.9
Atafar Z., Mesdaghinia A., Nouri J., Homaee M., . . . , Mahvi A.H. [78]	Effect of fertilizer application on soil heavy metal concentration	2010	*Environ. Monit. Assess.*, 160(1–4), 83–89.	482	40.2
Loggini B., Scartazza A., Brugnoli E., Navari-Izzo F. [70]	Antioxidative defense system, pigment composition, and photosynthetic efficiency in two wheat cultivars subjected to drought	1999	*Plant Physiol.*, 119(3), 1091–1099.	479	20.8
Avni R., Nave M., Barad O., Baruch K., . . . , Distelfeld A. [64]	Wild emmer genome architecture and diversity elucidate wheat evolution and domestication	2017	*Sci.*, 357(6346), 93–97.	478	95.6
Watson A., Ghosh S., Williams M.J., Cuddy W.S., . . . , Hickey L.T. [80]	Speed breeding is a powerful tool to accelerate crop research and breeding	2018	*Nature Plants*, 4(1), 23–29.	457	114.3
Almansouri M., Kinet J.-M., Lutts S. [72]	Effect of salt and osmotic stresses on germination in durum wheat (*Triticum durum* Desf.)	2001	*Plant Soil*, 231(2), 243–254.	442	21.0
Zhao F.J., Su Y.H., Dunham S.J., Rakszegi M., . . . , Shewry P.R. [79]	Variation in mineral micronutrient concentrations in grain of wheat lines of diverse origin	2009	*J. Cereal Sci.*, 49(2), 290–295.	350	26.9

Table 4. *Cont.*

Authors	Title	Year	Journal	Total Citations	Citations per Year
Maccaferri M., Harris N.S., Twardziok S.O., Pasam R.K., . . ., Cattivelli L. [60]	Durum wheat genome highlights past domestication signatures and future improvement targets	2019	*Nat. Genet.*, 51(5), 885–895.	342	114.0
De Vita P., Di Paolo E., Fecondo G., Di Fonzo N., Pisante M. [81]	No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in southern Italy	2007	*Soil Tillage Res.*, 92(1–2), 69–78.	339	22.6
Vaccari F.P., Baronti S., Lugato E., Genesio L., . . ., Miglietta F. [82]	Biochar as a strategy to sequester carbon and increase yield in durum wheat	2011	*Eur. J. Agron.*, 34(4), 231–238.	314	28.5
Maccaferri M., Sanguineti M.C., Corneti S., Ortega J.L.A., . . ., Tuberosa R. [76]	Quantitative trait loci for grain yield and adaptation of durum wheat (Triticum durum Desf.) across a wide range of water availability	2008	*Genetics*, 178(1), 489–511.	305	21.8
James R.A., Blake C., Byrt C.S., Munns R. [74]	Major genes for Na+ exclusion, Nax1 and Nax2 (wheat HKT1;4 and HKT1;5), decrease Na^+ accumulation in bread wheat leaves under saline and waterlogged conditions	2011	*J. Exp. Bot.*, 62(8), 2939–2947.	302	27.5

Considering the papers with a higher number of citations per year, two recent articles, with an average number of 114.0 and 95.6 citations, report the genome sequencing of the durum wheat [60] and of the wild emmer wheat [64] and discuss the domestication and evolution of wheat and the future improvement targets. Another recent paper [80], with a high average number of 114.3 citations, is related to the so-called method “speed breeding”, which allows for achieving up to six generations per year, and its integration with advanced breeding technologies such as genome editing and genomic selection. These three papers were published in *Nature Genetics*, *Science*, and *Nature Plants*, respectively.

Many of the top 17 highly cited publications focused on different cereal crops, including durum wheat. For example, the most-cited article (n = 1382 citations) [51] concerns the drought resistance and the grain yield response of durum wheat, bread wheat, triticale, and barley; the second most-cited paper (n = 599 citations) reports different salinity screening methods in five subspecies of *T. turgidum* [75]; and the third most-cited article (n = 542 citations) [69] discusses the improving intrinsic water-use efficiency and the grain yield of bread wheat, durum wheat, and barley.

3.11.2. Research Trends

A set of maps that showed clusters of co-occurring key terms obtained by the bibliometric mapping analysis made it possible to identify the main research topics on durum wheat during the previous 60 years. The temporal evolution of the durum wheat studies was examined by using the mapping approach in three different time slices of two decades each. Comparing the maps (presence, absence, and repositioning of terms) enables the acquisition of important details on the dynamic of research topics and themes addressed in durum wheat research.

In the first period (1961–1980), despite the low frequency of co-occurrence terms due to the low number of published articles in indexed journals, the term map (Figure 6) displays six well-defined clusters representing six research topics. The relatively high-frequency terms “chromosome pairing” and “polyploids” in the red cluster indicate research interest in the genomic relationships between *Triticinae* species, interspecific gene transfer, and production of synthetic polyploids (triticale, tritipyrum). The presence of “mutagenic treatments” and “mutations” (yellow cluster) denotes investigations on mutagenesis to analyze the effects of mutagenic treatments and to identify useful mutants for breeding programs. The term “dwarfing genes” in the violet cluster highlights research on the effects of the *Rht* genes in durum wheat and their use in breeding programs to realize semidwarf varieties. The other three clusters indicate some research interest in studies on "grain composition", "plant viruses", and "disease resistance".

Looking at the term map of the next period (1981–2000) (Figure 7), it can be seen how the red cluster on interspecific hybridization and polyploidy, represented by the keywords "interspecific hybridization", "polyploids", and "chromosome pairing", continues to have a high research interest; terms such as "*Aegilops tauschii*", "*T. monococcum*", and "*Dasypyrum villosum*" are related to studies on wheat evolution and interspecific gene transfer. In this cluster, the terms "genetic markers" and "RFLP markers" refer to a novel research theme on the development of molecular markers and their application in the genetic analysis of quantitative traits. In the yellow cluster, the occurrence of novel and more specific terms such as "water stress", "drought stress", and "drought resistance" denotes an emphasis on the investigation of abiotic stresses and responses to grain yield and yield-related traits, adaptation to semi-arid conditions, and genetic resources for drought tolerance/resistance. The terms "pathogenicity" and "genetic resistance" in the violet cluster indicate studies on the virulence of pathogens and the analysis of the primary and secondary gene pools for novel resistance genes. From the period 1961–1980 (Figure 6) to 1981–2000 (Figure 7), it is possible to observe that the cluster "grain composition" tends to separate into two closely but well-defined clusters. Grain and end-product quality research (green cluster) was mainly conducted about the amount and composition of grain storage proteins, starch, and lipids, the deficiency of micronutrients such as iron, zinc, and copper, and the presence of heavy metal contaminants. The closeness of this cluster to the "grain protein and health" emerging cluster (blue) is related not only to the effects of the prolamin components on the semolina technological properties in the pasta-making process but mainly highlights studies on the effects of gluten quantity and strength on intolerant patients and particularly to the effects of some gliadin peptides on coeliac disease.

Figure 8 shows the research topics over the 2001–2022 period to which special attention should be paid since it represents the current state of global durum wheat research. The same information is presented as an overlay map according to the date of publication ("term year map", Figure 9). While yellow and green colors in this year's map indicate more recent articles that reflect changing research interest trends, the blue color indicates earlier publication dates and those research areas that were thoroughly investigated in the past, and the focus has shifted to other areas as a result of investigations' findings or as the terms themselves became more specialized and represented by a yellow color, such as "diversity" and "phenotypic variation". The key terms "QTL mapping", "GWAS", and "genetic marker" are well represented in the yellow cluster (Figure 8), demonstrating that both genomics and quantitative genetics are relevant topics of durum wheat research. This cluster is tightly interconnected with the more recent emerging topic of "molecular genetics", represented by the key terms "DNA-sequences", "gene expression", "plant proteins", and "promoter region" (blue cluster), denoting a recent strong interest in the molecular mechanisms of the control and regulation of relevant traits. The terms "physiology", "heat stress", and "salt tolerance" in this cluster indicate recent studies in understanding the physiological and molecular plant responses to changing environmental conditions. It is important to note that the analysis of the 2001–2022 term map has made it possible to identify and separate both applied and basic research on durum wheat, represented by the "biodiversity and genomics" yellow cluster and the "molecular genetics" blue cluster.

The violet cluster includes terms related to various plant diseases and pests ("fusarium head blight", "Septoria", "*Micosphaerella graminicola*", and "Insecta"), while the term "disease resistance" is shifted to the yellow cluster as many studies focused on genetic control and breeding for disease resistance. The green cluster includes some specific terms such as "glucose blood level", "glycemic index", "dietary fiber", "starch digestibility", "quality control", and "coeliac disease", denoting a great emphasis in the last decades in investigations of food safety in relation to human health. This cluster, however, also includes key terms ("pasta quality", "flour", "starch", and "proteins") that were represented in two different clusters in the previous period (1981–2000), suggesting that technological and nutritional quality are always relevant topics of durum wheat research.

Figure 9. The keyword year map based on durum wheat publications from 2001 to 2022 (the light green and yellow colors stand for more recent terms, while the blue and dark green ones represent earlier ones).

Over the past two decades, sustainable farming has emerged as a compelling research area with the potential to enhance durum and bread wheat productivity, improve grain quality, and safeguard the environment in rainfed wheat production regions. This emphasis on sustainable farming aligns with the recently presented Strategic Research Agenda (SRA) by the Wheat Initiative [83], which underscores the need for intensified research efforts focused on the genetic control and role of root system architecture, a concept already advocated in durum wheat [84]. The terms "tillage systems", "zero tillage", and "*Vicia faba*" present in the red cluster indicate recent studies on minimal soil disturbance, soil cover management, and crop rotations as key components of conservation agriculture. Phosphorous and nitrogen use efficiency were the investigated strategies to reduce the application of fertilizers to soils and lower the environmental impact. Another recent research theme concerns the presence and availability of soil minerals, both for their essential role as micronutrient elements in plant growth (iron, copper, zinc, and sulfur) and for their phytotoxicity (lead and nickel) and accumulation (cadmium) in the grain.

4. Conclusions and Future Perspectives

A bibliometric mapping analysis in the durum wheat research was carried out with the main objectives of quantifying the documents published by journals, countries, and research institutions and identifying topics and trends and their interaction and development over time in the world. A total of 7512 documents from the Scopus database were analyzed by the VOSviewer software, and bibliometric maps illustrating the main research topics in three different periods were generated and visualized. This study has found that: (i) the number of scientific documents increased exponentially from n = 3–15 per year in the period 1961–1980 to an average of n = 329.4 documents per year in the decade 2011–2020, thus showing the fast growth of durum wheat research; (ii) the majority of the articles

(91.6%) were published in indexed journals and just a low percentage (3.4%) in conference proceedings; (iii) the most active journals publishing on durum wheat were the *Journal of Cereal Science*, *Euphytica*, *Theoretical and Applied Genetics*, *Cereal Research Communications*, and *Cereal Chemistry;* (iv) the most active contributing countries were Italy, the USA, Canada, Spain, and France; (v) abiotic stresses (drought and salinity) and water-use efficiency were the research themes of the top three articles that received more citations over the years; (vi) some of the observed research topics (e.g., mutagenesis and interspecific hybridization) seem to lose their research interest in favor of novel topics (e.g., molecular genetics and conservation farming); (vii) the current state of durum wheat research is characterized by well-defined topics of study including biodiversity, genomics and breeding, gene isolation, QTL mapping and cloning, molecular biology, technological and nutritional quality of durum end-products, food safety and human health, sustainable farming, abiotic and biotic resistance; (viii) over time, the clusters increase in size and complexity due to the growing number of publications and the trend in the multidisciplinary research in addressing the growing challenges of durum wheat production and end-product improvement with the climate changes and consumer demands. Durum wheat, a tetraploid wheat species, is extensively cultivated in Mediterranean regions, North America, and Canada. This valuable source of protein and calories is utilized in various end-products, including pasta, bread, and semolina. Despite significant advancements in durum production per unit area over the past decades, future production is poised to encounter unprecedented challenges stemming from global climate change, water scarcity in arid and semi-arid environments, and rising consumer demand for sustainable and organic food production. Additionally, excessive use of diverse fertilizers and pesticides exacerbates environmental pollution and ecological degradation.

Advances in molecular technologies, such as whole-genome sequencing, GWAS, trait dissection, gene discovery, transcriptomics, proteomics, metabolomics, high-throughput phenotyping, and speed breeding, can offer a wealth of genetic information that can expedite durum wheat improvement. While genome editing has made significant strides in recent years, precision genome editing in wheat remains a considerable challenge. Novel genome editing tools, including multiplex genome editing, gene replacement, and genotype-independent genome editing, hold the potential to revolutionize wheat functional genomics. Integrating genome editing with other molecular breeding strategies presents a powerful approach to accelerating wheat improvement. This combined approach could pave the way for developing innovative wheat varieties that not only support sustainable agriculture and environmental health but also adapt effectively to the challenges of climate change. Innovative breeding methodologies based on molecular tools can facilitate the efficient pyramiding of desirable alleles into commercial varieties, rapidly enhancing wheat traits without compromising other elite agronomic characteristics or introducing undesirable genes. Genomic selection could be more extensively employed to predict the genetic value of lines for specific traits and select the best lines without requiring costly and time-consuming field trials.

Conservation tillage practices can contribute to improved soil health, reduced soil erosion, and water conservation. These practices are expected to become increasingly prevalent in durum wheat production, as they can lead to significant economic and environmental damage reduction. Sustainable durum production should involve improved nutrient management and greater use of integrated pest management through various methods, including biological control, cultural practices, and pesticides. Precision agriculture technologies, such as GPS-guided tractors and data collected on crops and soil conditions, can inform decisions regarding irrigation, fertilization, and pest control, helping to improve resource use efficiency and reduce environmental impact.

In addition to these considerations, several challenges need to be addressed to enhance the quality of durum wheat end-products. These include improving protein quality and content, gluten strength, functional properties, and sensory quality to produce better pasta, enhancing higher levels of micronutrients, reducing the amount of some antinutrients, and developing durum varieties with hypoimmunogenic gluten that are safe for coeliac disease and gluten-sensitive patients.

Currently, durum wheat knowledge is concentrated in a few countries with the necessary infrastructure and funds. However, initiatives are underway to share knowledge, infrastructure, and genetic materials more widely. For instance, the Wheat Initiative, launched in 2011, aims to enhance communication and increase access to information, resources, and technologies for all countries. It also establishes Expert Working Groups (EWGs) to bring together experts on specific topics relevant to the Wheat Initiative's goals. The EWG on Durum Wheat Genomics and Breeding aims to promote research on improving durum wheat productivity and quality and collaborates with the scientific community active in bread wheat genomics. The worldwide durum wheat community has worked together to create two germplasm collections that represent the natural diversity of tetraploid wheat. The result of this effort is a global platform for tetraploid wheat diversity that includes two reference panels, the Tetraploid Wheat Global Collection (TGC) and the Global Durum Panel (GDP), which are publicly available for genomics research and breeding [61,62].

A perfect picture of the growth and current state of the field cannot be exhaustively painted by bibliometric analysis alone. Constraints in the term map production and analyses (bibliometric dataset, map production, visualization, interpretation, etc.) could generate a loss of information and lead to a simplified representation of a discipline or research area. The search strategy employed to compile the corpus of literature on durum wheat research may have omitted some pertinent studies, thus limiting the scope of this study's conclusions. Despite these limitations, the bibliometric mapping approach represents a useful tool to provide general, comprehensive knowledge of the structure and progress of research in a scientific field and can help young researchers and policymakers identify and develop novel and advanced research themes.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ijpb15010012/s1. Figure S1: Term map based on durum wheat publications in Italy from 2001 to 2022. Figure S2: Term map based on durum wheat publications in the USA from 2001 to 2022. Figure S3: Term map based on durum wheat publications in Spain from 2001 to 2022. Figure S4: Term map based on durum wheat publications in Canada from 2001 to 2022. Figure S5: Term map based on durum wheat publications in France from 2001 to 2022. Figure S6: Term map based on durum wheat publications in Australia from 2001 to 2022.

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