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Article Review: The Role of Botany in Forensic Investigations

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Abstract. Botany is the study of plants and plant life. Forensic botany is the study of plants, their relation to law and legal issues and can be used as evidence in a case. The characteristics and parts of each plant can be used as evidence when found on the body or things related to a person or the scene of a case. Botanical evidence found at a crime scene can be used to assist the investigation process related to the relationship between the victim, the perpetrator and the scene. The evidence found can be evidence that can be seen directly and microscopic evidence that requires laboratory analysis for identification, therefore forensic botanical analysis must be carried out by experts in the field of botany. Forensic botanical evidence in an investigation can provide information related to the estimated time of death, how long the victim was buried, the cause and manner of death.

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1. Introduction

Botany is a branch of biology that studies plants and plant life. Forensic botany is the study of plants and how they relate to the law and legal issues that can be used as evidence in a case. Trace evidence from plants can be used for a variety of purposes, such as drawing connections between perpetrators, victims, crime scenes, and objects related to a case. These connections are made by linking and comparing them with the evidence obtained. However, the use of forensic botany is limited in both criminal and civil cases, as not many forensic scientists are trained in this field, and the importance of using evidence from plants, animals, and insects is still underappreciated in the investigation of a case (Raje et al., 2022).

Despite its usefulness, forensic botany also faces several limitations and challenges. Environmental factors such as wind, rain, and seasonal variation can alter or destroy botanical evidence, complicating its interpretation (Morabito & Somma, 2023). Additionally, the risk of contamination is significant—pollen or plant fragments may adhere to investigators' clothing or tools, or be secondarily transferred, thus affecting the integrity of the chain of custody (Oliveira et al., 2023). Another major challenge lies

in the legal admissibility of botanical evidence in court; often, courts require a high threshold of scientific validation, while forensic botany still lacks standardized protocols in some regions. The limited availability of qualified forensic botanists further constrains its routine use in crime scene investigations, making it highly specialized and underutilized (Kunchhal & Kaur, 2023).

Objects or individuals found at the scene can be linked based on contact, and traces left behind such as fragments, terrestrial plant populations, algae or fungi. Botanical elements that play a role in forensic investigations such as seeds, fruits, stems, leaves, roots, algae or plant fragments both macroscopically and microscopically. On a microscopic scale, pollen, spores and microalgae can be observed mixed in the soil as organic components at the scene. To connect or separate the victim from the suspect, the movement of plant elements from around the victim or suspect can be observed to determine the exact location of the incident, however, this can be observed if the incident occurred outdoors or there is evidence of certain plants (Morabito, 2023). Morphological diversity and seasonal variations make it possible to recognize plants and can infer other details such as the location of the crime, whether the body was moved after the murder, how long the body was buried and whether there were other suspects present at the scene (Kunchhal, 2023).

This article discusses the use and role of botany in forensic investigations with certain cases related to botanical forensics. Literature searches were conducted through online databases, such as Google Scholar, Elsevier, and several textbooks related to forensic botany.

2. The Methods

This study employs a narrative literature review approach to explore the role of botany in forensic investigations, highlighting its applications, recent advancements, and associated challenges. This method was chosen for its flexibility in synthesizing information across a wide range of sources and identifying recurring themes and developments within the field.

The literature was collected through comprehensive searches in academic databases such as Google Scholar, ScienceDirect, Elsevier, SpringerLink, and ResearchGate. The keywords used during the search process included: forensic botany, botanical evidence, post-mortem interval estimation, forensic palynology, crime scene vegetation, and botanical trace analysis.

Inclusion criteria for the reviewed literature were:

- Scientific articles and reference books published between 2005 and 2024, with an emphasis on recent studies from 2018 to 2024,
- Publications in English and Indonesian that are directly relevant to forensic botany,
- Peer-reviewed literature discussing analytical techniques, case applications, and legal or environmental limitations in forensic botany.

Exclusion criteria included:

- Non-scientific or non-peer-reviewed materials, such as opinion pieces, news articles, and unpublished reports,
- Literature focusing solely on plant science without any forensic relevance.

Selected literature was analyzed qualitatively and thematically. The analysis was structured around key topics such as:

- Types and forms of botanical evidence found at crime scenes,
- Analytical techniques including microscopic (e.g., SEM) and molecular (e.g., plant DNA) methods,
- The use of botanical data in estimating time of death and crime scene location,
- Real-world forensic case studies involving plant evidence,
- Challenges in the legal admissibility and reliability of botanical evidence.

The findings from this narrative review were synthesized into a comprehensive discussion of the importance of forensic botany in criminal investigations, emphasizing its interdisciplinary nature and the need for standardized procedures and expert collaboration in forensic science.

3. Result and Discussion

3.1. Forensic botany

Forensic Botany is a field of plant science that assists in crime scene investigations and/or completing investigations into murder, kidnapping and sexual assault cases and focuses primarily on plant identification. The forensic aspect relates to the identification of evidence, related to the crime scene (TKP), collection of evidence, securing evidence, analysis or scientific testing of evidence or samples found and investigating whether or not the evidence is acceptable. On the other hand, the botanical aspects observed in forensic investigations generally focus on the anatomy, growth and development and taxonomy of plants to assist in the identification of certain plant species. (Kunchhal, 2023). Analysis of forensic botanical evidence must be carried out by someone who is truly an expert and trained in the field of forensic botany.

Plants or plant parts found on the body of the victim, suspect or at the scene of the crime can be used as supporting evidence in solving a crime case. Morphological diversity and seasonal variations make it possible to recognize plants and can conclude other details such as the location of the crime, whether the body was moved after the murder, how long the body was buried and whether there was a suspect present at the scene. (Kunchhal, 2023).

The basic characteristics of plants are important things that must be understood by analysts in identifying plants as evidence in a case. In botany, the habits of a plant can describe the tendencies or characteristics of a plant, one of which is woody or herbaceous plants, the shape and type of leaves, flowers, roots, fruits, and how a plant reproduces can describe the characteristics or characteristics of a plant. Therefore, forensic botanical analysis can only be carried out by someone who is an expert and trained in botany. (Hall, 2012)

In fact, the presence of important plant species can be very useful in forensics and is defined as the use of plant science as evidence in court. Forensic science encompasses many subdisciplines. It can be further divided into several subspecialties of botany, including plant anatomy (the study of cellular features), plant systematics (taxonomy and species identification), palynology (the study of pollen), plant ecology (plant succession patterns), and limnology (the study of freshwater ecology). Identification of plant species can help determine the geographic origin of samples and provide links between crime scenes and suspects, test alibis, and confirm (Aquila, 2014).

Forensic botanical analysis involves multiple techniques beyond morphological observation. In recent years, DNA barcoding, microscopic pollen analysis, and spectroscopic methods have been increasingly used to identify plant species with high accuracy (Wiltshire, 2016; Oliveira *et al.*, 2023). These approaches are especially useful when botanical evidence is fragmented or degraded. For instance, the use of plant chloroplast DNA enables species identification even from trace samples, which is crucial in linking suspects to crime scenes (Rogers, 2018).

3.2. The role of botany in forensic investigations

The application of plant science in legal investigations plays a growing role in forensic casework, particularly in establishing links between suspects, victims, and crime scenes. Plants, due to their geographical specificity and seasonal growth, can serve as silent witnesses to crime. Linking plant material to a specific location or time can either support or disprove a suspect's alibi. For example, the presence of region-specific seeds, pollen, or fragments under a vehicle or on clothing can indicate whether a suspect was present at a crime scene (Hall, 2012). Botanical evidence has demonstrated

particular strength in identifying the geographic origin of a crime scene. During crime scene investigations, plant material collected from a victim or suspect is compared with vegetation from a suspected location, enabling investigators to assess consistency or discover secondary or staged crime scenes (Aquila, 2018). Typically, botanists are involved after the body is recovered by police, highlighting the importance of prompt evidence collection from clothing, body surfaces, personal items, and even internal organs. As Oliveira (2023) notes, maintaining the integrity of such fragile evidence is essential and often overlooked.

Recent developments between 2018 and 2023 have further supported the integration of botanical sciences into forensic methodology. A comprehensive review by Oliveira et al. (2023) outlines advancements such as DNA barcoding, scanning electron microscopy (SEM), and metabolomics for accurate species-level identification, particularly when plant remains are fragmented or decomposed. These molecular techniques complement traditional taxonomy, reducing ambiguity in forensic interpretation. Moreover, forensic palynology, the analysis of pollen and spores has become a pivotal tool for locating crime scenes and tracking movement. Rodrigues et al. (2021) showed how pollen trapped in shoe soles was matched with endemic plant species using GIS databases, helping police narrow down a missing person's location. This approach demonstrates how geographic mapping of plant distributions enhances forensic reconstructions.

However, forensic botany is not without limitations. The reliability of botanical evidence can be compromised by environmental contamination, cross-transfer of material, or temporal degradation. In an experimental study, Weiss et al. (2023) observed how factors such as fabric type and weather conditions affected the transferability and retention of plant material. These findings emphasize the importance of rapid and controlled sample collection at the crime scene to preserve evidentiary value.

In response to these challenges, technology is playing a transformative role. Nascimento *et al.* (2022) introduced PALINOVIC, a machine learning–based tool capable of identifying pollen types from microscopic imagery with over 90% accuracy. This innovation is especially useful in jurisdictions where trained palynologists are scarce. Despite the growing body of research and application, admissibility in court remains a concern. Many legal systems demand validated protocols and expert witness testimony to consider botanical evidence credible. As Ortiz and Gardeazábal (2023) argue, wider adoption of forensic botany depends on interdisciplinary cooperation, including standardized field methods and the development of global reference libraries for rapid identification.

Ultimately, forensic botany has moved beyond mere environmental observation to become a scientifically robust discipline. With advances in molecular biology, geospatial analysis, and digital identification tools, the field is increasingly capable of providing strong, court-admissible evidence. Yet, challenges persist particularly in terms of training, protocol harmonization, and data reliability. Continued research and cross-sector collaboration are essential for maximizing its potential in modern forensic science.

3.3. Botanical evidence

A researcher should note the location of flowering plants and shrubs, broken wood fragments, broken tree branches or trunks, trampled areas containing plants, and any plants that produce seeds or fruit. In addition, any food items found at the crime scene should be noted, as they may be useful later in establishing or refuting an alibi or in determining the time of death (Coyle, 2005)

Identification of botanical evidence found at the crime scene in complete condition can be directly identified by botanists, however, if only fragmentation or degradation is found, then molecular methods can help the plant identification process. One of the molecular approaches carried out is by examining

plant DNA. DNA comparison can be very useful where only fragments of plant material are available that cannot be identified by microscopic techniques (Wiltshire, 2016).

For DNA analysis of botanical samples, many of the same considerations apply as for testing for human identity. Two factors must be considered in obtaining sufficient amounts of plant DNA for profiling: the size of the plant fragment and the ability of the analyst to mechanically break down the plant cell walls to release sufficient DNA content. The size of the plant fragment can rarely be increased beyond initially collecting as many samples as possible from the crime scene. In particular, food with bite marks should also be considered and carefully recorded. Photography, video, and audio recordings along with simple diagrams can be useful later in the reconstruction of the crime scene. In particular, sketches of the outdoor landscape at the crime scene and weather conditions can be very important in establishing botanical relationships especially since some plant species can be considered as temporary evidence based on growing season (Coyle, 2005)

Plant material in the stomach contents is most likely to be collected during autopsy by the medical examiner. Botanical evidence found in the field is most often preserved by simply pressing the plant material and allowing it to dry naturally on a piece of paper as in Figure 1, because plants retain nearly all of their morphological characteristics. In addition, photography is an important method of evidence collection used to document physical characteristics observed at the crime scene prior to the drying process (Hall, 2012).

Figure 1. Example of botanical evidence storage, and identification information can be written on the evidence sheet (Hall, 2012).

In general, the methods for collecting evidence from a crime scene are as follows: (i) Collecting any evidence from the possible route the suspect took to and from the scene, (ii) collecting evidence from the crime scene, especially plants typical of the surrounding habitat, (iii) conducting a careful search to find any remaining evidence throughout the scene (Hall, 2012).

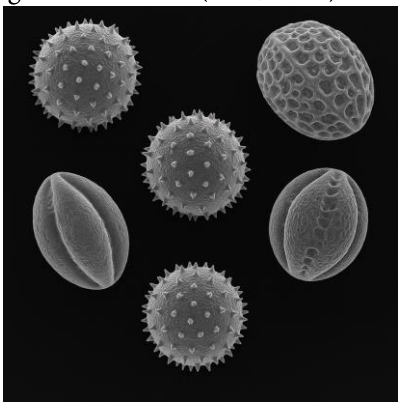

Figure 2. SEM image of pollen grains used in forensic palynology (Oliveira, 2023).

Another modern approach is the use of palynological databases and geospatial analysis of pollen to pinpoint geographical origins. For example, forensic palynology has been applied in solving cases of missing persons by analyzing soil traces from clothing, which revealed pollen from endemic plant species only found in a certain forest area, guiding investigators to the correct location (Morabito, 2023). Figure 2 shows an example of microscopic pollen analysis using Scanning Electron Microscopy (SEM), which allows species-level identification and helps determine time and location of contact.

3.4. Cause of death estimation

Botanical or plant evidence in the victim's body can be found in cases of death due to exposure to poisonous plants, often death occurs after ingestion of the trigger plant. To confirm this poisoning, investigators may need botanical or toxicological expertise to identify the plant or poison that caused death. Proper evidence and sample collection techniques must be followed and evaluated by a qualified forensic botanist (Rogers, 2018). In addition, for cases of plant poisoning, the results of the examination of the victim's stomach contents during autopsy can be analyzed to determine the type of plant consumed and assisted with chemical analysis. Some regions in the world have a higher frequency of plant poisoning (Hall, 2012). Finding plant evidence on a person's body can also indicate the cause of death. For example, the discovery of wood chips from Castanea sativa embedded in the skull fracture identifies that the wooden object was used as a murder weapon. Plant chips or parts can also indicate the manner of death, such as in one case where berries and twigs were found in the victim's hair, indicating that the victim fell from a building, and hit a berry tree at the location (Oliviera, 2023).

Accidents or crimes in the water are quite common, in the investigation of this case algae examination or diatom analysis is often done to find out the cause of death of a person. Diatoms are small algae found in all types of water, when someone drowns, they will try to inhale oxygen so that the surrounding water can enter the respiratory tract, this can cause diatoms to enter the person's body. The force of this inhalation allows the alveolar membrane in the lungs to rupture, and diatoms can enter the bloodstream and continue to flow to organs in the body. If the body enters the water after death, water with diatoms may be able to enter the lungs due to mechanical pressure, but diatoms cannot enter the bloodstream because the low pressure cannot break the capillaries. This condition can be used as one of the forensic evidence in a drowning case (Hall, 2012). A documented forensic case in Italy involved the death of a child in which fragments of *Conium maculatum* (poison hemlock) were found in the stomach and oral cavity. Toxicological analysis confirmed the presence of coniine, a neurotoxic alkaloid. The combination of botanical and chemical evidence led to the conclusion of accidental ingestion (Aquila *et al.*, 2014).

3.5. Post mortem interval estimation or time buried

Forensic botanists can sometimes estimate the time a body has been in its current location, based on the anatomy of the in situ plants and their developmental stages (Ermida, 2022). Botanical evidence can be used to help estimate the rough Post Mortem Interval (PMI) by estimating the minimum time required for plants to grow to the stage observed on the body or grave found. Likewise, soil signs around the body's discovery by observing abnormal vegetation can provide clues to the possibility of a hidden body or grave site (Rogers, 2018). According to Iqbal (2018), it is stated that plants can provide important clues in estimating PMI through plant patterns, life cycles and physiology. Such as the discovery of skeletal remains that have begun to be covered in green algae, moss or shrubs, based on the growth of these plants, an estimate of the age of death or PMI of the body can be obtained, of course by taking into account the time or process of decomposition of the body.

Figure 3. Moss growing on human bone remains can estimate PMI (Hall, 2012).

In collecting any plant evidence, an important step to take is for a qualified botanist to name the plant and interpret the evidence found. This botanist can testify in court as an expert witness (Hall, 2012). The study of plant growth and vegetation patterns can also be used in determining the PMI estimate accurately, such as observing and analyzing the condition of broken branches, lack of chlorophyll, or the length of new shoots on plants at the scene (see Figure 3). In addition, palynological evidence can also be used if found at a location or a person's body to determine the time since death. Analysis of pollen that is carefully taken from the body of the corpse is identified by forensic palynologists by adjusting its life cycle and also makes it possible to determine the period in which death occurred (Ermida, 2022).

Forensic studies conducted in Australia and Portugal have used growth rates of mosses and shrubs to develop models for estimating PMI with ±30-day accuracy, depending on plant type and environment (Ermida et al., 2022; Iqbal, 2018). In cold climates, PMI estimation based on lichen growth on bone has also shown promising results, though it requires region-specific calibration.

3.6. Crime scene location

There are many types of forensic evidence that may contain traces of plant material in the form of leaf fragments and pollen. Additionally, dust evidence samples can be informative in reconstructing potential geographic locations where evidence may have been transported or moved. As with many areas of forensic testing, the time of first collection of the sample or evidence is an important milestone to consider. Experiments performed can sometimes provide information about the expected time for pollen to settle. Additionally, the dominance of one plant species over another can provide an indication of the season or geographic location where the plant or tree was flowering at a particular time. (Coyle, 2005).

Case Study: In a 2019 homicide case in the United Kingdom, fragments of Urtica dioica (stinging nettle) were found on a suspect's pants. The plant is seasonal and grows only in specific marshland areas. Pollen analysis confirmed that the fragments matched those found at the secondary crime scene, thus invalidating the suspect’s alibi and supporting prosecution claims (Wiltshire, 2016).

4. Conclusion

Forensic botany plays a significant role in the analysis of a crime, especially one that occurs in the wild. It takes a truly competent expert in botany to be able to analyze and identify the botanical evidence found, and botanical evidence is often ignored in crime cases, because its use in investigating a case is still very rare. Forensic botanical evidence can be in the form of evidence that can be seen directly or in

microscopic form that requires further analysis in the identification process. Botanical analysis in a case can help in estimating the cause of death, time of death and location of the crime. Future research in forensic botany should focus on developing standardized protocols, expanding palynological and botanical DNA reference libraries, and increasing collaboration between botanists and forensic professionals. Additionally, training modules and certification programs are necessary to establish forensic botany as a widely accepted discipline within forensic sciences.

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