Bangladesh Rice Journal 29 (1), 2025

BRJ

Contents lists available at Banglajol

Bangladesh Rice Journal

journal homepage: www.banglajol.info/index.php/BRJ

Half a Century of Rice Research in Bangladesh: A Critical Review on Bibliometric Growth

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A R T I C L E   I N F O

Keywords:
Agriculture
Bangladesh
Bibliometric
Oryza sativa
Rice
Sustainability

A B S T R A C T

Bangladesh holds the third largest rice area and the fourth position of its production in the world. The crop alone occupies the three-fourths of annual agricultural land and rice is the synonym of food in Bangladesh. As best of knowledge, no earlier investigation explored the landscape of rice research in Bangladesh through bibliometric approaches. Using the database records of SCOPUS, a meticulous analysis of 1284 articles was conducted spanning the years 1974 to 2022, with specialized software tools viz. VOSviewer, Biblioshiny, and OriginPro. The articles were authored by 3358 scholars from 193 different institutions across 76 countries and disseminated through 424 distinct journals. The annual average growth rate of publications in this domain was found to be 10.76%. Due to elitism of the subject matter, obviously Bangladesh had been the leading country in this field of publications. Among the numerous organizations, Bangladesh Rice Research Institute had achieved the highest rank, followed by Bangladesh Agricultural University and the International Rice Research Institute. The current study has further identified the three most prominent journals in which these articles were published: Field Crops Research, Environmental Science & Technology, and Science of the Total Environment. According to SCOPUS definition, these research publications are clustered into several categories including mainly Agriculture & Biology; Environmental Sciences; Social Sciences; and Biotechnology, Genetic Engineering & Molecular Biology. A cluster analysis of keywords explicitly pointed to 'Rice and Bangladesh' as the focal point of interest within this research area. As a look to the immediate future, forthcoming studies should emphasize the mechanization in rice cultivation, C4 plant type of rice, and premium quality rice for harnessing global market. It is a comprehensive review which may serve as a valuable reference for formulating research priorities to combat global food security challenges

1. Introduction

Rice (*Oryza sativa* L) is the food grain that shaped the cultures, diets, and the economy of billions of Asians. In this vast region, rice is more than food, rice is life. Obviously, it is a staple food for two-thirds of the population in the world (Sen et al., 2020). Rice grain is mostly used as human food, contrasting to other cereals, which are extensively used as feed (Palacpac, 1980). Currently, the total hectarage of global rice planting was recorded at 160 million hectares that represents approximately one-tenth of the cultivated area in the world (Atlas Big, 2023). In the world ranking of rice cultivation, although

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https://doi.org/10.3329/brj.v29i1.86214

Bangladesh holds the third largest rice area, its position is the fourth in terms of grain production. Compared to Bangladesh, rice area in China, India and Indonesia is less than one-fourth of the cultivated area (Atlas Big, 2023; Kabir et al., 2021; Wikipedia, 2023). For approximately 167 million people in Bangladesh, rice has been contributing 97% of total food grain production (BBS, 2020; FPMU, 2020). Rice is the synonym of food in the country (Shahidullah et al., 2008) and here 'food security' almost entirely depends on 'rice security' (Brolley, 2015). Rice security is not only an economic issue but also an important parameter for determining social and political stability in the country (Nath, 2015). Per capita average intake of rice in the country is about 367 g day^{-1}, which provides nearly 60% of total calories and 50% of total proteins for adults (BBS, 2016). Almost 48% of rural workers are in some way involved in the rice production for their livelihood. Contribution of the rice crop to the value of crop sub-sector is nearby 70% (Mottaleb & Mishra, 2016).

Rice plant has wide adaptability from top of the hill to coast of sea. There are broadly recognized five ecosystems, viz. (a) irrigated ecosystem, (b) rainfed lowland, (c) deepwater, (d) tidal wetland, and (e) upland ecosystem (Khush, 1984). All of the rice growing environments are dispersedly present in Bangladesh. Boro is cultivated during dry winter season in irrigated ecosystem. Transplant Aman represents the rainfed lowland and tidal wetland, whereas Aus is an upland crop and Broadcast Aman represents deep-water rice ecosystem (Nasim et al., 2018). However, with the introduction of modern rice varieties, the association between paddy ecotype and ecosystem is fading (Miah et al., 2004).

Rice research in Bangladesh started its journey in 1910. In course of time, the modern era of rice research in the country started in the mid-sixties (Rahman et al., 2023). Realizing the extraordinary importance of rice in socioeconomic and political aspect, Bangladesh Rice Research Institute (BRRI) was established on the 1st October 1970 (BRRI, 2014). In its initial stage, rice scientists addressed the research for higher grain yield in the favourable ecosystem, however, in course of time, rice research has been facing various global and natural challenges (Kabir et al., 2016). Consequently, the scholars of BRRI as well as other institutions and different universities expanded their activities in the field of variety development on drought tolerance (Brammer, 1987; Torres et al., 2013), flash flood and submergence (Iftekharuddaula et al., 2015; Iftekharuddaula et al., 2016), pest management and disease resistance (Chowdhury et al., 2015; Cork et al., 2005; Howlader & Matin, 1988; Khanam et al., 2016), weed management and allelopathy (Islam & Molla, 2001; Rashid et al., 2012; Salam & Kato-Noguc, 2010; Salam & Kato-Noguchi, 2009), salt stress and salinity management (Al-Forkan et al., 2005; Islam et al., 2016; Lisa et al., 2011), arsenic contamination in soil and rice grain (Abedin et al., 2002; Meharg & Rahman, 2003), global warming and green-house gas emission in the rice land (Ali et al., 2014; Gaihre et al., 2015), integrated rice-fish culture (Frei et al., 2007; Haroon & Pittman, 1997; Mustow, 2002) and food policy and socio-economic aspects of rice cultivation (Bera & Kelley, 1990; Chowdhury et al., 2022). The country is at the reach of food grain sufficiency and the time and human desire raised the demand of quality rice (Kabir et al., 2021). Perceptibly, rice scientists are implementing research on aromatic and premium quality rice (Shahidullah et al., 2011; Shahidullah et al., 2010; Shahidullah et al., 2009), zinc enriched rice (Ara et al., 2019; Mayer et al., 2007), β-carotene enriched golden rice (Biswas et al., 2021; Swamy et al., 2019) and biofortification of rice food (Hotz et al., 2015; Promthai et al., 2009). All of the above-mentioned studies collectively had built a strong foundation for the advancement of rice research of Bangladesh up to the global standard.

Bibliometric analysis is a broad-aspect as well as multidisciplinary research methodology based on computer engineering, database management, and statistical procedures (Chen et al., 2016). It has a difference from 'conventional reviews' and 'meta-analyses', and has many advantages, which includes visual analyses of datasets of contributing authors, journal sources, keywords, institutions, etc.; quantitative cum statistical analyses of the research trend and characteristics of certain topics (Chen et al., 2014; Shahidullah et al., 2024); research into the frontiers and hotspots; and knowledge disseminations and interactions among different disciplines (Lv et al., 2021). In the current years, bibliometric analysis has attained a widespread recognition and application across diverse domains of research (Chen et al., 2014; Shahidullah et al., 2025; Shahidullah et al., 2024). Nevertheless, documentation of rice research in Bangladesh on the basis of bibliometric approaches received a little attension.

The current study aims to provide an inclusive overview of existing academic literature in the connection of rice research in the country, identifying research thrusts, trends as well as emerging research issues, particularly in relation to the alignment of sustainable and nutrient-enriched food production. The specific research query (RQ) includes:

RQ1 : What is the annual progress of scientific documentations on rice research in Bangladesh?

RQ2 : Who are the leading contributors, which are important journals, and which are active institutions for contribution to the documentations?

RQ3 : Which are the articles that make substantial influence in the field of rice research in the country?

RQ4 : Which level of cooperation exist among the institutions and countries engaged in the research, and how the collaborations are helping the research landscape?

RQ5 : What are the emerging research issues, and what trends could be discerned within existing scientific literature on rice?

2. Materials and methods

The SCOPUS dataset has been used as the information source for the analysis in the current study. This study employed broadly two techniques, the 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) for a systematic review of articles included in the investigation and the Bibliometric Analysis. On the 1st October 2023, a search had been conducted in the Scopus database, using the search query ((TITLE (rice AND bangladesh) OR ABS (rice AND bangladesh)) AND (LIMIT-TO (LANGUAGE, "English") AND PUBYEAR > 1973 AND PUBYEAR < 2023) AND (LIMIT-TO (DOCTYPE, "ar")) AND (EXCLUDE (PUBSTAGE, "aip")). This query string initially resulted in 2140 documents. We did not limit the starting time of publication documents, however, in fact, it is available from 1974 and not before the year. After excluding all the documents published in 2023 for its incompleteness, the number was downgraded to 2024 (Fig. 1). Then the documents were brought in the limit of English language and journal articles. Then A manual sorting process refined the dataset, discarding the rest of irrelevant articles, finally yielding a concrete set of 1,284 articles. Selected articles were downloaded and then saved in "csv" file format along with complete records of citation data. We opted the SCOPUS database was for its reputation, for maintaining multidimension data selection, indexing standards, confirming reliability and the quality of database. Extensive coverage of SCOPUS, especially within our targeted academic disciplines, particularly was aligned with the research domain. In the present time, this database is rigorously used to accomplish the bibliometric analysis in the scientific investigation (Guerrero-Bote et al., 2021; Hashem et al., 2023; Magadán-Díaz & Rivas-García, 2022; Sau & Nayak, 2022; Sevillano-Jimenez et al., 2023).

We got several basic information from preliminary analysis of the database itself, including authorship of the articles, disciplinary distribution of the documents along with yearly growth rates, journal sources, institutional affiliations as well as countries of origin. The analysis yielded various metrics viz. ranks, frequency, ratios, trends, network analysis, co-authorship, citations, and co-word analysis. Software tools like 'R' with Biblioshiny package (Aria & Cuccurullo, 2017) along with VOSviewer 1.6.19 (the Netherlands Center for Scientific & Technological Research) were employed for in-depth advanced analysis. These are powerful tools that facilitated the mapping of keyword co-occurrence for the identification of fundamental research directions and detection of emerging research hotspots. For more visual representations of the findings, MS Excel 365 & OriginPro 2023b were also used to prepare numerous graphs.

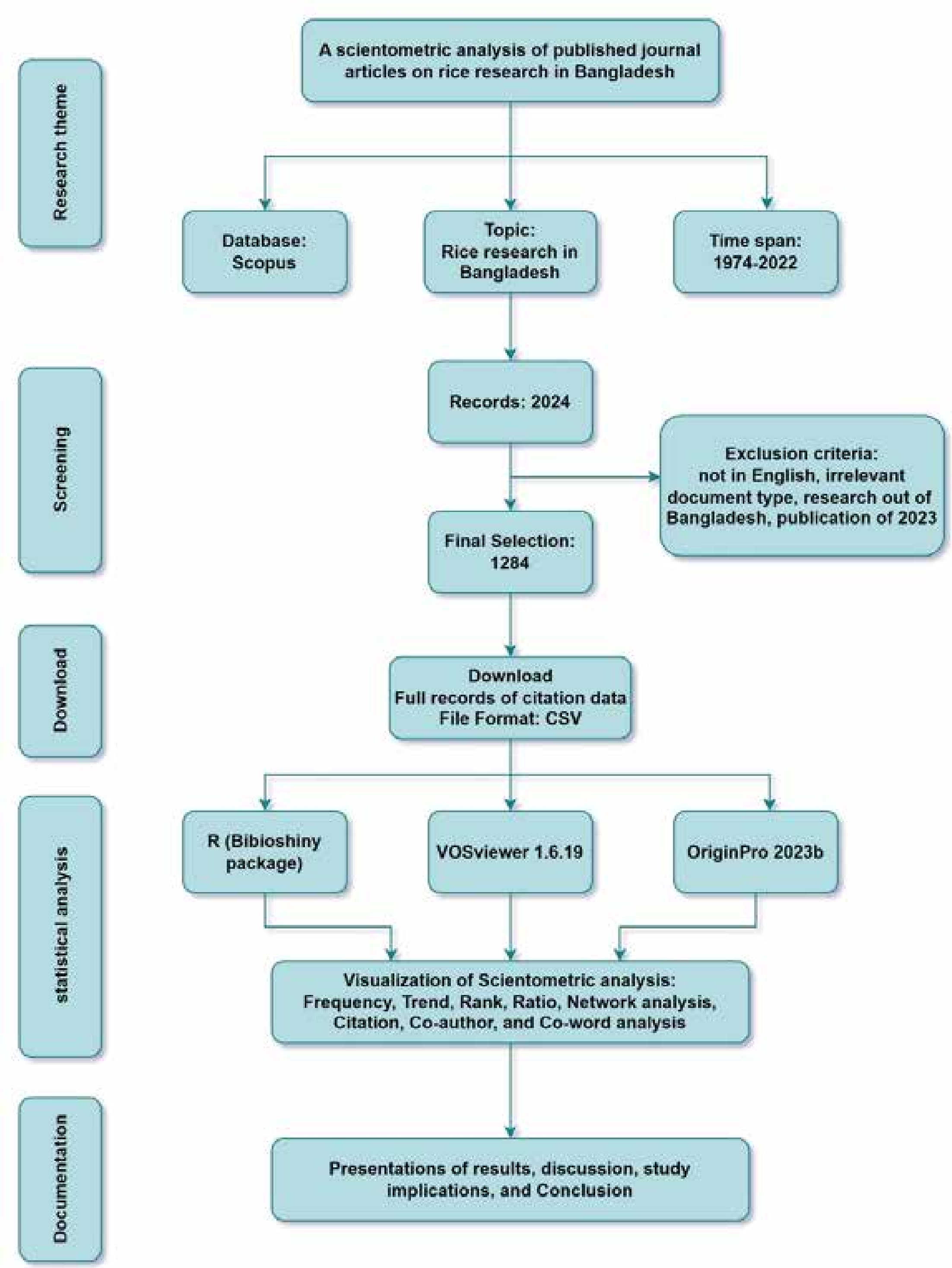

Fig. 1. A flow diagram for bibliometric analysis.

3. Results

3.1. Descriptive statistics of rice research in Bangladesh

Descriptive statistics of the rice research in Bangladesh offer profound intuitions into its scientific as well as practical implications. In the analysis of 1284 documents on rice research in the country, a total of 3358 authors were enlisted. Among them 80 authors had had single-authored articles, contributing to a sum of 108 single-authored publications in the dataset. A research article, the most pioneer in this domain, was published in 1974 (Shahjahan, 1974). A consistent growth in scientific publications at average rate of 10.76% was recorded in the half-a-century time series. The phenomenon signifies the growing scientific interest in Bangladesh rice research, recognizing its importance to address food security and also sustainable intensification. In the total time span, an average number of per document citations stood at 27.95. The growth rate of publications showed a slow increase until 1989, remained fairly stable until 2000, and performed a better growth up to 2022 (Fig. 2). The surge of publications in 2021-22 hints at evolving trends of developments that warrant a continuous attention on future research issues. Moreover, the distribution pattern of the publications has been visually represented in Figure 3, where the publication counting appears as an over number at 1708. This happened due to multi-categoric nature of numerous articles. Within the SCOPUS distribution, 43% of the articles fell under the category of Agricultural and Biological Sciences, 19% in Environmental Sciences, 9% in Social Sciences, 7% in Biochemistry Genetics and Molecular Biology, with the remaining dispersed across six other disciplines. The multidisciplinary involvement in research highlights the needs of holistic approach for understanding complex dynamics in research systems in Bangladesh rice. In sum, the current findings might be helpful for policy formulation, academic enrichment of scholars and students. It might also serve in the practical applications for sustainable agricultural development, reducing ecological impacts, and ensuring food security.

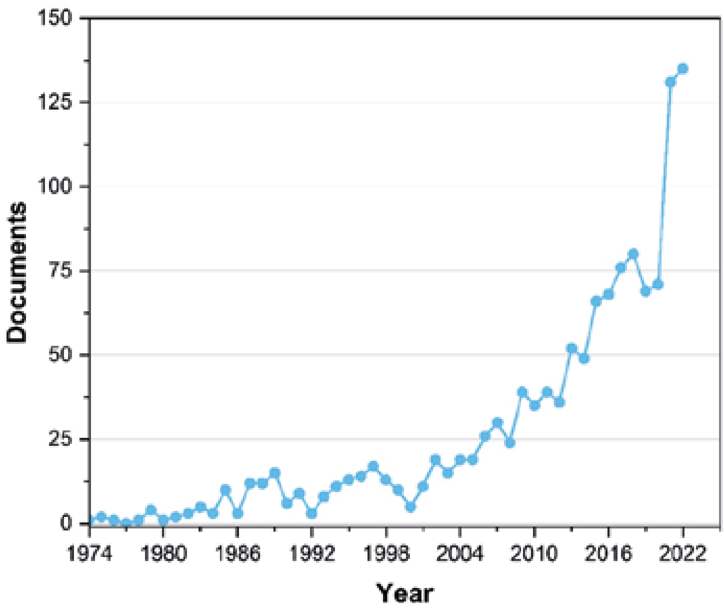

Fig. 2. Periodic distribution trends of publications of rice research in Bangladesh from 1974 to 2022.

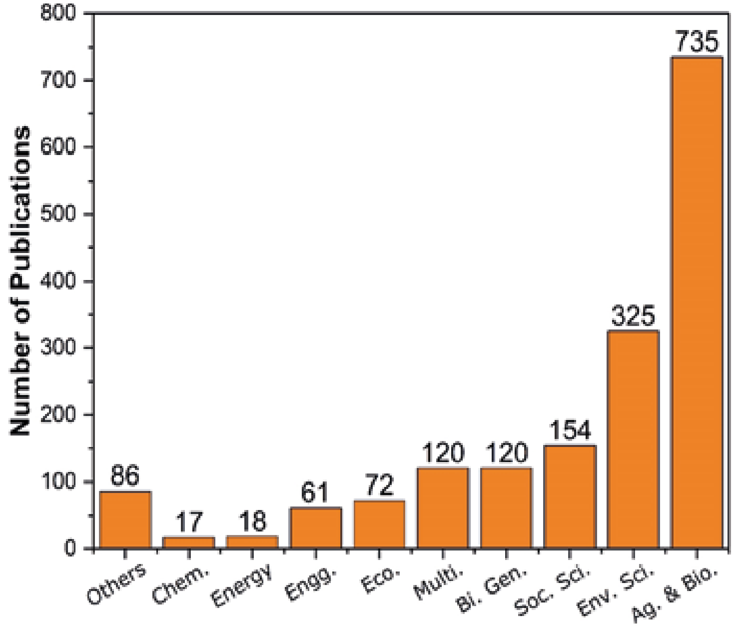

Fig. 3. A distribution pattern of published papers in different categories in rice research of Bangladesh.
Note: Multi. = Multidisciplinary subject, Bi.Gen. = Biotechnology, Genetic Engg. and Molecular Biology.

3.2. Leading contributors, organizations, and countries

Fig. 4 (a-d) illustrates a list of top 10 authors according four distinct criteria. In the viewpoint with number of publications, M.R. Islam from Bangladesh Agricultural University (BAU), appeared as the most creative author was responsible for 38 publications, constituting 2.96% of the total, followed by A.A. Meharg (University of Aberdeen) with 24 and Bell R.W. (Murdoch University) with 21 publications, accounting for 1.87% and 1.63% of total number of scientific articles. In consideration of total citations, A.A. Meharg is the top-ranking author with 4499 citations, while the second most influential author was F.J. Zhao (Rothamsted Research, UK) for 2052 citations. In an assessment method of h-index, A.A. Meharg occupied the highest score of 22 followed by M.R. Islam with scores 19. Norton G.J. (University of Aberdeen) and Bell R.W. both attained an equal score of 15. In the calculation of the g-index, M.R. Islam again achieved the first position with 25 score. AA Meharg ranked in the 2nd position with 24 score followed by Jahiruddin M (BAU) and S Rahman (University of Plymouth) with 19 score. Authorship analysis in this sub-section provides valuable understandings on key contributors in the rice research of Bangladesh. It might be helpful for other researchers to harvest their talents and feasible collaboration for the advancement in sustainable agriculture.

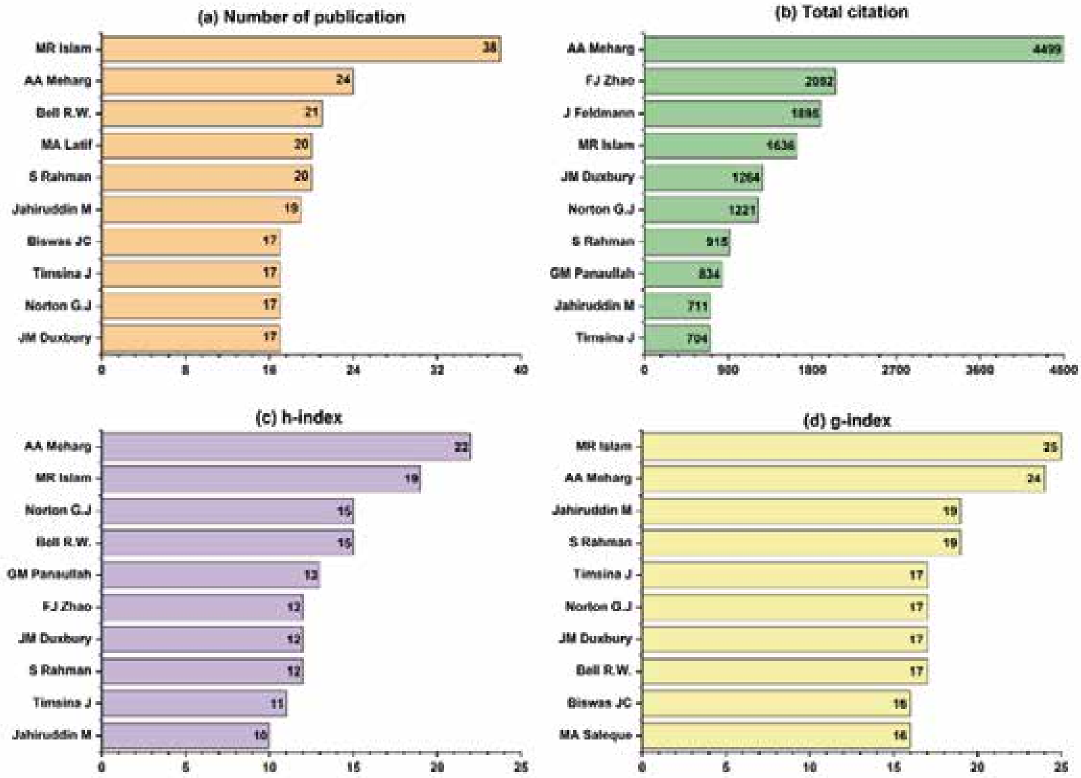

Fig. 4. (a) Authors ranked by number of publications (top 10), (b) Authors ranked by total citations (top 10), (c) Authors ranked by h-index (top 10), (d) Authors ranked by g-index (top 10).

In the compilation of research institutions, Fig. 5(a) presents the list of top ten contributors. The Bangladesh Rice Research Institute (BRRI) stands at the top position with 451 research documents, constituting 35% of the total publications, followed by Bangladesh Agricultural University (BAU) with 280 publications, accounting for 22%. The International Rice Research Institute (IRRI) holds the third position with 208 publications, representing 16% of total. The Bangladesh Agricultural Research Institute (BARI) and the University of Aberdeen jointly holds the 4th position producing 124 publications each, amounting to about 10% contribution individually.

The current review study deals with rice research exclusively in Bangladesh. Obviously, Bangladesh emerged as the foremost contributor, producing 714 research papers. Among those, 436 papers were exclusively produced by Bangladesh itself and the rest were with international collaboration (Fig. 5b). Considering international and inter-institute collaboration, the total count exceeded due to overlap, resulting in a recorded contribution of 56% for Bangladesh. The USA, Australia, United Kingdom and all other countries in the descending order contributed from their part in the publication of the articles. In this list, a notable matter is that the majority of articles were written with international collaboration. The collaboration and research initiatives within Bangladesh and abroad have made a notable impact on the global landscape of sustainable agriculture.

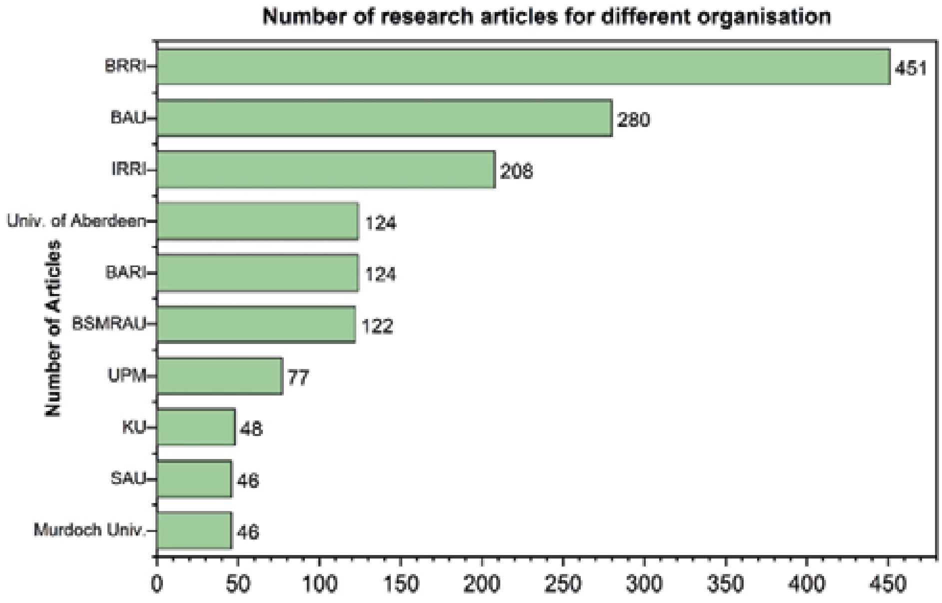

Fig. 5 (a). Ranking of the research entities for the number of publications (top 10).

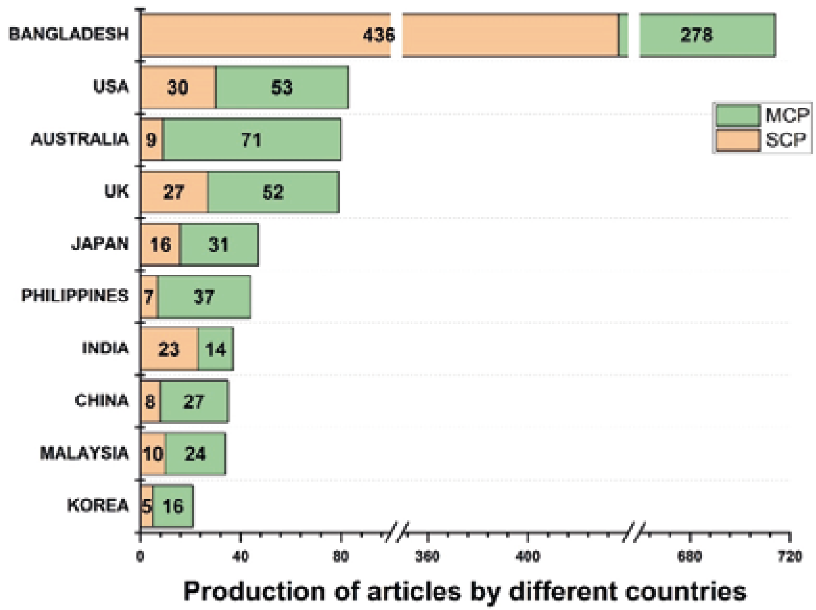

Fig. 5 (b). Ranking of the countries on the basis of number of publications (top 10).
Note: MCP = Multiple country production; SCP = Single country production.

3.3. Most dominant journals

The research articles appeared in 424 journals. Among those sources 15 dominating journals had been found to contain 21% of the publications (Table 1). The highest-ranking Field Crops Research published 41 articles mainly on system research including long-term yield trend of rice (Saleque et al., 2004), rice-wheat system (Adhikari et al., 1999), system of rice intensification (Latif et al., 2005), nitrogen use efficiency and nitrogen budgeting (Hossain et al., 2012; Hossain et al., 2005), tillage system and planting method (Haque et al., 2016; Hossen et al., 2018; Rashid et al., 2018). Environmental Science and Technology produced 29 and Science of the Total Environment published 25 papers covering the area mainly of heavy metal (viz. arsenic, cadmium etc.) contamination in soil and water, uptake and distribution of heavy metals in different parts of rice plants, health risk assessment and its remediation (Abedin et al., 2002; Al Rmalli et al., 2005; Halder et al., 2013; Meharg & Rahman, 2003; Rahman et al., 2006). The fourth top journal, Sustainability (Switzerland) in its 23 papers, had focused the research green-house gas emission, weed regimes and crop diversity (Ahmed et al., 2020; Alam et al., 2021; Haque et al., 2021). Focusing area of the fifth important journal Agroforestry Systems was impact assessment of climate change and various analyses of secondary data source using different simulation models (Matthews et al., 1997; Mottaleb et al., 2015; Sarker et al., 2012). The published papers in Communications in Soil Science and Plant Analysis mainly were on role of macro and micronutrients in paddy soil, nutrient management, farmers' empirical knowledge on nutrient management, organic amendments and soil health (Haque et al., 2019; Haque et al., 2015; Moslehuddin et al., 1999; Paul et al., 2014; Saha et al., 2007; Saleque et al., 1998; Saleque et al., 2004; Saleque et al., 2007). The seventh raking PLOS One produced the documents concentrating on food and nutrition security, demand-supply chain, germplasm analysis (Ara et al., 2019; Islam et al., 2018; Jiang et al., 2021). The next source is Bangladesh Journal of Botany whose publications cover the research area on insect and disease management, soil salinity and heavy metal contamination in soil (Rahman et al., 1970; Shamsi et al., 2003; Ullah et al., 2017). Agricultural Water Management, a journal assigned for specific research area, published 15 articles on assessment of water consumption and irrigation requirements, economic analysis of various irrigation models (Islam et al., 2018; Jensen et al., 1993; Maniruzzaman et al., 2015). The published documents of the journal AMA, Agricultural Mechanization in Asia, Africa and Latin America mainly highlighted the post-harvest technology of rice, also some experiments on field machineries (Basunia & Abe, 2001; Hossen et al., 2013; Islam et al., 2004). There were 14 articles in Plant and Soil where main importance was paid on biofertilizer and toxicity of irrigation water (Abedin et al., 2002; Khan et al., 2009; Mian & Stewart, 1985). Articles of the journal Crop Protection mainly deals with rice nematode diseases, major insect pests and crop loss assessment due to biotic factors (Catling et al., 1987; Datta et al., 2021; Khanam et al., 2016). Agriculture, Ecosystems and Environment published papers in relation to rice-fish, rice-based cropping systems, socio-economic and environmental constraints in rice farming (Hossain et al., 2016; Mustow, 2002; Rahman, 2015). The emphasis of Land Use Policy was on land ownership system, adoption studies on farming enterprises and technologies, analysis of farmers perceptions and risk management of different farming systems (Kabir et al., 2020; Kabir et al., 2017; Rahman & Rahman, 2009). Research on Crops covered several thematic areas viz. planting time, nutrient and weed management, special quality rice (Afrin et al., 2015; Islam et al., 2014; Sarwar et al., 2022).

Table 1
Top journals by number of publications (> 10 publications) on rice research in Bangladesh up to 2022.

Rank	Journal name	Publisher	Number of papers published	Ratio (%)	ACFPY	Area of research
1	*Field Crops Research*	Elsevier B.V.	41	3.19	45.15	System research, soil nitrogen, tillage and planting method
2	*Environmental Science and Technology*	American Chem. Society	29	2.26	171.86	Heavy metal contamination and mitigation
3	*Science of the Total Environment*	Elsevier B.V.	25	1.95	54.12	Heavy metal contamination and health risk assessment
4	*Sustainability (Switzerland)*	MDPI	23	1.79	14.52	Environmental risk, and biotic and abiotic stress
5	*Agricultural Systems*	Elsevier Ltd	19	1.48	42.95	System analysis with statistical models
6	*Communications in Soil Science and Plant Analysis*	Taylor and Francis Inc.	17	1.32	15.06	Fertilizer management in rice based cropping systems
7	*PLOS One*	Public Library of Science	16	1.25	28.31	Germplasm assessment, Food and nutrition security
8	*Bangladesh Journal of Botany*	Bangladesh Bot. Society	16	1.25	3.56	Pest management and disease resistance, and problem soils.
9	*Agricultural Water Management*	Elsevier B.V.	15	1.17	34.13	Water management in rice field
10	*AMA, Agricultural Mechanization in Asia, Africa and Latin America*	Farm Machinery Industrial Research Corp.	15	1.17	4.60	Agricultural Mechanization
11	*Plant and Soil*	Springer Int. Publishing	14	1.09	86.86	Soil microbiology and contaminated water
12	*Crop Protection*	Elsevier Ltd	13	1.01	17.69	Pest management
13	*Agriculture, Ecosystems and Environment*	Elsevier B.V.	11	0.56	35.73	Agro-ecosystem and integrated rice farming
14	*Land Use Policy*	Elsevier Ltd	10	0.78	66.40	Socio-economic studies of farming enterprises
15	*Research on Crops*	Gaurav Publications	10	0.78	0.80	Crop management

Note: ACFPY denotes the average cited frequency per year.

3.4. Most influential documents

Out of 1,284 articles only 19 papers achieved the citation frequency 200 and above (Table 2). Fourteen articles, out 19 most cited articles, reported toxic elements (arsenic and cadmium) in rice. The first and the second most cited articles, which documented the arsenic contamination levels in irrigation water, paddy soil, and rice samples had touched 836 and 628 citations, respectively (Meharg & Rahman, 2003; Meharg et al., 2009). The article reported a wide range of variations over locations, countries and food sources. Discoveries of the analyses encouraged a lot of follower scholars to execute research works to find out the available form of arsenic, its concentration in different water and food sources, its toxicity levels, detrimental effect on health and its mitigation strategies (Polizzotto et al., 2013; Roberts et al., 2010; Zhao et al., 2013). The number three publication is followed by 588 citations. It was a massive laboratory work on molecular genetics of rice germplasm in Bangladesh and other Asian countries (Glaszmann, 1987). Here the germplasms were separated on the basis of genetic makeup into six groups. Genetic variability is a basic pre-requisite for varietal improvement. In fact, this fundamental work is being used as a reference for many investigators (Khan et al., 2017; Parsons et al., 1997; Suh et al., 1997). The 4th, 6th to12th, 14th and 18th highlighted a hotspot research area on arsenic toxicity. In those investigations, the authors surveyed and collected water samples of different sources, samples of rice plants, rice grain, rice husk, rice bran, brown rice, white (polished) rice, parboiled rice, un-parboiled rice, cooked rice and various food items of vegetables and animal sources. After determination of arsenic concentrations, they hypothesized some relationship or linkage among different factors, identified several determinants and proposed various ways to overcome the problems (Abedin et al., 2002; Duxbury et al., 2003; Khan et al., 2017; Meharg et al., 2008; Panaullah et al., 2009; Rahman et al., 2007; Zavala & Duxbury, 2008). The above-mentioned studies received citation in subsequent publications (Fulda et al., 2013; Meharg et al., 2013; Rahman et al., 2014; Zhao et al., 2013). The 5th publication was on the basis of a global survey and laboratory analysis of cadmium concentrations in food samples. From a survey of 12 countries on four continents, Cd levels in rice grain were the highest in Bangladesh and Sri Lanka, with both these countries correspondingly having high per capita rice intakes (Meharg et al., 2013). After arsenic, cadmium also attracted the researchers for burning health hazard issues, and the work was cited 355 times in scientific literature (Shahriar et al., 2022; Shi et al., 2020). The third most cited article (Glaszmann, 1987), which had

588 citations, was on molecular genetics of rice germplasm in Bangladesh and other Asian countries were separated the germplasms on the basis of genetic makeup into six groups. Genetic variability is a basic pre-requisite for varietal improvement. Several investigators (Khan et al., 2017; Parsons et al., 1997; Saleque et al., 2004; Suh et al., 1997) cited fundamental work. The 13th most cited paper, which described the cost analysis and output efficiency of rice farming, obtained 246 citations. Allocative inefficiency was low due to over-use of labour forces, deviated rates of input use and inferior market facility (Coelli et al., 2002). Cost minimization is a crucial issue in successful rice production and food security. This type of research is a continuous thrust, and that is why the successor scholars cited the reference (Ladha et al., 2016; Rahman, 2003, 2009). The 15th ranking cited paper offered attention on a very serious issue of climate change concerning the use of groundwater for rice cultivation in dry season (Shahid, 2011). The groundwater level is depleted in dry season and it is recharged in monsoon in Bangladesh. However, over exploitation of groundwater than its annual recharge is a serious threat for environment, agriculture and future population. Localized monitoring and evaluation of groundwater status should get special priority. This perception encouraged the researchers to continue groundwater research and they followed the above-mentioned reference (Acharjee et al., 2017; Acharjee et al., 2017; Ahmed et al., 2017). Finally, the 19th article has focused a different dimension of research that is invariably important for the nation at a glance. It discussed the negative impact of land fragmentation and current resource ownership system (Rahman & Rahman, 2009). Better policy adoption may overcome the current constraints. Many scientists have executed various socio-economic investigations concerning rice production, technology adoption and farmers perception (Alam et al., 2014; Roy & Chan, 2015; Roy et al., 2013).

Table 2

Top published papers on rice research in Bangladesh ranked by citations (>200 citations) (up to 1st October 2023).

Title of the research article	CF	ACFPY	Key findings	Ref.	Journal
1. Arsenic contamination of Bangladesh paddy field soils: Implications for rice contribution to arsenic consumption	836	39.81	Rice cultivated with arsenic contaminated groundwater had high arsenic concentrations	(Meharg & Rahman, 2003)	EST
2. Geographical variation in total and inorganic arsenic content of polished (white) rice	628	41.87	Total arsenic content of rice varied significantly across different countries	(Meharg *et al.*, 2009)	EST
3. Isozymes and classification of Asian rice varieties	588	15.89	Provide insights into the isozymes and classification of Asian rice varieties	(Glaszmann, 1987)	TAG
4. Arsenic accumulation and metabolism in rice (Oryza sativa L.)	525	25.00	Emphasize the importance of the factors that influence arsenic accumulation and metabolism	(Abedin, Cresser, *et al.*, 2002)	EST
5. Variation in rice cadmium related to human exposure	355	32.27	Rice is a significant source of cadmium in the human diet	(Meharg *et al.*, 2013)	EST
6. Arsenic concentrations in rice, vegetables, and fish in Bangladesh: A preliminary study	350	17.50	Rice plants, especially the roots, had significantly higher levels of arsenic	(Das *et al.*, 2004)	EI
7. Speciation and localization of arsenic in white and brown rice grains	303	18.94	Arsenic was localized at surface in brown rice whereas it was dispersed throughout the kernel in white rice	(Meharg *et al.*, 2008)	EST
8. Arsenic uptake and accumulation in rice (Oryza sativa L.) irrigated with contaminated water	302	13.73	Arsenic concentrations in all plant parts increased with increasing arsenate absorption in irrigation water	(Abedin, Cotter-Howells, & Meharg, 2002)	PS
9. Arsenic in rice: I. Estimating normal levels of total arsenic in rice grain	257	16.06	Arsenic concentrations in rice from the U.S. and Europe were significantly higher than in Asia	(Zavala & Duxbury, 2008)	EST
10. Accumulation of arsenic in tissues of rice plant (Oryza sativa L.) and its distribution in fractions of rice grain	254	14.94	Arsenic content was higher in non-parboiled rice grain than that of parboiled rice	(Rahman *et al.*, 2007)	Chem
11. Groundwater dynamics and arsenic contamination in Bangladesh	250	13.89	Groundwater flow is dynamic, flushing the aquifer from decades to a century	(Harvey *et al.*, 2006)	CG
12. Arsenic toxicity to rice (Oryza sativa L.) in Bangladesh	248	16.53	Arsenic toxicity poses a significant threat to rice cultivation in Bangladesh	(Panaullah *et al.*, 2009)	PS
13. Technical, allocative, cost and scale efficiencies in Bangladesh rice cultivation: A non-parametric approach	246	11.18	Rice farms in Bangladesh have low levels of efficiencies	(Coelli *et al.*, 2002)	JAE
14. Effect of arsenic on photosynthesis, growth and yield of five widely cultivated rice (Oryza sativa L.) varieties in Bangladesh	228	13.41	Increasing soil arsenic concentrations led to a significant decrease in growth and yield of rice	(Azizur Rahman *et al.*, 2007)	Chem
15. Impact of climate change on irrigation water demand of dry season Boro rice in northwest Bangladesh	216	16.62	Increase in daily water use for irrigation, potentially worsening groundwater scarcity	(Shahid, 2011)	CC
16. Redox-controlled changes in cadmium solubility and solid-phase speciation in a paddy soil as affected by reducible sulfate and copper	215	19.55	In multi-metal contaminated paddy soils Cd may remain labile, which enhances the risk for Cd transfer into rice	(Fulda *et al.*, 2013)	EST
17. Simulating the impact of climate change on rice production in Asia and evaluating options for adaptation	212	7.85	Increased CO_2 level was found to increase grain yields	(Matthews *et al.*, 1997)	AS
18. Food chain aspects of arsenic contamination in Bangladesh: Effects on quality and productivity of rice	212	10.10	Rice yields and grain arsenic concentrations were higher in the winter season due to the greater use of groundwater for irrigation	(Duxbury *et al.*, 2003)	JESH
19. Impact of land fragmentation and resource ownership on productivity and efficiency: The case of rice producers in Bangladesh	204	13.60	Land fragmentation reduces rice output while ownership of key resources increases efficiency	(Rahman & Rahman, 2009)	LUP

Note: EST = Environmental Science and Technology; TAG = Theoretical and Applied Genetics; EI = Environment International; PS = Plant and Soil; Chem = Chemosphere; CG = Chemical Geology; JAE = Journal of Agricultural Economics; CC = Climatic Change; AS = Agricultural Systems; JESH = Journal of Environmental Science and Health; LUP = Land Use Policy; CF = Cited frequency, ACFPY = Average cited frequency per year.

3.5. Collaboration among the countries and organizations

Seventy-six countries participated to produce 1284 publications on rice research in Bangladesh, forming a sufficient cross-country co-authorship network. Among those, 38 countries, meeting the thresh-hold level of 5 documents, were used in the visualization of network map shaped by VOSviewer software (Fig. 6a). The countries are found to be stratified in this network map into six separate clusters. Each cluster is represented by a unique colour code. The magnitude of individual sphere within the map resembles the number of research articles belonging to each country, whereas the proximity of nations within clusters indicates the strength of collaboration. Among the clusters, the most dominant one is denoted by blue color, encompassing six countries, including Bangladesh, Australia, South Africa, Switzerland, Belgium and Samoa. The analytical results and the network map visualized the total link strength of individual country. The highest link strength was 56466 for Bangladesh, followed by Australia with 20095, USA with 20048 and UK with 13807. Pattern of cluster formation highlights a synergistic sharing in research interests of countries, exchange of knowledge and global-scale collaboration. As a whole, this collaborative network system might enrich the holistic thoughts of sustainable development in agriculture. The cooperative spirit would be effective to address the challenges in world food security.

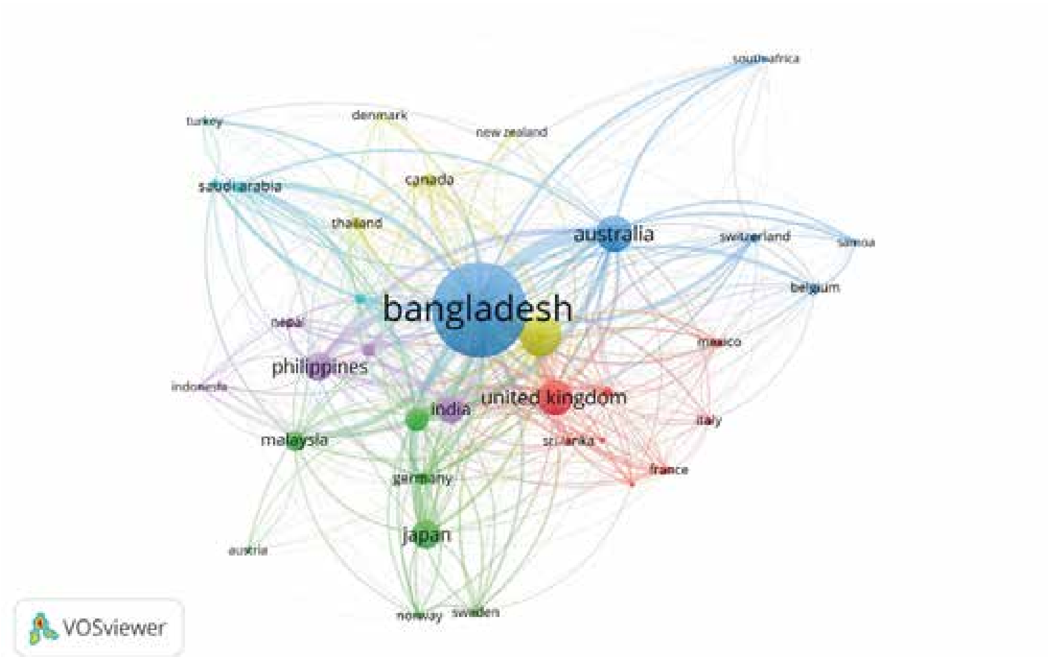

Fig. 6 (a). Collaboration network among the countries for the rice research in Bangladesh.

One hundred and ninety-three institutions contributed to produce 1284 research articles in the rice research of Bangladesh. A VOSviewer generated network map classified these organizations into seven discrete clusters. Each of the cluster is represented by a unique colour, reflecting their collaborative associations (Fig. 6b). Connections between the organizations are denoted by lines. Thickness of the lines indicated the strength of cooperation. Remarkably, the largest number of research institutions are predominantly situated in Bangladesh. In a sum, 43 in-country research entities are involved in its national rice research stream. Extensive collaboration among research establishments suggests the global commitment to advance knowledge sharing in this field. Clustering pattern and interconnectivity of institutions underscore the multidimensional as well as cooperative nature of research in this ground. Such collaborative approaches might enrich agricultural sciences and be helpful for the promotion of effective practices, ultimately supporting global food security cum overall agriculture.

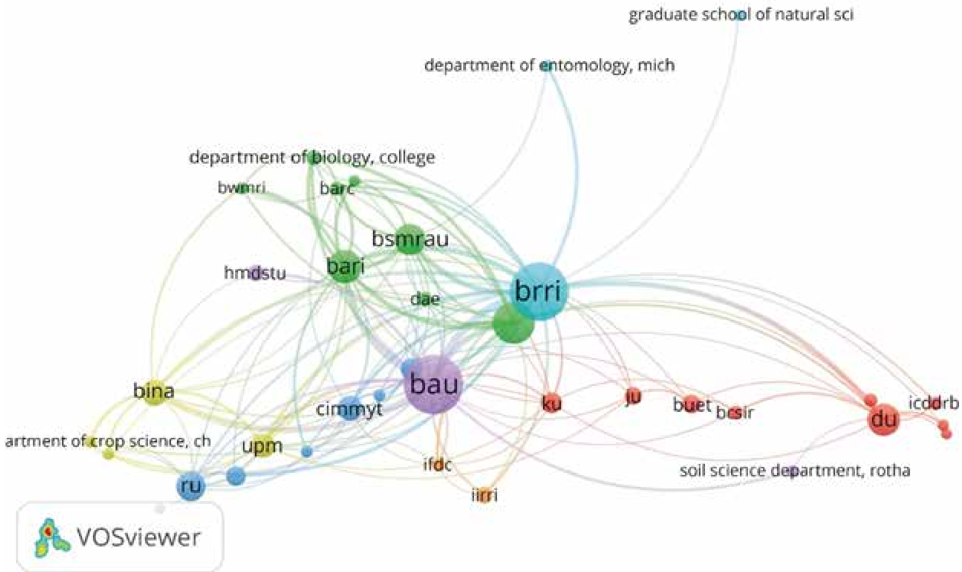

Fig. 6 (b). Collaboration network among the institutes for the rice research in Bangladesh.
BRRI = Bangladesh Rice Res. Inst.; BARI = Bangladesh Agric. Res. Inst.; BAU = Bangladesh Agric. Univ.; BSMRAU = Bangabandhu...Agric. Univ.; BINA = Bangladesh Inst. Nuclear Agric.; BARC = Bangladesh Agric. Res. Council; BWMRI = Bangladesh Wheat and Maize Res. Inst.; CIMMYT = Int. Centre for Maize and Wheat Improvement; DU = Dhaka University; ICDDRB = Int. Centre for Diarrheal Disease Res., Bangladesh; UPM = Universiti Putra Malaysia.

3.6. Collaboration among the countries and organizations

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Table 3
Main keywords used in rice research of Bangladesh in different periods.

Period	Main keywords (frequency)
1974 – 1983	Bangladesh (2), rice (2)
1984 – 1993	Bangladesh (28), developing country (10), rice production (9), rice (7), agricultural practice (4), grain (3), water management (3), high yielding variety (2), credit (2), irrigation (2), price stabilization (2), food production (2), higher plant (2), employment (2), technology adoption (2)
1994 – 2003	Bangladesh (65), rice (39), *Oryza sativa* (32), article (16), developing country (12), nonhuman (12), agriculture (9), *Triticum aestivum* (9); rice production (7), crop production (7), arsenic (7), crop yield (6), yield (6), productivity (6), irrigation (6), modelling approach (5), rice cropping (5), Asia (5), crops (5), environmental monitoring (5), plant growth (5), animalia (5)
2004 – 2013	Bangladesh (190), rice (155), *Oryza sativa* (89), article (79), Asia (78), South Asia (77), Eurasia (77), arsenic (67), soil (59), paddy field (45), groundwater (43), irrigation (39), soil pollution (35), crop yield (33), nonhuman (30), crop production (29), *Triticum aestivum* (26), food contamination (26), controlled study (26), water supply (25), water pollutants (24), crops (23), soil pollutants (23), cultivation (22), agriculture (22), groundwater pollution (21), bioaccumulation (21), concentration (35), grain (19), irrigation system (19), food security (18), cultivar (18), environmental monitoring (18), soil analysis (18), animalia (16), priority journal (15)
2014 – 2022	Bangladesh (348), rice (245), human (105), article (96), crop production (84), *Oryza* (76), crop yield (70), climate change (65), soil (56), agriculture (55), nonhuman (51), irrigation (48), fertilizer (48), food security (45), arsenic (45), controlled study (42), risk assessment (41), crops (39), paddy field (37), cultivation (37), *Oryza sativa* (34), food supply (34), cropping practice (33), chemistry (33), groundwater (29), water management (29), concentration (29), irrigation system (28), genetics (27), *Triticum aestivum* (27), wheat (27), fertilizer (48), coastal zone (25), sustainability (25), metabolism (24), salinity (24), farming system (24), health risk (23), food contamination (22), environmental monitoring (22), agricultural land (21), grain (21), procedures (21), profitability (21), agricultural management (21), female (21), drought (20), adaptive management (20), soil pollution (20), soil pollutants (20)

3.7. Keywords co-occurrence and cluster analysis

From a robust series of keyword, only 85 met the thresh-hold level of frequency 6. An inclusive analysis of these keywords in the field of rice research in Bangladesh revealed their categories into 10 discrete clusters summarized in Table 4. The 1st cluster mainly included the analysis of rice germplasms, grain yield of special quality rice, weed management, molecular genetics, and encompassed a total of 14 keywords. Within this cluster, 'rice' emerged as the most frequently occurring keyword, with a notable frequency of 196 and an average citation score of 37.06. It was followed by '*Oryza sativa*,' which exhibited a frequency of 30 and an average citation score of 30.32. The 2nd cluster placed a dense emphasis on salt tolerant rice, adoption and profitability of hybrid rice, global warming and irrigation method, incorporating 11 keywords. Notably, 'agriculture' took the lead in this cluster, boasting an average citation score of 36.76, while 'salinity' garnered a substantial average citation score of 17.79. In the 3rd cluster, the focus shifted towards rice-based integrated farming systems, soil fertility, and yield gap, encompassing 11 keywords. 'Wheat' emerged as the most prominent keyword in this research category, having an average citation score of 32.19, followed by 'productivity' with that score of 31.20. The 4th cluster was dedicated to the evaluation of water source and irrigation management in Boro rice, ecofriendly conservation agriculture and profitable cropping systems, comprising 11 keywords. Within this cluster, 'groundwater' secured the top position with a citation score of 62.26, closely trailed by 'irrigation' with a significant citation score of 36.47. The 5th cluster revolved around integrated rice-fish farming and socio-economic analysis of different technologies. This cluster comprised nine keywords, with 'Bangladesh' and 'technical efficiency' leading the way, boasting average citation scores of 29.70 and 15.64, respectively. The 6th cluster spotlighted research activities related to investigation of heavy metal contamination in rice plants and food chain, incorporating eight keywords. Within this cluster, 'arsenic' and 'soil' held dominance, with citation scores of 84.83 and 55.53, respectively. In the 7th cluster, the keywords were dominated by ‘climate change’ and Sustainability with citation scores of 28.66 and 20.41, respectively. In this domain main thrust was on the suitability assessment of farming system technologies in environmental stresses. The 8th cluster possessed seven keywords led by ‘deepwater rice’ with 11.15 citation scores and ‘water management’ with 20.31. It mainly discussed on physiology and ecosystem of deepwater rice, and mineral nutrition of rice plants. The 9th cluster had had four keywords and addressed the health risk of heavy metals in food stuffs. Finally, the 10th and last cluster, consisting of only two keywords, underscored the significance the issue of food security and poverty.

Table 4
Top journals by number of publications (> 10 publications) on rice research in Bangladesh up to 2022.

Cluster	No. of keywords	Terms (frequency and average citation score)
1#	14	Rice (196, 37.06); *Oryza sativa* L. (30, 30.32); Genetic diversity (13; 13.54); Grain yield (11, 6.73); Paddy soil (11, 33.73); Aromatic rice (7, 7.86); Aus (7, 21.00); Weed management (7, 14.71); Allelopathy (6, 8.67); Germination (6, 36.67); Landraces (6, 16.33); Resistance (6, 8.50); Screening (6, 12.83); SSR markers (6, 3.83)
2#	11	Agriculture (29, 36.76); Salinity (19, 17.79); South Asia (14, 59.43); Hybrid rice (10, 16.50); Profitability (9, 17.22); Alternate wetting and drying (7, 41.57); India (7, 23.86); Adoption (6, 13.33); Greenhouse gas emissions (6, 43.00); Methane (6, 24.33); Seasonality (6, 24.17)
3#	11	Wheat (16, 32.19); Productivity (15, 31.20); Rice yield (15, 25.80); Maize (9, 28.89); Panel data (8, 19.75) Rice straw (8, 14.38); Soil fertility (8, 19.88); Yield gap (8, 40.38); Cropping pattern (7, 6.86); Mungbean (6, 7.00); T. Aman rice (6, 13.17)
4#	11	Irrigation (36, 36.47); Boro rice (29, 11.17); Groundwater (19, 62.26); Water productivity (12, 21.50); Remote sensing (11, 32.64); Conservation agriculture (8, 33.88); Nitrogen use efficiency (8, 23.38); Temperature (8, 7.50); Carbon sequestration (7, 12.57); Cropping systems (7, 4.86); Economics (6, 15.17)
5#	9	Bangladesh (277, 29.70); Technical efficiency (14, 15.64); Rice production (11, 29.73); Efficiency (10, 7.30); Farmer (7, 20.29); Data envelopment analysis (6, 14.17); Fish (6, 37.00); Rice farmers (6, 15.83); Stochastic production frontier (6, 51.67)
6#	8	Arsenic (68, 55.53); Yield (33, 22.70); Soil (12, 84.83); Cadmium (9, 41.11); Water (9, 28.56); Food (7, 127.43); Diet (6, 48.50); Growth (6, 61.67)
7#	7	Climate change (61, 28.66); Sustainability (22, 20.41); Adaptation (20, 39.25) Drought (13, 31.69); Rice farming (11, 26.18); Cropping system (8, 16.88); Coastal zone (6, 29.33)
8#	7	Deepwater rice (13, 11.15); Water management (13, 20.31); Zinc (10, 13.50); Phosphorus (8, 37.88) Nitrogen (7, 25.14); *Oryza sativa* L. (6, 24.33); Regeneration (6, 8.33)
9#	4	Health risk (9, 36.78); Heavy metals (8, 64.38); Cereals (7, 30.71); Dietary intake (6, 38.50)
10#	2	Food security (44, 32.64); Poverty (6, 9.33)

Note: Only the words with frequency > 6 were considered in the cluster analysis.

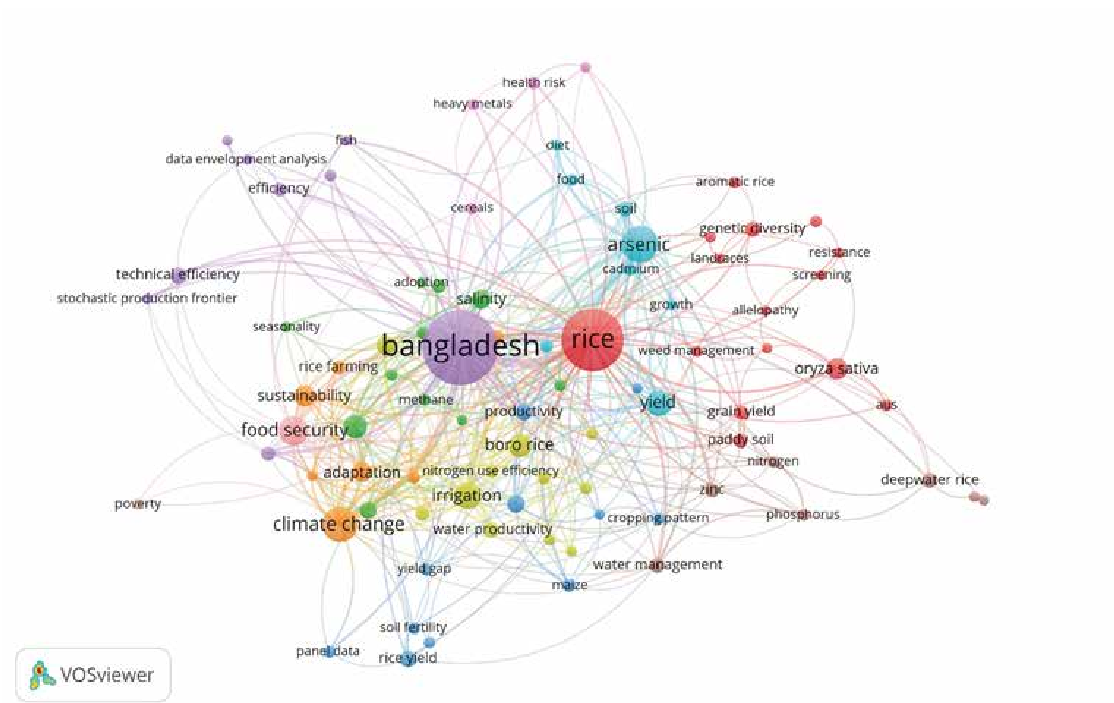

Fig. 7. Co-occurrence network of keywords in rice research of Bangladesh. Each node represents a keyword, with node size indicating frequency. Links between nodes signify co-occurrence, with thicker lines denoting more frequent associations.

3.8. Impact of rice research on socio-economics in Bangladesh

In the current investigation, a series of significant impact of rice research in Bangladesh had been perceived. At a glance, it is clear that, technological progress has helped the country to achieve self-sufficiency in rice production in 2001 from import-dependence, despite doubling of population since its independence in 1971 (Hossain et al., 2006). However, this success story is an accumulation of very specific numerous research fields. Some instances are cited here. A vast area of Bangladesh is vulnerable to flash flood. Submergence tolerant gene has been introgressed in a mega variety BR11. This new genotype offered a yield advantage of 1 to 3 t/ha, depending upon the duration of submergence. Due to their excellent performance in farmers' fields, it is opined that it has the potential to usher a second green revolution in the flood-prone rainfed rice areas (Singh et al., 2013). Short duration, early maturing transplanted Aman varieties efficiently mitigated acute food shortage in northern part of Bangladesh. In addition, it facilitated the timely establishment of the succeeding winter crop which is crucially related to rural employment (Rahman et al., 2018). Research on mechanization in rice cultivation also has significant contribution. Mechanical transplanting along with urea fertilizer deep placement in wet land rice establishment proved 30% urea saving and higher benefit-cost ratio (Hossen et al., 2019). Obviously, urea saving technology is not only an economic issue, but also it is helpful for the reduction of greenhouse gas emission. Boro rice cultivation in Bangladesh is exclusively dependent on groundwater. This valuable resource is declining in an alarming rate. So, the rice scientists developed alternate wetting and drying (AWD) technology that can save up to 40% of irrigation water (Uddin & Dhar, 2020). To meet up the demand of animal protein the scholars have offered integrated rice-fish production technology (Frei et al., 2007; Haroon & Pittman, 1997; Mustow, 2002). Sufficient level of different micronutrients viz. zinc, iron, beta carotene is a pre-requisite for balanced diet. For the alleviation of nutrition deficiency, several rice varieties and technologies are developed (Ara et al., 2019; Biswas et al., 2021; Mayer et al., 2007; Promthai et al., 2009; Swamy et al., 2019).

4. Discussion

Rice, with its extraordinary ecological adaptability (Datta & Surajit, 1981; Moomaw & Vergara, 1964; Nasim et al., 2018), dominates Bangladesh not only as the staple food (Brolley, 2015; Shahidullah et al., 2008) but also as a pillar of social stability, culture, and politics (Ahmed & Zeitlin, 1994; Nath, 2015). Beyond food security, the expanding industrial uses of rice husk, powder, and bran (Abedin & Das, 2014; Ahiduzzaman & Islam, 2016; Haque & Chowdhury, 1994; Islam et al., 1994; Reza et al., 2015; Sumy et al., 2012) highlight untapped opportunities for value addition that remain weakly connected to research and policy. Bangladesh's shift from a "Bottomless Basket" to a food-surplus nation (LaFranchi, 2015; Rahman et al., 2023) illustrates the transformative power of rice science. Yet the slow start of research output- initially focused on post-harvest loss in the 1970s (Shahjahan, 1974), the publication number has amplified and still now it is increasing. These findings showed that rice research in the country had received increasing attention from scholars due to national and global level food security challenges. Increasing food demand for the rising population in developing countries might push scholars for rice research to advance science (Nath, 2015).

Regarding individual country contributions, Bangladesh understandably holds the leading position in rice research. While early initiatives date back to 1910, the modern trajectory of rice research and development truly gained momentum with the institutional foundation set during the 1960s and 1970s (BRRI, 2014; Rahman et al., 2023). Establishment of key institutions such as Bangladesh Agricultural University and Bangladesh Rice Research Institute marked turning points, not merely as academic hubs but as catalysts for capacity building and innovation in the field. The expansion of research across additional universities with agricultural programs reflects a gradual diversification, yet the progress has remained uneven across institutions. Government support for academic career advancement and improved research environments has been decisive; however, this reliance on state-driven initiatives also underscores the vulnerability of research growth to shifting policy priorities. Investments in engineering and mechanization (Hossen et al., 2018), and later in genetic research (Khan et al., 2017), have enabled technological breakthroughs, though the sustainability of such advancements often hinges on continued funding and institutional commitment. Notably, external projects such as the Agricultural Research Management Project, PETRRA, and those supported by the Bill and Melinda Gates Foundation have played pivotal roles in strengthening laboratory infrastructure, scientist training, and field experimentation. While these contributions accelerated progress, they also highlight a dependence on project-based funding, raising concerns about long-term autonomy and consistency in research agendas.

Effective collaboration and communication among institutions stand as crucial pillars for improving research quality and developing skilled manpower (Edmondson & Harvey, 2018; Hsiao et al., 2012; Kezar, 2006). Authorship and institutional analyses reveal a few prolific scholars and institutions such as BRRI and BAU dominate output from the collaboration largely within national boundaries. Limited cross-country connectivity indicates that much more expansive and inclusive collaboration is both possible and necessary. The analysis further reveals an imbalance between domestic and international partnerships, where certain institutions, such as the Bangladesh Council for Scientific and Industrial Research (BCSIR), display notable weaknesses in both local and global linkages. Addressing these shortcomings may require policy-level incentives that encourage wider participation and joint initiatives. Moreover, geographical proximity continues to exert significant influence on communication and knowledge-sharing programs (Yuan & Sun, 2020), suggesting that regional collaborations could be strengthened through structured platforms. Beyond institutional networks, fostering balanced development across disciplines is equally important. Our multidisciplinary research analysis underscores notable variations in output levels across different fields call for greater emphasis on underrepresented domains such as ecology, engineering, and chemistry, where harnessing interdisciplinary strengths could substantially enrich the overall research landscape.

The keyword trend and cluster analysis reveal that rice research in Bangladesh has evolved in response to immediate pressures rather than long-term strategy. Early work on deepwater environments and pest management shifted toward high-yielding varieties, irrigation, and market issues, and later expanded to food safety and heavy metal contamination (Catling et al., 1983; Catling et al., 1980; Mujeri, 1991; Parikh, 1988; Ravallion, 1985; Saleh et al., 1989). While these areas gained global visibility, critical domains such as mechanization, sustainable land use, and post-harvest innovations remained comparatively neglected, suggesting an imbalance in research priorities.

Recent emphasis on climate adaptation, ecofriendly production systems, and molecular genetics (Aggarwal et al., 2004; Iftekharuddaula et al., 2015; Lisa et al., 2011; Rahman et al., 2016) demonstrates progress, yet attention to social and farming-system dimensions-such as gender, integration, and nutrient management (Ara et al., 2019; Hossen et al., 2019; Nabi, 2008; Neumann et al., 2011)-has been marginal. Persistent gaps are evident: despite advances in land preparation through mechanical approach, transplanting and harvesting remain largely traditional. Furthermore, the country holds 0.4 million hectares of deepwater rice area (Nasim et al., 2018), still lacks a modern variety. Similarly, promising technologies like wet-seeding remain constrained by the absence of anaerobic genotypes. C4 rice may be a research hotspot for breaking the yield ceiling of available rice cultivars. In the global rice trade, Bangladesh has a very limited access because of non-attainment of international standard of grain parameters. Sufficient importance should be paid to address this issue. Bangladesh has been importing hybrid rice seed in spite having potential hybrid varieties. Research could be strengthened for the development of field-level hybrid rice production technology and well-organized distribution channel. Demand of ready-made and fast-food items is increasing. This industrial side is fully dependent on imported wheat grain. Remarkably, gluten-sensitivity of wheat-based food is now a concern. This entails the quest for development of rice-based fast-food and bakery items, offering a compelling direction for forthcoming research efforts.

The evolving research focus on rice research aligns with several Sustainable Development Goals (SDGs). For instance, the increasing emphasis on environmental issues, soil health, and disease management (Ali et al., 2014; Khanam et al., 2016; Paul et al., 2014) corresponds to SDG 15 (Life on Land), which seeks to protect, restore, and promote sustainable use of terrestrial ecosystems. Additionally, the exploration of eco-friendly innovations like allelopathy, biofertilizer, biopesticide, vermicompost and use of pheromone trap for insect control (Cork et al., 2005; Hoque et al., 2022; Salam & Kato-Noguchi, 2009; Singh & Singh, 1987a) resonates with SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), contributing to efforts to combat climate change and promote sustainable energy solutions. Finally, the development of nutrition-enriched rice genotypes and the hybrid rice cultivars (Ibrahim et al., 2013; Swamy et al., 2019) are in line with SDG 2 (Zero Hunger), targeting to achieve food security and promote sustainability in agricultural development. These research directions hold promise for addressing critical global challenges while advancing progress towards these SDG targets.

5. Conclusion

Our study provides valuable understandings into the emerging landscape of rice research in Bangladesh. The annual progress of scientific documentation on rice research is substantial, with a consistent increase in publications over the years. It is increasingly evident that both national and international scientific communities are recognizing the vital role of Bangladesh rice in addressing global challenges. In particular, its significance is growing in the context of climate change adaptation and ensuring global food security. The leading contributors include reputed journals such as Field Crops Research, Environmental Science and Technology, Science of the Total Environment and Sustainability, along with active institutions like BRRI, BAU, BARI and several international centers as well as universities (e.g., IRRI, University of Aberdeen) that have provided major contributions to the scientific documentation. Our analysis encompassed a diverse range of crop ecosystems, comprising upland, lowland, irrigated and deepwater environments, which underscores the comprehensive nature of research in this domain. Highly cited articles on toxic elements (arsenic and cadmium) contamination and toxicity, rice-farming efficiency, climate-resilient rice, molecular breeding, and socio-economic investigation have made substantial influence on shaping the field of rice research in Bangladesh. Researchers from various disciplines, including Agriculture and Biology; Environmental Sciences; Social Sciences; Biotechnology, Genetic Engineering and Molecular Biology; multidisciplinary subject, Ecology and Engineering, have contributed to this multi-layered exploration. Keyword analysis revealed that 'Bangladesh and rice' emerged as the focal point of scientific investigation, reflecting its supremacy within this research domain. In addition, clustering of keywords into 10 distinguished research topics emphasized the multilateral nature of the research, encompassing yield performance, plant nutrition, pest management, environmental issues, economic analyses, integrated farming systems, soil fertility enhancement, sustainable resource management and food and nutrition security.

The study also highlights a fair level of cooperation among national institutions and between Bangladesh and international partners, particularly IRRI and other CGIAR centers, where such collaborations are strengthening the research landscape and facilitating technological innovations. As a look to the future, several landscapes of immediate investigations become apparent. The incorporation of mechanization into rice cultivation practices holds promise for optimizing resource utilization and enhancing overall efficiency. Exploring modern varieties for deepwater rice and anaerobic rice would satisfy the concerned dimensions. C4 rice may also be a research hotspot for breaking the yield ceiling of available rice cultivars. In the global rice trade, Bangladesh has a very limited access because of non-attainment of international standard of grain parameters, which also deserves a special attention. The current study provides an inclusive overview of the on-going research landscape, aiding the prioritization of research projects to address food security challenges judiciously. Emerging research issues include stress-tolerant rice varieties, carbon-smart farming, and grain quality improvement, with trends pointing towards climate adaptation, sustainability, and global competitiveness.

While this study offers an inclusive investigation of Bangladesh rice research, it is not without limitation. This analysis depends on data available up to a cutoff date. Therefore, the most recent developments might not be fully reflected. Moreover, the study mainly focuses on quantitative analysis and qualitative features of research. In-depth scientific inquiry and real applications of research findings are not critically addressed. The study is based on existing publications; and potential ongoing or unpublished research may not be accounted for in the analysis. The study solely considered SCOPUS database, which, while reputable, may not cover all relevant documents in the field. Forthcoming investigations could improve the research findings by adding more databases like WOSCC.

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