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Two decades of biotechnology research in plantation breeding: A systematic review

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Abstract. Riset Perkebunan Nusantara (RPN) has been carried out diverse research activities in plantation breeding for years. It has been a common understanding that the current biotechnology approach cannot be separated from plant breeding research. However, there has never been any review on research topic trends in RPN. This research was conducted to test the systematic review methodology upon a public database in the biotechnology approach implemented in plant breeding research. This systematic review was carried out on the research conducted by RPN over the last two decades published in global scientific papers. Surveys and screening of scientific papers were carried out using the PRISMA protocol to objectively obtain related research subjects. The survey traced 7,691 records from Google Scholar using specific keywords searches in which 4,041 scientific papers were obtained. The screening process retained 73 scientific papers related to RPN's historical roadmap for plant breeding using biotechnology. The highest number of publications was achieved in 2018 followed by a decrease in the number of publications until 2021. When viewed from the commodity, 26 of the total 73 selected records were studies on oil palm commodities followed by 19 on rubber trees and 10 on cocoa.

Keywords: Google Scholar, PRISMA, roadmap, molecular study, development study

1. Introduction

Riset Perkebunan Nusantara (RPN), which is a transformation of the Indonesian Research Institute for Plantation (LRPI), was born from a long journey of research in Indonesian plantation. RPN is currently a subsidiary of state-owned plantation company (Holding Perkebunan Nusantara PT Perkebunan Nusantara III). Carrying the status as a company, RPN provides technology services and plantation products related to its core of business. On the historical aspect, the Minister of Agriculture of the Republic of Indonesia through the letter No. 199 in 2009 supports the RPN continues to keep carrying out research and development activities in oil palm, rubber, coffee, cocoa, tea, quinine and sugarcane.

On the note, Riset Perkebunan Nusantara (RPN) has been carried out diverse research activities in plantation breeding for years. It has been a common understanding that the current biotechnology approach cannot be separated from plant breeding research [1,2]. However, there has never been any review on research topic trends in RPN which is central to define the future topics or roadmaps related to the needs of stakeholders.

Systematic review analyses have been used in several subjects in biotechnology such as defining public acceptance on the Genetic Modified Organisms (GMOs), commercializing new biotechnology



techniques in manufacturing sectors as well as assessing the potential of personalized agriculture with genomics [3–5]. The approach of meta-analysis research has successfully obtained the potential answers of those subjects. This can be achieved due to systematic reviews providing steps to reduce bias, highlight the precision, ensure reproducibility of data [6]. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methods was commonly used and well-established to perform systematic review [7,8].

This research was conducted to review the biotechnology approach used in plant breeding research in RPN on main commodities of estate crops. The meta-analysis referred to the PRISMA methodology including the search strategy, the inclusion and exclusion criteria as well as the assessment of the plantation breeding scope. The systematic review was then completed by detecting trends on the subject studied.

2. Methodology

The approach used in this systematic review refers to the PRISMA methodology [8]. The selection of studies included in the review started from a wider scope and then narrowed towards the application of biotechnology in breeding.

2.1. Search strategy

The search for biotechnology research in plantation breeding conducted in RPN was based on Google Scholar database. The collected studies were conducted between the years 2000-2021 carrying the keywords “*Riset Perkebunan Nusantara*”, “*Lembaga Riset Perkebunan Indonesia*”, “*Pusat Penelitian Bioteknologi dan Bioindustri Indonesia*”, “*Balai Penelitian Bioteknologi Perkebunan Indonesia*”, “*Pusat Penelitian Kelapa Sawit*”, “*Pusat Penelitian Karet*”, “*Pusat Penelitian Kopi dan Kakao Indonesia*”, “*Pusat Penelitian Teh dan Kina*”, and “*Pusat Penelitian Perkebunan Gula Indonesia*”. The search was carried out from 18 July 2021 to 12 August 2021. The data was saved in CSV format and recapitulated in a Microsoft Excel format file. Duplicated data was removed from the recapitulation before selection process to reduce the amount of data.

2.2. Initial inclusion and exclusion criteria

The inclusion and exclusion criteria used are:

- Studies conducted in 2000 and above.
- Study data with information of publication channel. Study data that do not have information of publication channel will be excluded from the review because the publication channel belong to the criteria for study inclusion.
- Peer-reviewed studies. Studies published through non-peer-reviewed publication channels, such as newsletters, magazines, reports, books, proceedings are excluded from the review.
- Studies on key commodities. The key commodities are oil palm, rubber, sugar cane, tea, coffee, cocoa, and coconut kopyor.
- Studies in the field of biotechnology for plant breeding. Non-biotechnological studies on breeding were excluded, such as pest and disease control of production plants, production enhancement by treatment of mature plants were excluded from the review process.
- Studies conducted by RPN researchers. Studies carried out by researchers or academics outside the RPN were excluded, even though they used facilities or planting material from the RPN.

2.3. Assessment plantation breeding scope

Assessment of the scope of the study was carried out on the data based on the available titles. The term biotechnology used in this review process is the study of improving plant characteristics through plant breeding especially involving engineering processes at the molecular, hormonal, and genetic levels [9]. Key words used as indications include clones, hormones, tissue culture, pollination, markers, genes/genetics, crosses, callus, embryos, culture, DNA, RNA, and other words that indicate the use of biotechnology and breeding in the study. In the assessment, this review separates conventional

biotechnology such as traditional crosses and studies that do not use modern biotechnology and excludes it from review.

2.4. Detecting trend

Trend detection was conducted based on the number of publications on publication channel, commodity, and the year of publication. In addition, the reviewed studies are divided based on the topic of study into pollination/pollinator/cross, gene/cloning/marker, and somatic/culture to facilitate grouping.

3. Results and discussion

3.1. Identification of studies via databases

The identification of targeted studies via databases was the essential step to obtain the initial and selected data for review. A total of 7,691 records as research documents from Google Scholar was achieved (Figure 1). Several records were removed. These flagged records were noted as duplicate (610 records), dated before 2000 (1,383 records) and noted as no publication data (1,657 records). A total number of 4,041 screened records excluded numbers of non-peer-reviewed (514 records), non-core commodities (1,040 records), irrelevant (2,182 records), and non-RPN researcher (216 records). In final step of screening, eighty-nine records were retrieved from previously exclusion of 15 duplicates and 1 non-available records. Finally, seventy-three records were included for review analysis.

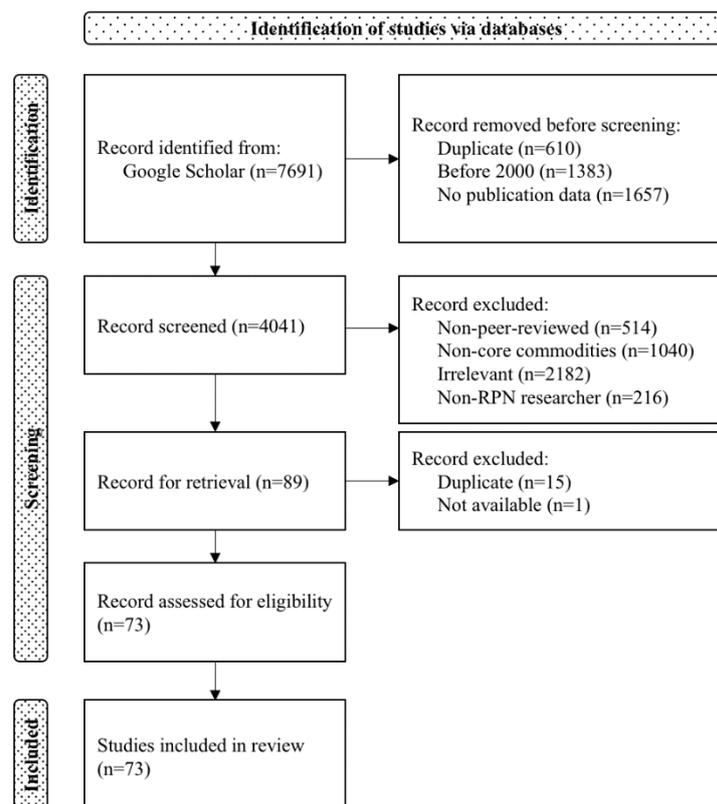


Figure 1. PRISMA flowchart of the review.

The limitation of the study was attached to the use of Google Scholar as a single source of reference database. However, it was noted that due to the specific subject related to the plantation, other databases such as PubMed or Cochrane certainly cannot be referred. This study showed as well that the key to a successful systematic review is to fixate on the inclusion and exclusion criteria. Most of the published papers of RPN were in Indonesian language in which searching criteria should be adapted to the condition.

3.2. Number of publications for two decades

The number of 73 publications for the final review was distributed across the years of study (Figure 2). The first four publications detected during these two decades was in 2003. The highest number of publications was achieved in 2018 followed by a decrease in the number of publications until 2021. When viewed from the commodity, 26 of the total 73 selected records were studies on oil palm commodities followed by 19 on rubber tree and 10 on cocoa (Figure 3).

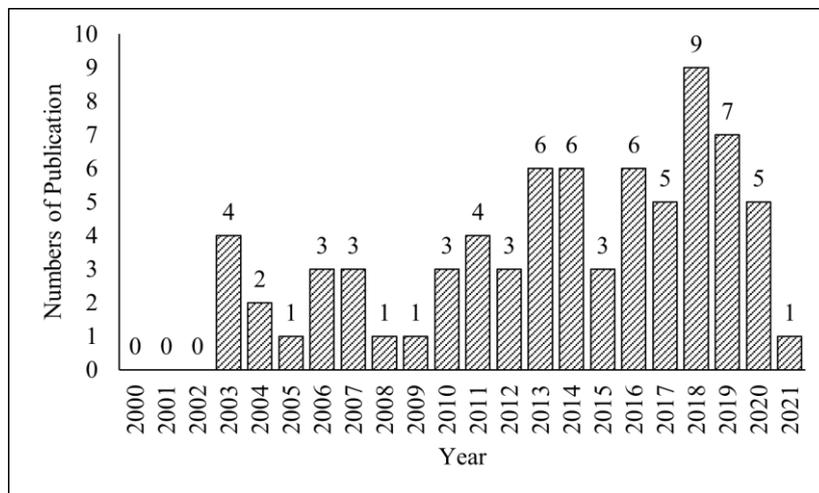


Figure 2. Publication distribution of biotechnology research in plantation breeding conducted by RPN over the last two decades.

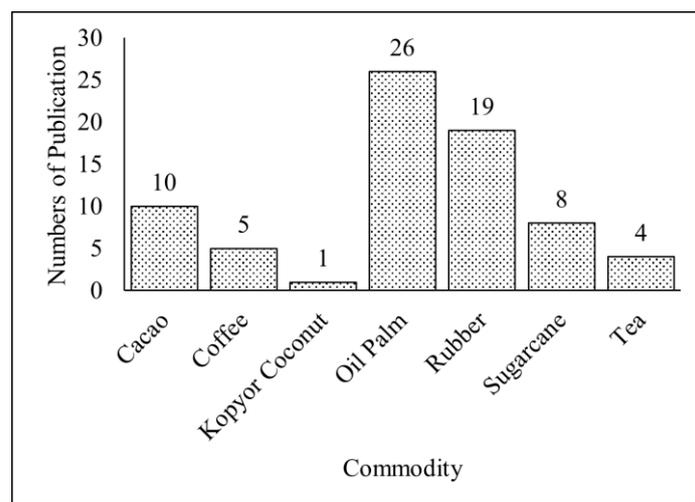


Figure 3. Numbers of publication in key commodities.

3.3. Type of journals for the published scientific papers

After retrieving from Google Scholar, a total of 20 journals accommodate the research results of RPN for the last twenty years (Table 1). The E-Journal Menara Perkebunan of the Indonesian Research Institute for Biotechnology and Bioindustry (<http://mp.tribb.org/index.php/mpjurnal/index>) published 35 scientific papers carrying the subjects of biotechnology plant breeding during the last two decades. The Rubber Research Journal (<https://ejournal.puslitkaret.co.id/index.php/jpk>) and the Palm Oil Research Journal (<https://jurnalkelapasawit.iopri.org/index.php/jpks>) are in second place with 6 scientific papers each.

Table 1. Publication channel of biotechnology research in plantation breeding conducted by RPN.

Journal Name	Numbers of Publication
AGRIN	2
AGRIVITA Journal of Agricultural Science	2
Biodiversitas	1
Biospecies	1
Journal of Oil Palm Research	2
Jurnal Agro	1
Jurnal Agroekoteknologi	1
Jurnal Penelitian Karet	6
Jurnal Penelitian Kelapa Sawit	6
Jurnal Penelitian Tanaman Industri	2
Jurnal Pertanian Tropik	1
Jurnal Produksi Tanaman	1
Jurnal Tanah dan Iklim	1
Jurnal Tanaman Industri dan Penyegar	1
Menara Perkebunan	35
Pelita Perkebunan	5
Review Penelitian Kopi dan Kakao	1
Revista Palmas	1
Warta Perkaretan	1
Warta PPKS	2
Total	73

3.4. Detecting trend

In general, keywords of research throughout twenty years were identified based on topics of study: pollination/pollinator/cross, gene/cloning/marker, and somatic/culture (Table 2). These topics of the study reflected the subjects of research carried out by RPN for the last two decades. The keywords were scattered among the years of research in oil palm (Table 3). The biotechnology approach on gene analysis supporting the development of DNA markers has been published in 2004. In general, worldwide research on the use of DNA markers and how this approach can accelerate the breeding of agricultural and plantation crops was highlighted in 2003-2004 [10,11]. Improvements to the Temporary Immersion System methodology published in 2002-2005 emphasize the use of the technology for woody plants including plantation crops, such as coffee and sugar cane [12,13]. In accordance, RPN published the micropropagation approaches of planting materials using somatic embryogenesis as well as

implementing the temporary immersion system in oil palm were published in 2007. Palm oil has the highest number of publications, so the discussion is focused on this commodity.

It could be understood that biotechnology research supporting conventional breeding such were implemented years before the results can be published. In RPN, several topics related to improvement of plant breeding in oil palm such as the pollinator insects, fruit sets, morphological analysis, disease assessment, physiological analyses were published in 2019. At the world level, in 2019, research on oil palm led to the theme of strengthening modern biotechnology such as genetic engineering and QTL to assist breeding programs [14, 15, 16]. In the same year, a systematic review of pollinators and pollination strategies in oil palm was published. The research focuses on modeling the relationship between pollination and fruit set [17,18]. In general, research trends in the scope of RPN are still correlated with world trends in the same year. This indicates that research on biotechnology in plant breeding at the RPN level is at the same pace as research on the same subject worldwide.

Table 2. Examples of several papers with several research topics.

No	Title	Publication	Year
1	Long-term study of <i>Bacillus thuringiensis</i> application to control <i>Tirathaba rufivena</i> , along with the impact to <i>Elaeidobius kamerunicus</i> , insect biodiversity and oil palm productivity [19]	Journal of Oil Palm Research	2018
2	Evaluasi Karakter Kompak Hasil Pengujian Keturunan Siklus Ketiga Program Pemuliaan Kelapa Sawit Pusat Penelitian Kelapa Sawit [20]	Jurnal Penelitian Kelapa Sawit	2019
3	Pertumbuhan dan perkembangan kalus embriogenik dan embrio somatik kelapa sawit (<i>Elaeis guineensis</i> Jacq.) pada sistem perendaman sesaat [21]	Menara Perkebunan	2007
4	Pembentukan akar in vitro planlet kelapa sawit (<i>Elaeis guineensis</i> Jacq.) dalam medium cair dengan penambahan auksin [22]	Menara Perkebunan	2010
5	Pengaruh Waktu Paparan Zat Pengatur Tumbuh Terhadap Tingkat Abnormalitas Klon Kelapa Sawit[23]	Jurnal Penelitian Kelapa Sawit	2020
6	Deteksi <i>Ganoderma</i> secara molekuler pada kebun kelapa sawit yang diberi perlakuan biofungisida Ganor [24]	Menara Perkebunan	2018
7	Profiling akumulasi transkrip gen pada akar bibit kelapa sawit (<i>Elaeis guineensis</i> Jacq.) rentan dan toleran terhadap <i>Ganoderma boninense</i> [25]	AGRIN	2019
8	Optimasi teknik isolasi RNA daun dan akar bibit kelapa sawit (<i>Elaeis guineensis</i> Jacq.) [26]	AGRIN	2019
9	Penggunaan Alkohol dan Sodium Hipoklorit sebagai Sterilan Tunggal untuk Sterilisasi Eksplan Kelapa Sawit [27]	Jurnal Penelitian Kelapa Sawit	2021

4. Conclusions and perspectives

In general, the future research activity on plantation breeding research using biotechnology approach in RPN would still be strengthen in the development of molecular markers to enhance the breeding selection, in the development of plant growth regulator to enhance productivity of new planting materials, as well as in the maintenance of clonal propagation using tissue culture such as somatic embryogenesis. The approach of new biotechnology technique such as genome editing using CRISPR/Cas9 was on the radar to better speed up the conventional breeding program as well as to identify important traits in estate crops related to productivity, diseases and post-harvest qualities.

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Table 3. Trend of the research in oil palm based on publication keywords.

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
enyl-cep reductase (enr), partial cloning, rt-pcr		haccase, biotin carboxylase, rt- pcr	in vitro culture, somatic embryogenesis temporary immersion- system	seedling, vegetative growth		in vitro rooting auxin, naa, iba root initiation, tissue culture	microenvironment, in vitro culture	elaeidobius kamerunicus, aggressivity, population dynamic, fruit set	heteromeric accase, palm oil biosynthesis, fruit fatty acid, race, pcr	elaeidobius kamerunicus, hatch and carry, pollen, fruit set		elaeidobius kamerunicus, introduction, seram island, fruit set		itrathaba rufivena, bacillus thurgingensis, elaeidobius kamerunicus, fruit set	elaeidobius kamerunicus, biocology, fruit set, incubation technique, transport	plant growth regulator, clone, abnormality	alcohol, explants, sodium hypochlorite, sterilization	
			acetyl-coa carboxylase, biotin carboxyl, carrier protein, dna variability			kasi, oleic acid			oil biosynthesis, over expression, acetyl-coa carboxylase			humic acid, azotobacter beijerinckii, aspergillus niger, nutrient, humic dystrodept		organic fungicides, stem rot, molecular analysis	insecticide, sensitivity, elaeidobius kamerunicus, male inflorescence	clone.abnormal ity, productivity		
																		height increment, drought, test method, rachis length, leaf area index response, fsw (lit), compact palm, rs
																		ganoderma, transcript accumulation profile, rt-ppcr, biomarker
																		optimization, ma isolation, kit, manual bio-si, chlorophyll, nitrate reductase activity, si- solubilizing microbes