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Integrating Pollen Analysis in Forensic Botany: Legal and Practical Recommendations for Criminal Justice in Arab Countries

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Abstract

This study explores the integration of pollen and spore analysis techniques within contemporary forensic botany to enhance criminal investigations and identify perpetrators. It underscores the significance of botanical evidence as a product of technological advancements, particularly in forensic botany. The research emphasizes the precision and reliability of botanical evidence, highlighting its superiority over traditional forms of evidence due to its longevity and resistance to tampering. Despite the absence of explicit provisions in many criminal procedural systems, the study advocates for the inclusion of pollen analysis techniques, considering their practicality, safety, and legitimacy. The study finds that botanical evidence effectively determines crime-related locations but needs additional support and safeguards. It recommends adding provisions in Arab penal laws for pollen analysis, assigning its examination to public prosecution in specific crimes, creating a national plant distribution database, and developing a legislative framework to protect individual rights while using botanical evidence in criminal justice.

Keywords: Botanical evidence, Pollen analysis, Forensic botany, Crime investigation, Legal and Laboratory safeguards, Legislative framework, Criminal justice

Introduction

The current era witnesses a technological revolution in criminal investigation and evidence, as well as advancements in communication and information technology. This revolution brings about fundamental changes in the realm of crime, aiding criminal justice agencies in unraveling crimes and solving intricate mysteries.

Pollen analysis, pioneered by Lennart von Post in Sweden in 1916 for noncriminal purposes, has since evolved into a crucial tool in forensic medicine. Wilhelm Klaus, an Austrian scientist, revolutionized forensic evidence with his discovery of pollen technology in the mid-20th century. Pollen grains, the male reproductive organs of plants, endure for millions of years due to their robust walls, making them invaluable in forensic investigations (Al-Jundi et al., 2004).

Forensic botany, epitomized by pollen technology, marks a significant advancement in criminal investigations, enabling agencies to attribute crimes to their perpetrators. This technology, integral to global scientific research, aids in uncovering crimes and identifying culprits through the analysis of pollen or spores in mud or dust samples from crime scenes (Adekanmbi et al., 2021, p.91).

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Despite its importance, there's a lack of legal regulations regarding the use of pollen technology and forensic botany in Arab legal systems. This absence questions the legitimacy of accepting botanical evidence like pollen and spores in criminal cases without clear legal guidelines. Hence, there's a pressing need for a legal framework to govern the use of pollen technology in criminal procedures, ensuring a balance between justice and the protection of the accused (Kwan, 2017).

Therefore, discussing the nature of pollen entails defining this particle and elucidating its types, as well as shedding light on its significance in criminal evidence. Additionally, it is crucial to address its legal validity in criminal evidence and its admissibility in proving criminal allegations. Studying the use of pollen technology in criminal evidence requires understanding the scientific aspects of this technology and the significance of its employment in the criminal field for identifying perpetrators and attributing crimes to them.

Literature Review

The inclusion of pollen analysis in forensic inquiries marks a significant stride in criminal science. Initiated by Lennart von Post's work in 1916 and advanced by Wilhelm Klaus in the mid-20th century, pollen technology has become indispensable for global law enforcement agencies (Al-Jundi et al., 2004). Through scrutinizing pollen grains and spores retrieved from crime scenes, forensic botanists can pinpoint geographical origins, furnishing crucial evidence to link suspects with unlawful acts (Halbritter et al., 2018). Despite its effectiveness, the absence of legal regulations governing pollen technology presents hurdles to its integration, particularly in Arab jurisdictions (Alotaibi et al., 2020). This underscores the urgent need for a robust legal framework to ensure the appropriate application of pollen analysis in legal proceedings while safeguarding the rights of the accused (Alotaibi et al., 2020).

The interdisciplinary nature of pollen analysis in forensic science underscores its potential to transform criminal investigations (Bator, 2022, P. 229). Beyond conventional methodologies, its utilization provides unparalleled insights into crime scenes and the identification of perpetrators. Yet, further exploration is imperative to address the legal and ethical considerations accompanying its use, particularly in regions lacking regulatory structures (Wiltshire, 2009). By bridging scientific innovation with legal mandates, the assimilation of pollen analysis into forensic practices has the potential to bolster the efficacy of criminal justice systems while preserving the rights of all individuals involved (Bajerlein et al., 2015).

Pollen particles are too small to be seen without a powerful electron microscope (Halbritter et al., 2018, p. 6). They have the remarkable ability to remain viable for millions of years and can travel through time and space (Martin, 2022). These tiny particles can stick to water, mud, or soil, and can be dispersed through the air, resisting various chemicals and oxidative substances along the way (Al-Jundi et al., 2004, P. 102).

The term "pollen" originates from the verb "make dust," indicating finely crushed particles suspended in the air (Halbritter et al., 2018, p. 6). Initially, "dust" refers to what is finely crushed from soil or other substances, making it easily airborne (Amato et al., 2001). In the context of plants, "dust" specifically refers to male reproductive cells (Bator, 2022, P. 229). In English, these particles are known as "pollen," a term derived from Latin meaning powder or dust.

Pollen dust comprises tiny particles from spores and pollen grains of various plants, serving as the male reproductive organs of trees and plants (Landsmeer et al., 2009). Carried by wind, they travel long distances and settle on surfaces, including clothing (Bator, 2022, P. 229). Additionally, they can enter human bodies through respiration, posing health risks for allergy sufferers. Identifying pollen grains and spores aids in identifying perpetrators as they are diverse and can be found in a single sample (Al-Jundi et al., 2004, P. 102). Forensic analysis of pollen helps differentiate criminals based on their locations, with recent studies confirming its reliability (Mildenhall et al., 2006, Pp. 164-165).

Vascular plants, most plants, include various types like ferns, which grow from spores found on their leaves in structures called "sori" (Smith et al., 2006, pp. 709-710). These plants are divided into seed plants, which produce seeds without flowers, and angiosperms, which produce seeds within flowers (Linkies et al., 2010). Conifers, a type of seed plant, are the largest plants on earth, with some living over four thousand years (Neale et al., 2019). Angiosperms, the other type, are widespread, with over 250,000 species including palms, grasses, and herbs (Bennett et al., 2011). They play a crucial role in plant reproduction, with flowers containing parts like stamens and pistils essential for this process (Linkies et al., 2010).

Botanical evidence, according to the researcher, refers to plants and trees where pollen or spores come from, revealing the environmental location of plant distribution linked to individuals' origins or presence (Al-Jundi et al., 2004, P. 105). Forensic pollen analysis involves using electron microscopes to examine pollen and spores from mud, dust, clay, or soil samples to uncover crimes and perpetrators by determining their geographic source and connecting them to the crime scene (Alotaibi et al., 2020, P. 1186).

Methodology

The study conducted a thorough review of current literature regarding the incorporation of pollen analysis in forensic inquiries, including case studies and empirical data. It will also scrutinize legal documents and policies concerning pollen analysis across different legal frameworks. The objective is to offer insights into the hurdles, progressions, and potential pathways forward within this domain.

Discussion and Analysis

i. The Use of the Pollen Technology in Criminal Field:

Pollen technology, despite being discovered in the mid-20th century, wasn't widely accepted globally until recently, including in Austria (Halbritter et al., 2018, p. 4-5). However, it has now become a crucial tool in criminal investigations in countries like the United Kingdom, New Zealand, and Australia (Mildenhall et al., 2006, p. 163). Forensic palynology's applications have broadened to include investigating crimes like murder, genocide, violence, rape, and terrorism, as well as fraud and economic crimes (Alotaibi et al., 2020, P. 1187).

Palynology is vital in criminal investigations for linking individuals to crime scenes, identifying objects, narrowing suspects, tracing travel, and locating graves (Mildenhall et al., 2006, p. 163). Pollen and other botanical evidence can help in cases like illegal logging, finding buried bodies, and wildlife crimes (Raje et al., 2022, p. 2). In Greater Manchester, a homicide investigation used pollen evidence to link a suspect to a crime scene, leading to a life sentence (Wiltshire, 2009, pp. 144-145).

Since the 1980s, New Zealand has used forensic botany, especially pollen and spores, to investigate crimes such as rape, robbery, sexual assault, and murder (Adekanmbi et al., 2021, p. 91). These techniques are applicable in cases like arson, assault, burglary, robbery, document forgery, counterfeiting, traffic accidents, poaching, drug-related offenses, smuggling, theft, and violent crimes (Alotaibi et al., 2020, P. 1189).

Botanical evidence like pollen, spores, and pollenkitt aids in identifying crime perpetrators by offering environmental and geographical clues (Bajerlein et al., 2015, P. 75). These particles necessitate electron microscopes and can pinpoint a suspect's whereabouts (Bajerlein et al., 2015, P. 77). Legally, botanical evidence refers to plant-related information, but clear rules are necessary to govern its use and testing.

Pollen technology helps identify crime perpetrators by analyzing samples of dust, soil, or other materials under a microscope to detect pollen grains or spores (Adekanmbi et al., 2021, p. 91). Pollen grains or spores can indicate a suspect's location or presence at a crime scene, helping to identify the perpetrator (Kumari et al., 2017, p. 2). Forensic botanist reports help identify perpetrators by comparing pollen samples with plant distribution databases, providing additional evidence, and aiding in convicting suspects (Alotaibi et al., 2020, P. 1189).

ii. The importance of pollen grains (pollen) in forensic evidence

Pollen grains play a crucial role in forensic evidence by helping identify the actual perpetrator of a crime (Wiltshire, 2009, p. 136). Through forensic pollen analysis, experiments have shown that these tiny male reproductive organs of plants, found in samples like mud, dust, or on clothing from crime scenes, as well as on the bodies of victims and perpetrators, can aid in pinpointing the true culprit (Mildenhall et al., 2006, p. 164). It's widely acknowledged in forensic science that samples from crime scenes or bodies often contain pollen grains or spores, adhering to the Locard Exchange Principle as they can cling to clothing and mix with water, dust, and mud (Ezegbogu, 2021, p. 206).

At crime scenes, we can find various botanical evidence such as pollen grains, seeds, leaves, flowers, wood, roots, bryophytes, mosses, lichens, fungi, diatoms, fruit, and bark (Raje et al., 2022, p. 2). Pollen analysis in forensics serves as technical evidence to identify criminals, particularly when traditional evidence-like blood or hair is absent (Bajerlein et al., 2015, P. 75). Criminals may unknowingly carry pollen from crime scenes on their clothes, shoes, or vehicles (Adekanmbi et al., 2021, p.95). Pollen grains can be found in various sources on the perpetrator's body, expanding the range of physical evidence (Guareschi et al., 2024, p. 5). They persist in materials like hair and clothing even after washing and can also be present in mud on shoes, dirt under fingernails, or tools used in crime (Kumari et al., 2017, p. 5). Additionally, pollen might be found in flesh tissues, bones, and food residues, further aiding forensic investigations (Guareschi et al., 2024, p. 4).

Locard's exchange principle applies to palynology, as pollen can be collected from various pieces of forensic evidence (Ezegbogu, 2021, p. 206). Palynomorphs are minute, transferable, durable, recoverable, and identifiable trace evidence (Ezegbogu, 2021, p. 206). However, the use of palynomorphs in forensics is challenging because there is insufficient experimental data for interpreting the findings (Guareschi et al., 2024, p. 4). Forensic pollen analysis provides vital evidence for identifying criminals, especially when traditional evidence is lacking. Perpetrators may unknowingly carry pollen and spores from crime scenes on their clothing or vehicles (Bator, 2022, Pp. 233-34). Sources of these particles on perpetrators are varied, expanding the pool of physical evidence. Pollen can be extracted from hair, clothing, mud on shoes, tools, or vehicle dust, aiding forensic investigations (Al-Jundi et al., 2004, pp. 112-116).

Pollen grain samples play a crucial role in identifying suspects and determining geographical origins in criminal investigations, especially when traditional evidence is scarce (Bator, 2022, p. 229). They are resilient to environmental factors and can be found in various environments, including hair, making them an ideal reservoir (Al-Jundi et al., 2004, p. 115). Crime scene samples should be preserved in clean plastic bags and dried to prevent bacterial growth. Advances in forensic science have improved pollen analysis techniques, emphasizing the importance of proper collection and preservation (Wiltshire, 2009, p. 141). Expert botanists should directly collect samples from crime scenes, but trained experts can also extract samples from surrounding areas (Mildenhall, Wiltshire and Bryant, 2006, p.165).

a. Conditions for the validity of forensic analysis of pollen grains

Forensic pollen analysis can reveal details like the source, type, and age of pollen and might link a suspect to a crime scene if the pollen matches (Bajerlein et al., 2015, p. 75). To avoid misuse, guidelines must ensure the suspect's procedural rights are protected during analysis (Al-Jundi et al., 2004, p. 113).

i. The technical standards for the forensic analysis of pollen grains

Forensic analysis of pollen samples in criminal cases demands a specialized palynology expert possessing advanced cognitive, specialized, and technical skills that are applicable worldwide (Bator, 2022, p. 242). The expert's report relies on the results of the analysis, which are based on complex scientific and technical principles, forming the basis for the court's comparison of pollen grains (Al-Jundi et al., 2004, p. 119).

ii. Collecting pollen grain samples

Locard's principle says criminals leave or take physical evidence, like pollen, which helps identify them (Kumari et al., 2017, p. 5). Pollen retains its unique characteristics even when transferred or exposed to chemicals (Crispino et al., 2011,

p. 157). Analyzing pollen on a suspect can reveal its origin and age, aiding investigations (Mildenhall et al., 2006, p. 166). Pollen's distinct traits allow analysts to link it to crime scenes, even when mixed with soil or other materials (Bator, 2022, p. 229; Al-Jundi et al., 2004, p. 112). Forensic palynologists collect pollen from suspects, victims, and crime scenes to make connections and assist investigations (Bajerlein et al., 2015, p. 73).

A forensic palynology expert collects pollen samples from crime scenes with the necessary skill to avoid damage or contamination (Bajerlein et al., 2015, P. 76). This ensures the samples are suitable for analysis, which is crucial for solving serious crimes due to the expertise and cost involved. In the absence of such an expert, law enforcement or forensic specialists can collect pollen samples if they have proper training (Al-Jundi et al., 2004, P. 110). They must understand the specific nature of the samples and how to collect them correctly, considering that crime scene conditions can vary. Therefore, they should:

- **Extract Comparative Samples**: Collect crime scene samples accurately and quickly, ensuring viable pollen for comparison (Bator, 2022, p. 229). Take samples from various points and distances to avoid random results and ensure thorough documentation (Raje et al., 2022, p.2). Matching samples require specialized skills (Mildenhall et al., 2006, p. 170).
- **Obtain Reference Plant Samples**: Use different methods to collect multiple pollen samples from the scene (Ezegbogu, 2021, p. 206). Store samples separately in plastic or combine them, keeping them in distilled water at near-freezing temperatures (Al-Jundi et al., 2004, p. 110). Preserve and document the crime scene (Kumar et al., 2017, p. 975).
- **Collect Evidential Pollen Samples**: Forensic experts gather pollen from suspects' bodies or belongings, focusing on clothing, shoes, and vehicle tires (Raje et al., 2022, p. 2; Mildenhall et al., 2006, p. 169; Ezegbogu, 2021, p. 207). Pollen trapped in shoes and vehicle tires can link suspects to the crime scene (Al-Jundi et al., 2004, p. 123).

iii. Processing and Analyzing Pollen Samples

Processing and analyzing pollen samples in forensic analysis involves several steps (Bator, 2022, p. 234). Experts collect samples from crime scenes or suspects, including liquids, solids, or dust (Alotaibi et al., 2020, p. 1186). Initial processing includes washing with diluted hydrochloric acid, hydrofluoric acid, and boiling hydrochloric acid to remove contaminants (Riding, 2021, pp. 9-10). In the lab, palynologists use microscopy to identify pollen and spores based on characteristics like shape, size, and surface features, and compare these to known sources (Adekanmbi et al., 2021, p. 96; Ezegbogu, 2021, p. 207). Descriptive features from scientific references aid identification but are not used for direct matching (Adekanmbi et al., 2021, p. 96).

For high-quality pollen matching, experts use toxic and etching acids to remove the internal parts of pollen grains while preserving the outer wall (Al-Jundi et al., 2004, P. 116). This process breaks down organic materials, cellulose, and silica inside the grains without affecting the resilient outer wall made of polymers with molecular weights typically ranging from 1000 to over 10,000 (Gentekos et al., 2019, p. 772).

Chemical treatment is essential for identifying pollen grains and spores because residues (0.5 microns) aren't visible with microscopes alone (Riding, 2021, pp. 9-10). Plants are often classified by families or genera, like Plantago lanceolata by family and Quercus by genus (De Lira Mota, 2020, p. 96; Crain and White, 2013, pp. 6-7). Some plants are identified by species within families, like Rubus chamaemorus, while others like Geum are also species-specific (Crain and White, 2013). Distinguishing similar pollen types within the Rosaceae family can be challenging (Kumari et al., 2017, p. 2). Garden and ornamental plants are vital in forensic investigations due to their variety (Al-Jundi et al., 2004).

Chemical treatment is necessary to remove internal structures and gather detailed information for accurate identification (Mildenhall et al., 2006, p. 170). Standard techniques alone can only identify the botanical family, not specific varieties (Kumar et al., 2017, p. 975). Both chemical treatment and standard techniques must be performed by skilled experts, with practical experience being crucial (Campos et al., 2021, pp. 15-17; Bator, 2022).

Crime scene samples often include not only modern pollen and spores but also fossilized bacteria from ancient times, requiring careful handling to distinguish between them (Nissan and Nissan, 2012). This applies to non-flowering vascular plants like ferns, mosses, and liverworts, which include ten thousand species with diverse characteristics (Riding, 2021). An expert needs a thorough understanding of these aspects to accurately identify and differentiate them based on genus, age, families, species, and characteristics (Bator, 2022, p. 235-236).

Forensic pollen analysis encounters challenges such as sample contamination, necessitating trained palynologists or experts for sample collection and storage (Al-Jundi et al., 2004, p. 127). Proper storage and collection methods from various crime scenes are vital. Successful analysis depends on well-equipped laboratories, precise equipment, and skilled experts (Nissan and Nissan, 2012).

Errors in pollen analysis can arise from human factors or issues with samples, such as contamination or damage, leading to lost evidence (Kumar et al., 2017, p. 975). High accuracy requires expert knowledge, a well-equipped lab, and strict adherence to technical standards (Al Ghazali, 1990, p. 140). Some of the most important standards that must be followed to ensure the success of forensic pollen analysis include (Ezegbogu, 2021, p. 208):

1. Pollen and spore analysis requires scanning electron microscopes because pollen grains are tiny—0.006 millimeters each, with 14,000 grains weighing just 1 gram (Fukuda and Ikeda, 2012, pp. 724-726).
2. Accurate sample collection from crime scenes and suspects, along with proper preservation and analysis in specialized labs, is essential. Documenting each step is crucial for future reference (Guareschi et al., 2024, pp. 5-6).

3. Pollen analysis methods aim to provide quantitative data. To avoid errors, careful sample collection, preservation, and analysis are needed, including chemical tests and accurate microscopy (Bator, 2022; Al-Jundi et al., 2004).
4. Pollen samples should be stored in plastic, metal, or paper containers, depending on the sample type. Forensic experts must follow strict technical rules to preserve data for criminal proceedings (Bator, 2022; Kumar et al., 2017, p. 975).

iv. Legitimacy of Pollen Testing and Its Probative Value

The use of advanced forensic techniques presents challenges, particularly as they may infringe on the rights of the accused (Faqir, 2023, p. 85, Faqir, 2013). The use of pollen grain technology also raises concerns about the legitimacy of testing and the evidential value of pollen dust analysis (Kwan, 2017, p. 318). To address these issues, the researcher proposes dividing this discussion into two sections as follows:

v. Legitimacy of Pollen Sample Testing

Pollen analysis technology is still underutilized in forensic evidence worldwide, with limited adoption by criminal investigation authorities, particularly in the United States (Raje et al., 2022, p. 1, Alhassan et al., 2024). New Zealand was an early adopter of pollen analysis in forensics, starting in the mid-20th century. Australia, the UK, and possibly Argentina and Austria, have since followed suit, despite its exclusion from the Federal Criminal Code and Procedures Act of 2010 (Bator, 2022, P. 244-45).

In Islamic law, using pollen grains as forensic evidence is accepted (Jadidi, 2021, p. 591). However, proving boundary violations and retribution crimes is complex, and the legitimacy of this technology in such cases is limited due to the principle of preventing suspicion (Faqir, 2023, p. 85; Alhassan, 2024). The Islamic Fiqh Academy acknowledges the use of modern methods in these cases (Hafez, 2019, p. 134). Pollen analysis can be used in crimes like theft, rape, drug trafficking, and pollution, but not in boundary and retribution crimes (Al-Jundi et al., 2004, Alrousan and Faqir, 2024).

In the United Arab Emirates, while there are no explicit legal provisions for pollen analysis tests, the judiciary allows criminal investigation authorities to order necessary medical and laboratory examinations when investigative needs require it (Omar and Mahdawi, 2020, 415). Despite current non-utilization of this technology in UAE forensic science, there is potential for its future application in solving crimes, given the alignment of criminal procedures with Islamic legislation (Sections 94-96 of the UAE Criminal Procedures Code No. 38 of 2022).

Forensic botany experts help criminal investigators gather pollen samples from suspects to provide vital crime timeline information (Bator, 2022, P. 233, Alrousan and Faqir, 2023). However, this raises legal concerns regarding potential privacy and bodily integrity violations. During criminal investigations, accused individuals have procedural rights, including privacy, silence, and bodily integrity (Kwan, 2017, p. 318). Extracting pollen from a suspect's clothing or outer skin is generally allowed, though body samples may infringe on rights. When harm is minimal, evidence collection takes precedence, except in self-incrimination cases (Al Ghazali, 1990, p. 138).

Pollen samples from suspects are seen as minor intrusions on individual freedoms and privacy, if they are legally justified and don't pose violence or significant risks (Kwan, 2017, p. 318). Legal constraints are few, but safeguards are crucial for a fair trial. Pollen analysis is promising in criminal investigations, especially genocide cases, but global adoption is limited by the lack of international regulations, local laws, and scientific forums (Wiltshire, 2009, p. 130).

vi. The probative value of pollen grains

Pollen grains, though tiny, are often found at crime scenes and help identify suspects (Guareschi et al., 2024, p. 6). Forensic palynologists compare pollen from crime scenes with suspects' belongings to link them to the crime (Bator, 2022, P. 241). The small size of pollen helps trace its origins. However, comparing crime scene pollen with reference samples is complex, requiring careful consideration of collection methods, processing, and environmental factors (Ezegbogu, 2021, p. 206).

Plants offer crucial forensic evidence in cases such as rape, burglary, and kidnapping (Raje et al., 2022, p. 2). They help determine causes of death, burial times, crime scene locations, and drug distribution. Pollen grains can suggest a defendant's presence but can't prove guilt alone and must be supported by other evidence, especially in serious crimes (Bator, 2022, p. 240). For expert testimony, the relevance of samples, valid methods, and proper chain of custody are essential. Effective techniques in pollen analysis include scooping and washing (Ezegbogu, 2021, p. 206).

Botanical trace evidence can link suspects, victims, crime scenes, and objects, but its use is limited because forensic scientists often lack training in this area, and evidence collection teams may not recognize its importance (Al Ghazali, 1990, p. 140). Academic scientists skilled in plant identification usually lack forensic training, further restricting their involvement (Raje et al., 2022, p. 2). Technologically advanced countries, like Austria, the UK, the US, Germany, Australia, Sweden, and Argentina, use pollen analysis in forensic investigations. For instance, Austria has used it since 1959, and in the UK, it's accepted as technical evidence. In 2015, pollen analysis in the US led to arrests in a child murder case (Guareschi et al., 2024, p. 6).

In Arab countries, pollen analysis isn't used in criminal investigations or accepted in court due to a lack of experts, storage, labs, and the high costs involved. However, Locard's principle of material exchange is applied in forensic practices (Kumari et al., 2017, p. 5). Physical evidence is key to uncovering the truth, leading to the use of modern scientific methods (Jadidi, 2021, p. 598). Pollen evidence, when backed by other evidence, is considered in criminal cases, but courts avoid definitive conclusions due to their judicial framework.

Findings and Results

1. Botanical evidence (pollen and spores) is a product of the forensic botany revolution. Identified through DNA analysis, it’s effectively used in Western countries and Australia to pinpoint a perpetrator's location by comparing samples from the crime scene with the country’s plant distribution.
2. Pollen and spores are superior to traditional evidence as they remain intact, are hard to tamper with, and help locate both the perpetrator and victim.
3. While pollen analysis isn't common in global criminal procedures, it’s practical, safe, and respects privacy, making it effective in identifying perpetrators.
4. Matching pollen from a crime scene with a suspect’s body and plant distribution databases can strongly suggest the suspect's presence, though additional evidence is needed to prove guilt.
5. Due to the importance of pollen analysis in court, there must be strict laboratory and legal guidelines to ensure its legitimacy.

Conclusion

The study addressed a highly important topic within the scope of contemporary forensic botany, specifically how pollen and spore analysis techniques can be utilized in criminal investigations to identify perpetrators. This technique contributes to solving crimes, bringing perpetrators to justice, and preventing impunity. The study discussed highly significant legal aspects regarding the use of pollen as forensic evidence, the technical and legal guarantees of this technique, and its legitimacy and evidentiary value in criminal courts.

Based on this, the study reached several conclusions and recommendations, which are summarized as follows:

1. The inclusion of a specific provision in the Arab penal procedure laws is proposed to permit the use of pollen analysis techniques for obtaining botanical evidence instead of relying solely on general provisions.
2. It is suggested that the decision to examine pollen obtained from the crime scene, the perpetrator’s body, or their belongings should be entrusted to the public prosecution, particularly in specific crimes.
3. The establishment of a national database in Arab countries for the geographical distribution of plants is recommended to aid in identifying perpetrators.
4. A legislative framework for the use of botanical evidence analysis techniques is proposed to ensure individual rights and freedoms while contributing to achieving criminal justice.

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