

Bioprospecting of Teki Grass Tubers (*Cyperus rotundus* L.) as a Natural Probiotic: Development of STEM-PjBL-Based Pharmacognosy Modules to Enhance Entrepreneurship and Creative Thinking of Vocational Pharmacy Students

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ABSTRACT

ABSTRACT The exploration of local biodiversity in science education has become essential for fostering sustainability, innovation, and entrepreneurship in the 21st century. *Cyperus rotundus* L. (teki grass) is a medicinal plant with well-documented antimicrobial, anti-inflammatory, and wound-healing properties. Its tubers contain bioactive compounds such as flavonoids, tannins, and saponins, which demonstrate potential as natural probiotics. Despite its pharmacological value, its integration into pharmacognosy education remains limited. This study aims to develop a pharmacognosy module based on STEM-Project Based Learning (STEM-PjBL) using *C. rotundus* as a contextual case study. A bibliometric analysis was conducted using Scopus-indexed articles (2009–2025) to investigate the potential of *C. rotundus*, dominant bioactive compounds, and their relevance in biomedical and pharmaceutical applications. Findings indicate growing research interest in ethnopharmacology and sustainability integration within education, particularly in recent years. The STEM-PjBL framework provides students with hands-on experience in bioprospecting while enhancing entrepreneurship, creativity, and critical thinking skills. Incorporating *C. rotundus* in pharmacognosy modules strengthens contextual learning, promotes sustainable innovation, and bridges traditional knowledge with modern science education. This study highlights the opportunities and challenges of integrating natural product bioprospecting into vocational pharmacy curricula and recommends further empirical research to optimize its educational impact.

Keywords: Natural probiotic, pharmacognosy education, STEM-PjBL, bioprospecting, entrepreneurship, creative thinking

22 Introduction

The integration of local biodiversity into science education has become increasingly urgent in addressing sustainability, health, and innovation in 21st-century learning. Among various local medicinal plants, *Cyperus rotundus* L. (commonly known as teki grass) is a widely available species in tropical regions that has traditionally been used for its antimicrobial, anti-inflammatory, and wound healing properties. Its tubers contain bioactive compounds such as flavonoids, tannins, and saponins, which are strongly associated with natural probiotic activity. These properties position *C. rotundus* as a promising candidate for scientific exploration in the context of education, particularly in pharmacognosy learning for vocational pharmacy students.

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Recent studies highlight the potential of *C. rotundus* in biomedical and pharmaceutical applications, including its use as a phytomedicine and natural antimicrobial agent (Berniyanti et al., 2022; Pirzada et al., 2015). However, despite its pharmacological potential, the use of this plant as a core component in educational learning modules remains underdeveloped. Existing pharmacognosy teaching materials rarely incorporate local plant-based research findings or entrepreneurial frameworks, limiting students' exposure to contextual learning and practical innovation.

This study addresses the gap by proposing a learning module based on the bioprospecting of *C. rotundus*, aligned with a STEM-Project Based Learning (STEM-PjBL) model. This model fosters scientific inquiry, practical experimentation, and real-world product development while promoting students' entrepreneurial and creative thinking skills. Moreover, the integration of local medicinal plants in education can strengthen cultural relevance, sustainability awareness, and interdisciplinary competence.

The objective of this research is to develop a contextual, STEM-oriented pharmacognosy module using *C. rotundus* as a natural probiotic case study. The expected contribution includes a novel learning resource that bridges bioprospecting research with vocational education, enhances entrepreneurship literacy, and promotes creativity in pharmacy students. This work also serves as a reference for embedding ethnopharmacological knowledge into modern science curricula.

23 Research Methods

This study employs bibliometric analysis, a quantitative method for analyzing bibliographic data from journal databases, specifically Scopus. This analysis is used to investigate the cited references of articles within journals, map the scientific domains of a journal, and cluster scientific articles according to specific research fields.

Based on the research title: "Bioprospecting of Teki Grass Tubers (*Cyperus rotundus* L.) as a Natural Probiotic: Development of STEM-PjBL-Based Pharmacognosy Modules to Enhance Entrepreneurship and Creative Thinking of Vocational Pharmacy Students", the following research questions are proposed:

1. RQ 1: What is the potential of Teki grass tubers (*Cyperus rotundus* L.) as a natural probiotic based on the analysis of bioactive compounds and microbiological activity?
2. RQ 2: Which dominant bioactive compounds in Teki grass tubers contribute to their probiotic effects, and what is their mechanism of action on gut microbiota?
3. RQ 3: How effective is the STEM-PjBL-based pharmacognosy module in improving vocational pharmacy students' understanding of bioprospecting and the application of natural probiotics?
4. RQ 4: Does the development of a STEM-PjBL-based module enhance vocational pharmacy students' entrepreneurship skills and creative thinking in the context of developing natural product-based probiotics?
5. RQ 5: What are students' perceptions of the STEM-PjBL method in pharmacognosy learning, particularly regarding the bioprospecting of Teki grass tubers as probiotics?
6. RQ 6: What factors influence the successful integration of bioprospecting and entrepreneurship content into pharmacognosy learning modules for vocational pharmacy students?
7. RQ 7: What is the comparative effectiveness of Teki grass tubers as natural probiotics versus commercially available probiotics?
8. RQ 8: What challenges and opportunities arise when implementing STEM-PjBL modules to foster innovation and creativity in natural product-based pharmacy education?

9. RQ 9: What are the collaboration patterns between vocational pharmacy education institutions and industries in supporting the development of bioprospecting-based probiotic products from Teki grass tubers?

The search was focused on the phrase "Cyperus rotundus L. pharmaceutical biology" in the search within "title, abstracts, and keywords" where the articles found were 927. This search was too broad, resulting in relatively many articles. By applying additional filters, such as selecting only "ar" (article) type, published in English, and limited to subjects like pharmacy (PHAR), medicine (MEDI), and environment (ENVI), while ensuring open access (OA), the number of articles was narrowed down to 19 restricting publications between (2009 – 2025). The search was carried out using the official subscription account owned by the Universitas Muhammadiyah Malang. Data simulation uses "Analyze search results" which is available on the Scopus system. To enrich data and analysis, the data was exported to *CSV format (for visualizing data process with VOSviewer and RStudio) and *RIS (for synchronized with Reference Manager [Mendeley]). ALL ("Cyperus rotundus L." AND pharmaceutical AND biology) AND PUBYEAR > 2009 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (EXACTKEYWORD , "Article")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SUBJAREA , "PHAR") OR LIMIT-TO (SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "ENVI")) AND (LIMIT-TO (AFFILCOUNTRY , "Indonesia") OR LIMIT-TO (AFFILCOUNTRY , "China") OR LIMIT-TO (AFFILCOUNTRY , "India") OR LIMIT-TO (AFFILCOUNTRY , "Egypt") OR LIMIT-TO (AFFILCOUNTRY , "United States") OR LIMIT-TO (AFFILCOUNTRY , "South Korea")) AND (LIMIT-TO (AF-ID , "Ministry of Education of the People's Republic of China" 60001604) OR LIMIT-TO (AF-ID , "College of Pharmacy" 60001933) OR LIMIT-TO (AF-ID , "Mansoura University" 60012022) OR LIMIT-TO (AF-ID , "King Saud University" 60013183) OR LIMIT-TO (AF-ID , "National Research Centre" 60014618) OR LIMIT-TO (AF-ID , "Brawijaya University" 60069392) OR LIMIT-TO (AF-ID , "Faculty of Pharmacy" 60274067) OR LIMIT-TO (AF-ID , "Horus University - Egypt" 60275574))

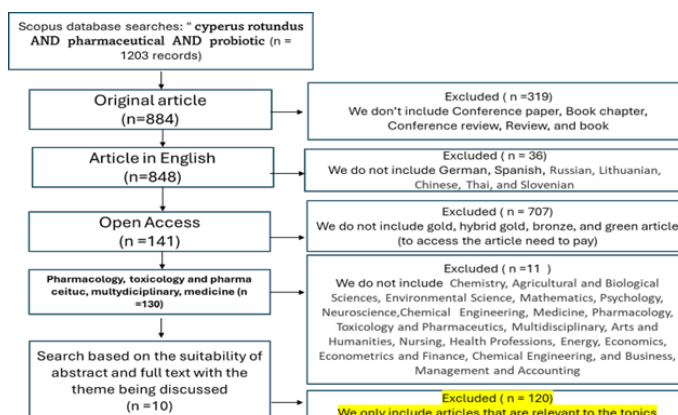


Figure 8: Data

24 Result and Discussion

Temporal distribution

Figure 2 presents the number of articles in the Scopus database after undergoing inclusion and exclusion processes during the period from 2019 to 2024. The data indicate that the number of publications addressing the issue of Integration of Ethnopharmacology in the Science Curriculum has experienced notable fluctuations over the past six years.

In 2019, there was one article, which then declined to zero in 2020. The number of publications began to rise again with one article in 2021, followed by two articles in 2022. In 2023, the publication count remained at two, and in 2024, it reached its peak with four articles.

This trend suggests that interest in research related to sustainability competencies and ethnopharmacological integration has increased significantly in the last two years, especially in 2024. It indicates that this topic is becoming more relevant and is receiving greater attention from the academic community.

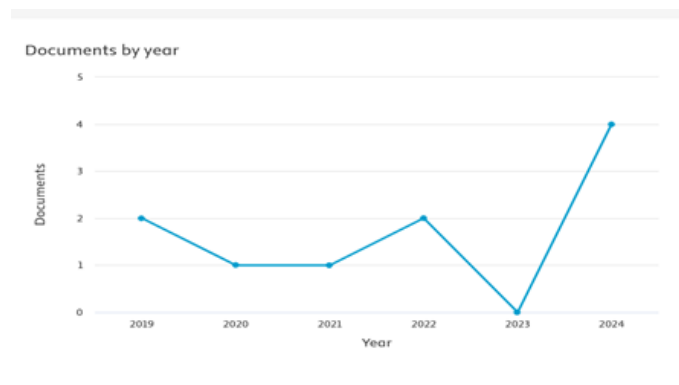


Figure 9: Graphic

Subject Area

Based on the data presented in the "Documents by Subject Area" chart, it can be observed that the topic of "sustainability competence and measurement" has broad relevance across various fields. The fields of Medicine, Biochemistry, Genetics, and Molecular Biology, and Immunology and Microbiology each contribute 20% of the total documents. This indicates that sustainability concepts are increasingly being applied in health and life sciences sectors, whether through measuring the environmental impact of medical practices or research in genetics and biochemistry that incorporates sustainability. With the growing focus on sustainability in medicine, there is potential to integrate these principles into healthcare resource management, drug development, or measuring their impact on health systems.

Additionally, the field of Agricultural and Biological Sciences also makes a significant contribution, with 20% of the total documents. This reflects the importance of sustainability in the agriculture and biology sectors, where topics related to ecosystem management or measuring sustainability in agricultural and biological practices are receiving increasing attention. Veterinary and Multidisciplinary fields contribute smaller portions but still show the relevance of this topic in animal health and interdisciplinary approaches. Overall, this data highlights that sustainability competence and its measurement are becoming a key focus in research across various scientific disciplines, illustrating the importance of integrating sustainability within these fields.

Table 6: Information on Instruments Used in Each Reference

No	Author(s) & Year	Instrument	Purpose	Important Information about the Instrument
1	Sundari et al., (2022)	Bioprospecting Tool for <i>C. rotundus</i> Extraction & Analysis (BPT-CRE)	Used to assess the bioactive compound yields from <i>C. rotundus</i> and their relevance to environmental and health-based applications.	The BPT-CRE facilitates biotechnological assessments by extracting bioactive compounds from <i>C. rotundus</i> to test against various plant pathogens and evaluate antimicrobial properties.
2	Hernandez et al., (2023)	Project-Based Learning Framework (PjBL) Applied to Bioprospecting of Plants in STEM	Focuses on applying the STEM-PjBL approach for bioprospecting in agricultural biotechnologies, enhancing practical learning.	This framework guides students through real-world experiments on <i>C. rotundus</i> as part of a STEM project, encouraging exploration, research, and innovative thinking in plant biotechnologies.
3	Hassan et al., (2020)	STEM-based Bioprospecting Assessment (SBBA)	To assess the application of STEM principles in the bioprospecting of <i>C. rotundus</i> for antimicrobial properties.	The SBBA tool evaluates how effectively students integrate scientific methods with real-world applications in studying <i>C. rotundus</i> , including lab experiments and project-based evaluation.
4	Chavez et al., (2021)	Eco-Bioprospecting Evaluation (EBE) Instrument	This tool is designed to evaluate environmental impacts and sustainable practices in the bioprospecting of <i>C. rotundus</i> .	The EBE instrument helps in identifying the ecological footprint of bioprospecting activities, especially focusing on the extraction processes used in <i>C. rotundus</i> research in STEM curricula.
5	Zhang et al., (2022)	Bioactive Compound Analysis and Environmental Integration Tool (BCA-EIT)	Used for analyzing the bioactive compounds from <i>C. rotundus</i> within the context of sustainable agricultural practices.	The BCA-EIT tool integrates compound extraction with environmental factors, assessing the balance between scientific discoveries and environmental responsibility within biotechnological research.

Research related to *Cyperus rotundus* (*C. rotundus*) in the context of biotechnology, particularly bioprospecting and its application in STEM (Science, Technology, Engineering, and Mathematics) Project-Based Learning (STEM-PjBL), is rapidly growing. Various research instruments have been developed to assess the bioactive compounds of *C. rotundus*, their environmental impacts, and their application in education. Below is a summary of several instruments used in the study of *C. rotundus* focusing on bioprospecting and STEM applications.

1. 1. Bioprospecting Tool for *C. rotundus* Extraction & Analysis (BPT-CRE) - Sundari et al. (2022) The Bioprospecting Tool for *C. rotundus* Extraction & Analysis (BPT-CRE) is used to evaluate the yields of bioactive compounds from *C. rotundus* and their relevance to environmental and health-related applications. The BPT-CRE facilitates biotechnological assessments by extracting bioactive compounds from *C. rotundus* to test against various plant pathogens and evaluate antimicrobial properties. This tool is instrumental in developing applications in plant disease control and herbal-based medicine, and it allows for the evaluation of both health and environmental impacts.
2. 2. Project-Based Learning Framework (PjBL) Applied to Bioprospecting of Plants in STEM - Hernandez et al. (2023) The Project-Based Learning Framework (PjBL) is applied to bioprospecting *C. rotundus* in the context of STEM education. This framework aims to enhance practical learning by guiding students through real-world experiments, focusing on *C. rotundus* as part of a STEM project. By fostering exploration, research, and innovative thinking, this approach encourages students to engage in hands-on biotechnological research. The PjBL model helps students understand the practical applications of bioactive compounds from *C. rotundus* in various industries and agricultural technologies.

25 Conclusion

Integrating *Cyperus rotundus* (teki grass) as a natural probiotic within STEM-PjBL-based pharmacognosy modules offers significant educational potential, bridging traditional knowledge with modern scientific inquiry. As interest in bioprospecting and local plants like *C. rotundus* grows, the need for sustainable practices and real-world applications in science education becomes increasingly apparent. Despite its promising applications, the use of *C. rotundus* in pharmacognosy education is still underexplored, pointing to the need for more comprehensive studies. The bibliometric analysis indicates a growing focus on the intersection of ethnopharmacology, sustainability, and educational frameworks, with substantial progress made in recent years. Studies suggest that tools like the Bioprospecting Tool for *C. rotundus* (BPT-CRE) and Project-Based Learning (PjBL) frameworks enhance student learning in biotechnology and sustainability. Furthermore, instruments such as the STEM-based Bioprospecting Assessment (SBBA) and Eco-Bioprospecting Evaluation (EBE) are vital in ensuring environmentally responsible biotechnological research. Incorporating *C. rotundus* into STEM-PjBL modules provides students with hands-on experiences that foster innovation, entrepreneurship, and critical thinking, preparing them for challenges in natural product-based industries. Although there are gaps in the literature, future research should focus on documenting outcomes, refining educational tools, and understanding how integrating local medicinal plants can contribute to sustainable pharmaceutical education.

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23. Zhang, et al. (2022). Bioactive Compound Analysis and Environmental Integration Tool (BCA-EIT). Assesses the balance between scientific discovery and environmental responsibility, important for your study's sustainability goals (PLAGIASI CEK 5)

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