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Bibliometrics of Agricultural Crop Variety Development

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ABSTRACT

This study aims to map and analyze the global research landscape of agricultural crop variety development using a bibliometric approach. Data were retrieved from the Scopus database and analyzed using VOSviewer to identify research trends, thematic structures, collaboration networks, and emerging topics within the field. The results reveal that the scientific discourse is dominated by three interconnected themes: genetic innovation and plant breeding, plant physiological and biochemical research, and sustainability-oriented agricultural systems. Keyword co-occurrence analysis shows that concepts such as crops, agriculture, genetics, crop production, and sustainable development form the core intellectual structure, while overlay visualization indicates a shift toward advanced technologies such as gene editing, machine learning, and climate-resilient crop improvement. Density analysis highlights strong research intensity around food security and climate change, emphasizing the growing role of environmental challenges in shaping research priorities. Collaboration analyses demonstrate that countries such as China, India, and the United States act as central hubs in global scientific networks, supported by international agricultural research institutions. This study provides a comprehensive overview of the evolution, collaboration patterns, and future research directions in agricultural crop variety development, offering valuable insights for researchers, policymakers, and practitioners seeking to advance sustainable agricultural innovation.

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1. INTRODUCTION

Agricultural crop variety development has long been a cornerstone of global food security, rural livelihoods, and economic growth [1], [2]. Since the early domestication of plants, farmers and breeders have continuously selected and improved crop varieties to enhance yield, resilience, and adaptability to diverse agroecological conditions [3]. The scientific advancement of plant breeding accelerated significantly in the twentieth century with the integration of genetics, biotechnology, and data-driven approaches. The Green Revolution, for instance, demonstrated how improved crop varieties combined with agronomic innovations could dramatically increase productivity and reduce hunger in many regions [4], [5]. Today, the development of crop varieties remains central to addressing

challenges such as population growth, climate change, land degradation, and emerging pests and diseases [6], [7].

In recent decades, crop variety development has become increasingly complex and interdisciplinary. Modern breeding integrates molecular genetics, genomic selection, phenomics, bioinformatics, and participatory breeding approaches. Advances in biotechnology, including marker-assisted selection and genome editing, have shortened breeding cycles and enhanced precision [8]. At the same time, socio-economic considerations—such as farmer preferences, market demand, intellectual property rights, and seed systems—play an influential role in determining which varieties are developed and disseminated. As a result, research outputs related to agricultural crop variety development have expanded rapidly across scientific disciplines, institutions, and countries [9].

The rapid growth of scientific literature in this domain creates both opportunities and challenges. On one hand, the expansion of research outputs reflects dynamic innovation and collaboration in crop improvement. On the other hand, the proliferation of publications makes it increasingly difficult to synthesize trends, identify influential contributors, and map the intellectual structure of the field. Bibliometrics, defined as the quantitative analysis of academic literature, provides systematic tools to evaluate research productivity, collaboration networks, thematic evolution, and citation impact [10]. Through bibliometric analysis, researchers can uncover patterns that are not readily visible through traditional narrative reviews, such as emerging research clusters, leading institutions, and shifts in research priorities over time.

Bibliometric studies have been widely applied in agriculture and related sciences to assess research performance, knowledge diffusion, and innovation trajectories. For example, bibliometric analyses have examined trends in climate-smart agriculture, sustainable intensification, and biotechnology research, revealing evolving thematic focuses and international collaboration patterns [11]. However, while crop variety development is a fundamental pillar of agricultural research, comprehensive bibliometric assessments specifically dedicated to this domain remain relatively limited. Existing reviews often concentrate on particular crops, technologies, or regions, rather than offering a holistic evaluation of the field's overall scientific landscape.

Given the strategic importance of crop variety development in achieving the Sustainable Development Goals (SDGs), particularly those related to zero hunger, poverty reduction, and climate action, it is essential to understand how research in this field has evolved. Identifying the most productive countries, institutions, authors, and journals can help policymakers and funding agencies allocate resources more effectively. Furthermore, mapping thematic trends—such as the rise of genomic tools, climate-resilient breeding, or participatory approaches—can illuminate future research directions. A bibliometric approach thus offers a valuable evidence-based framework for evaluating the trajectory, structure, and impact of agricultural crop variety development research at the global level.

Despite the recognized importance of agricultural crop variety development, there is a lack of comprehensive quantitative assessments that systematically map the scientific output, collaboration networks, and thematic evolution of this field. The growing volume of publications across diverse disciplines has created fragmentation, making it difficult to identify dominant research themes, influential contributors, and emerging innovations. Without a structured bibliometric analysis, stakeholders—including researchers, policymakers, and funding agencies—may lack a clear understanding of research gaps, global disparities in contributions, and shifting priorities in crop improvement science. This limitation hinders strategic planning, efficient resource allocation, and the effective translation of research into sustainable agricultural outcomes. The objective of this

study is to conduct a comprehensive bibliometric analysis of global research on agricultural crop variety development.

2. METHODS

This study employed a quantitative bibliometric research design to systematically analyze the scientific literature on agricultural crop variety development. Bibliometric analysis was chosen because it enables the objective evaluation of publication patterns, citation structures, and collaboration networks within a defined research domain. The study followed a structured workflow consisting of database selection, search strategy formulation, data extraction, data cleaning, and performance and science mapping analyses. Scopus was used to retrieve relevant documents due to its extensive coverage of agricultural and life sciences literature. The search strategy incorporated a combination of keywords and Boolean operators related to "crop variety development," "plant breeding," "cultivar development," and related terms to ensure inclusivity while maintaining relevance. The search was limited to journal articles and review papers published in English within a defined time span to ensure consistency and comparability of bibliometric indicators.

After data retrieval, the bibliographic information—including authors, titles, abstracts, keywords, publication years, institutions, countries, citations, and source titles—was exported in compatible formats for analysis. Data cleaning and preprocessing were conducted to remove duplicate records, unify author names and institutional affiliations, and standardize keywords to reduce inconsistencies caused by variations in spelling or terminology. The cleaned dataset was then analyzed using VOSviewer to perform descriptive and network analyses. Science mapping techniques—including co-authorship analysis, co-citation analysis, bibliographic coupling, and keyword co-occurrence analysis—were applied to visualize collaboration networks, intellectual structures, and thematic clusters within the field.

To further explore the evolution of research themes, temporal analyses of keywords and thematic mapping were conducted. Keywords were categorized based on frequency, centrality, and density to identify motor themes, emerging or declining themes, niche themes, and basic themes within agricultural crop variety development research. Citation analysis was used to determine influential publications and foundational works shaping the field. Network visualization maps were interpreted by examining node size, link strength, and cluster formation to understand relationships among authors, institutions, and research topics.

3. RESULTS AND DISCUSSION

3.1 Keyword Co-Occurrence Network

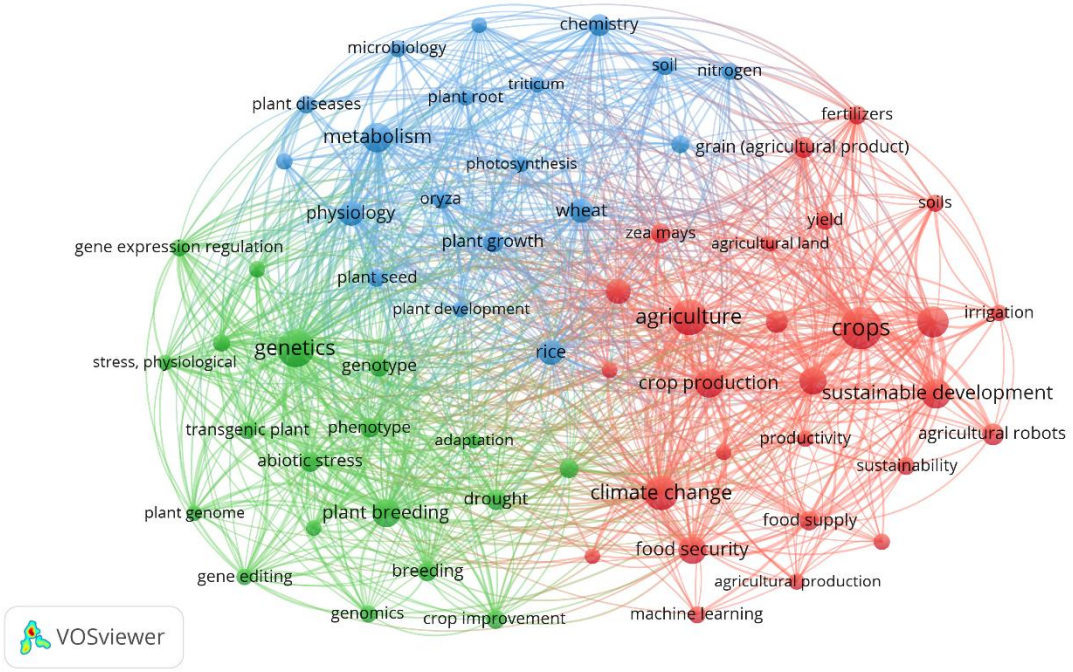

Figure 1. Network Visualization
Source: Data Analysis Result, 2026

Figure 1 reveals a highly interconnected research landscape in agricultural crop variety development, structured into several thematic clusters that reflect the multidimensional nature of modern agricultural science. The central positioning of terms such as agriculture, crops, and crop production indicates that the field is strongly anchored in applied agricultural outcomes, linking biological innovation with production efficiency and sustainability goals. The dense interconnections among nodes suggest that studies rarely focus on a single discipline; instead, they integrate agronomy, biotechnology, and environmental science to address complex agricultural challenges.

The red cluster primarily represents themes related to agricultural systems, sustainability, and productivity. Keywords such as sustainable development, food security, irrigation, productivity, and agricultural robots highlight a growing emphasis on technological adoption and sustainable intensification. The presence of climate change near the center of this cluster indicates that environmental pressures are driving research toward resilient crop systems. This cluster suggests that crop variety development is increasingly framed within global sustainability agendas, where yield improvement must be balanced with environmental stewardship and resource efficiency.

The green cluster reflects a strong focus on genetics and molecular breeding approaches. Terms such as genetics, genomics, gene editing, plant breeding, and abiotic stress demonstrate that contemporary research heavily relies on biotechnological advancements to develop resilient crop varieties. The connections between phenotype, genotype, and stress physiology indicate a shift toward precision breeding strategies that integrate molecular data with environmental adaptation. This cluster highlights how crop improvement is evolving from conventional breeding toward genomic-assisted innovation, emphasizing resilience to drought, stress, and changing climatic conditions.

Meanwhile, the blue cluster emphasizes physiological and biochemical processes underlying plant growth and development. Keywords like metabolism, photosynthesis, plant physiology, soil,

nitrogen, and microbiology suggest a strong foundational research base aimed at understanding plant–environment interactions. The inclusion of specific crop references such as wheat, rice, and triticum indicates that staple crops remain central to experimental research. This cluster serves as a scientific bridge between genetic innovation and agronomic application, demonstrating how physiological insights inform the design of improved crop varieties.

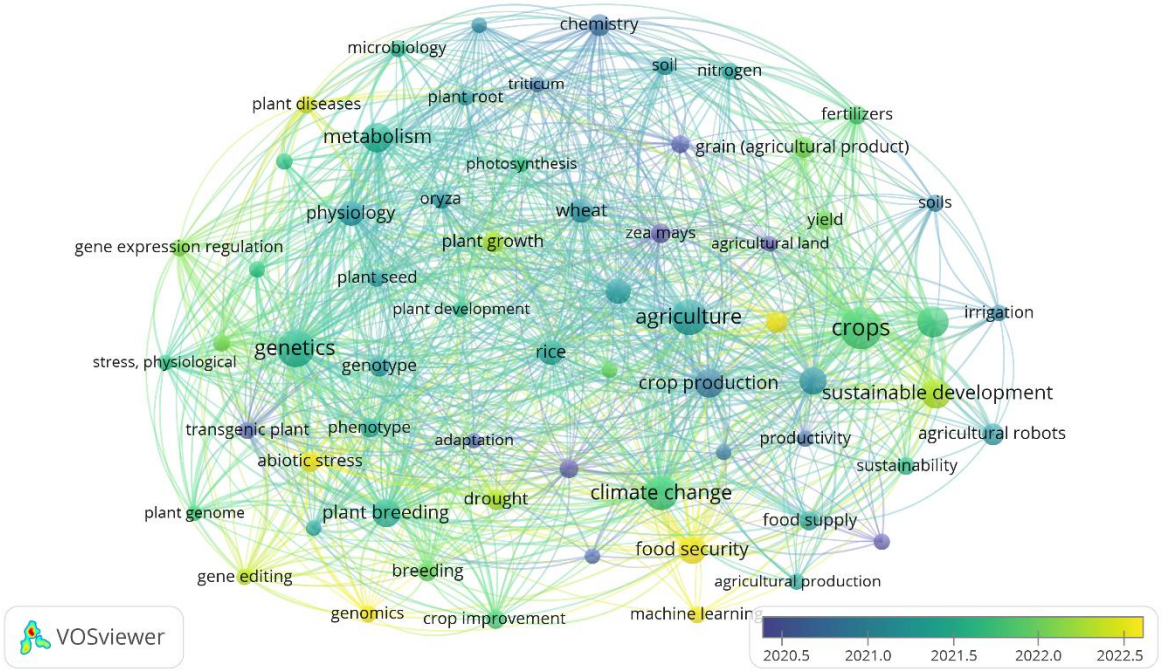

Figure 2. Overlay Visualization

Source: Data Analysis Result, 2026

Figure 2 illustrates the temporal evolution of research themes in agricultural crop variety development, where color gradients indicate shifts in scholarly focus over time. Earlier research topics, represented by darker blue tones, are primarily associated with foundational agricultural science, including soil, chemistry, nitrogen, and basic plant physiology. This suggests that early studies were strongly rooted in understanding agronomic and biochemical processes that underpin crop productivity. Such themes reflect the traditional scientific base that laid the groundwork for later innovations in breeding and sustainable agriculture.

Research appearing in green tones represents a transitional phase in which genetics, plant breeding, and physiological adaptation gained significant attention. Keywords such as genetics, plant breeding, abiotic stress, and genotype indicate the growing integration of molecular biology into crop improvement strategies during this period. The presence of staple crops like rice, wheat, and zea mays demonstrates that applied breeding research remained central, while increasing attention to climate change and adaptation suggests a shift toward resilience-focused agricultural innovation. This phase highlights how researchers began combining genetic knowledge with environmental challenges to improve crop varieties.

More recent topics, shown in yellow tones, reveal emerging research directions centered on sustainability and digital transformation. Keywords such as food security, machine learning, gene editing, and crop improvement indicate that contemporary studies are increasingly oriented toward advanced technologies and global sustainability goals. The movement of crops and sustainable development toward

warmer colors suggests a current emphasis on integrating biotechnology with precision agriculture and data-driven approaches.

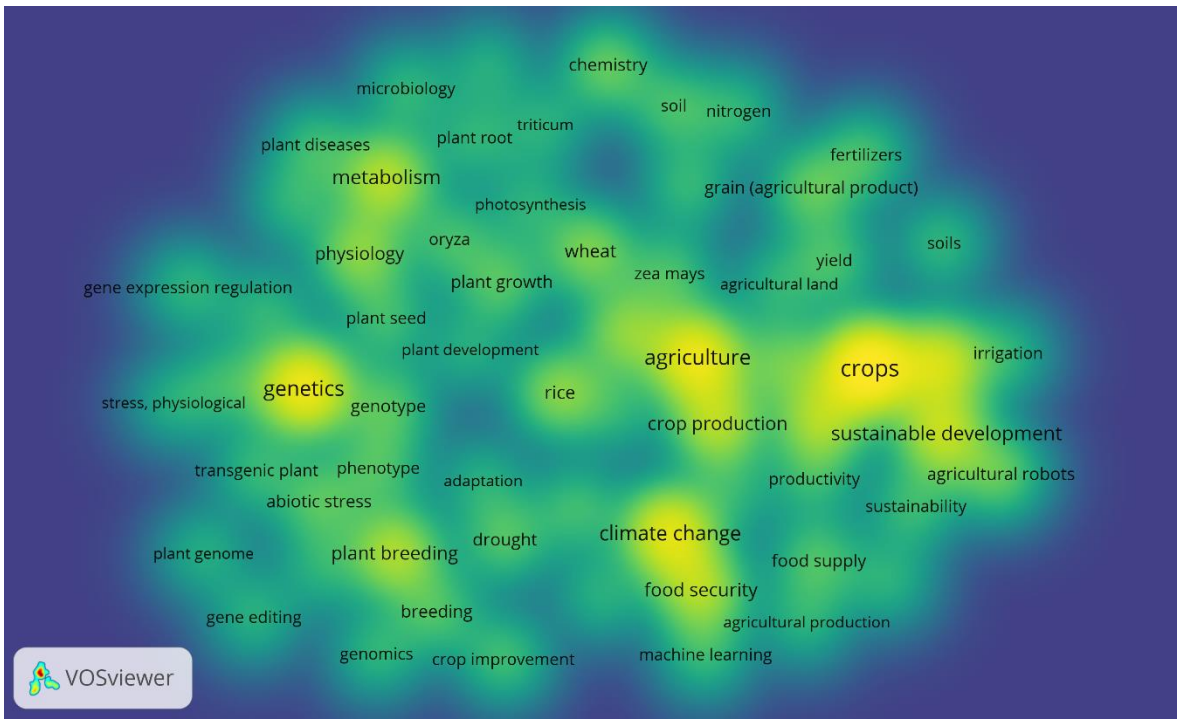

Figure 3. Density Visualization
Source: Data Analysis Result, 2026

Figure 3 highlights the most intensively researched themes within agricultural crop variety development, where brighter yellow areas represent topics with high frequency and strong interconnections. The highest concentration appears around keywords such as crops, agriculture, genetics, and crop production, indicating that the core of the scientific discourse focuses on improving crop performance through both agronomic practices and genetic innovation. The strong presence of sustainable development and climate change near these central areas suggests that current research is increasingly shaped by global challenges related to food security, environmental sustainability, and agricultural resilience.

In addition, the visualization reveals secondary but important research concentrations around plant physiology and breeding-related themes, including metabolism, physiology, plant breeding, and abiotic stress. These areas demonstrate the continued importance of understanding biological mechanisms to support advanced crop improvement strategies. Meanwhile, emerging topics such as machine learning and gene editing appear with moderate density, indicating growing scholarly attention but still developing maturity compared to traditional genetic and agronomic research themes.

3.2 Co-Authorship Network

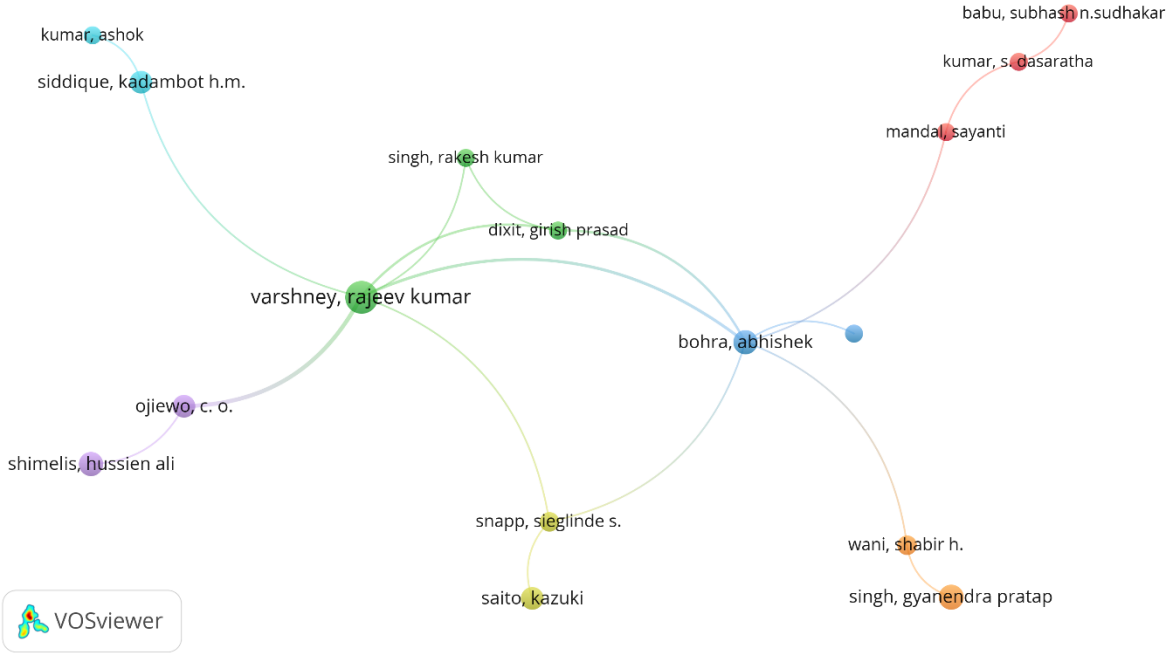

Figure 4. Author Collaboration Visualization
Source: Data Analysis Result, 2026

Figure 4 illustrates a relatively fragmented collaboration structure within the research field of agricultural crop variety development, where several small author clusters are connected through a few central scholars. Authors such as Varshney, Rajeev Kumar and Bohra, Abhishek appear as key bridging nodes, linking multiple research groups and indicating their significant role in fostering collaborative networks and knowledge exchange. Surrounding them are smaller clusters representing localized collaborations, including partnerships among researchers like Singh, Rakesh Kumar, Dixit, Girish Prasad, and others, suggesting thematic or institutional research alliances. The presence of several isolated or weakly connected groups implies that although collaboration exists, the field still shows opportunities for stronger global integration and interdisciplinary partnerships to enhance innovation and research impact in crop variety development studies.

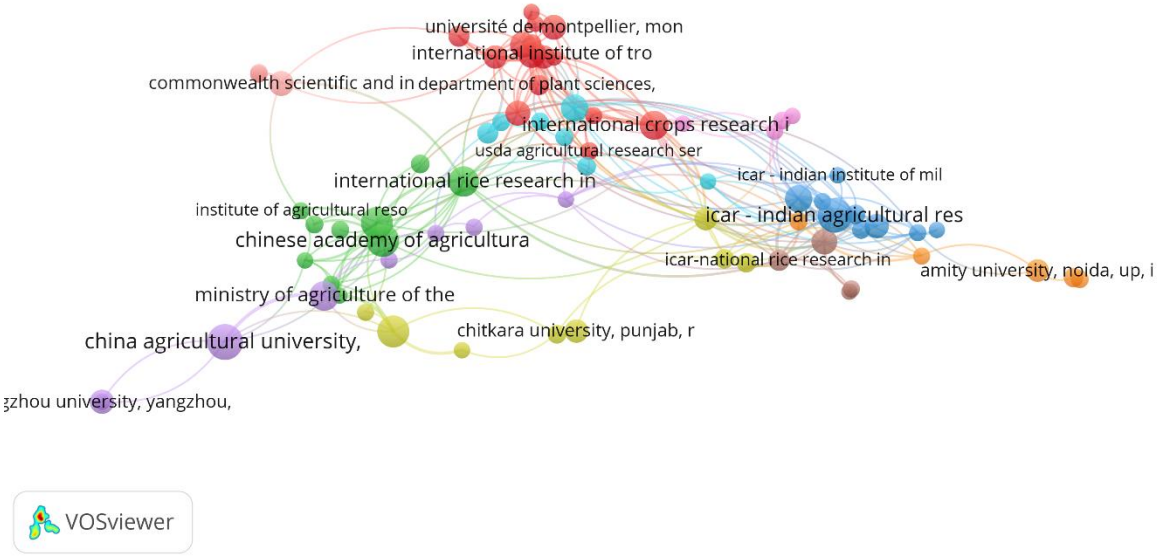

Figure 5. Affiliation Collaboration Visualization
Source: Data Analysis Result, 2026

Figure 5 demonstrates that research on agricultural crop variety development is driven by a combination of international research centers, national agricultural institutes, and leading universities. Institutions such as the International Crops Research Institute, International Rice Research Institute (IRRI), ICAR–Indian Agricultural Research Institute, and the Chinese Academy of Agricultural Sciences appear as central hubs, indicating their strong influence in facilitating global research partnerships. The dense interconnections among these organizations suggest that crop variety development is highly collaborative and internationally oriented, particularly involving partnerships between Asian agricultural institutes and global research organizations like USDA and European universities such as Université de Montpellier. Additionally, the presence of government ministries and specialized agricultural research bodies highlights the applied and policy-driven nature of this field, where institutional cooperation plays a crucial role in advancing sustainable crop innovation and addressing global food security challenges.

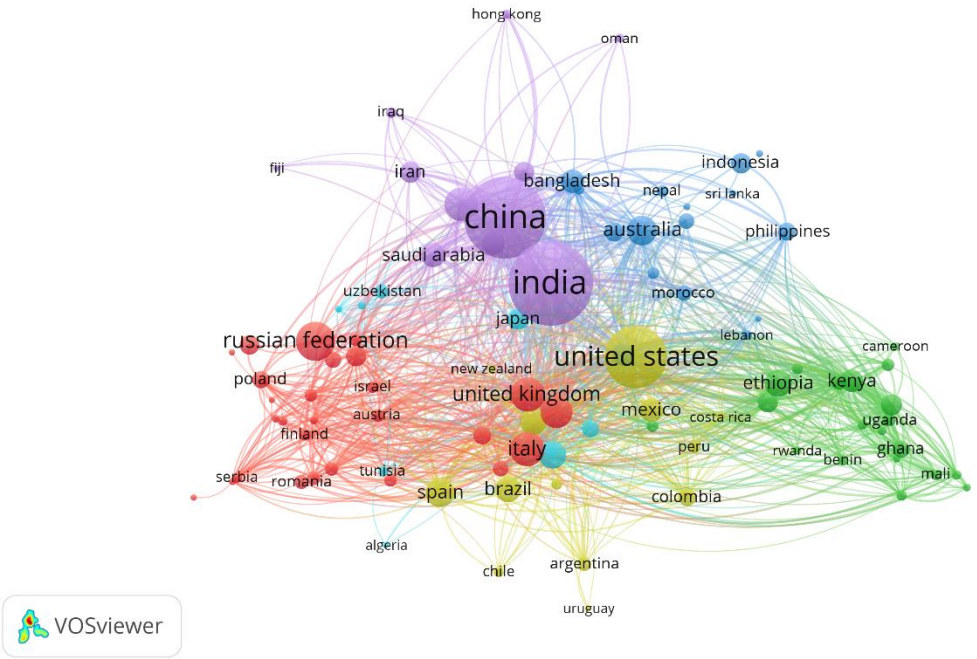

Figure 6. Country Collaboration Visualization
Source: Data Analysis Result, 2026

Figure 6 illustrates a highly interconnected global research landscape in agricultural crop variety development, with major scientific contributions concentrated in several leading nations. Countries such as China, India, and the United States appear as dominant hubs, reflecting their strong research productivity and extensive international partnerships. China and India occupy central positions, indicating their significant roles in advancing crop improvement research, particularly in regions facing food security and climate challenges. The United Kingdom and Italy serve as important connectors linking European collaborations, while countries in Africa—such as Kenya, Ethiopia, Ghana, and Uganda—form a distinct cluster that highlights growing research engagement related to agricultural sustainability and development. Meanwhile, emerging participation from Southeast Asian countries, including Indonesia and the Philippines, suggests increasing regional involvement in collaborative agricultural innovation.

3.3 Citation Analysis

Table 1. Top Cited Research

Citations	Authors and year	Title
5091	[12]	Pyrolysis of wood/biomass for bio-oil: A critical review
3261	[13]	Heat tolerance in plants: An overview
1691	[14]	Assessing the impact of the Green Revolution, 1960 to 2000
1553	[15]	Plant tolerance to high temperature in a changing environment: Scientific fundamentals and production of heat stress-tolerant crops
1506	[16]	Systemic insecticides (Neonicotinoids and fipronil): Trends, uses, mode of action and metabolites
1392	[17]	World salinization with emphasis on Australia
1351	[18]	A map of rice genome variation reveals the origin of cultivated rice

Citations	Authors and year	Title
1349	[19]	Microbial phosphorus solubilization and its potential for use in sustainable agriculture
1345	[20]	Regulation of OsSPL14 by OsmiR156 defines ideal plant architecture in rice
1194	[21]	Consequences of climate change for European agricultural productivity, land use and policy

Source: Scopus, 2026

Discussion

Overvirew of Findings

This bibliometric analysis provides a comprehensive overview of the intellectual structure and evolution of research on agricultural crop variety development. The keyword co-occurrence analysis reveals that the field is built upon three dominant scientific pillars: genetic innovation and plant breeding, plant physiological and biochemical research, and sustainability-oriented agricultural systems. Central themes such as crops, agriculture, genetics, and crop production demonstrate that contemporary research integrates biological sciences with agronomic practices to improve productivity and resilience. The overlay visualization further indicates a temporal shift from traditional agronomy and soil science toward advanced technologies, including gene editing, machine learning, and climate-adaptive crop improvement strategies. This evolution highlights the transformation of crop variety development into an interdisciplinary domain that combines biotechnology, environmental science, and digital agriculture.

The density visualization reinforces these findings by identifying core research hotspots around genetics, sustainability, and crop productivity. The strong presence of topics related to climate change and food security suggests that scientific attention is increasingly directed toward addressing global challenges such as resource scarcity, environmental degradation, and population growth. Moreover, the co-authorship and institutional collaboration networks reveal that innovation in this field is strongly driven by a relatively small number of influential researchers and international research organizations. Key institutions, including global agricultural research centers and national agricultural institutes, play a crucial role in facilitating knowledge exchange and advancing technological progress. These collaborative patterns indicate that agricultural crop variety development is not only a scientific endeavor but also a policy-driven and globally coordinated research area.

Theoretical and Practical Implications

From a theoretical perspective, the findings demonstrate that agricultural crop variety development has shifted from a predominantly agronomic paradigm toward a systems-oriented innovation framework. The integration of genetic research with sustainability and digital technologies reflects the emergence of a new research paradigm where crop improvement is viewed as part of a broader socio-ecological system. This shift aligns with contemporary agricultural innovation theories emphasizing resilience, sustainability transitions, and technological convergence.

Practically, the results highlight the increasing role of advanced technologies such as gene editing, artificial intelligence, and precision agriculture in shaping future research directions. Policymakers and research institutions may leverage these insights to prioritize funding for interdisciplinary programs that combine biotechnology with climate adaptation strategies. Additionally, the strong involvement of international research centers underscores the importance of collaborative platforms in accelerating crop variety development, particularly for regions vulnerable to food insecurity.

4. CONCLUSION

This bibliometric study demonstrates that research on agricultural crop variety development has evolved into an interdisciplinary and globally collaborative field shaped by advances in genetics, plant physiology, and sustainability-oriented agricultural systems. The analysis reveals that core research themes are increasingly driven by challenges related to climate change, food security, and technological innovation, with emerging directions emphasizing gene editing, machine learning, and precision agriculture. Collaboration networks highlight the dominant roles of major agricultural research nations and international institutions in advancing scientific progress, while also indicating opportunities for broader cross-regional and interdisciplinary partnerships.

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