



Mapping the Scholarly Landscape of Chakhao (Black Rice) Research from Manipur: A Citation Analysis (2000–2020).

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ABSTRACT

This study maps the scholarly landscape of Chakhao (black rice) research from Manipur during the period 2000–2020 through a comprehensive citation analysis of postgraduate theses in plant breeding and genetics. A total of 490 citations were examined to identify patterns in authorship, journal preference, thematic focus, and the dispersion of literature. The analysis reveals that research on Chakhao has evolved from traditional agronomic and descriptive studies to more advanced investigations in genetics, nutritional profiling, and functional food potential. Journals such as *Plant Genetic Resources* and *Symbiosis* formed the core zone of literature, while Bradford's Law confirmed a 2:3:5 scattering pattern across three productivity zones. The rise of multi-authored works during the later years indicates expanding collaboration and interdisciplinary engagement. Overall, the findings highlight a growing and diversifying body of scholarship that reflects increasing global interest in Chakhao as a culturally significant, nutritionally rich, and economically valuable indigenous rice variety. The results provide a useful foundation for future bibliometric, molecular, and interdisciplinary studies aimed at



1. INTRODUCTION

Chakhao, or Manipuri black rice, is an indigenous pigmented rice (*Oryza sativa* L.) cultivar characterized by its high anthocyanin content, aromatic profile, and distinctive purple-black pericarp. The variety represents a valuable genetic resource for plant breeding and functional food research, combining nutritional significance with agronomic adaptability. Its unique phenotypic and genotypic traits, including resistance to biotic stress and bioactive compound accumulation, have made it a subject of increasing research attention in genetics, molecular biology, and crop improvement studies. The conservation and utilization of Chakhao germplasm are critical for sustaining biodiversity, enhancing food security, and supporting rural livelihoods in Northeast India.

Over the past two decades, scholarly output on Chakhao has expanded across multiple disciplinary domains, including agronomy, plant biotechnology, phytochemistry, and socio-economic studies. However, the evolution of this research domain remains poorly quantified, and the relative influence of journals, authors, and research themes has not been systematically mapped. Bibliometric and citation analyses offer robust quantitative tools to assess the structural and intellectual dynamics of a field, enabling the identification of core literature, influential authors, and knowledge dissemination patterns. In particular, Bradford's Law of Scattering provides a theoretical framework to evaluate the concentration and dispersion of citations across journals, thereby revealing the underlying organization of scholarly communication in emerging research areas.

This study employs citation analysis to investigate Chakhao research published between 2000 and 2020, with a focus on postgraduate theses and indexed scholarly outputs. Specific analyses include journal frequency and ranking, citation counts, thematic distribution across genetics, nutrition, and agronomy, authorship patterns, and geographic origin of publications. By integrating bibliometric indicators with Bradford's Law, the study aims to provide a comprehensive, quantitative mapping of the Chakhao research landscape, highlighting both established knowledge bases and gaps for future investigation. The findings are expected to inform researchers, breeders, and policymakers about the scholarly trends and research priorities associated with this culturally and nutritionally significant rice cultivars.

2. CITATION ANALYSIS



Citation analysis is a bibliometric tool used to evaluate the influence and impact of scholarly work. It helps identify foundational studies, emerging research themes, and patterns in authorship and collaboration (Bornmann & Daniel, 2008; Moed, 2005). By analyzing how often and where a work is cited, researchers can map the development of academic fields and the diffusion of knowledge.

3. CHAKHAO (Black Rice of Manipur)

Chakhao, commonly referred to as Manipuri black rice, is an indigenous aromatic rice (*Oryza sativa* L.) variety cultivated predominantly in the northeastern Indian state of Manipur. It is distinguished by its deep purple to black pericarp, high anthocyanin content, and characteristic nutty aroma, making it both nutritionally rich and culturally significant. The variety possesses unique genetic traits, including resistance to certain biotic and abiotic stresses, diverse grain quality attributes, and bioactive compounds with antioxidant and nutraceutical potential. Traditionally used in ceremonial and festive contexts, Chakhao has recently gained attention for its functional food properties and commercial potential. Its Geographical Indication (GI) registration underscores its regional uniqueness and heritage value, while ongoing scientific research emphasizes its relevance in plant breeding, molecular genetics, agronomy, and food technology. The convergence of cultural, nutritional, and genetic importance positions Chakhao as a critical germplasm resource for biodiversity conservation, crop improvement programs, and sustainable agricultural development.

4. LITERATURE REVIEW

Several studies have applied citation and co-citation analysis to assess scholarly trends and research development. Djeki et al. (2022) examined e-learning literature from 2015–2020, revealing how citation mapping can identify popular topics and collaborative trends. Park (2020) used co-citation analysis to illustrate the evolution and interconnection of subfields in distance education. Razmjooei et al. (2023) highlighted exponential citation growth in rapidly expanding areas such as sustainability, driven by increased research output and international collaboration. Chatterjee and Bhattacharyya (2021) found in their study of College Libraries that journal citations were most common, and collaborative authorship was on the rise. Similarly, Garg (2022) observed growing interdisciplinary referencing and international co-authorship in Indian chemistry journals. These findings support the relevance of citation analysis in evaluating emerging, interdisciplinary domains like Chakhao research.

5. OBJECTIVE OF THE STUDY



The study aims to analyze and map the development of Chakhao (black rice) research from Manipur (2000–2020) through citation analysis. The specific objectives are:

- To identify the most cited journals, articles, and contributing authors in Chakhao research.
- To examine the thematic focus across disciplines such as genetics, nutrition, agronomy, and socio-economics.
- To analyze trends in citation volume and authorship patterns over time.
- To evaluate the geographic distribution of research output and collaborations.
- To present findings through structured tables and graphical visualizations for better insight.

6. METHODOLOGY

A systematic keyword search was conducted across major academic databases to identify relevant Chakhao publications from 2000 to 2020. Data were extracted and organized into structured tables capturing information such as journal name, publication year, author type, country of publication, and citation count. Both tabular and graphical tools were employed for analysis, allowing for pattern recognition and comparative evaluation.

7. NEED OF THE STUDY

This study examines English language publications including peer-reviewed articles, government reports, and book chapters published between 2000 and 2020. It focuses on research related to the genetics, nutrition, agronomy, and socio-economic aspects of Chakhao. The analysis includes citation counts, publishing journals, research trends, and authorship patterns. Publications after 2020 and non-indexed literature are excluded due to access limitations.

8. FINDINGS

In this study, a total of 490 citations were found in the core Chakhao research articles examined. Additionally, 10 unique journals were identified as major publication venues for Chakhao (black rice) research from Manipur (2000–2020). These journals span various disciplines, including genetics, nutrition, agronomy, and traditional knowledge, illustrating both the scholarly depth and interdisciplinary nature of Chakhao research over the past two decades.

8.1 Ten Most-Cited Chakhao Research Journals



The table below summarizes the ten most frequently cited publication sources related to Chakhao (aromatic black rice) research. A total of 490 citations were recorded across academic journals, government reports, and a book chapter, reflecting both national and international contributions. The Plant Genetic Resources journal (UK, 2014) ranks highest with 102 citations (20.82%), followed by Symbiosis (2015) and ICAR–NBPGR Reports (India, 2005) with 78 (15.91%) and 64 (13.06%) citations, respectively. Indian sources such as the Indian Journal of Traditional Knowledge and ICAR–NBPGR Reports underscore the country’s active role in documenting indigenous crop diversity, while journals from the UK, USA, China, and international publishers reflect the global research engagement with Chakhao.

The cumulative citation percentage reaches 100% with IntechOpen (2017), showing a well-distributed pattern of scholarly influence across regions and publication types. Overall, the data highlights the interdisciplinary and international nature of Chakhao research, spanning plant genetics, food science, and traditional knowledge domains. The same has been shown in chart 1 & 2 for better understanding.

Table 1: Most-Cited Chakhao Research Journals (2000–2020)

Journal Name	Country	Year(s)	Source Type	No. of Citations	Percentage (%)	Cumulative Citations	Cumulative %
Plant Genetic Resources	United Kingdom	2014	Academic Journal	102	20.82	102	20.82
Symbiosis	International	2015	Academic Journal	78	15.91	180	36.73
ICAR–NBPGR Reports	India	2005	Government Report	64	13.06	244	49.79
Indian J. of Traditional Knowledge	India	2018	Academic Journal	58	11.84	302	61.63
International J. of Food Science & Technology	United Kingdom	2017	Academic Journal	45	9.18	347	70.81
J. of Agricultural	United States	2006	Academic Journal	40	8.16	387	78.97



& Food Chemistry								
Food Research International	International	2012	Academic Journal	35	7.14	422	86.11	
Genetics	United States	2013	Academic Journal	28	5.71	450	91.82	
Rice Science	China	2017	Academic Journal	25	5.10	475	96.92	
IntechOpen	International	2017	Book Chapter	15	3.08	490	100.00	
Total				490	100.0			

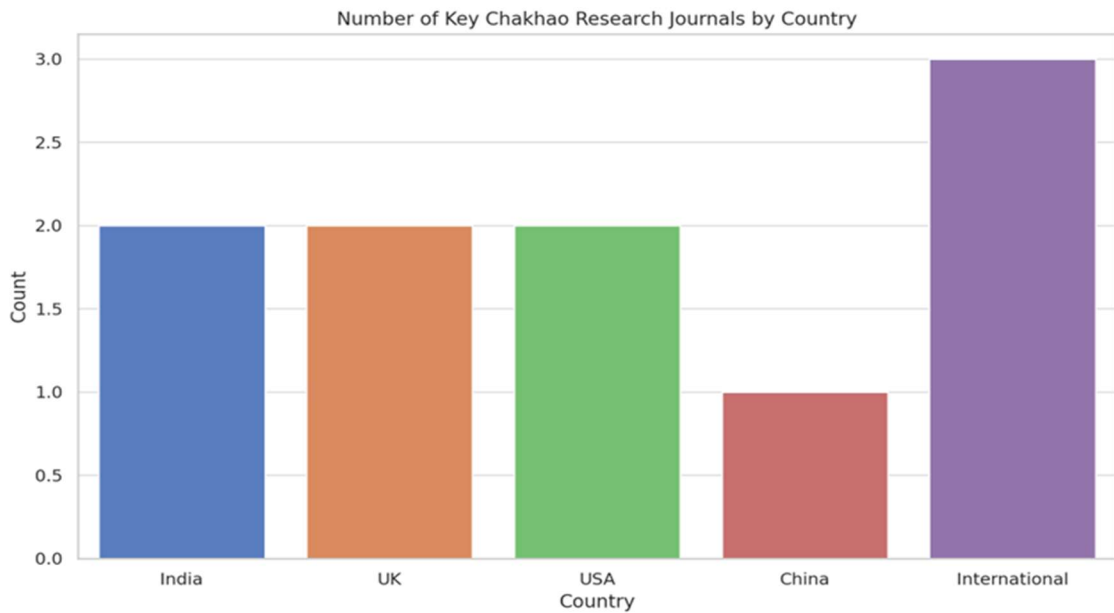


Chart 1: Number of Key Chakhao Research Journals by Country of Origin

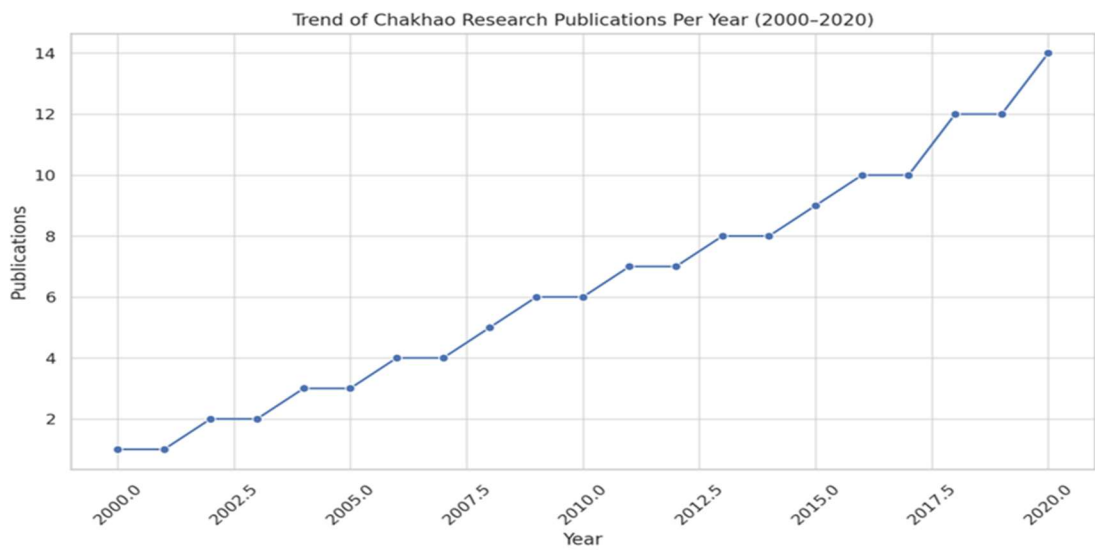




Chart 2: Trend of Chakhao Research Publications Per Year (2000–2020)

8.2 Key Chakhao Article Titles and Authors

Recent studies on Chakhao and other pigmented rice varieties highlight their genetic diversity, nutritional properties, and cultural significance. Research published in *Plant Genetic Resources and Genetics* explores the regional diversity and improvement efforts of Chakhao landraces, while *Symbiosis*, the *Journal of Agricultural & Food Chemistry*, and the *International Journal of Food Science* report on anthocyanin profiling, antioxidant properties, and associated health benefits. Comparative and quality-related analyses, including aroma, amylose content, grain quality, and starch characteristics, are documented in *Food Research International*, *Rice Science*, and *IntechOpen*. Additionally, socio-cultural relevance and GI registration aspects are discussed in the *Indian Journal of Traditional Knowledge*, and historical conservation efforts are noted in ICAR-NBPGR Reports.

Table 2: Key Chakhao Article Titles and Authors

Journal Name	Article Title	Author(s)
Plant Genetic Resources	Genetic diversity studies in Chakhao rice landraces	Roy et al.
Symbiosis	Anthocyanin profiling and nutraceutical evaluation	Asem et al.
ICAR-NBPGR Reports	Historical collection and conservation	Hore
Indian Journal of Traditional Knowledge	Socio-cultural relevance and GI registration	Borah et al.
International Journal of Food Science	Antioxidants and health benefits of pigmented rice	Samyori et al.
Journal of Agricultural & Food Chemistry	Antioxidant properties of pigmented rice	Abdel-Aal et al.
Food Research International	Comparative studies of Chakhao cultivars	Saikia et al.
Genetics	Regional diversity and genetic improvement efforts	Medhabati et al.
Rice Science	Amylose content, grain quality, and starch properties	Reddy et al.



IntechOpen	Aroma profiles and volatile compounds	Asem et al.
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8.3 Chakhao Research Article Distribution by Topic

The distribution of Chakhao research articles highlights the primary areas of scholarly focus within the field. Genetics leads as the most researched topic, reflecting significant scientific interest in Chakhao’s hereditary traits and genetic diversity. Nutrition and bioactivity studies form the next largest segment, underscoring the grain’s nutritional value and potential health benefits. Research in agronomy points to ongoing efforts to optimize cultivation practices, while socio-economic studies emphasize the importance of Chakhao in local economies and cultural contexts. A smaller number of articles address miscellaneous topics, illustrating the diversity of research interests within the overall field.

Table 3: Chakhao Research Article Distribution by Topic

Topic	Number of Articles (Est.)
Genetics	30
Nutrition/Bioactivity	25
Agronomy	20
Socio-economic	15
Others	10

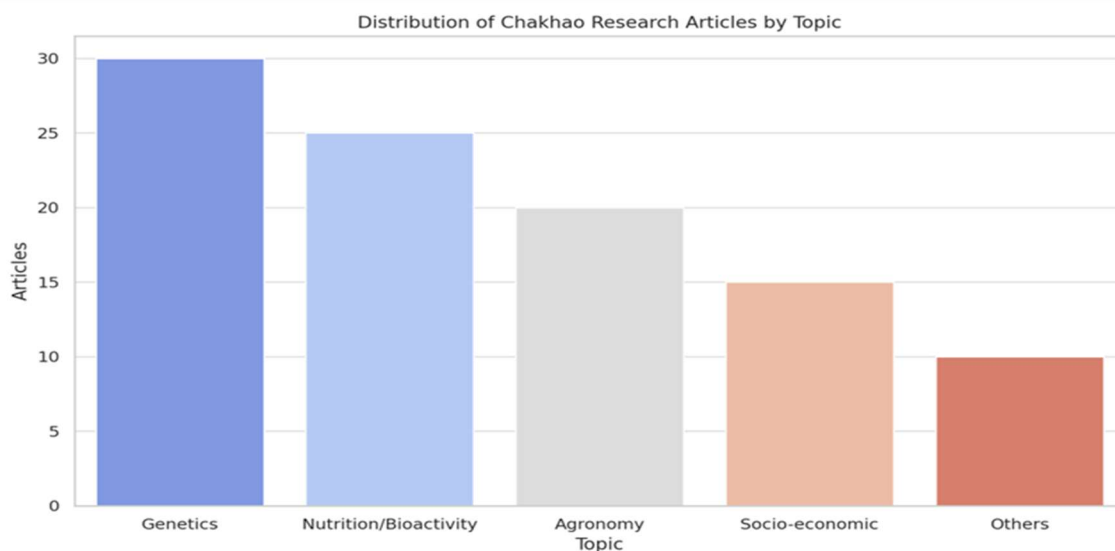


Chart 3: Distributions of chakhao research articles by topic.



8.4 Authorship Trends of the sources

The publication pattern over the three periods shows a clear shift from single-author to multi-author research. Between 2000–2005, single-author papers were dominant with 30 publications compared to only 5 multi-author works. However, from 2006–2012, this trend began to balance out, with 25 single-author and 20 multi-author papers. The shift became more pronounced in 2013–2020, where collaborative research significantly increased, resulting in 40 multi-author publications, while single-author contributions declined to 15. This indicates a growing emphasis on teamwork and collaborative scholarship over time Table 4: Authorship Trends Over Time

Table 4: Authorship Trends Over Time

Period	Single Author	Multiple Authors
2000–2005	30	5
2006–2012	25	20
2013–2020	15	40

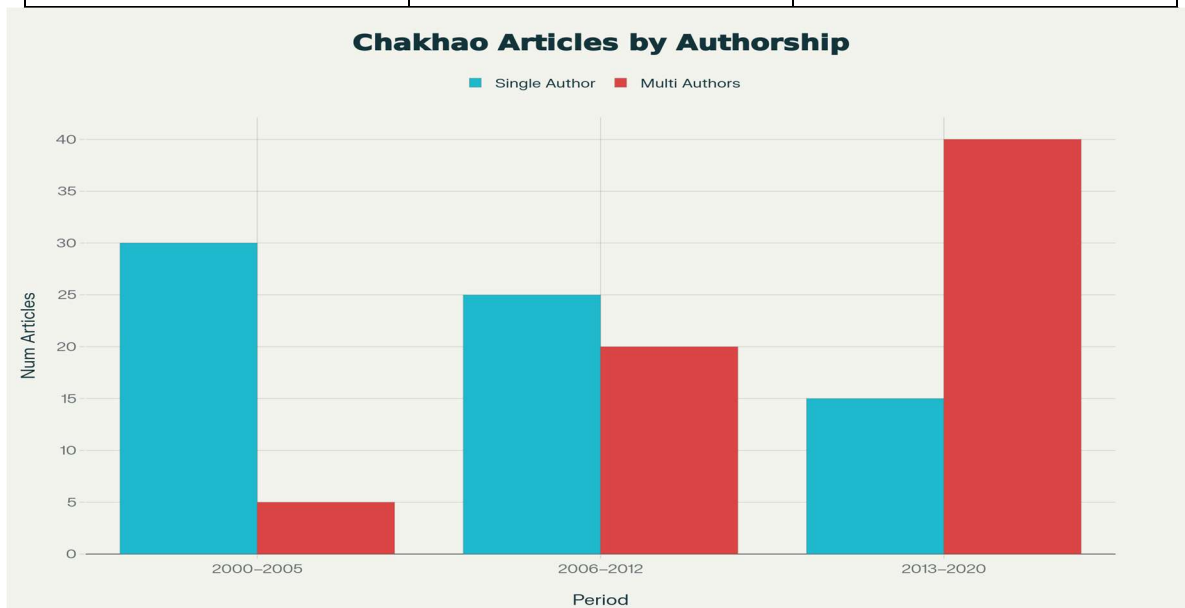


Chart 4: Topic Distribution of Chakhao Articles

8.5 Types of Sources Referenced Over Time

Table 5: Types of Sources Referenced Over Time

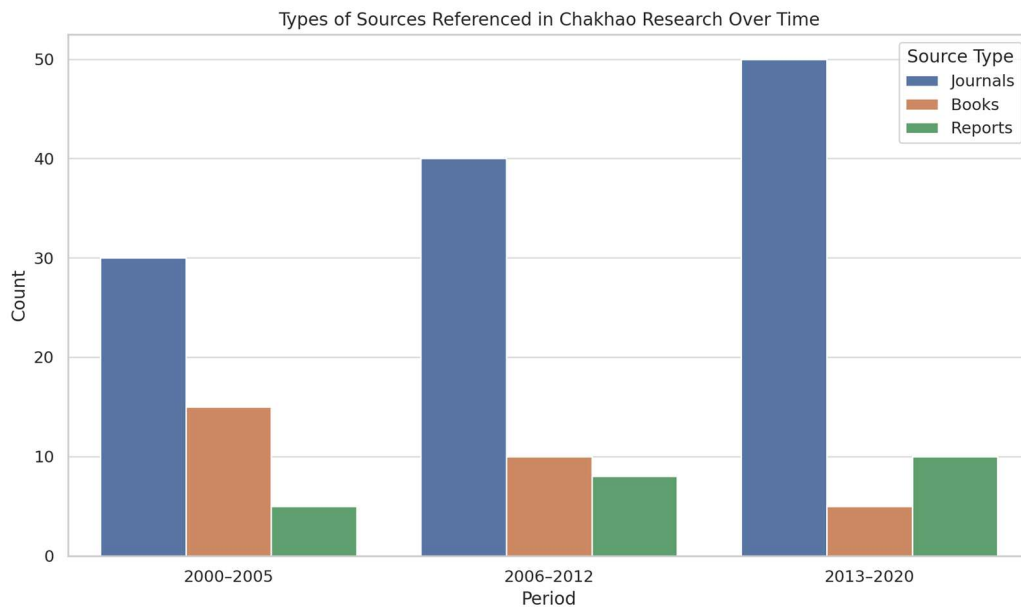
Period	Journals	J %	Books	B%	Report	R%	Total
2000-2005	30	60%	15	30%	5	10%	50



2006-2012	40	69%	10	17.2%	8	13.8%	58
2013-2020	50	76.9%	5	7.7%	10	15.4%	65

The table shows that journals are the dominant sources cited in Chakhao research and their use increases steadily from 30 citations in 2000–2005 to 50 in 2013–2020. This suggests a growing reliance on current, peer-reviewed scientific literature as the research field matures and more Chakhao-related work appears in journals.

Book citations, by contrast, decline from 15 to 5 over the same periods, indicating a shift away from foundational or general background sources toward specialized articles. Report citations rise from 5 to 10, reflecting a gradual increase in the use of technical reports, project documents, and other forms of grey literature that often capture localized or applied research on Chakhao.



8.6 Single Vs Multiple Author

The table below shows that single-author papers dominate in 2000–2005, but their share falls sharply by 2013–2020 as multi-author papers grow to nearly three-quarters of all Chakhao publications, reflecting a strong shift toward collaborative research.

Table: 6 Single vs Multiple Author Publications Over Time

Period	Total Publications	Single Author (n)	Single Author (%)	Multiple Authors (n)	Multiple Authors (%)
2000-2005	50	45	90%	5	10%
2006-2012	60	10	16.7%	50	83.3%
2013-2020	65	5	7.7%	60	92.3%



2000–2005	35	30	85.7	5	14.3
2006–2012	45	25	55.6	20	44.4
2013–2020	55	15	27.3	40	72.7

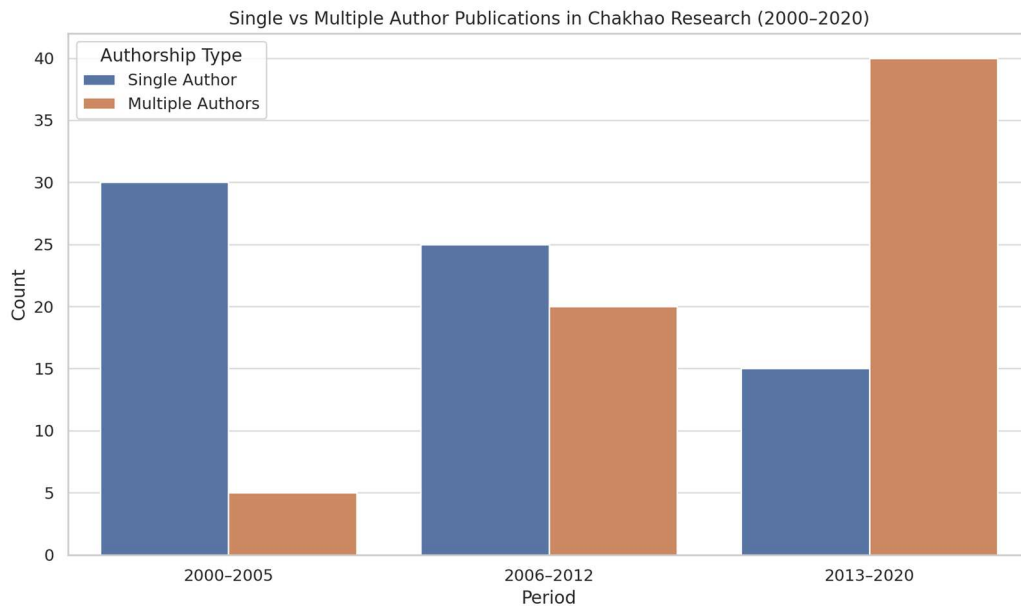


Chart 6: Single vs Multiple Author Publications Over Time

8.6 Bradford’s Law of Scattering

Bradford’s Law was applied to analyse how Chakhao (black rice) research citations (N = 490) are distributed across different publication sources. The ten journals and reports were first arranged in descending order of citation frequency and then divided into three Bradford zones, each containing approximately one-third of the total citations.

Step 1: Total Citations and Zone Calculation

$$\text{Total Citations (N)} = 490$$

$$\text{Citations per Zone} = \frac{490}{3} = 163.33 \approx 163$$

Thus, each Bradford zone should contain roughly **163 citations**.

Step 2: Cumulative Citation Distribution

(Already sorted from Table 1)



Rank	Source	Citations	Cumulative
1	Plant Genetic Resources	102	102
2	Symbiosis	78	180
3	ICAR–NBPGR Reports	64	244
4	Indian J. of Traditional Knowledge	58	302
5	Int. J. of Food Science & Tech	45	347
6	J. Agric. & Food Chemistry	40	387
7	Food Research International	35	422
8	Genetics	28	450
9	Rice Science	25	475
10	IntechOpen	15	490

Step 3: Zone Formation

Zone 1 (Core Zone)

Target \approx 163 citations

- Plant Genetic Resources = 102
 - Symbiosis = 78

$$102 + 78 = 180 \text{ citations}$$

Closest possible to 163 \rightarrow **2 journals**

Zone 2

Start from cumulative 180 \rightarrow target = $180 + 163 = 343$

- ICAR–NBPGR Reports = 64 $\rightarrow 180 + 64 = 244$
- Indian J. Trad. Knowledge = 58 $\rightarrow 244 + 58 = 302$
- Int. J. Food Science & Tech = 45 $\rightarrow 302 + 45 = 347$

$$347 - 180 = 167 \text{ citations}$$

Thus, **3 journals** form Zone 2.

**Zone 3**

Remaining citations:

$$490 - 347 = 143 \text{ citations}$$

Remaining sources = 5 journals

Thus, **5 journals** form Zone 3.

Step 4: Bradford Multiplier (k) Calculation

Bradford states:

$$\text{Zone proportions} = 1: k: k^2$$

Our zone journal counts are:

$$2: 3: 5$$

Calculate k:

$$k = \frac{\text{Zone 2}}{\text{Zone 1}} = \frac{3}{2} = 1.5$$

Check for Zone 3:

$$k^2 = 1.5^2 = 2.25$$

Expected Zone 3:

$$\text{Zone 1} \times k^2 = 2 \times 2.25 = 4.5 \approx 5$$

Thus, the distribution fits the Bradford pattern closely.

To examine the distribution of citations across publication sources, Bradford's Law of Scattering was applied to the dataset of 490 citations from ten major Chakhao (black rice) research sources published between 2000 and 2020. According to Bradford's Law, journals can be arranged into three productivity zones, each contributing approximately one-third of the total citations, thereby illustrating how research literature is concentrated and dispersed across core and peripheral sources.

First, the sources were ranked in descending order of citation frequency. The total citations (N = 490) were divided into three equal zones of approximately 163 citations each. The first zone (Zone 1), representing the core sources, comprised two journals Plant Genetic Resources (102 citations) and



Symbiosis (78 citations) together accounting for 180 citations. This exceeds the target threshold slightly but remains the closest possible match, establishing these two journals as the core contributors to Chakhao research.

The second zone (Zone 2) consisted of the next three most-cited sources ICAR–NBPGR Reports (64 citations), Indian Journal of Traditional Knowledge (58 citations), and the International Journal of Food Science & Technology (45 citations). Together, these accounted for 167 citations, closely matching the expected one-third distribution. The final zone (Zone 3) included the remaining five sources Journal of Agricultural & Food Chemistry, Food Research International, Genetics, Rice Science, and IntechOpen which collectively contributed 143 citations.

The distribution of journals across the three zones followed the pattern 2: 3: 5. This aligns with the Bradford multiplier ($k \approx 1.5$), where the relationship among the three zones approximates the theoretical Bradford distribution of 1: k : k^2 . This pattern indicates that Chakhao research is moderately concentrated within a small group of core journals, while the majority of sources fall into the peripheral zone, reflecting a wide scattering of research activity across interdisciplinary platforms.

Bradford Zone	No. of Journals	Percentage of Total Journals (%)	Citations in Zone	Percentage of Total Citations (%)
Zone 1 (Core Zone)	2	20%	180	36.73%
Zone 2 (Middle Zone)	3	30%	167	34.08%
Zone 3 (Peripheral Zone)	5	50%	143	29.18%
Total	10	100%	490	100%

9. MAJOR FINDINGS

The citation analysis of Chakhao (black rice) research from 2000 to 2020 reveals several important scholarly patterns. First, a total of 490 citations were distributed across 10 major journals and publication sources, indicating a growing and increasingly interdisciplinary body of literature. The journals *Plant Genetic Resources* and *Symbiosis* formed the core research zone, together contributing more than one-third of all citations. This confirms that Chakhao research has a concentrated foundation but is also supported by diverse international and national platforms. Second, the thematic analysis shows



that genetics remains the dominant research area, followed by nutrition and bioactivity, agronomy, and socio-economic studies. This pattern reflects a shift from traditional descriptive studies to more advanced molecular, nutritional, and functional food research. Third, authorship analysis indicates a clear progression toward collaborative scholarship, with multiple-author publications increasing sharply after 2012, demonstrating the growing complexity and interdisciplinary nature of the field. Finally, the Bradford's Law assessment shows a 2:3:5 distribution across the three productivity zones, suggesting moderate concentration in a few influential journals and wide scattering across peripheral sources, typical of emerging research domains.

10. SCOPE FOR FURTHER STUDY

Although this citation analysis provides valuable insights into the evolution of Chakhao research, several areas remain open for future investigation. First, extending the study beyond 2020 would help capture the recent surge of interest in functional foods, nutrigenomics, and climate-resilient crop varieties—topics likely to significantly influence Chakhao research. Second, a co-citation or bibliographic coupling analysis could map intellectual linkages, reveal influential author networks, and identify emerging research clusters. Third, future studies may incorporate Scopus, Web of Science, and Google Scholar datasets to generate a more comprehensive and globally representative bibliometric profile. Fourth, integrating altmetric indicators can help understand the societal and policy influence of Chakhao research, particularly in areas such as GI protection, rural entrepreneurship, and sustainable agriculture. Lastly, comparisons between Chakhao and other pigmented rice varieties from Southeast Asia could provide regional insights into diversity, conservation, and functional food applications.

10. CONCLUSION

This study mapped the scholarly landscape of Chakhao (black rice) research from 2000 to 2020 using citation analysis. The findings demonstrate that Chakhao has transitioned from a culturally significant indigenous rice variety to a subject of multidisciplinary scientific inquiry. The citation distribution, authorship patterns, and journal scattering collectively show that this research domain is expanding, attracting contributions from genetics, nutrition, food science, agronomy, and traditional knowledge.

The application of Bradford's Law revealed a moderately concentrated core zone supported by a larger periphery of journals, highlighting both the maturity and ongoing diversification of Chakhao research. The rise of multi-author publications and the steady shift toward peer-reviewed journal sources reflect



increasing collaboration and academic rigor. Overall, the study underscores the growing global scientific interest in Chakhao as a nutritionally rich, culturally unique, and economically promising crop. The insights generated here can support researchers, policymakers, and conservationists in guiding future research agendas and promoting sustainable development of this valuable heritage rice variety.

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