A BIBLIOMETRIC ANALYSIS OF *CLITORIA TERNATEA*

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ABSTRACT: *Clitoria ternatea* L. has gained more attention from the scientific community in the recent years due to its potential biological properties including antidiabetic, anticancer, anti-inflammatory and antimicrobial activities. This explains the increment in the number of scientific studies done on the plant. However, there is no available paper found on the bibliometric analysis of *C. ternatea* specifying the important relationship between the content of the bioactive compounds, the types of research and the geographical diversity. Thus, this study aims to conduct a bibliometric analysis on the research trends, spatial distribution and related bioactive compounds of the *C. ternatea*. Search term ("*Clitoria ternatea*") OR ("Blue Butterfly Pea flower") is used as the keyword in SCOPUS database and 598 publications were found within the period of 1954 until 2020. The growth of publications showed a sharp increase in 2011 and 2018 and keep growing throughout the years since then. The VOSviewer programme was used to analyze keywords, countries, bioactive compounds, medicinal benefits and authors through visual knowledge mapping to assess the research trends. However, only 43% of the publications were selected for further analysis subsequent to screening stage. Results on the relationship between *C. ternatea* and bioactive compounds showed that antioxidant was the most frequently encountered pharmaceutical potential and anthocyanin was the most frequently encountered biological properties. The geographical distribution analyses showed that most researches were originated from Southeast Asian countries. The bibliometric analysis performed in this study has identified trends in *C. ternatea* plant from 1954 to 2020, which will guide the future directions in this research field.

KEY WORDS: *Clitoria ternatea, Medicinal plant, Bioactive compounds, Functional food, Bibliometric analysis*

1. INTRODUCTION

Nowadays, people prefer to utilize natural based products because they are safe and free from synthetic and artificial ingredients. Humans have been using natural products since prehistoric times and with limited knowledge and sources, they have done numerous trials and errors to learn how to recognize, prepare, formulate, and utilize suitable plants to be used for their ailments [1]. *C. ternatea*, generally known as blue butterfly pea flower is a herbal plant which comes from Fabaceae family. The Fabaceae is a large pea or bean family of flowering plants with medicinal benefits. The *C. ternatea* plant species is easy to maintain, and it can be widely found in Africa, Asia and Central America [2]. Flavonoids, anthocyanins, steroids, saponins, taraxerol and tannins are some of the bioactive compounds

found in in this plant [3-4]. Over the years, *C. ternatea* has gained interest within the research community due to its benefits in agriculture and medicine including the potential as anti-inflammatory, analgesic, antipyretic, antidiabetic and antioxidant activity [5].

The morphology of *C. ternatea* comprises flowers, fresh and old pods, leaves, and roots as shown in Fig. 1. There are varieties of distinct shapes of the flower and colour influenced by geographical locations that *Clitoria Ternatea* stems from. Fig. 2 showcases the different flower types and colours of *C. ternatea*. The most distinct trait of the flower, however, is the inner part which resembles that of the female genitalia, hence the name "Clitoria".

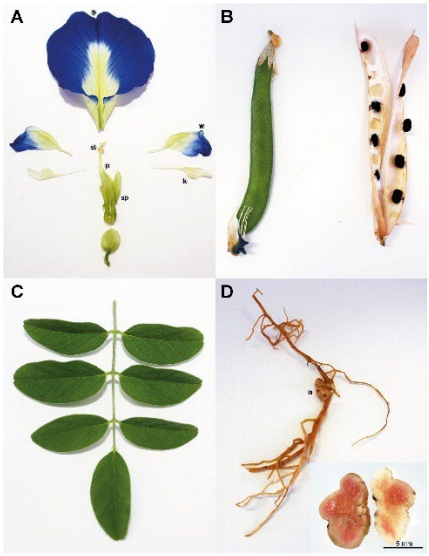

Fig. 1. Morphology of C. ternatea plant (A: flower, B: pods, C: leaves, D: roots with nodules). Adopted from Oguis et al., 2019

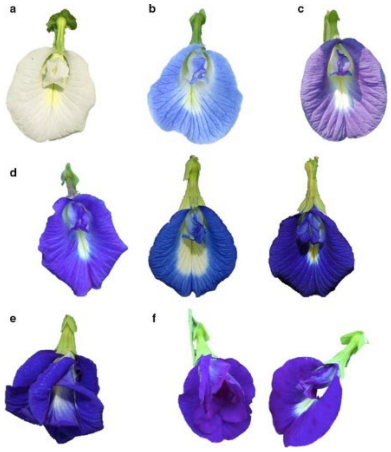

Fig. 2. Distinct flower types and colours of *C. ternatea* - a = white, single flower; b = light blue, single flower; c = light purple, single flower; d = dark blue-dark purple, single flower; e = dark blue-dark purple, double flower; f = dark blue-dark purple, mixed (single and semi-double) flower. Adopted from Havananda & Luengwilai, 2019.

Bibliometric analysis is an interdisciplinary approach to discover any research trends since it quantitatively and qualititatively analyzes the production, growth, and consumption

of scientific publications [6]. [7] reported that the term "bibliometrics" was originally coined by Pritchard (1969) to replace the classical term "statistical bibliographies".

Previously, there have been numerous scientific studies of bibliometric analysis done on the application of natural remedies on various diseases. Some of them includes study on the use of herbal medicine for obesity and rheumatoid arthritis [8] and [9] respectively, prevention and treatment of gastric ulcer [10], cytotoxicity and toxicity assays of medicinal plant [11], anticancer activity of herbs [12], and trends for stroke research [13]. From these studies, it is proven that the bibliometric analysis is helpful in the process of discovering trend of studies.

In this study, bibliometric analysis is performed to investigate the research trends of *C. ternatea* studies while analysing the spatial distribution of the study and discovering the identified bioactive compounds. This method is selected because of its ability to discover the current research gap and predict future trend [14]. The types of bibliometric network relations that are commonly studied are citation, co-citation, bibliographic coupling, keyword co-occurrence and co-authorship. In this study, analysis on co-occurrences and bibliographic coupling are performed.

2. MATERIALS AND METHODS

The techniques of performing bibliometric analysis can be categorised into review technique, evaluative technique, and relational technique [15]. The review technique is a method which collect information from the bibliographic data of published documents and statistical analyses. Systematic review, meta-analysis and qualitative study are some examples of this technique. The evaluative technique measures the academic impact on three factors: (1) productivity (number of papers per year and per individual author), (2) impact metrics (total number of citations per year and per individual author/journal and so forth, and (3) hybrid metrics (average number of citations per paper, productivity and impact indeces [16 – 18]. The third technique namely the relational technique, allows for the exploration of the relationship between categories within a research field including the structure of a research topic and patterns among authors or affiliations [15]. The analyses performed by the relational technique can be grouped into bibliographic coupling, co-authorship analysis, co-citation analysis, and co-word analysis [18]. Among the three techniques, the review and evaluative techniques do not allow the identification of networks between the authors [15, 18]. Hence, this study utilized the relational technique for its bibliometric analysis. Details of the implementation of the relational technique im this study is discussed in Section 2.4. The bibliometric analysis in this study comprises four stages, database selection, data screening, data extraction and data analysis. The flow diagram of the selection stages is shown in Fig. 3.

2.1. Research Questions

The specific objectives of this study are to discover the research trends of *C. ternatea*, to examine the spatial distributions of its studies, and to identify the types of bioactive compounds possessed by this plant species. Following these research objectives, the present study intends to answer the following research questions:

RQ 1: What are the global research trends for blue butterfly pea flower species?

RQ 2: What are the spatial distributions of *C. ternatea* studies?

RQ 3: What are the bioactive compounds in the plants?

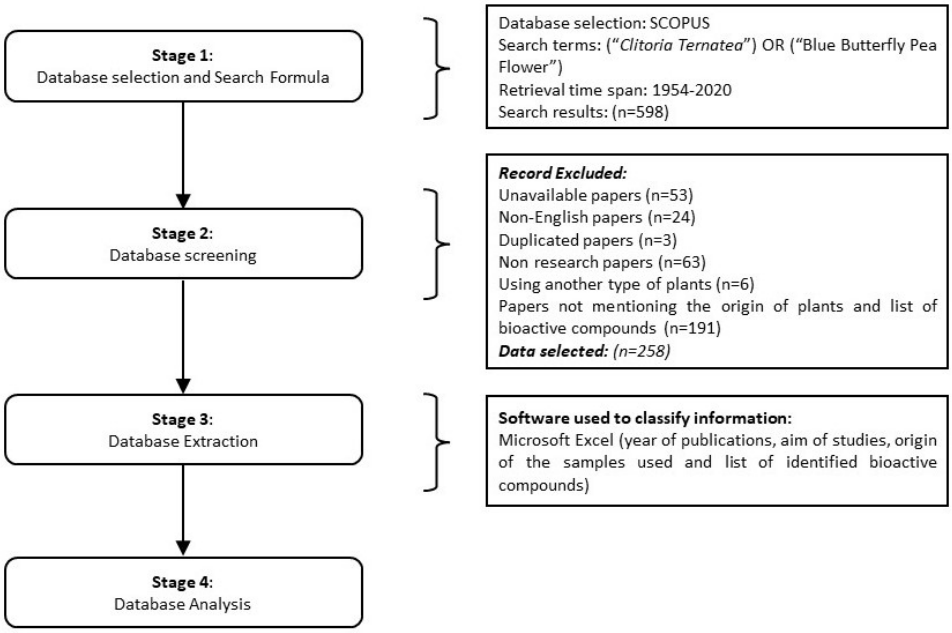

Fig. 3. Flow diagram of the selection process.

2.2. Database Selection

The first step in bibliometric analysis is to decide on the appropriate database to be used to obtain the relevant documents based on the established research questions. In this study, SCOPUS database was selected because it offers two methods of search; a basic and an advanced search in which complex and long search queries can accomplished the objective with high validity. Furthermore, this online database allows users to export the documents in various formats such as in Mendeley, RefWorks, RIS, .csv, BibTex and PlainText format.

2.2.1 Search Formula

The search applied used a Boolean operator 'OR' in which a combination of the words ("*Clitoria ternatea*") OR ("blue butterfly pea flower") is searched within article title, abstract and keywords (TITLE-ABS-KEY) field in SCOPUS website.

2.3 Data Screening and Data Extraction

The available publications among the obtained 598 number of results are downloaded in PDF format to ease further analysis. The titles and abstracts of selected papers are heavily screened. However, when the required information is not available in the title and the abstract, material and methods and conclusion sections are also screened. The whole paper screening following the inclusion and exclusion criteria listed in Table 1 is performed by six main steps. This screening result are extracted in Microsoft Excel in form of tables to classify the required information according to the year of publication, aim of studies, origin of the samples used and list of identified bioactive compounds.

Table 1: Inclusion and exclusion criteria for data screening

Criteria	Decision
Articles must be written in English language	Inclusion
Duplicated articles within the same search results	Exclusion
Reviews, conference abstract and systematic review articles	Exclusion
Articles must mention the origin of the plant sample used	Inclusion
Article must list down the bioactive compounds in the plant	Inclusion
Articles that are not available or accessible	Exclusion
Articles using samples of another type of plants	Exclusion

Firstly, within the 598 papers found, it was identified that there were 53 unavailable papers mainly because these papers did not provide the DOI numbers of the documents and most of them were old papers that were unaccessible. Secondly, there were 24 papers that did not use English language and the languages used were Spanish, Portuguese, German and Japanese languages. Next, the three duplicated papers were removed. In the fourth screening step, the non-research papers including review articles, erratum articles and letters totalled 63 papers and all of them were excluded.

Then, six papers using plant types other than *Clitoria Ternatea* were also rejected. Finally, in the final step, it is found out that there are 176 papers that do not mention the list of bioactive compounds screened, seven papers that do not state the origin of the plant samples used and there are eight papers that stated less info on the required information in which both the origin of the samples and bioactive compounds are not listed. Overall, 258 documents are qualified and selected for further data analysis. The selected publications are then analysed to obtain the visual projection of bibliometric study.

2.4 Data Analysis

The selected publications are exported from SCOPUS in a CSV format (comma separated values) to enable the visualization of data analysis through VOSviewer software version 1.6.15.

In applying the relational techniques for the bibliometric analysis, the VOSviewer was set up according to the following sequence. Firstly, in the create map pop-up, choose the create a map based on bibliographic data option. Secondly, under choose data source, select the read data from bibliographic database file. Next, select the corresponding folder or files, and finally under the choose type of analysis and counting method, choose co-occurence for type of analysis, authors for unit of analysis, and full counting for counting method.

3. RESULTS AND DISCUSSION

3.1 Distribution of Publications by Years

Search result from SCOPUS obtained 598 publications. The retrieval time span is from 1954 to 2020. This result excludes the publications from the year 2021 onwards whilst not limiting the earliest year of the publications occurrence in order to indicate the year

researchers started to discover *C. ternatea* species. Overall, there was an increasing trend in the number of publications per year from 1954 to 2020 as shown in Fig. 4. This increment indicates that people start to acknowledge the potential benefits of this plant species. From these 598 publications, 258 publications were selected after data screening is performed according to the criteria listed in Table 1.

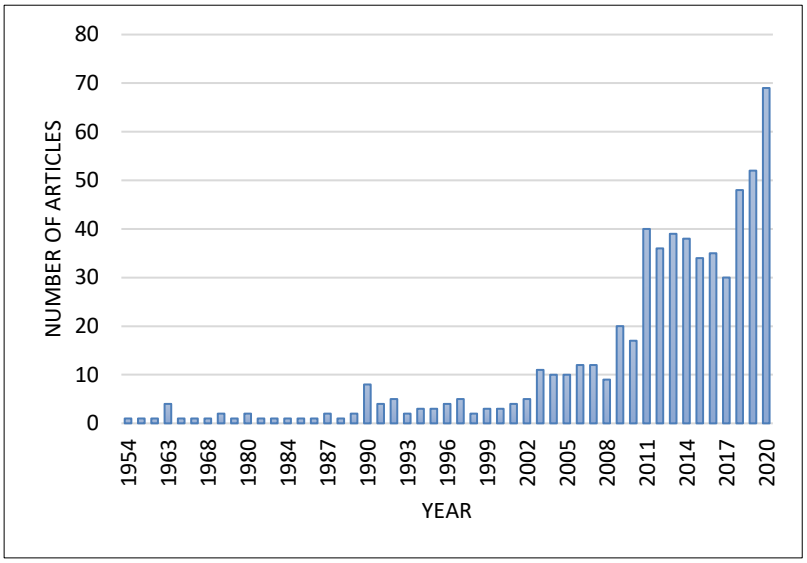

Fig. 4. Distribution of *C. ternatea* studies.

3.2 Keywords

Analysis performed on the co-occurrence of keywords identified 754 keywords used by authors in their studies. Fig. 5 shows circles of different sizes that represent the frequency of occurrences of the keywords used by the authors. A bigger circle indicates that the keywords are frequently used. The most frequent keywords used are *C. ternatea* with 93 occurrences followed by antioxidant with 20 occurrences, anthocyanin with 17 occurrences and butterfly pea with 16 occurrences (Table 2). The keywords used in the publications allow for tracking the evidence of the topics that have been studied related to *C. ternatea*.

3.3 Research Trends

Fig. 6 shows the research trends of the 258 publications which spans over 24 themes, with phytochemical and pharmacological as the two highly discussed themes. This shows that the potentials of *C. ternatea* have attracted the interest of diverse scientific fields. The scope of phytochemical researches covers the extraction, screening and identification of the bioactive compounds in *C. ternatea*. The next trending research fields are pharmacological and pharmaceutical studies. Pharmacological researches focused on how the chemical compounds affect the body systems while pharmaceutical researches is a study about drug development, physical and chemical properties of the drugs and their tolerable dosage [19]. For *C. ternatea,* its medicinal potentials were tested such for various biological properties including antidiabetic, anticancer and anti-inflammatory [20]. In agricultural sector, *C. ternatea* are tested as ruminant feeding and as pesticides [21]. For plant cell culturing, they are studied to establish a mass production of *C. ternatea* followed by testing on their antimicrobial and antibacterial activities [22-23].

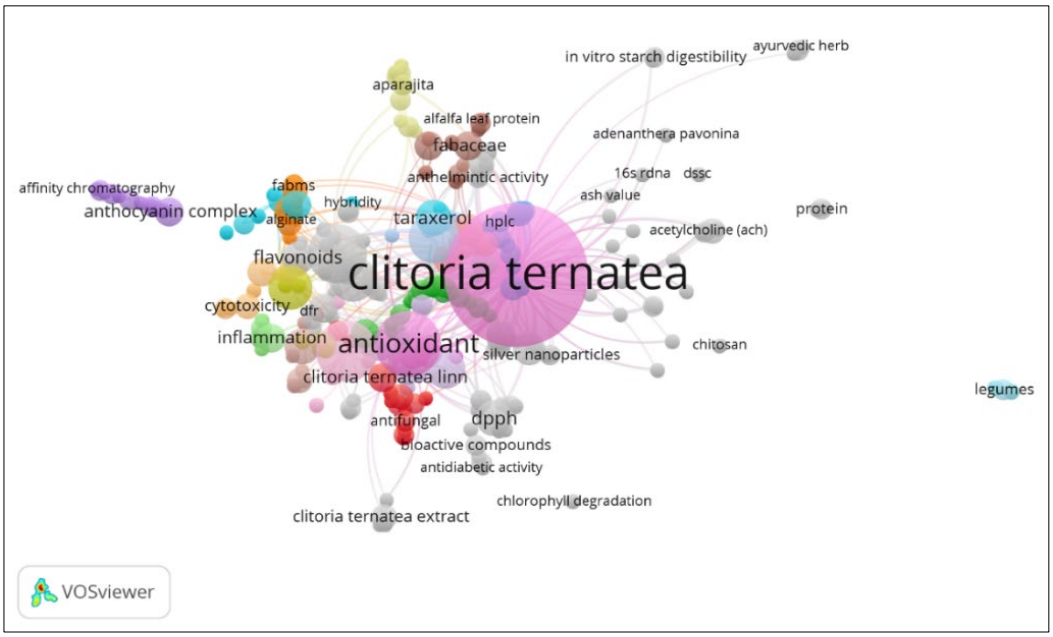

Fig. 5. Mapping on co-occurrences of author keywords related to *Clitoria ternatea*.

Table 2: Top 10 keywords used by authors in studies.

Number	Keywords	Occurrences
1	*Clitoria ternatea*	93
2	Antioxidant	20
3	Anthocyanin	17
4	Butterfly pea	16
5	*Clitoria ternatea* L.	12
6	Antioxidant activity	10
7	Anthocyanins	9
8	Antibacterial activity	7
9	DPPH	6
10	Response surface methodology	6

In the study of dye colorant, this plant is mostly tested for their applications in hair dye, textiles and food industries [24-26]. In food and nutrition study, *C. ternatea* are used not only to improve quality of food but to bring positive health effects to human bodies. Their extracts are also used to synthesize the nanoparticles in nanotechnology as they are safe to environment. In characterization scope, this plant species is characterized to determine their morphology and phenology traits [22].

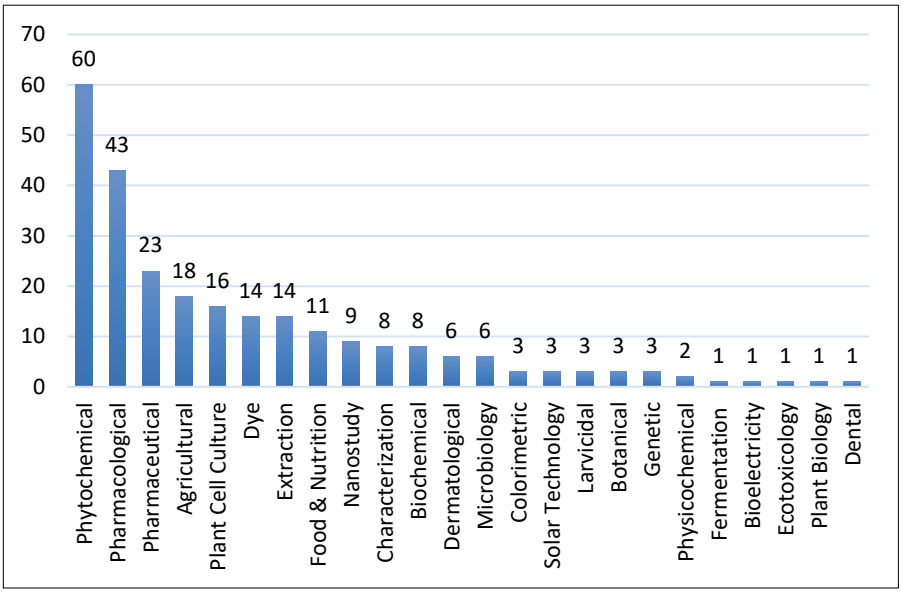

Fig. 6. Research trends of *C. ternatea* studies analysed from 258 papers.

3.4 Countries

Fig. 7 shows the visual mapping of the countries where the publications were published. The analysis is performed on the bibliographic coupling with geographical distributions. The bigger the circles is, the higher the numbers of publications published by the countries. The circles that are close together represent the publications that are citing the same publications and based on bibliographic coupling, they are strongly related to each other [24]. The countries with the most contribution to educational research literatures were made as focal points in the visual map [27]. Among 32 countries, India topped the list with 107 papers, followed by Thailand (40), Malaysia (39), Japan (18), Indonesia (16) and United States (16). Based on Fig. 8, India also topped the list of the origin that the plant samples were used by the researchers to carry out their studies. This is because, in India, *C. ternatea* is widely used as one of the Ayurvedic treatment and thus, various studies are conducted by the researchers in India including verification of its authentication in pharmaceutical industries [19, 28]. From these two results, India is possibly a country with a rich source of natural biodiversity.

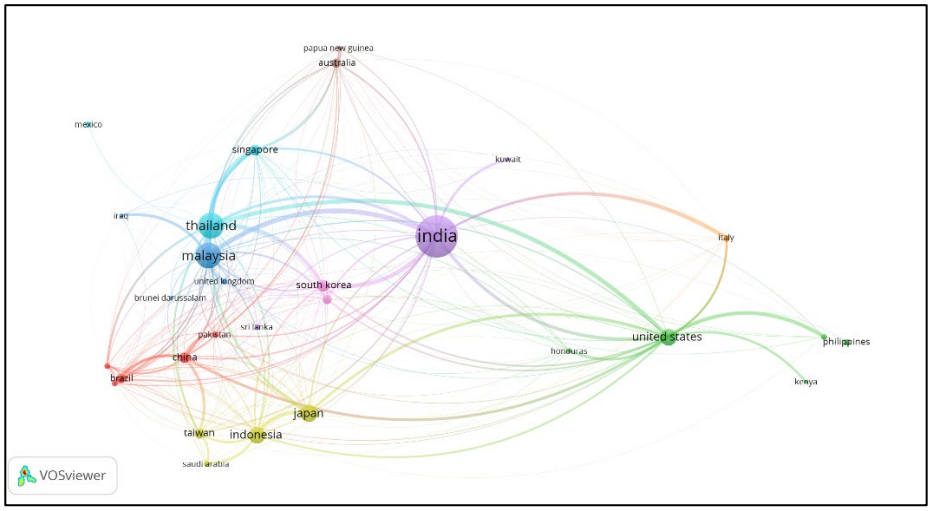

Fig. 7. Mapping on bibliographic coupling of geographic distributions of publications.

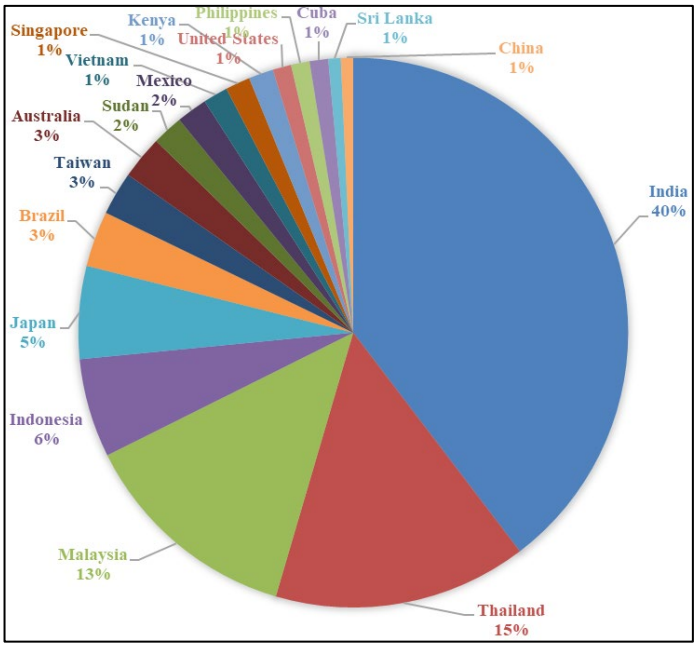

Fig. 8. Papers percentage for origin of plant samples by researchers.

3.5 Bioactive Compounds

Table 4 shows the list of some of the identified bioactive compounds from the morphology of the *C. ternatea* species. It shows that some parts of this plant have a unique bioactive compound and some parts have bioactive compounds that are similar to other parts. For example, the petals contaithocyanin which are not found in other parts of the plant whilst flavonoids can be found in both seeds and petals. The variations of the phytochemicals in *C. ternatea* explains the increment of researches performed on them in recent years.

Table 4: Morphology of *C. ternatea* and its corresponding bioactive compounds

Morphology of *C. ternatea*	**Bioactive compounds**	**Reference**
Roots	Taraxerol	[19]
Seeds	Sterols, alkaloids, glycosides, saponins, tannins,phenolic compounds & flavonoids	[29]
Whole plants	Alkaloids, glycosides, flavonoids, tannins, saponin & steroids	[4]
Roots, stems and leaves	Taraxerol and β-sitosterol	[30]
Petals	Anthocyanins and flavonoids	[3]

4. CONCLUSION

This study shows that the numbers of research performed on *C. ternatea* species has been increasing in the over the years. Recently, *C. ternatea* has been tested more profoundly in the area of solar cells, nanoparticles and colorimetric studies. This shows that the usage of this plant is not limited to only medicinal purposes and nutritional food intake. Moreover, the analysis of this study shows that phytochemical traits of *C. ternatea* are not affected by plant morphologies, but they are slightly affected by geographical distributions of the plants. The aim of identifying the spatial distributions of this study is generally achieved of which India topped the other countries by contributing the most to the publications of studies in *C. ternatea*. Bibliometric analysis supported the results of research trends and spatial distribution of studies through the mapping visualization of the studies on the author keywords and publication countries since the VOSviewer software compressed large amount of data into a result of data visualization. In conclusion, this bibliometric analysis provides a comprehensive overview of the research trends on *C. ternatea* studies and can facilitate its future studies.

ACKNOWLEDGEMENT

Authors wishing to acknowledge the Department of Chemical Engineering and Sustainability, Kulliyyah of Engineering, IIUM for providing support to conduct this study.

REFERENCES

[1] Yuan H, Ma Q, Ye L, Piao G. (2016) The traditional medicine and modern medicine from natural products. Molecules, 21(5):559.

[2] Singh NK, Gupta JK, Shah K, Mishra P, Tripathi A, Chauhan NS, Upmanyu N. (2017) A Review on Clitoria ternatea (Linn.): Chemistry and Pharmacology Medicinal Plants and Its Therapeutic Uses Hyderabad, India: OMICS International.

[3] Jaafar NF, Ramli ME, Salleh MR. (2020) Extraction condition of Clitorea ternatea flower on antioxidant activities, total phenolic, total flavonoid and total anthocyanin contents Trop. Life Sci. Res., 31(2):1–17.

[4] Kanthal LK, Naidu AVR, Lakshmi PN, Baburao Y, Bhar K. (2016) Evaluation of cytotoxic activity and anthelmintic property of chloroform extract of Clitoria ternatea L. Int. J. Curr.

Pharm. Res., 8(4):73.
[5] Oguis GK, Gilding EK, Jackson MA, Craik D.J. (2019) Butterfly pea (Clitoria ternatea), a cyclotide-bearing plant with applications in agriculture and medicine. Front. Plant Sci., 10:645.
[6] Ellegaard O, Wallin JA. (2015) The bibliometric analysis of scholarly production: How great is the impact? Scientometrics, 105:1809-1831.
[7] Moral-Muñoz JA, Herrera-Viedma E, Santisteban-Espejo, A, Cobo MJ. (2020) Software tools for conducting bibliometric analysis in science: An up-to-date review. Information Professional, 29(1).
[8] Seo Y, Park HS, Kim H, Kim KW, Cho JH, Chung WS, Song MY. (2022). A bibliometric analysis of research on herbal medicine for obesity over the past 20 years. Medicine, 101(23):e29240.
[9] Kang DY, Kim H, Kim KW, Chung WS. (2022) Bibliometric analysis of research relating to the use of herbal medicine for rheumatoid arthritis between 1991 to 2021. Medicine, 101(37):e30413.
[10] Wang X, Wang X, Wen M, Li, X. (2023) Bibliometric analysis of literature on prevention and treatment of gastric ulcer with natural medicines. Journal of Future Foods, 3(3): 225-233.
[11] Júnior ECF, Costa BP, Freira JCP, Melo WOS, Pessôa HLF, Gomes DQC, Costa EMMB, Pereira JV. (2019) Use of erythrocytes in cytotoxicity and toxicity assays of medicinal plant extracts: Analysis of their application and bibliometric study. Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas, 18:359-377.
[12] Basu T, Mallik A, Mandal N. (2017) Evolving importance of anticancer research using herbal medicine: a scientometric analysis. Scientometrics, 110(3):1375-1396.
[13] Huang L, Shi X, Zhang, N. et al. Bibliometric analysis of trends and issues in traditional medicine for stroke research: 2004–2018. BMC Complement Med Ther 20, 39 (2020). https://doi.org/10.1186/s12906-020-2832-x.
[14] Van Eck NJ, Waltman L. (2014) Visualizing bibliometric networks in measuring scholarly impact cham. Springer International Publishing, 285–320.
[15] Fabregat-Aibar L, Barberà-Mariné MG, Terceño A, Pié L. (2019). A bibliometric and visualization analysis of socially responsible funds, 11(9): 2526.
[16] Hall CM. (2011) Publish and perish? Bibliometric analysis, journal ranking and the assessment of research quality in tourism. Tour. Manag., 32:16-27.
[17] Hirsch JE. (2005) An index to quantify an individual's scientific research output. In Proceedings of the National Academy of Sciences, Stuttgart, Germany, 102(2005): 16569–16572.
[18] Zupic I, ˇCater, T. Bibliometric methods in management and organization. Organ. Res. Methods.
[19] Kumar V, Mukherjee K, Kumar S, Mal M, Mukherjee PK. (2008) Validation of HPTLC method for the analysis of Taraxerol in Clitoria ternatea. Phytochem. Anal., 19(3): 244-250.
[20] Das A, Priya GS, Deepesh SP, Edwin AR, Vihashinee E, Rubiga A, Megavathini S, Eswaran J, Bindhu J. (2020) Antibacterial and in vitro anticancer study of methanol extracts of Clitoria ternatea leaves. J. Nat. Remedies, 20(2):96-102.
[21] García-Ferrer L, Bolaños-Aguilar ED, Lagunes-Espinoza LC, Ramos-Juárez J, Osorio-Arce MM. (2016) Concentration of phenolic compounds in tropical forage fabaceae at different regrowth time. Agrociencia, 50(4):429-440.
[22] Barik DP, Naik SK, Mudgal A, Chand PK. (2007) Rapid plant regeneration through in vitro axillary shoot proliferation of butterfly pea (Clitoria ternatea L.) a twinning legume In Vitro Cell. Dev. Biol. Plant, 43(2):144-148.
[23] Arumugam M, Panneerselvam R. (2012) In vitro propagation and antibacterial activity of Clitoria ternatea Linn. Asian Pac. J. Trop. Biomed., 2(2):S870–S875.
[24] Priprem A, Saodaeng K, Lertrat K. (2014) Thermal stability and hair dye of anthocyanin complex from Zea mays L. Clitoria ternatea. L. Appl. Mech. Mater, 563:375–378.
[25] Kanchana R, Fernandes A, Bhat B, Budkule S, Dessai S, Mohan R. (2013) Dyeing of textiles

with natural dyes -an eco-friendly approach Int. J. Chem. Tech. Res., 5(5):2102–2109.

[26] Charurungsipong P, Tangduangdee C, Amornraksa S, Asavasanti S, Lin J. (2020) Improvement of anthocyanin stability in butterfly pea flower extract by co-pigmentation with catechin E3S Web Conf, 141:03008.

[27] Güneş E, Üstündağ MT, Yalçın H, Safran M. (2017) Investigating educational research articles (1980-2014) in terms of bibliometric indicators. Int. Online J. Educ. Sci., 101-117.

[28] Patel ND, Kanaki NS. (2020) Fingerprint analysis of Shankhpushpi for species discrimination by HPLC coupled with chemometric methods. J. Liq. Chromatogr. Relat. Technol., 43(13–14):455-463.

[29] Kalyan BV, Kothandam H, Palaniyappan V, Praveen AR. (2011) Hypoglycaemic activity of seed extract of Clitoria ternatea Linn in streptozotocin-induced diabetic. Rats Pharmacogn. J., 3(19):45-47.

[30] Makasana J, Dholakiya BZ, Gajbhiye NA, Bishoyi AK, Raju S. (2016) Assessment of chemicaldiversity in Clitoria ternatea accessions by an improved and validated HPTLC method. Indian Journal of Agricultural Sciences, 86(9):1133-1139.