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Research trend in latex harvesting of rubber tree *(Hevea brasiliensis* Muell. Arg.) based on bibliographic analysis

Tendencia de investigación en la cosecha de látex del árbol del caucho (*Hevea brasiliensis* Muell. Arg.) basada en análisis bibliográfico

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Abstract

The rubber plant (*Hevea brasiliensis* Muell. Arg.) is the main natural rubber-producing species. Researches on rubber has been carried out for more than a century. Researchers and academics should stay up to date with the current scientific issues including latex harvesting in *H. brasiliensis* Muell. Arg. This article presents a bibliometric analysis of scientific literature indexed by Scopus and published from 2018 to 2022. The literature was categorized into three sub-topics *i.e.*, latex harvesting techniques (38 papers), physiological mechanisms (41 papers), and oxidative stress induced by latex harvesting practices (18 papers). Metadata validation was performed using Mendeley reference management software and bibliometric analysis was carried out using VOSviewer bibliometric network visualization software. The results on the latex harvesting technique showed that most of the articles were related to the development of automatic tapping machines. This indicates a trend that latex harvesting techniques are likely shifting from manual tapping to fully automated methods using machines and robots. In terms of physiological mechanisms related to latex production, the mechanism of rubber biosynthesis and ethylene response at the genomic, transcriptomic, and proteomic levels predominated the finding. Research on oxidative stress induced by tapping mainly focuses on the effects of mechanical wounding and ethylene stimulation, while research on antioxidants is still limited. In the past five years, biotechnology and molecular analysis are the main tools to study physiological mechanisms and oxidative stress. This can be a consideration for scientists and research institutions to develop laboratories and human resources to be able to conduct molecular-based research.

Keywords: *Hevea brasiliensis* Muell. Arg.*,* ethylene stimulation, mechanization, oxidative stress, rubber biosynthesis.

Resumen

La planta de caucho (*Hevea brasiliensis* Muell. Arg.) es la principal especie productora de caucho natural. Investigaciones sobre caucho se han llevado a cabo durante más de un siglo. Los investigadores y académicos deben mantenerse al día con los temas científicos actuales, incluidos la recolección de látex en *H. brasiliensis*. Este artículo presenta un análisis bibliométrico de la literatura científica indexada por Scopus y publicada entre 2018 y 2022. La literatura se clasificó en tres subtemas, por ejemplo, técnicas de recolección de látex (38 artículos), mecanismos fisiológicos

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(41 artículos) y estrés oxidativo inducido por prácticas de recolección de látex (18 artículos). La validación de los metadatos se realizó con el software de gestión de referencias Mendeley y el análisis bibliométrico se llevó a cabo con el software de visualización de redes bibliométricas VOSviewer. Los resultados sobre las técnicas de recolección de látex mostraron que la mayoría de los artículos estaban relacionados con el desarrollo de máquinas automáticas de roscado. Esto indica una tendencia de que las técnicas de recolección de látex probablemente estén cambiando de la extracción manual a métodos totalmente automatizados que utilizan máquinas y robots. En cuanto a los mecanismos fisiológicos relacionados con la producción de látex, el mecanismo de biosíntesis del caucho y la respuesta del etileno a nivel genómico, transcriptómico y proteómico predominaron en el hallazgo. La investigación sobre el estrés oxidativo inducido por el roscado se centra principalmente en los efectos de las heridas mecánicas y la estimulación con etileno, mientras que la investigación sobre los antioxidantes aún es limitada. En los últimos cinco años, la biotecnología y el análisis molecular son las principales herramientas para estudiar los mecanismos fisiológicos y el estrés oxidativo. Esto puede ser una consideración para los científicos y las instituciones de investigación para el desarrollo de laboratorios y recursos humanos con los que se pueda realizar investigaciones de base molecular.

Palabras claves: *Hevea brasiliensis* Muell. Arg., estimulación con etileno, mecanización, estrés oxidativo, biosíntesis de caucho.

Introduction

The rubber plant (*Hevea brasiliensis* Muell. Arg.) is the main natural rubber-producing species. This perennial plant has been cultivated for more than a century, mainly in the south and southeast Asia and in tropical regions from Africa and America (Pinizzotto, 2019). The most economical part is the latex, which is synthesized in special cells called laticifers. Latex harvesting of latex is performed through tapping; slicing the bark tissues so that the latex can flow out. The rubber tapping system evolved from many slices in one tree to one or two slices to extend the economic life as well as the use of ethylene stimulants to increase yields and save labor costs (Junaidi, 2020). Several tapping methods have been tested to obtain high yields, including the puncture tapping system (de Soyza & Samaranayake, 1983; Hamzah & Gomez, 1981), the upward tapping system (Obouayeba et al., 2008; Pulchérie et al., 2021) and the double-cut tapping system (Chantuma et al., 2011; Rukkhun et al., 2012). Tapping research is mainly carried out in natural rubber-producing countries and several research institutions from non-producing countries are interested in tropical plantation crops.

Besides tapping techniques, in the last few decades, studies on the physiology of latex have developed rapidly, for example, latex diagnosis (LD), a method for estimating the plants' physiological condition by determining dry rubber, sucrose, inorganic phosphate, and thiol contents in latex (Adou et al., 2017; Jacob et al., 1995; Nair et al., 2004). LD aims to support production optimization and minimizes the negative impact of tapping on plant health. Additionally, the mechanism of rubber biosynthesis, response to ethylene stimulants, and oxidative stress caused by tapping activity were also investigated in depth.

For researchers, academics including students, and research institutions, it is very important to stay up to date with the latest research developments. In today's internet era, online publication allows an article to be accessed worldwide. This offers an opportunity to be aware of research activities in other parts of the world. Bibliometric analysis is a popular and rigorous method for analyzing scientific data. It allows the generation of evolutionary nuances and identifies the emerging areas of a specific field. A keyword analysis could identify the most popular subjects covered by bibliometric analysis (Donthu et al., 2021; Ellegaard & Wallin, 2015). Thanks to reference management and bibliographic tools and software, analyses nowadays can be performed in various material categories such as journal articles, books, theses, patents, and even reports. To our knowledge, a bibliographic

analysis of latex harvesting of rubber trees has not been reported.

Although the internet provides abundant papers related to latex harvesting, some of them are probably repetitious or modifications of previous research so they may have insignificant novelty. Scopus is one reputable abstract and citation database. Journals indexed by Scopus are considered to have high quality and often are used as a standard for scientific publication. To capture the evolution of the subject, a bibliometric analysis, using VOSviewer software, was carried out using journal articles and conference proceedings indexed by Scopus in the last five years (2018 to 2022). The analysis was aimed mainly to capture the popular keywords used by the authors in the field of latex harvesting techniques, physiological mechanisms, and oxidative stress induced by latex harvesting practices. The results will allow researchers, academics, and policymakers to develop research programs including breeding, yield optimization, and harvesting mechanization.

Material and methods

Articles searching

The strategy and software used in this work are presented in Figure 1. The articles were assessed from Scopus and published from January 2018 to March 2022. Online searching was conducted in three sub-topics *i.e.*, harvesting practices, physiological mechanism, and oxidative stress induced by harvesting practices. The keywords for latex harvesting practice were TITLE-ABS-KEY ((“hevea brasiliensis” OR “natural rubber”) AND (“harvesting” OR “tapping” OR “stimulation” OR “yield” OR “latex production”)) AND (LIMIT-TO (PUBYEAR,2022) OR LIMIT-TO (PUBYEAR,2021) OR LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018)). Searching keywords for the biological mechanism underlying latex production were TITLE-ABS-KEY ((“hevea brasiliensis” OR “ natural rubber”) AND (“harvesting” OR “tapping” OR “stimulation” OR “yield” OR “latex production” OR “biosynthesis” OR “regeneration” OR “metabolism”)) AND (LIMIT-TO (PUBYEAR,2022) OR LIMIT-TO (PUBYEAR,2021) OR LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018)). The keywords for online searching related to abiotic stress induced by tapping activities were TITLE-ABS-KEY ((“hevea brasiliensis” OR “natural rubber”) AND (“harvesting” OR “tapping” OR “stimulation” OR “wounding” OR “ oxidative stress” OR “stress response” OR “panel dryness” OR “antioxidant”)) AND (LIMIT-TO (PUBYEAR,2022) OR LIMIT-TO (PUBYEAR,2021) OR LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR, 2018)). All selected articles were exported to Mendeley reference management software, version 1.19.4 (Mendeley, 2020).

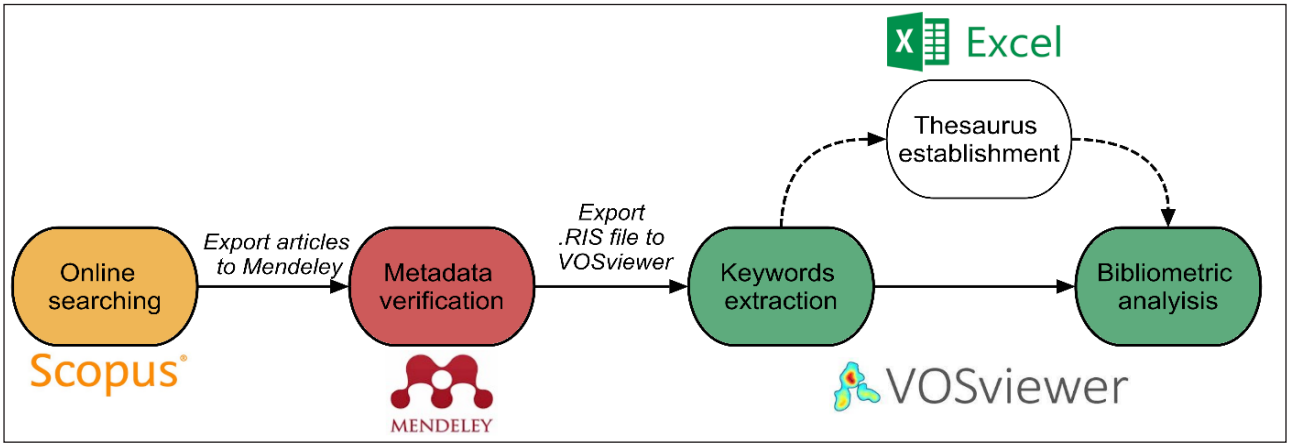

Figure 1. Activities and software used in the bibliometric work

Metadata verification

In Mendeley, the metadata of each article was checked, including title, year, authors, and keywords. According to the relevance, one article might be included in more than one sub-topics. A text file was generated for each sub-topic and was transferred to VOSviewer bibliometric network software version 1.6.18 (van Eck & Waltman, 2022).

Thesaurus establishment

A text file containing a list of keywords was extracted from VOSviewer. The thesaurus, a list of merged keywords with similar meanings was established for each sub-topic in a Microsoft Excel file version 16.0.4266.1001 (Microsoft Office Professional Plus, 2016).

Bibliometric networks construction and visualization

A network map was generated for each sub-topic based on the occurrence of the keyword. This step provided keyword clusters in the "items" section. The keywords in each cluster were noted for each sub-topic. Overlay visualization was selected to identify the evolution of keywords used by the authors. For harvesting practices and oxidative stress, the maps were established using a minimum of two occurrences, while for physiological mechanisms using three minimum occurrences.

Results

Data description

Scopus was accessed to select papers for the bibliometric analysis. Literature search allowed to identify of 95 papers related to latex harvesting published from 2018 to 2022. Of this amount, 38 papers (40.0 %) were articles that studied harvesting practices, including tapping systems trials, ethylene stimulation, and the development of harvesting machines. A total of 41 papers (43.2 %) reported the results of physiology research, mainly dealing with laticifer development, rubber biosynthesis, and ethylene response. In the sub-topic oxidative stress induced by harvesting practice, only 16 papers (16.8 %) mainly reported the effect of mechanical wounding, ethephon stimulation, and Reactive Oxygen Species (ROS) scavenging (Figure 2A). List of papers used in the analysis is presented in the Supplementary data.

In the last five years, the number of publications on latex harvesting tended to decrease (Figure 2B). In 2018, 26 papers were found, dominated by physiological mechanisms and harvesting practices studies. In 2019, the number of published papers decreased to 23 papers. Compared to 2018, a significant decrease was encountered for the sub-topic physiological mechanism, while for harvesting practice paper increases and oxidative stress remained constant. In 2020 and 2021, the number of published papers continued decreasing to 21 and 15 papers, respectively. Research in harvesting practice dropped drastically to 5 papers. For physiological mechanisms, an increase occurred in 2020 (11 papers) but dropped in 2021 (8 papers). For oxidative stress, 5 papers in 2020 and 2 papers in 2021 were identified. In 2022 (data accessed in March 2022), 10 papers were identified 5 papers for harvesting practice, 4 papers for physiological mechanisms, and 1 paper for oxidative stress respectively.

Current research on latex harvesting practices

To understand the current method in latex harvesting, the bibliographic analysis was carried out using papers related to harvesting practices, including, the tapping system, ethephon stimulation, and tapping machine. The online search allowed the identification of 38 papers related to this topic. According to the occurrence, co-authorship analysis by countries showed that the authors of the papers were mainly from major natural rubber-producing countries, including China (14 documents), Thailand (9 documents), Indonesia (5 documents), and India (3 documents). Other producing countries such as Brazil and Malaysia were found in 2 documents, respectively, while Sri Lanka and Vietnam only appeared in one paper. Interestingly, the

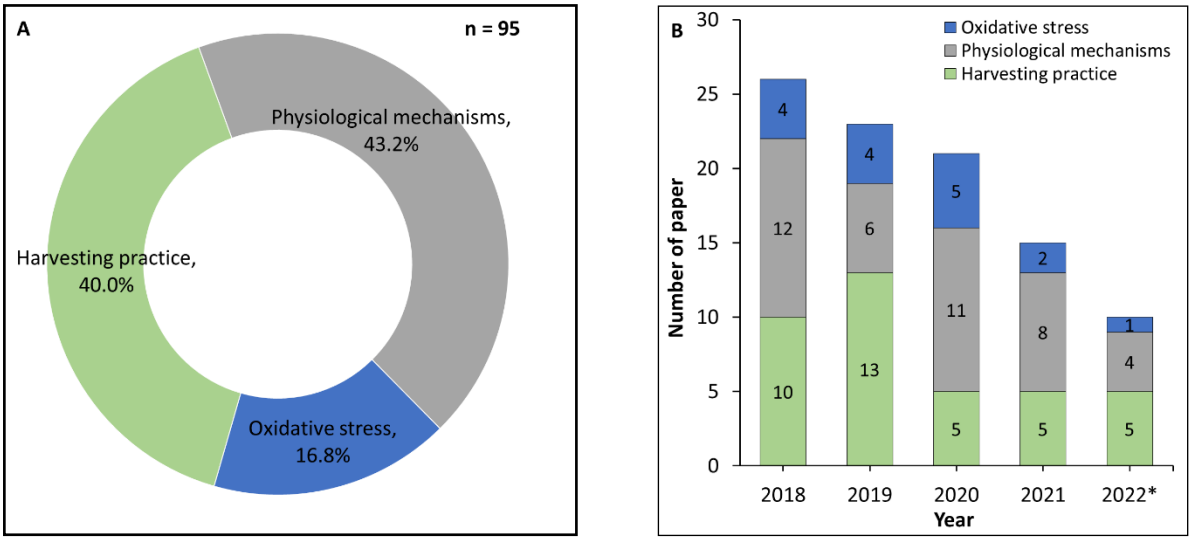

Figure 2. The proportion of literature by sub-topic (A) and number of literature by year (B) used in the bibliographic analysis

contributions of authors from non-producing countries were identified, including, Germany (2 documents), France, Taiwan, and the United States of America (1 document, respectively).

Following the thesaurus establishment and limiting two minimum occurrences, 54 keywords were identified. The overlay map indicated that papers published in 2018 – 2020 were directed to yield optimization and cost efficiency through tapping mechanization (Figure 3). The yield optimization was conducted through a tapping system and ethephon stimulation modifications supported by latex diagnosis (Attanayake et al., 2018; Yunta & Dede, 2019). In this period, studies on semi-automatic and automatic tapping

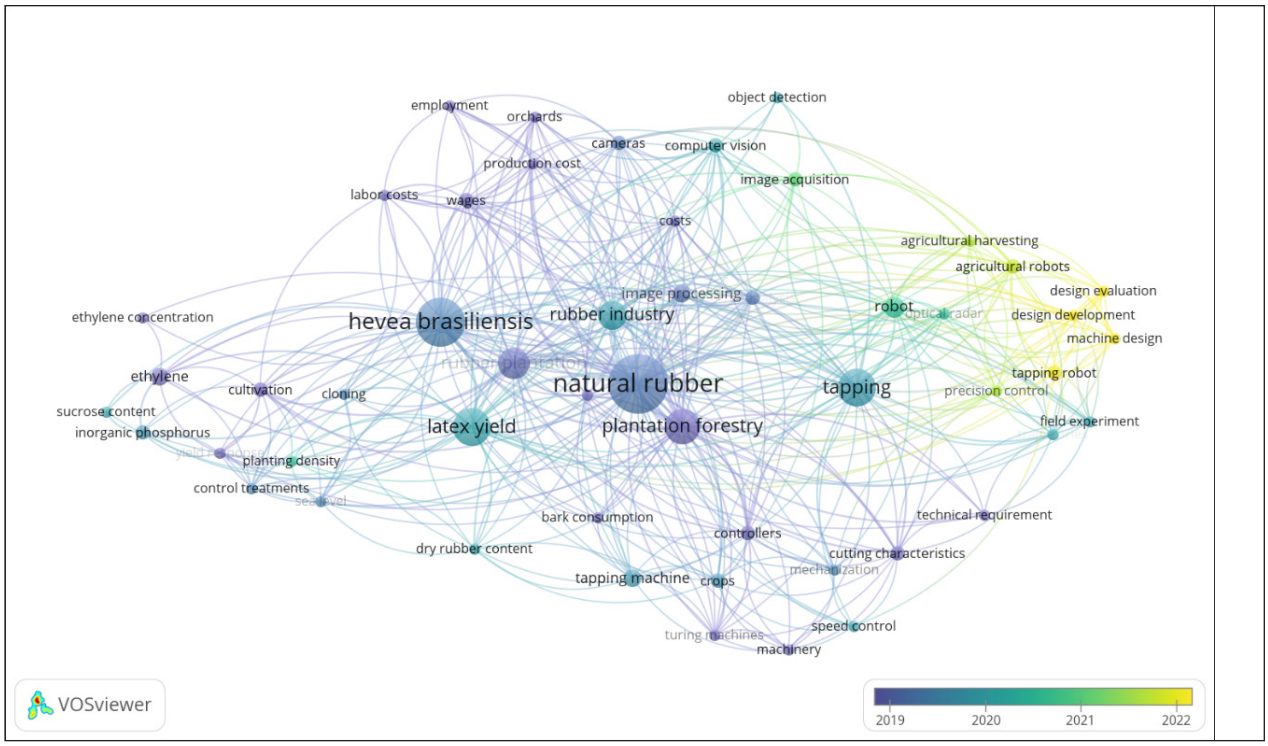

Figure 3. Overlay map of keywords related to latex harvesting practices using two minimum occurrences threshold from 38 papers included in the analysis. The bigger circle indicates a higher frequency of appearance of the keyword. Lines show networks among keywords.

machines were frequently reported (Deepthi et al., 2020; Zhang et al., 2019; Zhang et al., 2018. Although research on tapping systems was still conducted, for example, studies by Long et al. (2018), Pereira et al. (2018), and Budiasih et al. (2020). This typical work was rarely published in Scopus-indexed journals in the last two years (2021 – 2022). In this period, published papers were mostly related to automated tapping machine development. Keywords such as robotics, automation, and design development predominated the finding; for example, papers from Gao et al. (2021) Wongtanawijit & Khaorapapong (2021), and Wang et al. (2022).

Five clusters were generated (Table 1). Cluster 1 consists of keywords related to latex yield, including cultivation, planting density, ethylene, and ethylene concentration. These keywords indicate the effort of yield optimization through planting space modification and ethylene stimulation. In this cluster, three latex diagnostic parameters *i.e.*, dry rubber content, sucrose content, and inorganic phosphorus appeared, indicating a combination of tapping practice and latex physiological monitoring. Clusters 2 – 5 were mostly dedicated to mechanization. In cluster 2, tapping and robot are dominant parameters followed by keywords related to them such as design evaluation, optical radar, and precision control. Cluster 3 expressed the implementation of mechanization in rubber plantations linked to employment, wages, production cost, and labor cost. Cluster 4 consists of tapping machine characteristics such as cutting characteristics, bark consumption, and speed control, while cluster 5 is mainly related to image acquisition and processing.

Research on physiological mechanisms related to latex harvesting

Physiological mechanisms related to rubber production are important knowledge for breeding and yield optimization. Literature searching on this topic resulted in 41 scientific papers. The top five co-authorship came from China (25 documents), Japan (5 documents), France and Thailand (4 documents, respectively), and India (3 documents). The rest were identified from Indonesia, Russia, and the United States of America (2 documents, respectively), and Malaysia, Canada, and Brazil (1 document, respectively).

The physiological studies in *H. brasiliensis* included rubber biosynthesis (Jayashree et al., 2018; Liu et al., 2020) ethylene response mechanism (Gao et al., 2018; Nakano et al., 2021), and enzymes involved in rubber biosynthesis (Amerik et al., 2018; Li et al., 2020). The overlay map showed that in 2018 and 2019; research on enzyme and protein was frequently reported, while in 2020 – 2022, research on rubber biosynthesis and ethylene mechanism were dominant (Figure 4). Interestingly, most studies a molecular approach; for example, keywords related to gene expression, including gene expression profiling and regulation appeared throughout the observation period.

Using three-minimum occurrences thresholds, 51 keywords were divided into four clusters (Table 2). Cluster 1 was mostly related to gene expression, suggested by keywords transcriptome, proteomics, up-regulation, down-regulation, and gene ontology. In cluster 2, metabolism, biochemistry, and genetics were dominant keywords linked to other keywords such as rubber transferase, cis-penyltransferase, and promoter region suggesting the enzymatic investigation related to rubber production. Cluster 3 was related to the rubber biosynthesis mechanism with keywords including laticifer, jasmonate, transcription factor, and genetic analysis. Cluster 4 had ethylene as the dominant keyword linked to ethylene derivative, gene expression profiling, gene expression regulation, and protein interaction suggesting the works on the ethylene mechanism underlying latex production in *H. brasiliensis*.

Research keywords related to oxidative stress induced by harvesting practices

In rubber plantations, latex is harvested through tapping activity and ethylene stimulation. These practices induce the accumulation of reactive oxygen species (ROS) (Annamalainathan et

Table 1. Keyword clusters in research related to harvesting practice (n = 38). Data were derived from VOSviewer with two minimum occurrences. The number in brackets expresses the occurrence.

Cluster 1	Cluster 2	Cluster 3
natural rubber (24)	tapping (12)	plantation forestry (11)
Hevea brasiliensis (18)	robot (5)	rubber plantation (9)
latex yield (12)	agricultural robots (3)	rubber industry (8)
ethylene (4)	tapping robot (3)	cameras (3)
cultivation (3)	agricultural harvesting (2)	error analysis (3)
inorganic phosphorus (3)	design development (2)	Thailand (3)
cloning (2)	design evaluation (2)	wages (3)
control treatments (2)	field experiment (2)	automatic machines (2)
dry rubber content (2)	machine design (2)	costs (2)
ethylene concentration (2)	optical radar (2)	employment (2)
planting density (2)	precision control (2)	labor costs (2)
sea level (2)	technical requirement (2)	orchards (2)
sucrose content (2)	trajectories (2)	production cost (2)
yield response (2)		
Cluster 4	**Cluster 5**	
tapping machine (4)	image processing (4)	
controllers (3)	computer vision (3)	
crops (3)	image acquisition (3)	
cutting characteristics (3)	agriculture (2)	
bark consumption (2)	object detection (2)	
machinery (2)		
mechanization (2)		
speed control (2)		
turing machines (2)		

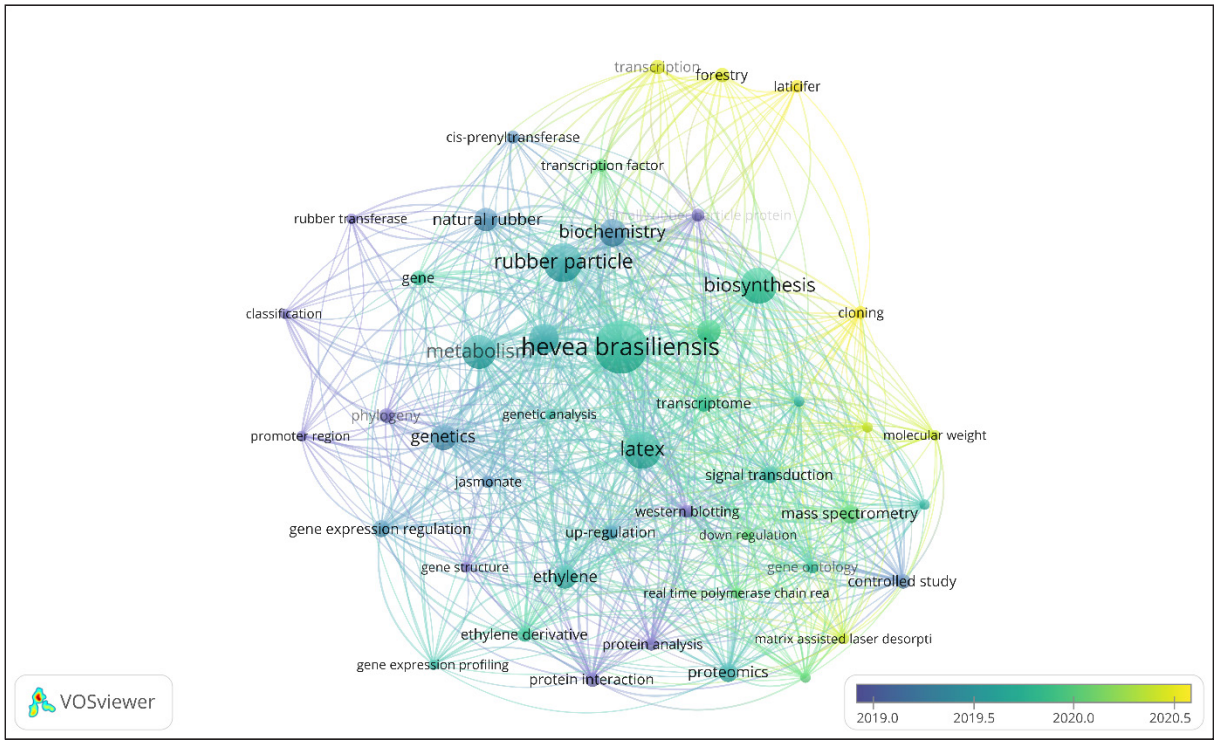

Figure 4. Overlay map of keywords related to the physiological mechanism using three minimum occurrences threshold from 41 papers included in the analysis. The bigger circle indicates a higher frequency of appearance of the keyword. Lines show networks among keywords.

Table 2. Keyword clusters in research related to physiological mechanisms underlying latex production practice (n = 41). Data were derived from VOSviewer with three minimum occurrences. The number in brackets expresses the occurrence

Cluster 1	*Cluster 2*
latex (21)	rubber particle (22)
mass spectrometry (7)	metabolism (18)
proteomics (7)	protein (15)
signal transduction (6)	biochemistry (13)
transcriptome (6)	genetics (12)
unclassified drug (6)	natural rubber (10)
controlled study (5)	gene (5)
up-regulation (5)	phylogeny (5)
cloning (4)	cis-prenyltransferase (4)
gene ontology (4)	classification (3)
protein analysis (4)	promoter region (3)
western blotting (4)	rubber transferase (3)
down-regulation (3)	
matrix-assisted laser desorption ionization (3)	
molecular weight (3)	
polyacrylamide gel electrophoresis (3)	
quantitative analysis (3)	
real-time polymerase chain reaction (3)	
sucrose transporter (3)	
two-dimensional gel electrophoresis (3)	
Cluster 3	*Cluster 4*
Hevea brasiliensis (37)	ethylene (10)
biosynthesis (20)	article (9)
gene expression (10)	gene expression regulation (6)
forestry (5)	nonhuman (6)
transcription (5)	ethylene derivative (5)
jasmonate (4)	protein interaction (5)
laticifer (4)	drug effect (4)
small rubber particle protein (4)	gene expression profiling (3)
transcription factor (4)	
gene structure (3)	
genetic analysis (3)	

al., 2001; Zhang et al., 2017). To capture recent keywords in studies related to abiotic stress-induced tapping practice, 16 scientific papers were analyzed. The co-authorship analysis based on the occurrence showed that the author came from China (12 documents), Indonesia (2 documents), France, Japan, Colombia, Sri Lanka, and Thailand with 1 document, respectively.

The overlay map related to studies on oxidative stress induced by harvesting activity showed that papers published in 2018 consisted of keywords such as laticifer cells, jasmonic acid, ethylene concentration, phylogeny, and adaptation. Keywords such as ethylene, metabolism, gene structure, proteomics, and signal transduction are found in a paper published in 2019, while keywords tapping panel dryness (TPD), biochemistry, and gene expression appeared in most recent papers (2020 – 2022, Figure 5)

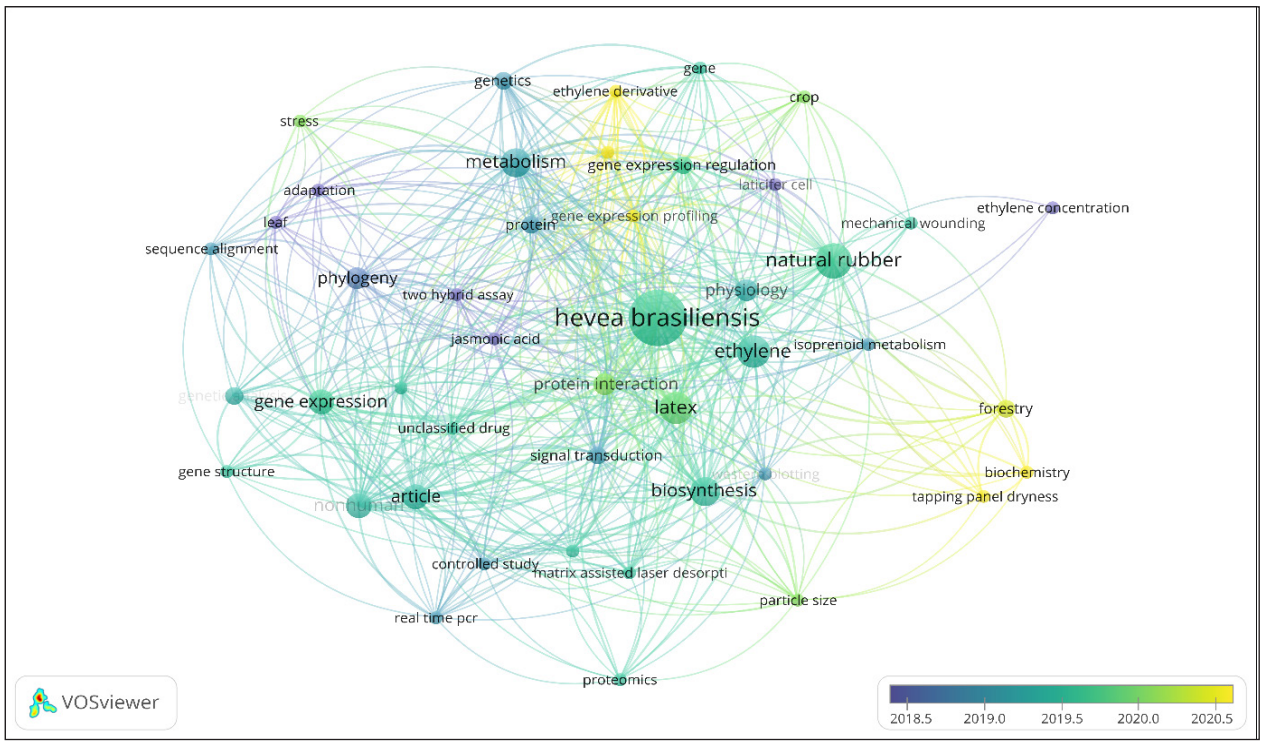

Figure 5. Overlay map of keywords related to oxidative stress due to harvesting practice using two minimum occurrences thresholds from 16 papers included in the analysis. The bigger circle indicates a higher frequency of appearance of the keyword. Lines show networks among keywords.

Forty-five keywords were generated and grouped into five clusters after two minimum appearances limitation were applied (Table 3). Cluster 1 was related to ethylene stimulation and mechanical wounding with a strong link to biosynthesis, isoprene metabolism, and TPD. Cluster 2 included keywords such as gene expression, gene structure, and jasmonic acid. Cluster 3 covered proteomic studies including protein interaction, signal transduction, and particle size. Cluster 4 is related to metabolism, gene expression, gene expression profiling, and genetics, while cluster 5 is related to stress, adaptation, and sequence alignment.

Discussion

H. brasiliensis is an interesting plant to study since it is one of the important agricultural commodities in several countries and its products are used worldwide. Research in latex harvesting has been carried out for more than a century, since the beginning of rubber cultivation. To understand the current development of latex harvesting research through popular keywords used by the authors in the field of latex harvesting techniques, physiological mechanisms, and oxidative stress induced by latex harvesting practices, a bibliometric analysis was carried out using 95 papers from Scopus-indexed journals published between 2018 and 2022. The research was mainly carried out in natural rubber-producing countries such as China, Thailand, Indonesia, Malaysia, Cote d'Ivoire, India, and Brazil. Some authors also come from non-producing countries such as France, Russia, Canada, and Germany.

The results indicate that the method for harvesting latex (40 % of total papers analyzed) and its physiological mechanisms related to rubber production (43 %) attracted more attention from scientists than the impact of harvesting on the free radical accumulation (17 %), although the three sub-topics mutually support the realization of production in rubber plantations. In the last five years, the number of papers published tended to decrease. This may be due to strict activity restrictions during COVID-19 so research activities in the field might be postponed

Table 3 Keyword clusters in research related to oxidative stress induced by harvesting practice (n = 16). Data were derived from VOSviewer with two minimum occurrences. The number in brackets expresses the occurrence

Cluster 1	*Cluster 2*	*Cluster 3*
Hevea brasiliensis (15)	article (5)	latex (7)
natural rubber (8)	gene expression (5)	protein interaction (4)
ethylene (7)	nonhuman (5)	signal transduction (3)
biosynthesis (6)	phylogeny (4)	controlled study (2)
physiology (4)	genetic analysis (3)	matrix-assisted laser desorption (2)
forestry (3)	gene structure (2)	particle size (2)
biochemistry (2)	jasmonic acid (2)	proteomics (2)
ethylene concentration (2)	protein analysis (2)	two-dimensional gel electrophoresis (2)
isoprenoid metabolism (2)	real-time PCR (2)	western blotting (2)
laticifer cell (2)	two-hybrid assay (2)	
mechanical wounding (2)	unclassified drug (2)	
tapping panel dryness (2)		
Cluster 4	*Cluster 5*	
metabolism (6)	protein (3)	
gene expression regulation (3)	adaptation (2)	
genetics (2)	leaf (2)	
crop (2)	sequence alignment (2)	
drug effect (2)	stress (2)	
ethylene derivative (2)		
gene (2)		
gene expression profiling (2)		

(Panthee & Tiwari, 2020). Restrictions on cross-country travel also affect research activities, especially for collaborative research involving several countries. COVID-19 also changed the scientific conference's operation. While online conferences might have advantages related to accessibility and costs, the loss of informal and spontaneous face-to-face interactions might lead some researchers to re-schedule the presentation of their research results (Bray et al., 2022). A meta-analysis conducted by Raynaud et al. (2021) showed an 18 % decrease in the production of non-COVID-19 research, including agriculture, from 2019 to 2021.

A tapping system and ethylene stimulation are the main tools for obtaining latex production in rubber plantations. However, this study showed that only four of 38 analyzed papers reported modification and evaluation of the suitability of the tapping system (Padjung et al., 2020; Pereira et al., 2018; Purwaningrum et al., 2019; Rukkhun et al., 2021 and five studies on ethylene stimulation (Attanayake et al., 2018; Long et al., 2018; Purwaningrum et al., 2019; Yunta & Dede, 2019; and Budiasih et al., 2020) Although much research has been published in these two fields, most of them were in journals unrecognized by Scopus. This suggests that research on these topics requires additional data such as LD and molecular analysis for a better explanation of the effect of tapping and stimulation. Alternatively, significant developments were exhibited in the expansion of latex harvesting machines. This may be driven by the increase in labor costs and the scarcity of skilled-tapper (Kadavil, 2012; Jin et al., 2022). With the support of sensory systems and the internet of things, latex harvesting is evolving toward fully automatic where machines and robots will replace human labor. To date, no tapping machines have been used in large-scale rubber plantations, so research on the development of tapping machines is likely to continue.

Rubber biosynthesis is studied intensively at the genomic and transcriptomic level, for example, papers from Jayashree et al. (2018) and Leclercq et al. (2020). These typical studies provide a better understanding of the rubber biosynthesis mechanism. Comparative proteomic analysis is also frequently used for studying phloem and xylem development (Prasongsansuk et al., 2020) hormonal stimulation (Choksawangkarn et al., 2020 and rubber molecular weight variation (Xin et al., 2021). Other works tried to identify molecular markers (Bini et al., 2022) and conducted molecular genetic analysis (Amerik et al., 2021), which is pivotal for the breeding program. The results indicated that molecular analysis is the main strategy to study biological mechanisms in *H. brasiliensis* in recent days. This should be considered by researchers in developing research proposals and scientific publications. To publish in a reputable journal, research that is supported by molecular data will have more advantages than presenting only field observation or experimental data. Therefore, researchers should be familiar with molecular analysis and its interpretation. For research institutions such as research centers and universities, it is necessary to consider developing appropriate laboratories and supporting human resources for research based on molecular analysis.

Studies of the effect of harvesting practice have mainly focused on the response to mechanical wounding and ethephon stimulation. Over-tapping and over-stimulation induce over-accumulation of ROS increasing the TPD occurrence (Putranto et al., 2015; Samuel et al., 2021). Zhang and collaborators identified the enzymes and antioxidants involved in ROS-scavenging mechanisms in laticifers. The antioxidant enzymes include catalase (CAT), ascorbate peroxidase (APX), glutathione peroxidase (GPX), glutathione reductase (GR), dehydroascorbate reductase (DHAR), monodehydroascobate reductase (MDHAR), glutathione synthase (GS), and glutamate-cysteine ligase (GCL); while main antioxidants are ascorbate, glutathione, carotenoid, and vitamin E (Zhang et al., 2017). Ascorbate-glutathione cycle plays an important role in the ROS-detoxification process through a reduction-oxidation (redox) reaction (Noctor & Foyer, 1998; Foyer & Noctor, 2011). Interestingly, only one paper by Huang and his team reported the study in metallothioneins (MTs), a ROS scavenger, in response to tapping (Huang et al., 2018). Thiol content, one of the LD parameters indicating stress level, is still poorly interpreted due to the requirement of reference data under low and high harvesting stress for interpretation (Junaidi et al., 2022). Therefore, studies on a simple and robust stress marker are important for mitigating the damaging effect of harvesting practice.

Conclusions

The bibliometric analysis allows to identify the keyword links, clusters, and chronological development of recent scientific literature on harvesting practices, physiological mechanisms, and oxidative stress induced by harvesting practices in *Hevea brasiliensis* Muell. Arg. In harvesting practice, the result indicated that the papers were mostly related to automated tapping machine development, suggesting that latex harvesting is evolving toward fully automatic where machines and robots will replace human labor. The study in physiology was mainly related to rubber biosynthesis, ethylene response, and proteins and enzymes involved in rubber biosynthesis. The results indicated that molecular analysis is the main strategy to study biological mechanisms in recent days. This should be considered by research institutions for developing appropriate laboratories and human resources. In terms of oxidative stress, the research mainly focuses on the effect of mechanical wounding and ethylene stimulation. Interestingly, the study of ROS scavenging mechanism is limited, suggesting that this field of research is worth investigating.

Author contributions

Elaboration and execution, development of methodology, conception and design; editing of articles and supervision of the study have involved all authors.

Conflicts of interest

The signing authors of this research work declare that they have no potential conflict of personal or economic interest with other people or organizations that could unduly influence this manuscript.

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