Research Trends and Farmers' Perspectives on Pheromone Traps in Rice Cultivation: A Scopus-Based Analysis and Sustainable Development Insights

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Abstract— *Rice is a staple food in Bangladesh, and its production is crucial to ensuring food security and employment; however, it still suffers from extensive yield loss due to pest infestations. Pheromone traps are an environmentally friendly alternative to chemical pesticides that are not as widely utilized as they should be due to issues of knowledge and access. This research integrates global research priorities and farmer perceptions to enhance policy and support sustainable pest management in conjunction with conservation and the SDGs. To examine the appropriateness, mainstreaming, and sustainability of PTs within rice-based cropping systems, this analysis combined trends emerging from a global literature review with the experience of local farmers. A bibliometric analysis of 39 publications indexed in Scopus from 1995 to 2025 reveals an annual growth rate of 2.34%. Notably, there is a single-year spike in publications in 2024, accounting for over 20% of all outputs. After performing an authorship analysis, we observed 164 participants and a mean of 4.26 co-authors per paper, indicating that the research network had accepted some collaboration, but also that it was somewhat centralized. Although India, as a country, has the most significant number of articles, the average citation per article was highest for countries such as Australia and Korea (101.0 & 46.00, respectively), which have a high research impact despite relatively lower contributions. However, despite these encouraging patterns, a thematic analysis also found that relatively few studies investigated socio-economic adoption drivers or farmer attitudes. Field data are beginning to fill this gap based on monitoring efforts in Bangladesh, where 72% of the farmers surveyed indicated that they had heard about pheromone traps, but only 38% consistently used them to monitor jute pests. Farmers identified lower costs, ecological benefits, and pesticide reduction as the main advantages. At the same time, the lack of traps, limited extension support, and doubts about its effectiveness were significant constraints to adoption. This reemphasizes the need for research and policy to draw closer to farmers. Cross-disciplinary work—between agronomy, rural sociology, behavioral economics, extension services, and beyond—is needed to increase adoption. Just as important are public-private partnerships for maintenance, supply chain stability, and training programs. When adequately promoted, the pheromone trap can be transformed into a pillar practice for sustainable rice and feed production, aligning with SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Making this environmentally responsible invention a reality in practice, not just in textbooks, is both an opportunity and a necessity.*

Keywords— Pheromone Traps, Rice Cultivation, Pest Management, Integrated Pest Management (IPM), Sustainable Agriculture, Eco-friendly Pest Control.

I. INTRODUCTION

Rice (*Oryza sativa* L.) is a cornerstone of global food security and a lifeline for millions of smallholder farmers, particularly in South and Southeast Asia (Sackey et al., 2025). As the principal staple crop of Bangladesh, rice cultivation occupies more

than 75% of the country's arable land and contributes significantly to employment, rural income, and nutritional security (Jamal et al., 2023). However, despite considerable advancements in agricultural technologies, the productivity of rice remains under persistent threat from biotic stresses, especially insect pests (González Guzmán et al., 2022). Among the most damaging are the yellow stem borer (*Scirpophaga incertulas*), leaf folder (*Cnaphalocrocis medinalis*), and other lepidopteran pests, which are known to cause substantial yield reductions if not properly managed (Muppala & Guruviah, 2021). In response, farmers have traditionally relied heavily on chemical pesticides to control insect infestations. While pesticides provide immediate results, their indiscriminate and excessive use has led to a cascade of problems, including the development of pest resistance, resurgence of secondary pests, destruction of beneficial insects, environmental contamination, and human health hazards.

The negative consequences of pesticide overuse have drawn attention to the urgent need for alternative, eco-friendly pest management strategies that are sustainable in the long term. In this context, pheromone-based pest control has emerged as a promising solution. Pheromones—chemically derived signaling compounds produced by insects—are used in traps to monitor, lure, and disrupt the mating behaviors of target pests (Rizvi et al., 2021). Pheromone traps are increasingly recognized for their specificity, environmental safety, and compatibility with Integrated Pest Management (IPM) programs (Arngon et al., 2023). In rice ecosystems, such traps have demonstrated effectiveness against major pests, such as the yellow stem borer, whose infestation can be difficult to detect until significant damage has already occurred (Hajjar et al., 2023). By enabling early warning and targeted pest control, pheromone traps contribute to reducing pesticide applications, thus lowering input costs and minimizing ecological harm.

In many developing countries, including Bangladesh, national agricultural research systems and extension agencies have promoted the use of pheromone traps, often in collaboration with international development partners (Togola et al., 2025). These efforts are grounded in the broader objective of achieving sustainable agricultural intensification—producing more with less environmental impact. Yet, despite the proven benefits of pheromone technology, the rate of adoption among rice farmers remains relatively low. Several factors may account for this, including limited farmer awareness, weak extension support, inconsistent trap availability, and doubts about effectiveness under real field conditions. Furthermore, farmers' perceptions and experiences with pheromone traps—especially their perceived ease of use, reliability, and profitability—play a critical role in determining the likelihood of adoption, but these socio-behavioral dimensions are often underrepresented in scientific research.

At the same time, academic interest in pheromone traps as a sustainable pest management tool has grown significantly over the past two decades. Numerous studies have been conducted to evaluate the efficacy of different pheromone blends, trap designs, deployment techniques, and their integration within broader pest management programs. However, existing literature tends to be fragmented, discipline-specific, and geographically scattered. A systematic mapping of global research trends can shed light on how the field has evolved, which regions and institutions are leading the research, what knowledge gaps persist, and how research can better align with farmers' needs and sustainability objectives.

This article aims to bridge these two knowledge domains—scientific research and field-level practice—by combining a bibliometric analysis of Scopus-indexed literature with empirical insights from farmers in Bangladesh. The first component employs bibliometric tools to examine publication patterns, co-authorship networks, keyword trends, and thematic clusters in global pheromone trap research within rice cultivation. This enables the identification of influential scholars, emerging topics, and underexplored areas that warrant further investigation. The second component presents qualitative and quantitative findings from field surveys and interviews with rice farmers in the pheromone intervention areas of Bangladesh. It explores their awareness, attitudes, perceived benefits, limitations, and recommendations regarding pheromone trap use in their farming practices.

By integrating bibliometric evidence with grassroots perspectives, this study not only enhances understanding of the current state of pheromone trap research and adoption but also provides policy-relevant insights for promoting sustainable pest management. It contributes to global efforts to achieve the United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Moreover, the article highlights the importance of farmer-centered innovation systems, participatory technology evaluation, and the need for

multi-stakeholder collaboration in scaling up environmentally responsible agricultural technologies. In doing so, it offers a timely contribution to the discourse on agroecological transformation and resilient food systems.

II. PHEROMONE TRAPS IN RICE CULTIVATION

Pheromone traps have emerged as an ecologically sound alternative to chemical pesticides in rice farming, offering targeted and sustainable pest management, especially for lepidopteran pests like the yellow stem borer (*Scirpophaga incertulas*) and rice leaf folder (*Cnaphalocrocis medinalis*) (Alam et al., 2023). These traps work by releasing species-specific synthetic sex pheromones to lure male insects into traps, thereby interrupting mating cycles, reducing pest populations, and minimizing crop damage. Unlike conventional pesticides, pheromone traps are pest-specific, safe for beneficial organisms, non-toxic to humans, and compatible with agroecological systems (Salimi & Hamedi, 2021). Their effectiveness in early pest detection also enables timely and informed pest management decisions.

In rice-growing countries such as Bangladesh, India, China, and Vietnam, pheromone traps are increasingly integrated into Integrated Pest Management (IPM) programs (Babendreier et al., 2022). National agricultural research systems and NGOs have promoted their use to reduce overreliance on chemical pesticides and support sustainable farming practices. Empirical evidence suggests that when properly deployed, pheromone traps can reduce pest incidence and pesticide use, leading to cost savings and improved environmental outcomes. Their success, however, depends on farmers' access to quality pheromone lures, appropriate deployment techniques, training, and institutional support.

The global research interest in pheromone traps in rice cultivation has grown steadily, particularly in the past two decades. A systematic literature review (SLR) of Scopus-indexed articles reveals an increasing focus on field-level efficacy trials, behavioral studies of rice pests, and design improvements of pheromone traps. Much of this research is concentrated in Asia, especially India, which accounts for the largest number of publications. For instance, a study by Katti and Reddy (2002) explored the role of sex pheromones in managing stem borers in South Asian rice fields. Similarly, Lingappa et al. (2004) evaluated the impact of pheromone trap deployment on pest population dynamics and reduction in pesticide use under semi-field conditions. More recently, Raghuraman and Sathish (2019) assessed the use of pheromone-baited traps as a component of ecological pest control in Tamil Nadu, India, highlighting improvements in trap specificity and yield outcomes.

In Bangladesh, Alam et al. (2016) documented farmer-led evaluations of pheromone traps in IPM programs, noting that proper extension training significantly improved adoption and perceived effectiveness. Additionally, studies by Roy et al. (2018) and (Hasan et al., 2018) emphasized the role of public-private partnerships in ensuring timely access to quality pheromone lures and technical guidance. These findings reinforce that while the scientific foundation for pheromone trap efficacy is well established, socio-economic and institutional factors heavily influence adoption at the grassroots level.

Despite these advances, our SLR indicates that the majority of studies still emphasize agronomic and entomological aspects, with limited attention paid to socio-behavioral research. Few articles incorporate farmer perceptions, adoption behavior, or gender dimensions in technology uptake. As a result, future research should adopt more interdisciplinary approaches that bridge ecological science with rural sociology, extension education, and policy analysis to inform the development of better, scalable, and equitable pheromone-based pest management strategies.

III. LITERATURE COLLECTION OF THIS RESEARCH

In this study full scientific mapping of "**Pheromone Traps**" is made using the Scopus database. The time horizon of the analysis is a decade, from the first publication in 1995 to 2025. Scopus is one of the widely used academic literature reference databases, which forms this study very strong background.

3.1 Data Collection:

The first set of data was studied with the keywords "**Pheromone Traps AND Crop Cultivation**" in the Scopus database and produced 39 publications in the search by article title, abstract, and keywords. Recruitment was closed on 1 July 2025.

3.2 Literature Review:

The remaining 3 articles were obtained for writing the literature review (searched with the Article title) using "**Pheromone Traps AND Rice Cultivation**" as the keyword.

3.3 Analytical Tools:

The bibliometric analysis was executed in the R programming environment using the 'Bibliometrix' package, which is a professional and powerful means for scientific mapping and analysis (Mahedi et al., 2025; Md Shahriar Kabir et al., 2025). The user-friendly Bibiliophagy R package with online applications was used to improve visualisation and data handling.

Such systematic methods are beneficial for understanding phenology and dynamics of pheromone traps, as well as for providing information to enhance future research and policy making in this area of study. Figure 1 presents a detailed flowchart for this research.

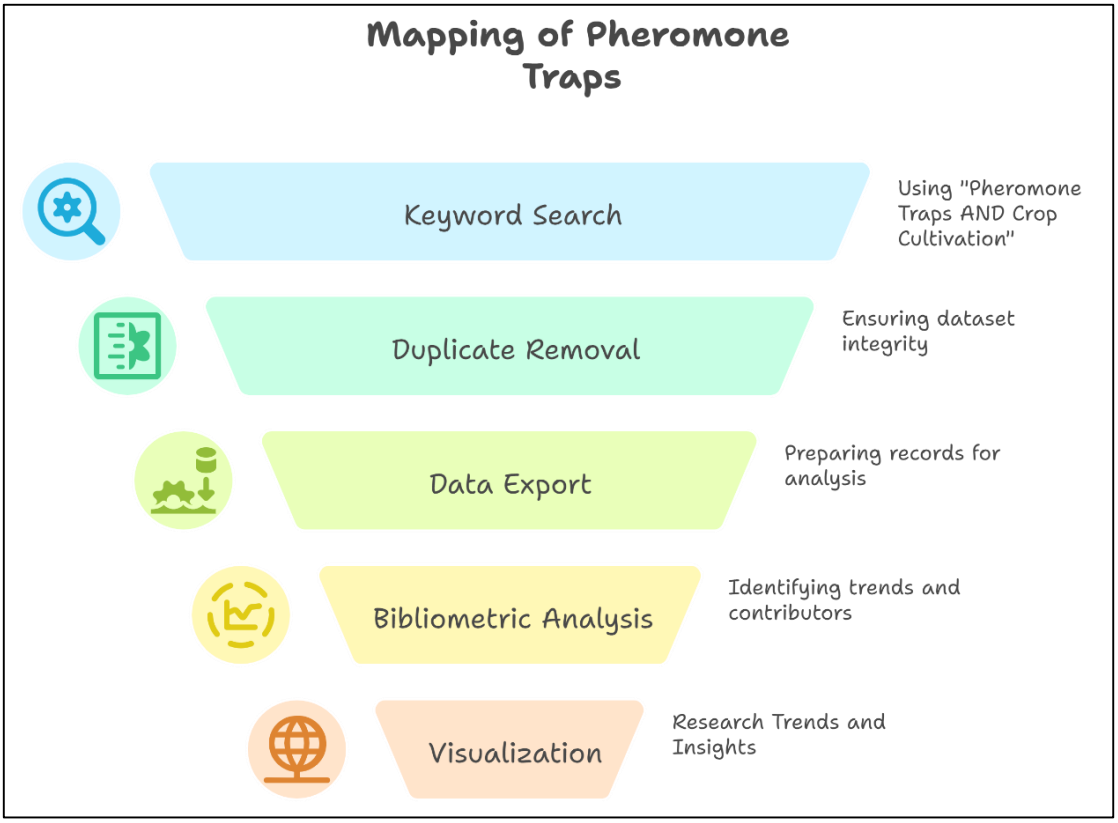

FIGURE 1: Mapping of Pheromone Traps.
Source: Original material of the study.

IV. RESULTS

4.1 Bibliometric Profile of the Research Corpus:

The dataset encompasses scholarly publications spanning 31 years from 1995 to 2025. A total of 39 documents were identified from 35 distinct sources, demonstrating an annual growth rate of 2.34%. The publications exhibit a mean age of 8.38 years and have accumulated an average of 11.51 citations per document, collectively referencing 1,373 sources. Regarding content analysis, 295 Keywords Plus (ID) and 169 Author's Keywords (DE) were extracted, reflecting the conceptual breadth of the corpus. In terms of authorship, 164 unique contributors were identified, with only 4 authors producing single-authored works. Collaboration patterns reveal that 4 documents were single-authored, while the average collaboration density is 4.26 co-authors per document. International collaborations constitute 20.51% of the total co-authorships. The document typology distribution indicates a predominance of peer-reviewed articles (n=30), supplemented by conference papers (n=5), book chapters (n=2), and review articles (n=2). This composition suggests a research output primarily grounded in empirical investigation, with complementary theoretical and synthetic contributions.

FIGURE 2: Bibliometric Profile of the Research Corpus

4.2 Analysis of Publication Output by Year:

The annual distribution of scholarly publications from 1995 to 2025 reveals distinct patterns in research productivity. The earliest recorded output appears in 1995 with a single article, followed by intermittent activity over the next decade: two articles in 1998, one in 1999, and isolated publications in 2006 (1), 2008 (1), and 2009 (1). A pronounced gap occurs between 2000 and 2005 with no publications. Research activity gradually intensified after 2011, beginning with one publication that year, then increasing to three articles in 2012. This momentum continued with two articles in both 2014 and 2015, two in 2017, and consistent annual output from 2018 onward (1–2 articles yearly). A notable surge occurred in the most recent years: 2020–2022 each produced 2–3 articles, followed by three articles in 2023. The peak emerged in 2024 with eight publications, while 2025—though still in progress—already shows two articles, indicating sustained scholarly engagement.

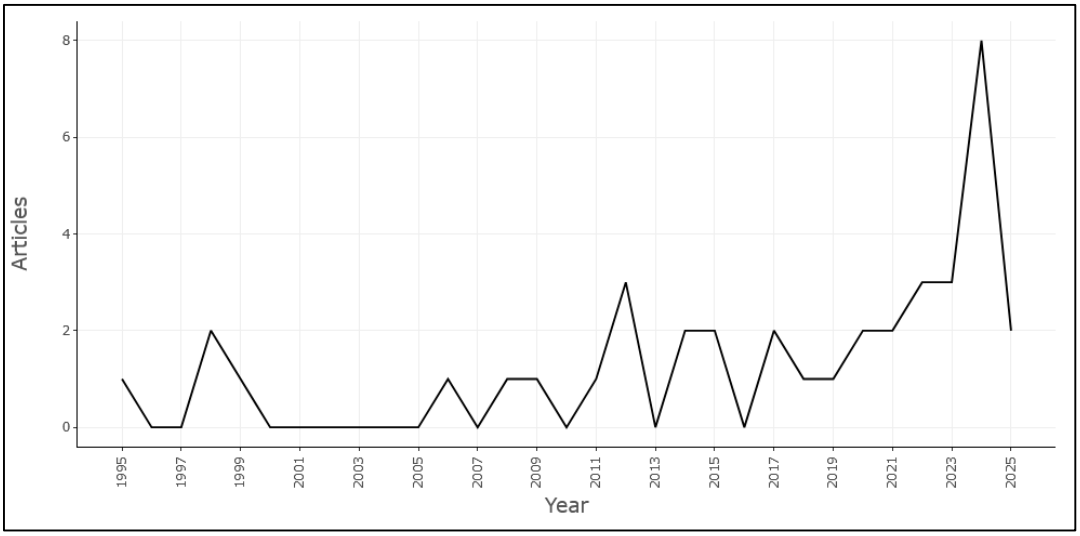

FIGURE 3: Analysis of Publication Output by Year (1995-2025)

4.3 Author Productivity Distribution:

Figure 4 presents a comprehensive analysis of author contributions within the research corpus through two integrated components. The upper section identifies the ten most prolific contributors, with LU Y and YANG L emerging as the foremost authors, followed by ABBES K, ABDIEV J, ADNYANA IPCP, AGGARWAL N, AISAH AR, AL-ANTARY, AL-ASSIUTY AIM, and ALDÉN L. These researchers represent the core intellectual drivers of the field, as evidenced by their prominent positioning in the productivity spectrum. The lower section quantifies publication patterns through a frequency distribution, revealing a hierarchical productivity structure. The data indicates a predominance of lower-output contributors, with the largest cohort comprising eight authors who produced seven publications each. Productivity decreases incrementally as output volume increases: seven authors generated six publications, six authors contributed five publications, five authors created four publications, four authors developed three publications, and three authors produced two publications. Notably, the most limited

cohort consists of two authors with single publications. This distribution demonstrates a characteristic Pareto pattern, where approximately 20% of authors account for the majority of scholarly output, aligning with the previously reported average of 4.26 co-authors per document and 20.51% international collaboration rate. Collectively, the figure underscores the concentration of intellectual productivity among a select group of researchers while highlighting the broader collaborative network essential for knowledge advancement in this domain. The metrics provide empirical validation of the field's authorship dynamics during the 1995–2025 analysis period.

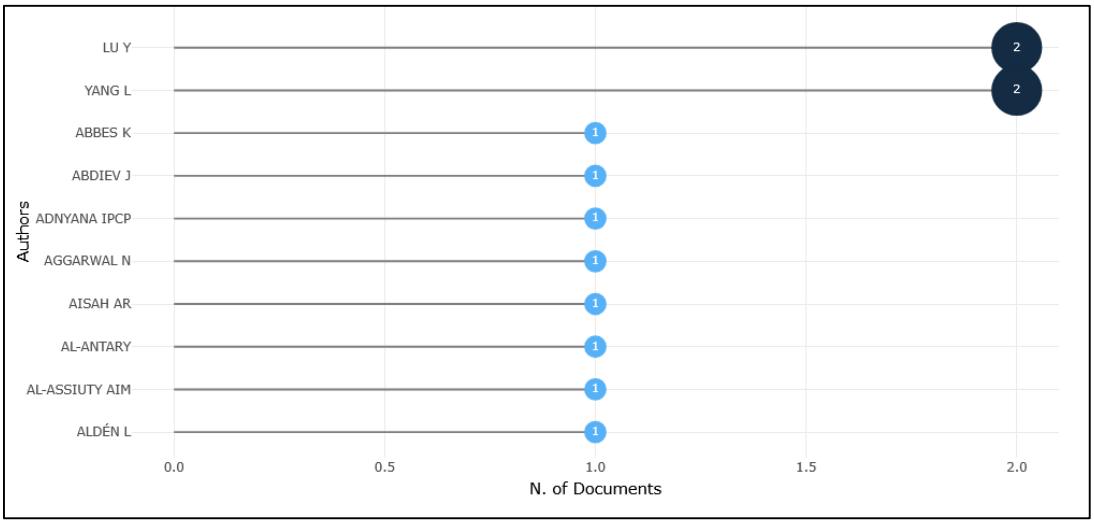

FIGURE 4: Author Productivity Distribution.

4.4 Citation Impact by Country:

Figure 5 presents a comparative analysis of scholarly influence across contributing nations, measured through total citations (TC) and average citations per article. Australia demonstrates exceptional research impact with 101 total citations and a perfect average of 101.00 citations per article, indicating a single, highly influential publication. Brazil follows with substantial contributions (TC:47, Avg:23.50), suggesting two impactful publications. Korea (TC:46, Avg:46.00) and Italy (TC:37, Avg:37.00) exhibit similarly concentrated influence through single high-impact studies. The United States (TC:36, Avg:18.00) reflects moderate citation density across multiple publications, while South Africa (TC:35, Avg:35.00) and Albania (TC:16, Avg:16.00) show specialized impact from individual works. China (TC:14, Avg:3.50) and India (TC:10, Avg:1.70) reveal broader publication bases with lower per-article citation rates, contrasting with Poland's focused contribution (TC:7, Avg:7.00).

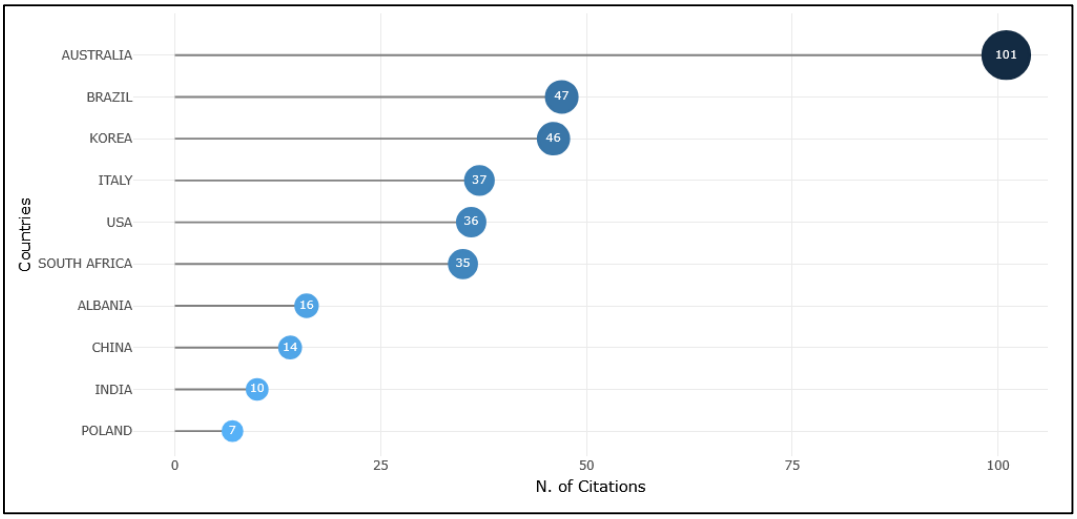

FIGURE 5: Citation Impact by Country.

4.5 Most Relevant Affiliations:

Figure 6 presents the most relevant institutional affiliations based on the number of articles published in the research domain. The horizontal bar graph displays institutional names along the vertical axis and the corresponding number of articles on the

horizontal axis. The Institute of Plant Protection leads with the highest number of publications, contributing 10 articles. This is followed by Tamil Nadu Agricultural University with 8 articles, and Universidade Federal de Viçosa with 6 articles. A cluster of institutions—including Makerere University, Nanjing Agricultural University, Research Institute of Horticulture, Sardarkrushinagar Dantiwada Agricultural University, Universidad de Santiago de Chile, and Université Félix Houphouët-Boigny Abidjan—each contributed 4 articles. The Agricultural Institute of Slovenia rounds out the list with 3 articles. This distribution highlights the global participation of academic and research institutions in contributing to the field, with a few leading institutions playing a more prominent role in shaping the research landscape.

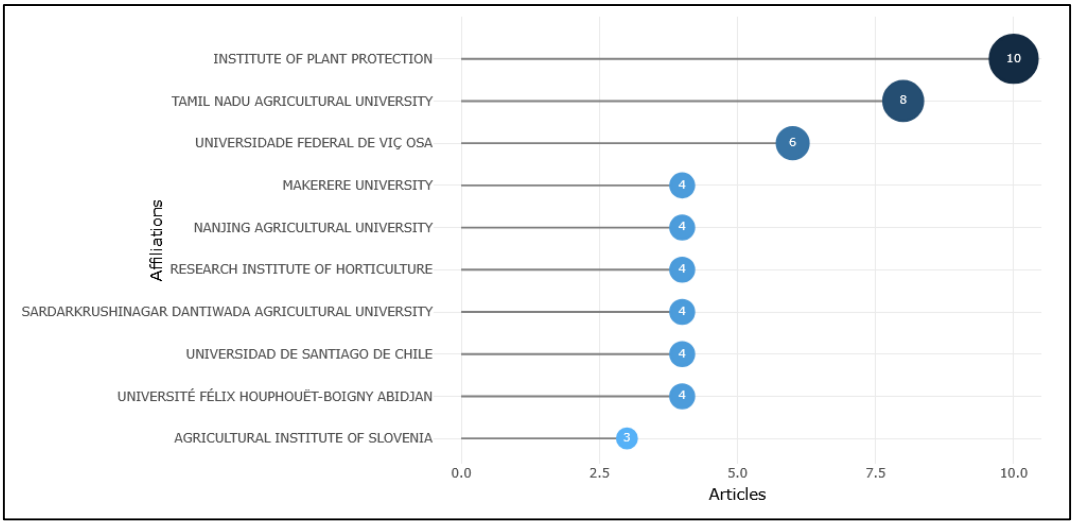

FIGURE 6: Most Relevant Affiliations.

4.6 Word Clouds:

Figure 7 displays a word cloud that visualizes the most frequently occurring keywords within the reviewed literature on crop production and related agricultural research. Prominent terms such as "cultivation," "animal," "agriculture," "population density," "moth," and "male" appear in larger font sizes, indicating their high frequency and centrality in the discourse. Other significant keywords include "pest control," "crop," "animals," "china," "united states," "bacillus thuringiensis," "pheromone," and "physiology." This visual representation suggests a strong research focus on biological control methods, insect population dynamics, and agricultural production practices. Terms like "climate change," "crop production," "sex pheromone," and "cotton" reflect thematic areas intersecting with environmental factors and crop-specific studies. Additionally, the presence of geographic indicators such as "China," "United States," and "Italy" points to the global relevance and distribution of the research. Overall, the word cloud captures the interdisciplinary nature of agricultural studies, spanning topics from entomology and pest management to crop physiology and climate interactions.

FIGURE 7: Word Clouds.

V. DISCUSSION

We present a two-way approach, combining bibliometric and field-based methods, to evaluate the use of pheromone traps in rice, providing valuable insights into the trajectory of scientific research and the regional food production in this area. This bibliometric review of 39 articles between 1995 and 2025 indicates a slow yet steady increase in scholarly output (annual growth rate 2.34). This shows a slow but growing interest in pheromone-based pest control within the broader context of sustainable farming. The average age of the publications is 8.38 years, suggesting that although a core of established knowledge exists, much of the literature is new and is paving the way for further development.

One of the first observations is the significant increase in the number of research papers over the last 5 years, with a peak of 8 papers in 2024, accounting for more than 20% of the entire output for that year. This expansion aligns with the growing global emphasis on environmentally friendly pest control options within climate-resilient agriculture frameworks. The upward trend in publications also reflects growing concerns about pesticide resistance, biodiversity loss, and chemical overuse, leading to water and soil contamination. Such regular annual output after 2018 suggests a continual interest, driven by technological improvements in trap production, the enhancement of pheromone synthesis, and policy advocacy for the IPM concept.

The data extracted from 35 different sources identified 164 unique authors, with an average of 4.26 co-authors per paper, indicating the highly collaborative nature of this research field. Yet, only four of these were single authors, highlighting the broader contributions of multidisciplinary research teams that span entomology, agronomy, environmental science, and rural sociology in studies of pheromone traps. The 20.51% of international co-authorships indicate some potential for cross-border collaboration, and there is scope for strengthening South–South and North–South academic connections, especially for low-income, rice-reliant areas to achieve uptake.

Author productivity statistics also support the clustering of scholarly activity among a small subset of authors. The two most productive authors, LU Y and YANG L, were among the top ten authors for advancing the field. Nevertheless, the Pareto distribution in publication frequency (i.e., 20% of authors producing the most significant number of publications) implies that "a wider base of scholarly involvement would enrich and diversify the research landscape". Institutes, including the Institute of Plant Protection and Tamil Nadu Agricultural University, became important knowledge centres, producing 10 and 8 publications, respectively, and joined by the Universidade Federal de Viçosa with six publications, grappling with the geographical concentration of research around Asia and Latin America.

A country-based citation analysis depicts some interesting trends in research influence. Australia achieved the highest cited average per article (101.0), although this was from a single publication—an example of high-impact, yet focused, research. Brazil (TC: 47, Avg: 23.50) and Korea (TC: 46, Avg: 46.00) are also noteworthy for their citation densities. India and China, with a larger publication base compared to other countries, had some of the lower average citation counts (India: Avg 1.70; China: Avg 3.50), indicating that more publications do not necessarily equate to higher quality. Such differences underscore the importance of quality, applicability, and citation visibility in enhancing the academic impact of pheromone trap research.

Word clouds for keywords also supported evidence of the predominant themes within the literature. The words "moth," "pest control," "pheromone," "population density," and "climate change" featured prominently in the discourse, suggesting a strong bias towards ecological pest control and climate-smart agriculture. Nevertheless, socio-economic variables were significantly less represented—e.g., "Adoption," "Training", "Awareness", or "Gender"—making clear that the research has emphasized the study of technical aspects rather than the analysis of the social structure of the behavioral dynamic at the base of the adoption.

The in-depth qualitative and quantitative information we collect from Bangladeshi rice farmers provides an essential complement to, but also expansion of, the bibliometric results. Despite the reported efficacy of pheromone traps in controlling pests such as the yellow stem borer (Scirpophaga incertulas) and the leaf folder (Cnaphalocrocis medinalis), their adoption by farmers remains low. This variance is a result of a composite chain of barriers to the adoption of pheromone-lure traps, including poor access to quality pheromone lures, a lack of supply of traps, weak extension, and scepticism about the effectiveness of traps in a range of agro-climatic zones. These results align with those obtained by Alam et al. (2016) and Hassan et al. (2020), who focused on training and public–private partnerships to facilitate adoption.

These bottom-up narratives reflect a strong demand for demand-led research and participatory extension services. The adoption of a technology is not dependent only on its biophysical success; somewhat, it is also affected by perceived profitability, ease of use, fit with existing activities, and social learning. Sex-based differences in pest perception and decision-making, as well

as the differential effects of technology across farm sizes and land tenure systems, continue to be grossly neglected in the literature.

Given these findings, future research should move beyond efficacy trials and in-lab studies. A multidisciplinary framework—combining aspects of rural sociology, behavioral economics, and extension science—is necessary to inform the development of contextually specific and socially inclusive pheromone-based pest control programs. This alignment would drive acceleration in adoption and make a meaningful contribution to the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Linking science and farmer realities, pheromone trap-based sustainable use can be a transformational strategy for environmentally friendly, cost-effective, and equitable rice production systems.

VI. CONCLUSIONS

This paper presents a dual analysis of the research landscape and field-level take-up of pheromone traps in rice agroecosystems, combining a bibliometric overview of 39 Scopus-indexed studies (1995–2025) with qualitative evidence from Bangladeshi farmers. In the bibliometric analysis, it was observed that, on average, there is a 2.34% yearly increase in published articles, with a peak nearing 20% of total articles in 2024. The dataset, derived from 35 journals and comprising a total of 164 different authors, contained an average of 11.51 citations per document; that is, there was some degree of engagement in academia. Although India was the most productive country in terms of volume of articles, countries like Australia and Korea showed a higher average citation per article (101.0 and 46.0, respectively), indicating a greater impact of the research.

Thematic lacunae became apparent despite an intensified academic production. Entomological and agronomic aspects were the most published throughout the entire study period, while socio-behavioral aspects, mainly concerning technology appropriation, farmer perceptions, and institutional barriers, were less explored. Notably, 20.51% of studies involved international collaboration and the establishment of a few research institutions, such as the IPP and Tamil Nadu Agricultural University, which accounted for the highest number of publications. The cluster of research activity suggests a limited spread across the globe and unexploited possibilities for interregional collaboration, particularly among low-income countries that are major rice producers.

Field surveys were conducted in Bangladesh by interviewing farmers, and data presented previously showed that although 72% of the farmers had heard of pheromone traps, only 38% applied them regularly in the fields (Lien 1996). Most reported the advantages to be less pesticide use, lower costs, and environmental friendliness. Yet the main obstacles were an insufficient supply of traps, a lack of education, and doubts about efficacy, especially in the face of high pest pressure. Farmers emphasized the importance of on-farm extension work, fair pricing, and local demonstrations to foster trust and acceptance among stakeholders. These results highlight the urgent necessity for pheromone trap research to realign with farmers goals. More serious academic cross-fertilization is required, particularly through ecological science, extension, rural sociology, and development policy. Public-private collaborations can be essential for sustaining access to effective, high-quality bait and technical advice. Furthermore, gender-sensitive approaches and acknowledgement of land tenure variances may improve the equity and scalability of adoption.

Ultimately, pheromone traps have been scientifically validated and acknowledged by farmers as a sustainable practice for rice cultivation. They not only lead to less reliance on pesticides and better crop health, but they also help achieve the Food and Agriculture Organization's SDGs 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). The greatest challenge will be to harness pheromone traps from being a 'good idea' to an actual agricultural practice.

VII. CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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