

Forensic Use of *Bellis Perennis* L. (Asteraceae): Methods for Collection and Preservation of Plant Samples

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Abstract: The presence of plant-derived material can provide valuable evidence in legal proceedings, as it may corroborate or refute an alibi, determine the location of a person or object, estimate the time of death, or supply other relevant information in a criminal case. In this experiment, plant samples were collected and subsequently packaged and stored using different methods. The aim of this research was to monitor changes in plant samples, to monitor changes in physical properties of the plant *Bellis perennis* L. that was packaged in different ways and stored under different conditions in order to conclude which packaging and storage method was the most effective in preserving the characteristics. The physical properties that were monitored were: color, texture, shape, and odor of the plant material. The plants were packaged in paper bags, PVC bags, and herbarium, and were stored in the following temperature conditions: at room temperature and in the freezer. Changes in the plant were monitored through four phases, where one phase involves storing the plant for a week, and the plants were analyzed weekly. *Bellis perennis* L. is suitable for research because it is easy to find, collect and has flowers, which are important for monitoring changes.

Keywords: forensic botany, plant trace, collection and preservation of plant material, *Bellis perennis*.

1. INTRODUCTION

The field of forensic botany, when employed in a court of law, may prove to be of significant value in the resolution of criminal cases [1]. In this context, it is essential to enhance understanding and awareness of the evidential importance of traces of plant origin, not only among forensic practitioners responsible for their collection but also among members of the judiciary who determine their probative value in court. The collection and preservation of these samples are imperative, as they directly affect the quality and reliability of the evidence and the information obtained from them. Proper collection and storage of plant material help preserve its forensic value and enhance its credibility as evidence in court [2]. In this regard, the research focused on monitoring the physical changes in the plant (*color, shape, odor, and texture*) that had been packaged in different ways (in



paper bags, PVC bags, and herbarium sheets) and stored under different conditions (at room temperature and in a freezer) in order to determine which method is most effective for preserving the plant's characteristics. Preserving these characteristics is important in forensic cases, as they can provide valuable information for solving crimes. Proper collection and storage of plant material preserve its forensic value and improve its credibility as evidence in court [3, 4].

In this study, plant material samples were collected and subjected to different packaging and storage techniques over four phases, with each phase representing one week of storage, during which the plants were analyzed weekly. The aim was to observe how the method of packaging and storage conditions affect the physical characteristics of the samples. Based on these observations, the goal was to determine the optimal method for preserving the physical characteristics of plant material in crime scene investigation.

2. THE SIGNIFICANCE OF TRACES OF PLANT ORIGIN

Forensic botany employs a range of biological techniques to ascertain the identity of traces, utilizing characteristics such as appearance, color, composition, structure, growth patterns, reproductive strategies, dispersal mechanisms, lifestyle, environmental context and fossilized remains. The aforementioned characteristics serve as plant markers, facilitating the identification of specific plant species [2, 5].

The plant data collected from a crime scene are crucial for forensic analysis and can significantly aid in reconstructing events such as traffic accidents or murders [3]. The presence of plant material can be crucial in establishing several key facts, such as verifying an alibi, identifying a person or object at a particular location, determining the time of death, and clarifying the timing of other events [1]. In particular, when checking alibis, since plants grow in certain areas, an object or person can often be associated with that place by means of plants [6]. Also, with the help of plants, several locations can be combined and thus determine the movement, for example, of the victim or the perpetrator, which is relevant to the crime. On the other hand, the time of death can be determined with the help of plants. If the body has been lying in the open for a long time, plants may begin to grow over the body, through clothing or even through skeletal remains. The growth rate of different types of plants is known, and this can be used to estimate the minimum time since the body was in that place [7]. Also, observing the change in vegetation under the body that occurs when the body is lying on the ground is also important because the body exerts pressure and thus blocks light and oxygen to the plants below it. Yellowing, drying, or dying of plants occurs under the body, and then the degree of damage itself can be used to roughly determine the time when the body was in that place [8]. Pollen can indicate the time of year to which a body was exposed – because pollen is present on certain plants during certain seasons. Also, because pollen is invisible to the naked eye, when visiting illegal marijuana labs, no matter how hard criminals try to hide the evidence, an examination of jeans can reveal plant pollen trapped in the hems of the jeans. In addition, pollen easily sticks to hair, skin, objects, and equipment, and when microscopic examination reveals the presence of pollen on a person and compares it to pollen found in the illegal lab, it proves that the person was at that location [1, 8]. Biologists specialising in biochemical,



molecular, or botanical disciplines can assist in the interpretation of plant evidence. In addition, plants are associated with criminal activities, including the illicit trade in species with significant psychological and hallucinogenic effects [9].

3. PROCEDURE FOR HANDLING PLANT TRACES (CHAIN OF EVIDENCE)

The examination of botanical evidence at the scene of a criminal investigation, in addition to adherence to the established protocol for the handling of plant-derived materials, plays a pivotal role in shaping the subsequent course of the investigation [10].

a) Static and dynamic phase of investigation

In the event of a crime scene containing botanical evidence, an examination should be conducted to ascertain whether the plant material present can provide insight into the manner by which the suspect, victim, or vehicle entered or exited the scene [11]. The documentation of the inspection should include evidence of crushed or broken branches or any vegetation that has been moved. It is possible that the transportation of the body, whether by foot or vehicle, may result in damage to vegetation at the scene or along the route to the scene [7]. It is imperative to photograph and remove samples of damaged and displaced plants, which should be removed before other types of material evidence [2].

The collection method should be as follows [7]:

- 1) collect all evidence pertaining to the suspect's path leading to and from the scene;
- 2) collect evidence from the area, paying particular attention to plant species that are characteristic of the surrounding habitat;
- 3) conduct a meticulous search for residual evidence throughout the scene.

b) Where might one look to find evidence of plant origin?

It is evident that clothing and hair are optimal locations for the detection of plant traces. However, it is crucial to conduct a comprehensive examination of any item that may have been exposed to plant material. This encompasses pockets, cuffs, and textile seams, as these areas often conceal traces [8]. Items such as shoelaces and seams are also commonly overlooked but can yield minute traces of botanical evidence. For vehicle-related evidence, a thorough examination should be conducted on the axle, chassis, and wheels. Special attention should be given to the front bumper and radiator, as plant material tends to adhere to these surfaces. Smaller plant fragments can stick to wet, smooth surfaces and may be found on any part of the vehicle [7]. Plants have natural glandular secretions in leaves, fruits, seeds, and other plant parts that aid in their movement and adhesion to various surfaces. A fractured plant may exude its contents, thereby facilitating the attachment of plant parts to diverse surfaces. The plant species may also possess thorns, which can pierce the skin, clothing, and other materials with which it comes into contact [1, 10]. Plants often have hairs that help them adhere to surfaces, including clothing. Many suspects may not anticipate plants as evidence due to a lack of awareness of their significance [7].



c) The process of collecting and packaging traces of plant origin

1. A field or botanical print is positioned;
2. it is recommended that a minimum of 10–12 samples of different plant species be collected in the vicinity of the site in order to document the local vegetation;
3. it is recommended that each track be photographed in three stages: initially in its found state, then after it has been marked in relation to other tracks, and finally as an individual track. [7].

The apparatus used to press plants can be classified into the following categories [7]:

- a) the standard plant press;
- b) a field press;
- c) other types of field presses can be constructed with minimal effort by using a telephone directory or periodical as an improvised pressing tool. In this case, plant specimens are placed between the pages to maintain their shape and structure until they can be transferred to a standard herbarium press for proper drying and preservation.

d) Keeping (storing) traces of plant origin

It is recommended that traces of plant origin be stored in a cool and dry environment. Given that plants are biological organisms, it is essential that they be dried in order to ensure optimal preservation [12]. Each sample should be individually packaged and dried completely before transportation to the forensic laboratory. The process of drying will result in the cessation of biological processes within the plant. The optimal method for drying plants is to place them flat on cardboard and/or absorbent paper on both sides, with a weight placed on top [10]. Multiple plants can be stacked, provided they are separated by cardboard. It is permissible to stack several plants on top of one another, provided that they are separated by cardboard. It is recommended that the paper be changed daily in order to achieve optimal results with wet plants. Samples should also be stored in labelled containers to facilitate processing [7].

e) Documentation

The handling of plant trace evidence should follow and adhere to the same protocols as other forms of legally valid evidence. Comprehensive documentation must be maintained throughout the entire process, from the initial collection of the plant material at the scene to its final preservation [2]. This detailed documentation is essential to ensure that the evidence remains relevant and that the case can be reopened if necessary [7].

It is of the utmost importance that a number of different types of information are recorded as part of the scene processing procedure if the plant material is to be accepted as evidence. The following information should be documented, preferably on a botanical field data sheet: habitat, location of the venue, location of the evidence, and the individual responsible for the collection of the specimen (collector) [10, 13].

It is imperative that any individual engaged in the processing of leads maintains a comprehensive and accurate record of all pertinent evidence in a dedicated logbook [11]. The following information should be recorded in the logbook: date, item number, collection time, source type, plant height, flower colour, fruit colour, fruit shape, and frequency of occurrence [7].



4. MATERIALS AND METHODS

The plant species studied is *Bellis perennis* L., commonly known as the daisy, with regional names such as Krasuljak, Petrovac, and Belka. The plant is exempt from the regulations in four distinct ways:

1. whole plant with root (marked as 1 in pictures);
2. whole wet plant with root (marked as 1' in pictures);
3. flowerless plant (marked as 2 in the pictures);
4. rootless plant (marked as 3 in the pictures).

The packaging of exempt plants is conducted in three distinct ways:

- a) into paper bags
- b) in polyvinyl chloride (PVC) zip bags
- c) in the herbarium

The specimens were stored under different ambient conditions, namely:

- a) at room temperature
- b) in a freezer

Given the conditions under which this experiment was conducted, it was important to monitor certain parameters over a four-week period (divided into four phases). Changes and characteristics observed in the samples were documented during this time. Figure 1 shows satellite images of the collection site, with marked locations where the plant material was obtained.



Figure 1. a) Satellite image of the location where the samples of plant origin were collected (indicated by red arrow) – Pregrevica no. 68, Zemun, Belgrade. b) and c) Satellite image of the site where plant samples were collected – close up (indicated by red arrow).

Collection of plant material

The plants were collected in a variety of states (wet and dry, with roots and without roots, with flowers and without flowers) and packed in a range of materials, including PVC bags, paper, and herbarium. They were then stored in different ways (Table 1). The condition of the collected plants was monitored over a four-week period, comprising four distinct phases. Changes in the plant's physical characteristics such as color, odor, texture, and shape were monitored during four storage phases.



Table 1. *Interpretation of sample identification marks.*

Sample identification mark	Mark interpretation	Sample identification mark	Mark interpretation
1	Whole plant with root	A	At room temperature, in paper bags
1'	Whole wet plant with root	B	At room temperature, in polyvinyl chloride (PVC) zip bags
2	Flowerless plant	C	In a freezer, in paper bags
3	Rootless plant	D	In a freezer, in polyvinyl chloride (PVC) zip bags
		E	In the herbarium

It is recommended that, where feasible, the entire plant, including the root system, be collected. The plant should be extracted from the soil manually, using an axe or shovel, and the soil should be carefully dislodged from the root system. In some instances, the plants are of a size that exceeds the capacity of the available packaging. Subsequently, the plant should be folded in a zigzag or accordion pattern [13]. In the event that this is not feasible, the plant should be cut into sections, with each segment bearing the same basic proof number and an additional label indicating a specific region of the plant (e.g., top, middle, or root). In the case of large specimens, only a portion sufficient for precise identification should be collected [2] [7].

In addition to the aforementioned exclusion, it is essential to implement other methods to properly document and secure the scene, including the verbal method, which involves preparing an investigation report and a forensic examination report of the scene; the measurement-graphic method, which entails creating a sketch and a situational plan; and the photographic method, which consists of producing photographic documentation, all of which serve to accurately record and preserve the condition of the scene [11].

Detailed documentation for each collected sample should include the following information: collection date, geographic location, environmental conditions, and any specific observations relevant to the sample [7]. The registration number must be distinctive for each sample. In the event that one collected plant is divided into multiple segments, they are assigned the same identification number, accompanied by an additional description of the segment in question (e.g., top, stem, root) [13].

The model record list for the collection of plant material is shown in Figure 2.



ATTACHMENT FROM THE CRIME SCENE	Evidence No. _____
	Case File No. _____
	Type of Case: _____
	Suspected Offense: _____
	Confirmed Offense: _____
	Location of Incident: _____
	Date & Time of Incident: _____
TRACE EVIDENCE RECORD	
Type of Trace: _____	
Quantity / Extent: _____	
Sample / Evidence No.: _____	
Exact Location of Collection: _____	
Date & Time of Collection: _____	
Detailed Trace Description: _____	
Remarks / Observations: _____	
Forensic Examiner/Operative: _____	

Figure 2. Record list model.

5. RESULTS

The results from all four experimental phases are summarized in a table, with photographs provided for the most representative samples. The terms “minor”, “moderate”, and “severe” employed in the Results tables 2–6 are consistent with visual criteria that have been applied uniformly across all samples, encompassing the extent of color alteration, tissue integrity, and structural collapse.

Table 2. Overview of the results for Group A samples throughout the four experimental phases. The Group A samples were packaged in paper bags and stored under room temperature conditions. The results, presented in Table 2, indicate that the plant material remained well-preserved, showing no significant changes other than color modification and drying.

	Phase 1	Phase 2	Phase 3	Phase 4
1A	Whole plant stored in a paper bag at room temperature	- Leaves, flowers, and roots slightly darker in color - Plant dried up	- Slight color change - Leaves and roots darker and dried - Flower turned pink and dried - Plant remained intact	- No change from last week - Plant preserved
1A'	Whole wet plant stored in a paper bag at room temperature	- Leaves, flowers, and roots darker in color - Plant dried up	- Visible color change in roots, stem, and leaves - Flower with pink ends - Plant completely torn and dried - Plant preserved	- No change from last week - Plant preserved



2A	Flowerless plant stored in a paper bag at room temperature	- Leaves darker in color - Plant dried out	- Plant dried - Leaves, roots, and stem darker green, some yellowish leaves - Plant remained intact	- No change from last week - Plant preserved
3A	A rootless plant stored in a paper bag at room temperature	- Stem diameter reduced - Stem darker in color - Plant dried up	- Reduction in trunk diameter - Trunk color changed when dry - Flower dried, color unchanged - Plant preserved	- No change from last week - Plant preserved

Table 3. Overview of the results for Group B samples throughout the four experimental phases. The Group B samples were packaged in PVC zip-lock bags and stored under room temperature conditions. The results, presented in Table 3, indicate that the plant material showed extensive drying, color change, and partial decay, while some samples remained generally preserved.

	Phase 1	Phase 2	Phase 3	Phase 4
1B	Whole plant stored in a PVC zip-lock bag at room temperature	The plant is completely dried and its color changed from green to dark green and yellowish.	- Plant completely dried - Color changed throughout - Flower partly fallen off - Plant generally preserved	- No significant changes except complete desiccation of the plant - Plant generally intact
1B'	Whole wet plant stored in a PVC zip-lock bag at room temperature	Color changed to dark brown and yellowish; moisture remained; flower separated from stem, plant crushed, flower and leaves shriveled.	- Complete change in shape and appearance - Pieces fallen off and separated - Color completely changed	- Complete change in shape and appearance - Plant disintegrated and rotted - Color completely changed
2B	Flowerless plant stored in a PVC zip-lock bag at room temperature	- Color change in leaves (green → dark green and yellowish) - Leaves dried and plant remained preserved	- Completely dried and color changed - Leaves dark brown and "blinded"	- Complete color change and drying - Dark brown, dull leaves observed
3B	Rootless plant stored in a PVC zip-lock bag at room temperature	Slight color change in leaves, flower shrunk; plant preserved	- No change from last week - Plant preserved	- No change from last week - Plant preserved



Table 4. Overview of the results for Group C samples throughout the four experimental phases. The Group C samples were packaged in paper bags and stored under freezer conditions. The results, presented in Table 4, indicate that the samples remained largely preserved, with minor changes such as flower shriveling, flattening, and slight stem bending, while the plant structure and flower color were generally maintained.

	Phase 1	Phase 2	Phase 3	Phase 4
1C	A whole plant in a paper bag in the freezer	- Slight color change in stem and roots - Plant remains identical to collection (preserved)	- Color change in stem and roots - Flower turned purple - Reduction in stem diameter - Plant remained intact	- Flower shrivelled and flattened compared to previous week - Plant preserved
1C'	A whole wet plant kept in a paper bag in the freezer	- Slight color change in plant - Roots and flowers dried - Changes in stem diameter - Plant preserved	- Color change in plant - Roots and flowers dried - Stem diameter changed - Plant preserved	- No change from last week - Plant preserved
2C	A flowerless plant kept in a paper bag in the freezer	- Leaves darker and yellowish - Plant dried - Plant preserved	- Leaves darker and yellowish - Roots color changed - Plant dry - Plant preserved	- No change from last week - Plant preserved
3C	A rootless plant kept in a paper bag in the freezer	- Stem and flower leaf slightly darker green - Stem diameter reduced - Plant preserved	- Stem and flower leaf slightly darker green - Reduction in stem diameter - Flower color unchanged - Plant preserved	- Flower flattened - Stem bent - Flower color unchanged - Plant preserved

Table 5. Overview of the results for Group D samples throughout the four experimental phases. The Group D samples were packaged in paper bags and stored under freezer conditions. The results, presented in Table 5, indicate that the samples remained generally preserved, with minor changes including petal adhesion, residual moisture, desiccation, and yellowing of leaves and stems, while the plant structure was largely maintained.

	Phase 1	Phase 2	Phase 3	Phase 4
1D	The whole plant stored in the freezer in a PVC zip bag	- Only color of the plant changed - Plant preserved	- Color change in some leaves (some remain green, others darker) - Plant preserved	- No change from last week - Plant preserved
1D'	The whole wet plant stored in the freezer in a PVC zip bag	- Color of plant changed - Petals stuck together - Plant still wet but preserved	- Color change in roots and leaves (some leaves retained green but darkened) - Petals stuck together - Plant still damp - Plant preserved	- Petals stuck together - Plant still moist



2D	A flowerless plant stored in the freezer in a PVC zip bag	- Slight desiccation - Leaves darker green and yellowish - Plant remained intact	- Slight desiccation - Leaves darker green and yellowish - Plant remained intact	- Desiccation observed - Color change: leaves darker green and yellowish - Plant intact
3D	Rootless plant stored in a PVC zip bag in the freezer	- Stem and leaves darker - Plant preserved	- Stem and leaves darker green - Flower color unchanged - Plant preserved	- Yellowish changes observed on the stem - Plant preserved

Table 6. Overview of the results for Group E samples throughout the four experimental phases. The Group E samples were packaged and stored in the herbarium. The results, presented in Table 6, indicate that the samples remained fully preserved, showing no significant changes from the previous week, with complete drying observed in some cases.

	Phase 1	Phase 2	Phase 3	Phase 4
1E	The whole plant kept in the herbarium	Plant pressed; leaves darkened; flowers and roots unchanged; plant completely dried and preserved.	Plant pressed; petals shrunk; leaves changed color; flower and roots unchanged; plant completely dried and preserved.	- No change from last week - Plant preserved
1E'	A whole wet plant preserved in a herbarium	Plant completely dried (paper changed regularly due to wet collection); leaves darker green; root lighter; flowers unchanged; plant preserved.	- No changes from last week - Plant preserved	- No changes from last week - Plant preserved
2E	A flowerless plant preserved in a herbarium	Plant completely dried and preserved; roots slightly darker; leaves darker green and yellowish.	- No changes from last week - Plant preserved	- Completely dried and preserved - No changes from last week
3E	A rootless plant preserved in a herbarium	Plant completely dried; flower retained shape and color with pink tips; stem diameter reduced; leaves darker green and yellowish; plant preserved.	- No changes from last week - Plant preserved	- No changes from last week - Plant preserved

After a four-week monitoring period of the plant's physical characteristics, the interpretation was based on representative samples showing the greatest and least degree of preservation — specifically, those that remained entirely intact and those that underwent complete deterioration. The following text presents photographs of the most representative samples.

Figure 3 presents the Phase 1 collection and packaging of Group B plant samples that were stored at room temperature in polyvinyl chloride (PVC) zip bags.





Figure 3. Group B of samples (1B - Whole plant stored in a PVC zip-lock bag at room temperature; 1B' - Whole wet plant stored in a PVC zip-lock bag at room temperature; 2B - Flowerless plant stored in a PVC zip-lock bag at room temperature; 3B - Rootless plant stored in a PVC zip-lock bag at room temperature).

Figure 4 presents the Phase 4 collection and packaging of Group B plant samples that were stored at room temperature in polyvinyl chloride (PVC) zip bags.



Figure 4. Group B of samples (1B - Whole plant kept in a PVC zip-lock bag at room temperature; 1B' - Whole wet plant stored in a PVC zip bag at room temperature; 2B - Flowerless plant stored in a PVC zip bag at room temperature; 3B - Rootless plant stored at room temperature in a PVC zip bag.)

Figure 5 presents the Phase 1 collection and packaging of Group E plant samples that were stored in the herbarium (pressed at room temperature).



Figure 5. Group E of samples (1E - The whole plant kept in the herbarium; 1E' - A whole wet plant preserved in a herbarium; 2E - A flowerless plant preserved in a herbarium; 3E - A rootless plant preserved in a herbarium).



Figure 6 presents the Phase 4 collection and packaging of Group E plant samples that were stored in the herbarium (pressed at room temperature).



Figure 6. Group E of samples (1E – The whole plant in the herbarium; 1E' – A whole wet plant preserved in a herbarium; 2E – A flowerless plant preserved in a herbarium; 3E – A rootless plant preserved in a herbarium).

After the fourth phase of the study, the herbarium samples showed the best preservation — the plants remained intact and completely dried without significant alterations. Conversely, the samples stored in PVC zip-lock bags at room temperature displayed pronounced drying, color alteration, and partial decay, showing irreversible damage to their structure.

6. DISCUSSION

The method of preservation of the physical evidence is of great consequence, as it ensures the maintenance of the characteristics that are essential for forensic identification. In the event of inadequate storage of traces, the aforementioned characteristics may be compromised, thereby rendering identification unfeasible or unlikely.

The results obtained in this study demonstrate the significant influence of the packing and drying method on the condition of the plant, including factors such as moisture content, damage, and dimensions. We must note that all observed changes were assessed qualitatively through systematic visual inspection rather than numerical scoring, as the aim of the study was to document practical forensic preservation outcomes based on observable morphological degradation or preservation. It is imperative that samples collected in a wet state are stored in a dry and cool environment, as well as in plastic containers or refrigerators. In this experiment, wet samples were stored in a freezer in PVC zip bags, which was found to be the optimal method for preserving the characteristics of these samples. Furthermore, it has been demonstrated that the optimal storage conditions for the majority of the collected traces are a dry and cool environment. It is of the utmost importance that the plant be allowed to dry thoroughly and uniformly. The specimens that were maintained at room temperature in the herbarium exhibited the most favorable outcomes.

The results of the experimental study indicate that the optimal method for collection is to obtain the entire plant, including the root. The conditions under which a plant is kept are crucial. The findings indicate that maintaining the plant in the herbarium is the most effective method. During the storage period, the plant was kept at room temperature in a



dry environment, resulting in uniform and rapid desiccation. Additionally, the specimen remained intact and showed no signs of deterioration (Figure 5 and Figure 6, Group E). In contrast, a plant stored moist in a PVC zip bag at room temperature exhibited complete destruction, discoloration, and the shriveling and disintegration of parts (Figure 3 and Figure 4 – Group B). In these samples, progressive morphological changes were observed throughout all four storage phases due to dehydration and microbiological contamination caused by the external conditions in which the plant was stored (PVC bag and room temperature – high humidity led to the degradation of biological material). In addition to the external conditions affecting the changes in these plants, the condition is further worsened when the plant is collected wet (sample 1B'), which accelerates the growth of microorganisms and leads to tissue disintegration. In a closed environment, without air circulation, moisture accumulation creates anaerobic conditions that further promote the breakdown of organic structures. Therefore, this storage method proved to be completely ineffective and resulted in the destruction of the sample. When a plant is collected in a moist state, it is essential to store it in cooling devices that maintain a lower temperature. This is supported by the findings of this experiment, which demonstrated that preserving a moist plant by storing it in a freezer was effective.

The preparation of this experiment included a literature review in forensic botany to explore findings related to the collection and preservation of plant samples. While relevant information was identified, there were no detailed observations on the continuous monitoring of plant behavior under varying storage conditions to determine the optimal preservation method.

Margiotta et al. (2015) demonstrated that bryophyte fragments can link a suspect to a crime scene, highlighting their adhesive properties and the forensic potential of mosses (*Tortula muralis* Hedw.). However, bryophytes have a simple structure, high desiccation tolerance, and low metabolic activity compared to higher vascular plants. Therefore, while their results confirm the utility of botanical evidence, they do not provide information on how storage conditions might influence the morphology or integrity of more delicate higher plant tissues, which is critical for forensic applications involving leaves, stems, or flowers. In this context, the study's findings cannot be generalized to plant-origin trace evidence broadly, leaving a gap that this research addresses by monitoring morphological changes in higher plants under controlled storage conditions [14].

Kasprzyk (2023) provides a systematic review of plant identification methods, noting reliable, low-cost techniques suitable for small samples and emphasizing correct collection and transport. Yet the review explicitly acknowledges that post-collection storage is underexplored, and there is little empirical evidence on how factors such as moisture, temperature, or packaging affect evidence integrity over time. This is a key limitation because forensic practitioners must often store samples for days or weeks before analysis. The present study fills this gap by experimentally assessing how different storage conditions affect sample morphology and integrity, thereby providing actionable guidance for forensic protocols [15].

Miller et al. (2005) presented several cases where botanical evidence was used to lead and solve cases based on their investigative experiences. However, the paper does not compare different storage conditions for a single plant species [10].

Alotaibi et al. (2021) explored the diverse roles and significance of medicinal plants in forensic science, highlighting their dual potential as therapeutic agents and lethal poisons. When



administered in excessive quantities, these plants can be used as instruments of murder or suicide. The significance of collecting traces and remnants of toxic medicinal plants at crime scenes to assist in determining the cause of death has been previously discussed [16].

A comparative analysis of the aforementioned studies and the present findings highlight a significant gap in the literature regarding standardized methods for collecting, storing, and preserving plant-origin trace evidence. Earlier works primarily focused on the identification and classification of plant material, while overlooking the influence of environmental and procedural factors — such as humidity, temperature, and duration of storage — on the long-term integrity of botanical samples. The results of this study provide experimental evidence that different storage conditions significantly influence the preservation and morphological stability of plant materials, thereby enhancing the understanding of how botanical traces should be collected and maintained to ensure their reliability in forensic investigations, as the preserved morphological characteristics are essential for subsequent species identification.

7. CONCLUSION

Based on the findings of this research, the following conclusions can be drawn:

- It is crucial to enhance awareness of the significance and applicability of plant samples as evidence in criminal proceedings, as there is a general tendency to focus on other types of evidence at the crime scene while underestimating the potential importance of plant samples. This study contributes to that goal by experimentally demonstrating how different storage and preservation methods affect the condition and recognizability of plant samples, thereby offering practical guidelines for improving the forensic use of plant evidence. Proper awareness can help investigators recognize that plant evidence may be crucial for identifying victims or perpetrators, linking individuals to crime scenes, and supporting other investigative and legal processes. Currently, there is a greater emphasis on form and biological evidence, with plant evidence receiving comparatively less attention.
- In the case of plant material, it is advisable to collect the entire plant, including the root system, in order to obtain the most comprehensive data set. Each collected sample should be properly labelled (in a consistent manner both at the scene and in the investigative documentation), with a card attached to the package containing all the relevant information about the sample.
- To achieve the best preservation results, plant samples should be carefully pressed between sheets of absorbent paper or newspaper using a herbarium press. The press should be tightened evenly to ensure flat, uniform contact and allow air circulation. The absorbent paper should be checked and replaced regularly to prevent moisture accumulation and microbial contamination, such as mold growth or decay. The samples should be left to dry naturally in a well-ventilated space at room temperature for approximately 7–10 days, depending on ambient humidity, with optimal drying achieved when the samples become crisp but retain their natural color and structure. If the samples are moist or wet, they should be temporarily stored in sealed plastic containers or refrigerated packages at approximately 4°C until they can be safely pressed and dried. Freezing must be avoided, as it can damage the samples.



- After drying, collected plant samples should be stored in a cool, dry environment with low humidity (ideally below 50%), with each sample kept separately to prevent cross-contamination. Samples can be placed in cardboard folders or paper envelopes for drying under a press, which allows most samples to dry efficiently within the shortest possible time. To prevent insect infestation, it is important to use safe repellents at the drying and storage site, such as natural substances like dried lavender, neem leaves, or silica gel, while avoiding chemical repellents that may damage plant samples.

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