

Original Article

DOES THE LITERATURE PUBLISHED BY THE INSTITUTE FOR MEDICAL RESEARCH MALAYSIA FROM 2015 TO 2024 FIT BRADFORD'S LAW OF SCATTERING? A SCIENTOMETRIC ANALYSIS

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Submission Date:
2nd September 2025

Acceptance Date:
28th September 2025

Publication Date:
30th October 2025

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DOI:
<https://doi.org/10.63719/imrj.2025.11.02.010>

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ABSTRACT

Bradford's Law of Scattering, a foundational concept in bibliometrics, describes how research articles on a given subject are distributed across journals, with a small core of frequently used titles and a larger number of peripheral outlets. Determining the distribution of IMR will enable the institution's researchers to identify the core journals in their respective disciplines. This study applied Bradford's Law to examine the publication patterns of the Institute for Medical Research (IMR), Malaysia, using data retrieved from the Scopus database between 2015 and 2024. In addition, to test whether IMR's publications followed Bradford's Law, the dataset was analysed using the Bradford Multiplier (k), Bradford's graph formulation, and the Leimkuhler model. The analysis demonstrated that 1,188 articles were published across 552 different journals in the last decade, reflecting both the diversity of IMR's research output and the breadth of its readership. "Tropical Biomedicine" emerged as the most frequent outlet, publishing 46 of these articles. IMR's publications followed Bradford's Law closely, with an error margin of only 0.9%. Verification using the Leimkuhler model and Bradford's graphical Formulation further confirmed the fit, yielding an even smaller error rate of 0.078%. Complementary keyword mapping with VOSviewer revealed the thematic diversity of IMR's publications, spanning from medical entomology, public health, tool validation and reliability, nutrition, and immunology, among others.

KEYWORDS: Bradford's law of Scattering, Scopus, the Leimkuhler model, verbal Formulation, Bradford's graph

INTRODUCTION

Bradford's Law of Scattering illustrates the principle of diminishing returns and distribution in academic publishing. Formulated by Bradford in 1934, the law posits that within any specific subject area. A significant portion of research in a particular subject is typically disseminated through a select group of specialised journals, along with a few that operate on the periphery of the topic and several others that have a broader editorial focus (1). Consequently, the collection of journals within a particular field can be likened to a family tree, where each subsequent generation has a more significant number of publications than before. The practical implementation of Bradford's Law offers a framework for identifying journals that are not only prolific but also pertinent for addressing a specific area of knowledge (2).

The top third of these journals, referred to as Zone 1 or the core, are the most frequently cited within the literature of that field, making them particularly valuable to researchers. The middle third, known as Zone 2, comprises journals that receive an average level of citations, while the bottom third, or Zone 3 (the tail), includes journals that are rarely cited and are considered to have minimal relevance to the subject matter. Researchers have approached the definition of a subject area through lexical, semantic, and scattering perspectives, with some suggesting that inconsistencies in defining "subject" may not be critical as long as a consistent application is maintained. According to Bradford's law, the number of journals in the second and third zones is expected to be n and n^2 times greater than in the first zone. This relationship enables the estimation of the total number of journals that publish papers on a given subject once the quantities in the core and middle zones are established. Knowing the total number of journals can also help assess the extent of relevant information that may be missing from an incomplete search. Given the considerable time and effort required to locate sources for a systematic review, the ability to accurately estimate the volume and, if feasible, the quality of literature based on Bradford's law would be advantageous for such research endeavours (1).

Empirical validation of Bradford's law necessitates a comprehensive and extensive bibliography, a clearly defined topic, and a constrained period. This law has effectively assessed the literature across various fields, including Medicine (2)(3), nursing (4), engineering (5), and Finance (6). Nevertheless, there has been little research on the applicability of Bradford's law in forecasting the volume of literature by institution in Malaysia.

The Institute for Medical Research (IMR), recognised as Malaysia's oldest biomedical research institution, is equipped with a diverse range of advanced technological tools. Founded in 1900 by the British as the Institute of Pathology in Kuala Lumpur, IMR originated from a proposal by Sir Frank Swettenham Athelstane, the Resident-General of the Federation of Malaya. This proposal emerged in response to the decisions made at the Berlin Conference in 1885, which advocated for initiatives to enhance the local population's moral and material welfare and delve into the largely unexplored domain of tropical Medicine to improve public health and understand tropical diseases. This initiative aimed to establish a pathology institute in Malaya to facilitate ongoing scientific investigations into the causes, treatments, and prevention of epidemics such as beriberi and malaria. Over the years, IMR has expanded its scope and made substantial contributions to biomedical research and various medical fields. Its research initiatives have significantly advanced the knowledge, treatment, and management of several prominent tropical diseases in Malaysia and the Southeast Asian region, including beriberi, malaria, cholera, typhoid, smallpox, leprosy, tuberculosis, filariasis, Dengue, and nutritional deficiencies (7).

In line with the research conducted, researchers at IMR published research results in the form of writing, such as in journals, to disseminate research findings to serve as a reference for researchers in the same field, in addition to fulfilling the responsibility to solve current health problems faced by Malaysians from time to time through high-quality scientific research, as well as contributing to the body of knowledge in academia. Given the gap, we aimed to test the applicability of Bradford's law of scattering in predicting the number of articles published by the Institute for Medical Research, Ministry of Health, Malaysia, from 2015 to 2024. In Bradford's Law, the testing of publication from IMR helps researchers identify which journals act as the "core" outlets in a particular discipline and which ones play a more peripheral role. This insight is not only useful for mapping the intellectual structure of a field but also for guiding practical decisions. Testing the law will also shed light on how widely a research organisation's work is disseminated, whether its publications are concentrated in a few journals or spread across many, thereby influencing the visibility and impact of its research. In addition, verifying Bradford's Law in various contexts allowing researchers to evaluate whether theoretical models of literature distribution hold across disciplines and time periods. Such assessments can reveal whether a research field is becoming more specialised, with output clustering in a small number of journals, or increasingly interdisciplinary, with knowledge scattered more broadly. For institutions like the IMR, testing Bradford's Law also provides a benchmark for comparing their publishing patterns against global trends, offering valuable insights into the positioning and influence of their research output.

MATERIALS AND METHODS

We derived data from the Scopus database from the Institute for Medical Research, Ministry of Health, Malaysia. The Scopus database was selected because it consisted of over 23,000 indexed journals from more than 5,000 publishers, encompassing all fields of scientific research. Given that Scopus includes all the information available in Medline, it is undoubtedly a superior resource (8). The database offers two distinct search options: a basic search and an advanced search. Both methods enable complex and detailed search queries, ensuring highly accurate search results. Users can search for terms in various sections of Scopus, such as titles, titles/abstracts, journal names, author names, and affiliations, among others. Furthermore, data from Scopus is utilised by Times Higher Education and QS World Universities to develop and implement their global university ranking systems (9). It is widely recognised that Scopus indexes publications from reputable journals that maintain rigorous peer review processes and editorial oversight, enhancing the database's international credibility.

The primary data for this study were obtained from the Scopus database. We carried out a detailed search within the Information Science field, using the search terms ("Institute for Medical Research" or "Kuala Lumpur" or "Shah Alam" and "Malaysia") along with the criteria (LIMIT-TO (PUBYEAR, 2015) OR ... (LIMIT-TO (PUBYEAR, 2024))). We focused on articles categorised as "Review, Letter, Article" and limited our search to those published in English. The raw data we gathered was then downloaded in CSV format. Using MS Excel, we created a ranking list of journals along with the number of articles published. Over this extensive period, we identified 1,188 articles from 552 journals, and the data were exported to SPSS for further analysis. To ensure the bibliometric dataset was accurate and consistent, two researchers independently conducted data cleaning and management. Each researcher carefully reviewed the records for duplicate entries, incomplete metadata, and inconsistencies in author names, institutional affiliations, and journal titles. After their independent reviews, the two datasets were compared, and any discrepancies were discussed and resolved through consensus. If they could not reach an agreement, they sought a third opinion from a senior researcher. This dual-review process significantly improved the reliability of the dataset and minimised the chances of systematic errors in the analysis.

Data analysis commenced once the data were cleaned. Descriptive statistics were used to illustrate the number of articles published each year and to identify the top 30 journals in which IMR researchers published their work. These were organised in descending order based on article productivity and categorised into three zones: Zone 1, Zone 2, and Zone 3, according to the total number of articles. The application of Bradford's Law was executed in three stages, starting with an initial verbal formulation, then applying the Leimkuhler Model (10), and concluding with a graphical analysis. (11) . To complete the graph, the natural logarithm of the cumulative number of journals was calculated, which was interpreted to indicate the incompleteness of the "Bradford Bibliography." Additionally, we conducted an analysis of IMR publications from 2015 to 2024 using the Vos-Viewer software to determine the distribution of subject areas within these publications.

RESULTS

The analysis revealed that over a 10-year period (2015-2024), researchers at IMR published 1,188 articles in 552 different journals, with an average of 119 papers per year. The highest publication was in 2021, and the number of publications from 2014 to 2021 exceeded the average of 119 papers; correlation analysis showed a significant relationship between year and number of publications ($r = 0.762$, $p = 0.01$) (Figure 1).

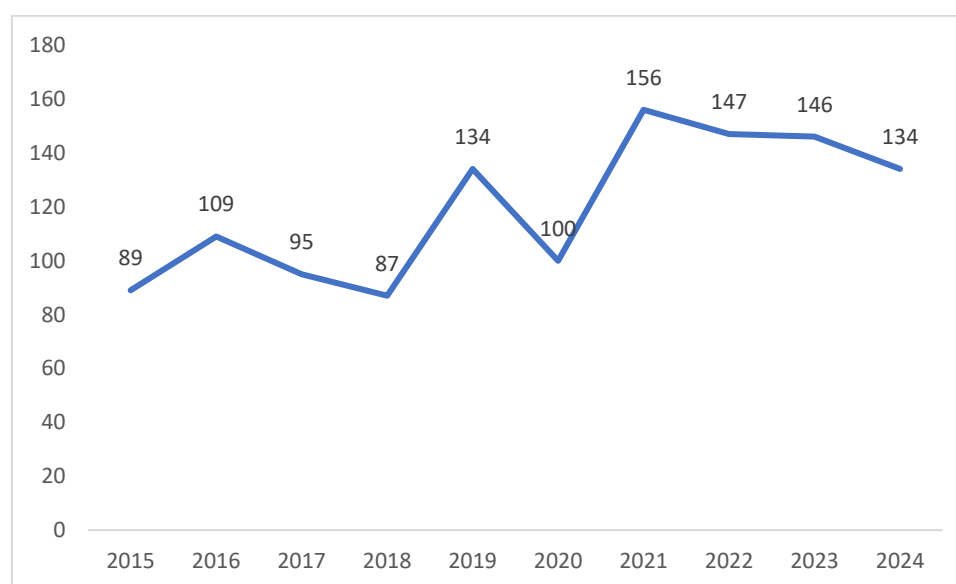


Figure 1. The number of scientific publications by IMR researchers from 2015 to 2024.

Table 1. The Core journals published the scientific papers for IMR researchers from 2015 to 2024.

No.	Journal	Number	Cumulative
1	Tropical Biomedicine	46	46
2	Southeast Asian Journal of Tropical Medicine and Public Health	28	74
3	PLoS ONE	25	99
4	Malaysian Journal of Medicine and Health Sciences	22	121
5	Tobacco Induced Diseases	21	142
6	Malaysian Journal of Pathology	19	161
7	Sains Malaysiana	16	177
8	International Journal of Environmental Research and Public Health	16	193
9	Scientific Reports	15	208
10	Molecules	13	221
11	Frontiers in Public Health	13	234
12	BMC Public Health	13	247
13	Malaysian Journal of Public Health Medicine	12	259
14	Genome Announcements	11	270
15	Nutrients	10	280
16	American Journal of Tropical Medicine and Hygiene	10	290
17	Serangga	9	299
18	Cochrane Database of Systematic Reviews	9	308
19	BMC Complementary and Alternative Medicine	9	317
20	Asian Pacific Journal of Tropical Medicine	9	326
21	JMIR Research Protocols	8	334
22	International Journal of Infectious Diseases	8	342
23	Asian Pacific Journal of Cancer Prevention	8	350
24	Journal of Medical Entomology	7	357
25	International Medical Journal	7	364

26	International Journal of Antimicrobial Agents	7	371
27	Heliyon	7	378
28	BMJ Open	7	385
29	BMC Infectious Diseases	7	392
30	Vaccine	6	398

Table 1 presents the core journal (zone 1) of IMR from 2015 to 2024, among the IMR researchers who published the most articles in Tropical Medicine (n = 46, 3.9%), followed by the Southeast Asian Journal of Tropical Medicine and Public Health, which published 28 papers (2.4%). The top five journals covered 12.0% (n=142) of the papers published in the last 10 years.

Application of Bradford's law

The following explanations are provided along with the results to assess the suitability of journal distribution according to Bradford's law's verbal Formulation. The initial section focuses on the theory's verbal Formulation, utilising data from all periodical references organised by citation frequency in descending order. The subsequent section analyses graphical representations derived from the same dataset.

a) Verbal Formulation

The features of highly productive journals that were used to assess the verbal Formulation of Bradford's law are listed in Table 2. In order to test the verbal Formulation of Bradford's law, this table contains the rank, number of journals, cumulative number of journals, number of articles, and cumulative sum of articles. The journals are divided into three productivity zones using Bradford's approach, and the verbal Formulation is verified using the scattering law. The frequency of articles is shown in Table 2 in order of highest to lowest. Three hundred ninety-eight papers from 30 journals, 394 from 135, and 396 from 387 were included in this analysis. The results show that one-third of the total papers were published in the first 30 journals, another third were published in the next 135 journals, and the remaining 387 journals made up the remaining.

Table 3 illustrates the distribution of journals, their corresponding citation counts across the three zones, and the value of Bradford's multiplier. According to Bradford, the relationship between the zones is expressed as $1:n:n^2$. In this study, the ratio of each zone is 30:135:387, which does conform to Bradford's expected distribution. Consequently, the Formulation may be adjusted to better align with the observed journal distribution pattern, where 30 signifies the number of journals in the nucleus and $k = 3.68$ serves as the multiplier.

Table 2. Scattering of Journals and Articles published by IMR researchers from 2015 to 2024 over Bradford's Zones

Zone	Number of papers	Number of Journal	Bradford's multiplier
1	398	30	
2	394	135	4.50
3	396	387	2.86
			7.36
Total	1188	552	Average 3.68

Bradford's multiplier (k) = 3.68

Bradford law

$30 \times 1: 30 \times 3.68: 30 \times 3.68^2$

30: 110.4: 406.72

$(30 + 110.4 + 406.72 - 552) / 552 = (547.12 - 552) / 552$

$= 4.88 / 552 \times 100$

$= 0.0088 \times 100$

$= 0.88\%$

Here, the error percentage is low, and the present data confirm Bradford's Law.

Verification of Bradford Law through Application of the Leimkuhler Model

The Leimkuhler model later verified the Bradford law of scattering, as expressed in the verbal Formula. We investigated the applications of Bradford's Law. The number of articles distribution was divided into three zones ($p = 3$, where p denotes the Number of Zones), and then the mathematical Formula, Application of the Leimkuhler model, was used.

For testing Bradford's law, the 552 journals are divided into three zones. Since Bradford assumes that there should be a minimum of three zones, i.e., $p = 3$, then the value of k can be calculated using Formula (4).

In this research, the models proposed by Bradford's law and Leimkuhler are evaluated to confirm the distribution of literature of microbiology (10). Leimkuhler created a model derived from Bradford's verbal Formulation, as illustrated below:

$$R(r) = a \log(1 + br)$$

Where, $r = 1, 2, 3, \dots$

Egghe described the Leimkuhler model as stated in Egghe (1990)(12):

$$a = Y_0 / \log k$$

$$b = k - 1 / r_0$$

where r_0 - is the number of sources in the first Bradford Group

Y_0 - the number of items in every Bradford group (all these groups of items being of equal size) and

k – the Bradford multiplier

$R(r)$ is the cumulative number of items produced by the sources of rank 1,2,3... r, and a and b are constants appearing in the law of Leimkuhler (10).

Egghe (1990) (12) has shown the mathematical Formula for calculating the Bradford Multiplier K as

$$k = (e^y y^m)^{1/p}$$

Where y is Euler's number ($e^y = 1.781$)

$$p = 3$$

If the sources are ranked in decreasing order of productivity, then y_m is the number of items in the most productive sources.

r_o = number of journals in Bradford's first zone

T = Total number of journals in Bradford zone

$$K = (1.781 \times 46)/3$$

$$K = 81.571/3$$

$$K = 4.3368$$

$$r_o = T(k - 1) / (k^p - 1)$$

Where T stands for the Total number of Journals = 552

$$r_o = 552 (4.3368 - 1) / (4.3368^3 - 1)$$

$$r_o = 552 \times 3.3368 / 81.5658 - 1$$

$$r_o = 1841.9136 / 80.5658$$

$$r_o = 22.86$$

Different Bradford zones can be obtained by varying the values of k and r_o .

$$\text{Thus } r_o: r_o \times k: r_o \times k^2 = 1:n:n^2$$

$$\text{Nucleus zone or } r_o \times 1 = 22.88 \times 1 = 22.88$$

$$\text{Nucleus zone } r^1 = r_o \times k = 22.88 \times 4.3368 = 99.23$$

$$\text{Nucleus zone } r^2 = r_o \times k^2 = 22.88 \times (4.3368)^2 = 22.88 \times 18.81 = 430.37$$

The percentage of error is

$$\begin{aligned} 22.88 + 99.23 + 43.32 - 552 / 552 &= 552.43 - 552 / 552 \\ &= 0.43 / 552 \times 100 \\ &= 0.078\% \end{aligned}$$

The percentage error is negligible. The number of journals in the nucleus is 22.88, and the mean value of the Bradford multiplier is 4.37. Applying the Leimkuhler model to the data set reveals that the Bradford law fits very well, with a multiplier of 4.3368.

Bradford's Graph Formulation

This subsequent stage seeks to reinforce the verbal explanation by consistently presenting scientific publications. Figure 2 depicts a logarithmic graph, where the cumulative number of journal titles represented on the horizontal axis and the cumulative number of scientific papers on the vertical axis. This graph is referred to as "Bradford's Bibliography"(11), as it supports the distribution outlined by Bradford's law, which reveals three distinct areas: (i) a rapid ascent from the baseline, (ii) a notable linear relationship between two variables, and (iii) a tail-end of the distribution where a 'droop' is evident, indicating a lack of completeness. In any "Bradford Bibliograph" (refer to Figure 2), the core journals are identified as the points located at the initial curved section of the graph before it transitions into a straight line. The upper portion of the curve, known as the "Groos droop," was interpreted by Brookes as a representation of the incompleteness inherent in the "Bradford Bibliography."

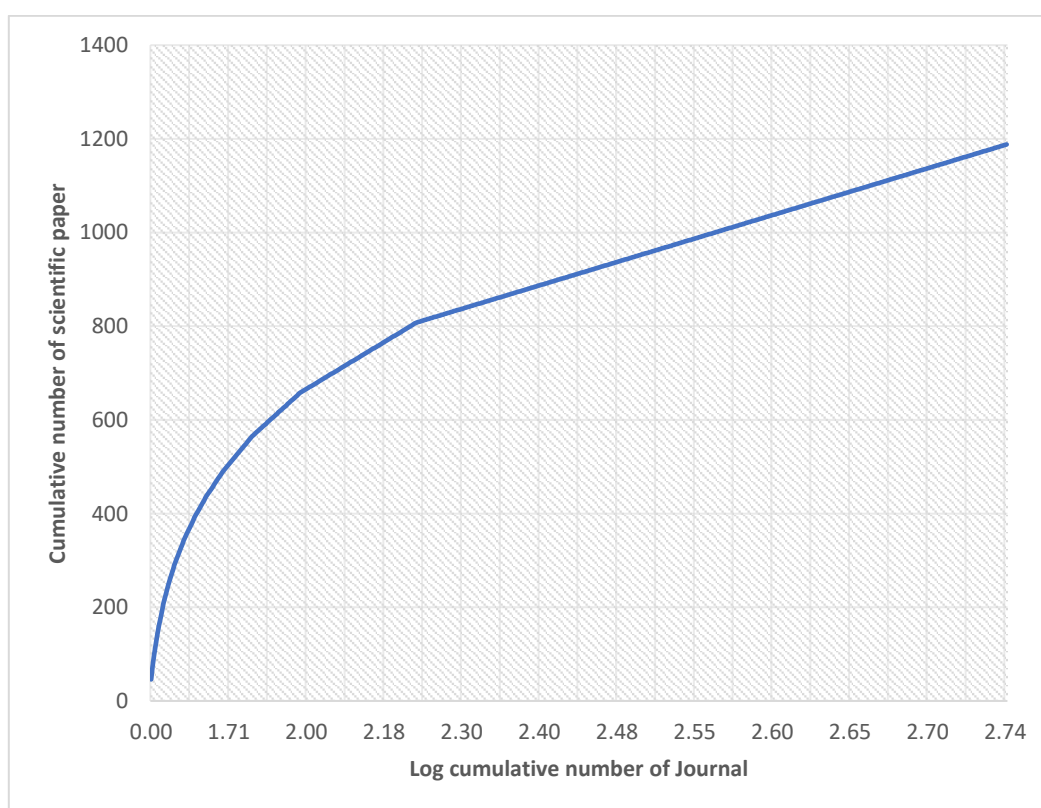


Figure 2. Bradford's graph for article distribution in Journals

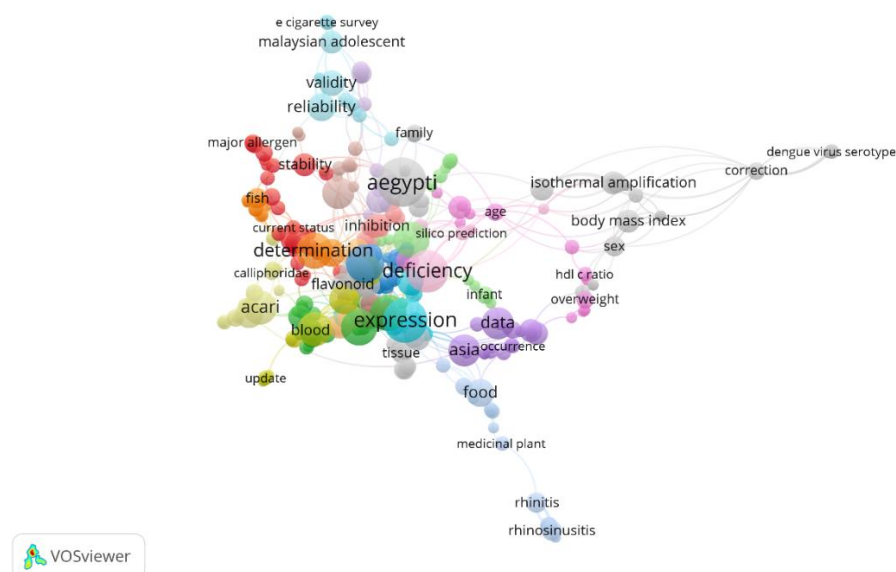


Figure 3. VOS viewer output of scientific titles published by IMR researchers from 2015 to 2024.

The analysis presented in Figure 3, which utilised VOSviewer, has revealed several distinct thematic clusters within the research output. Key terms such as *Aedes aegypti*, determination, deficiency, and expression underscore the institution's strong focus on vector biology, molecular mechanisms, and health-related outcomes. The clustering pattern showcases a range of core domains. For instance, the red cluster is associated with allergens, food stability, and biochemical inhibition, indicating potential research areas in food safety and allergen studies. The green cluster features terms such as acari, blood, flavonoid, and tissue, reflecting work in parasitology, immunology, and molecular biology.

Meanwhile, the blue cluster, which encompasses food and medicinal plants, suggests the need for investigations into nutritional and ethnopharmacological aspects. On the other hand, the purple cluster is characterised by demographic and health-related terms such as age, sex, body mass index, and overweight, indicating a focus on public health and epidemiology. The grey cluster, with keywords like isothermal amplification and dengue virus serotype, represents research in molecular diagnostics and virology. Additionally, the light blue cluster connects terms such as Malaysian adolescent, validity, and reliability, emphasising survey-based and behavioural studies, particularly regarding tobacco or e-cigarette use. Finally, clinical conditions such as rhinitis and rhinosinusitis form a distinct, light purple cluster, indicating research related to ENT (ear, nose, and throat). In summary, this mapping reveals that the institution's research portfolio is diverse, yet firmly anchored in several key themes: vector biology and diseases associated with mosquitoes, molecular and biochemical studies, public health and epidemiology, as well as nutrition and clinical sciences. The connections among the clusters, especially between *Aedes aegypti* and deficiency and expression, suggest an interdisciplinary approach.

DISCUSSION

This research has demonstrated a steady increase in the publication of scientific papers from IMR researchers over the last decade. This trend is encouraging, as it indicates that research in IMR is gaining traction and becoming increasingly focused. In this study, all three conditions have been adequately met. By employing a Bradford multiplier of 3.68, thirty core journals were identified and are detailed in Table 1. The journal distribution pattern of scientific papers published during 2015-2024 from IMR fit the Bradford distribution pattern similarly when Egghe's model (12) was applied to the same data set for the verification of Bradford's law, and found that both the data sets fit Bradford's distribution pattern with an unequal number of articles in the three zones. The data also revealed that most of the IMR journal distribution patterns of scientific papers published between 2015 and 2024 from IMR fit the Bradford distribution pattern. Similarly, when Egghe's model was applied to the same dataset to verify Bradford's law, both datasets fit Bradford's distribution pattern with an unequal number of articles in the three zones. The data also revealed that most IMR research publications were multidiscipline IMR publications are not concentrated much in core or nucleus journals; this is the view that each centre in IMR has different research interests and expertise, e.g. the Infectious Disease Research Centre more focus on infectious diseases such as Dengue, etc., Special Resource Centre published their research work in the validity and reliability of the instruments (Figure 3).

Nevertheless, the findings are contradicted by the outcome of a study by Thamaraiselvi and Lakshmi (2022) (13). The Research Publications of Manonmaniam Sundaranar University from 1992 to 2020 reported a relationship of 45:109:477 for the study, with a substantial percentage of error (13.82%). This indicates that Bradford's law does not fit the output of the university. The number of publications from 2014 to 2021 exceeded the average; in the same note, our finding is also consistent with Rajib and Singh (14), who analysed the production of the Central Institute of Plastics Engineering and Technology using the Scopus database and found that the production did not fit into the Bradford law of scattering. These conflicting findings could stem from the differences in expertise and the nature of research between IMR and the university and institute in India. IMR tends to focus on well-defined disciplines that rely on a specific set of core journals. For instance, biomedical or clinical institutes often exhibit strong Bradford patterns because they consistently publish in a limited number of specialised journals. On the flip side, the institutions we've mentioned might have a broader or more interdisciplinary profile, which may not align with Bradford's Law. Their researchers publish across a wide range of subjects—from science and technology to the social sciences—so the distribution of articles may not follow the expected core-periphery pattern. Likewise, smaller institutions with fewer publications may not produce enough data for the statistical regularities of Bradford's Law to manifest. Other factors also come into play. Publication strategies (like whether they target international or local journals), institutional collaborations, and differences in database indexing can all influence whether the law applies. In summary, institutions that are heavily research-focused in a narrow field tend to align more closely with Bradford's Law, while those with broader, more scattered research outputs often do not (17-19).

Taking a closer look at Bradford's Law in the realm of institutional research output reveals a host of practical implications. For starters, it helps pinpoint the key journals where an institution's research tends to be published, shedding light on the platforms that play a crucial role in boosting its visibility and academic reputation. This insight can guide publication strategies, encouraging researchers to target high-impact or discipline-specific journals rather than diluting their efforts across a wide range of outlets. Additionally, these findings are valuable for library and resource management, as they empower administrators to make smart choices about which journals to prioritise for subscriptions and long-term access. Moreover, applying Bradford's Law offers a way to benchmark research performance against peer institutions, showing whether a particular organisation's output is

concentrated in a select few specialised journals or spread out over a broader spectrum of outlets. A close adherence to the law might suggest a strong disciplinary focus, while any deviations could indicate a more interdisciplinary research approach. Ultimately, these insights can be harnessed to boost institutional visibility by shaping decisions around collaborations, preferred publication venues, and indexing strategies, thus enhancing the institution's reputation in the global research landscape. (22).

CONCLUSION

The study revealed that the output of IMR publications from 2015 to 2024 aligns with Bradford's law of scattering, given the error is less than one percent. These findings provide a fresh perspective for IMR researchers, suggesting they consider submitting their work to the core journals highlighted in this research. Moreover, the implications of this study extend beyond the researchers; they have a broader impact. For instance, librarians can use the identified core journals to make informed subscription choices, ensuring that institutional resources are directed toward the most relevant and frequently accessed publications. Likewise, institutional leaders and research managers can leverage these insights to inform broader research strategies. These findings might involve pinpointing key areas for publication, creating incentives for researchers, and aligning institutional goals with visibility in high-impact journals. Future research could build on this study by applying Bradford's Law to other Malaysian research institutions. These findings would enable a comparison of journal scattering patterns across different organizations and fields. Such analyses could provide richer insights into the national publication landscape, highlighting both commonalities and differences in research focus, collaboration trends, and dissemination methods. Additionally, applying the law over various time periods would shed light on how publication patterns evolve, offering valuable evidence about shifts in institutional research priorities and the degree of interdisciplinarity in Malaysian research output.

Author Contributions: KHL: conception or design of the work; KHL, YLC, AAM, MHMH, NSS: acquisition, analysis, or interpretation of data for the work; KHL, YLC, JHL & HLL: drafting the work or reviewing it critically for important intellectual content.

Funding: The Ministry of Health Malaysia supported this work without funding.

Informed Consent Statement: No ethical approval is required as the data are extracted from Scopus database.

Data Availability: The data supporting this research are available from the authors upon reasonable request.

Acknowledgements: We thank the Director-General of Health Malaysia for permission to publish this article.

Conflicts of Interest: Authors have no conflicts of interest to declare.

CITATION

Lim, K. H., Cheong, Y. L., Lim, J. H., Marine, A. A., Mat Hashim, M. H., Saidin, N. S., & Lim, H. L. (2025). Does the literature published by the Institute for Medical Research Malaysia from 2015 to 2024 fit Bradford's law of scattering? A scientometric analysis. *International Medical Research Journal*, 11(2). <https://doi.org/https://doi.org/10.63719/imrj.2025.11.02.010>

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