DNA & Crime:
Can DNA analysis assist in disrupting the illegal trade in cannabis?

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Table of Contents

SECTION 1:

Cannabis, DNA, and Law Enforcement.

Introduction

Cannabis, a genus of plants, a narcotic, and a multi-billion dollar global economy[1]. While some biologists disagree, it is widely accepted that the Cannabis genus can typically be divided into three primary species: Cannabis Sativa, Cannabis Indica, and the less commercially significant, Cannabis Ruderalis[2]. This distinction is vital because the psychoactive and industrial uses of the plant is determined by the concentration of specific secondary metabolites (molecules produced from biological chemicals reactions), primarily that of the cannabinoids Tetrahydrocannabinol (THC) and Cannabidiol (CBD)[3]. Due to the presence of an estimated 130 different cannabinoids with any given cannabis species (including hybrids), legal definitions often hinge on thresholds to differentiate medical and industrial substances from illegal intoxicants[4].

The challenge for policing the illegal trade of narcotics often lies in effectively tracing the origin and linking criminal activity via other intelligence methods. In order to reliably distinguish legal cultivation from illicit enterprise, Law Enforcement Agencies (LEAs) may utilise Forensic Botany Techniques, such as the analysis of a plant's genetic makeup, in order to stop these sophisticated, large-scale, and often international criminal networks. By examining the unique genetic signature of seized material, LEAs can potentially determine the geographic origin of the plant, connect samples to a common source/network, and can crucially shift reliance from circumstantial to scientifically backed evidence. It is on this fundamental basis that this essay draws its core argument; the forensic DNA analysis of Cannabis can effectively and significantly assist policing efforts in disrupting the illegal trade through methods such as tracing, linking and mapping, when (and only when) backing more robust investigatory methods and intelligence gathering techniques.

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[3] Cleveland Clinic (2023). Marijuana (Cannabis, Weed). [online] Cleveland Clinic. Available at: https://my.clevelandclinic.org/health/articles/4392-marijuana-cannabis [Accessed 27 Nov. 2025].

[4] United States' Congress (2018). Agriculture Improvement Act of 2018. [online] Available at: https://www.congress.gov/115/bills/hr2/BILLS-115hr2enr.pdf [Accessed 27 Nov. 2025].

Plant DNA and the basics of botany.

The Cannabis plants, as do most forms of organic life, contains two primary forms of DNA: nuclear DNA (nDNA), and mitochondrial DNA (mtDNA), however - unlike its fauna cousins - most flora also have a third major source of DNA, Chloroplast DNA (cpDNA)[5]. The genes encoded within this DNA dictate the plant's morphology, growth characteristics, and, most importantly, its chemical profile, including the ratio and concentration of cannabinoids, which is of paramount importance to criminal classification. Non-Nuclear DNA provide a direct, stable link to the maternal line[6], allowing researchers to trace the genetic history and origin of a plant even across hybridisation events. By establishing databases of these genetic markers from seized and known geographical samples, forensic botany provides the objective, scientific evidence required to effectively dismantle sophisticated criminal distribution networks.

As previously stated, cannabinoid cultivation has historically centred on two phenotypes: C. Sativa (associated with tall stature, long flowering times, and a head-high effect)[7] and C. Indica (known for shorter, bushier plants, shorter flowering times, and a body-high effect)[8], ignoring the lesser C. Ruderalis. While these different species of cannabis have had differing historical and practical lineages, the commercial market has resulted in cross-breading, leading to countless "hybrid" strains[9] that defy simple morphological classification and constraints. This high level of genetic mixing necessitates a robust molecular approach for accurate identification and origin-tracing. This is due to the fact that crossbreeding allows for an increase in desired traits, such as resistance to disease, higher yield, and artificially increased concentration in chosen metabolites.

The mode of growth significantly affects the resulting genetic profile of an illicit crop. Asexual cultivation, commonly referred to as cutting or cloning, involves taking cuttings from a 'mother plant' and then using that cutting to develop new roots. Every clone is genetically identical, creating a powerful molecular signature for linking entire grow

[5] Levin, S.A. (2013). Encyclopedia of biodiversity. 2nd ed. [online] San Diego: Academic Press. Available at: https://www.sciencedirect.com/referencework/9780123847201/encyclopedia-of-biodiversity [Accessed 27 Nov. 2025].

[6] Shen, J. and others (2025). A nuclear-encoded endonuclease governs the paternal transmission of mitochondria in Cucumis plants. Nature Communications, [online] 16(1). doi:https://doi.org/10.1038/s41467-025-59568-7.

[7] Emerald Harvest Team (2025). Cannabis Plant Morphology . [online] Emeraldharvest.co. Available at: https://emeraldharvest.co/cannabis-plant-morphology/ [Accessed 27 Nov. 2025].

[8] Ibidem, Footnote № 7

[9] Arnold, M. (2022). What Are Hybrid Cannabis Strains & How Are They Created? [online] Royal Queen Seeds. Available at: https://www.royalqueenseeds.com/uk/blog-what-are-hybrid-cannabis-strains-how-are-they-created-n752 [Accessed 28 Nov. 2025].

operations to that single mother plant. Conversely, sexual cultivation from seeds results in genetically unique offspring due to the random assortment of parental chromosomes (recombination), leading to greater variability within a population. Forensic analysis must therefore account for the propagation strategy to correctly interpret genetic findings, especially when considering the legal complications. While growing cannabis is a crime within the UK, under section 6(2) of the Misuse of Drugs Act 1971[10], the possession of cannabis seeds is NOT a crime, as long as they are not germinated for growing cannabis plants.

The use of asexual cultivation of cannabis plants is - from a strictly logistical position - advantageous over sexual cultivation; while sexual cultivation allows for greater genetic diversity (which can help to mitigate the effects of blight and disease[11]) the illicit trade of cannabis almost entirely relies on the cannabis gynoecia ("female plants") as the content of THC is drastically higher than the androecium bearing plants[12]. Furthermore, pseudo-hermaphroditism (better described as monoecy, due to the fact that true hermaphroditism requires both sexual organs on the same flower) is widespread within cannabis species. With the street value of marijuana exceeding “£10/g or £180/oz..” (according to an anonymous informant, during a private interview conducted for this essay) [13], analysing the genetic make up of these plants allows forensic botanists and LEAs to identify and regulate the cultivation of cannabis accordingly.

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[10] HM Government (2020). Misuse of Drugs Act 1971. [online] Legislation.gov.uk. Available at: https://www.legislation.gov.uk/ukpga/1971/38/section/6 [Accessed 26 Nov. 2025].

[11] Berkley (2021). Monoculture and the Irish Potato Famine: cases of missing genetic variation - Understanding Evolution. [online] Understanding Evolution. Available at: https://evolution.berkeley.edu/the-relevance-of-evolution/agriculture/monoculture-and-the-irish-potato-famine-cases-of-missing-genetic-variation/ [Accessed 27 Nov. 2025].

[12] Alkarim, R. (2025). Male and Female Cannabis Plants: These Are the Differences – nowomed. [online] nowomed. Available at: https://nowomed.com.au/blog/male-female-cannabis/ [Accessed 27 Nov. 2025].

[13] Anon (2025). An Anonymous Interview on the Street Value of Narcotics. 25 Nov.

Network Analysis on Trade

As stated earlier, LEAs utilise forensic botany to help with the analysis of the genotype and phenotype of cannabis specimens, applying network theory[14] to map out the illicit trade of cannabis from grow site to suppliers. The core structure consists of four distinct layers: grow sites (source nodes), regional distributors (intermediate nodes), bulk movers (transportation nodes), and sellers (endpoint nodes)[15]. Each specimen of cannabis seized generates a DNA signature that can be matched against other samples, creating links between nodes and revealing the hidden connections within the trafficking network.

Network analysis focuses on identifying crucial elements within this structure. Central nodes emerge as high-degree points with multiple connections, while super-producers[16] are identified as grow sites linked to numerous distributors. Distribution hubs become apparent through their position in facilitating movement between clusters. By analysing DNA matches and distribution patterns, LEAs can classify nodes into these categories and prioritise targets for disruption. Edge analysis[17] further refines understanding by weighting connections based on DNA match frequency, seized material volume, and temporal patterns of activity. Strategic disruption targets emerge from this analysis, as primary targets include nodes with high degree centrality (bridges between major clusters, super-producer grow sites, and major distribution hubs), while secondary targets encompass supporting infrastructure such as alternative distribution routes, and backup supply chains. This tiered approach allows law enforcement to systematically dismantle networks while maintaining operational flexibility.

Network theory in practise follows three distinct phases: Initial, Expansion and, Maintenance. The initial phase begins with high-volume seizures in major cities and their surrounding areas, establishing baseline DNA profiles and mapping the basic network structure. The expansion phase extends to secondary markets and smaller seizures, refining the network and identifying emerging patterns. Finally, the maintenance phase involves regular network updates, continuous DNA sampling, pattern recognition, and adaptive targeting strategies, inducing as much disruption as possible.

[14] Computer Laboratory (Cambridge) (n.d.). Introduction to Network Introduction to Network Theory Theory. [online] Available at: https://www.cl.cam.ac.uk/teaching/1011/PrincComm/slides/graph_theory_1-11.pdf.

[15] Duijn, P.A.C., Kashirin, V. and Sloot, P.M.A. (2014). The Relative Ineffectiveness of Criminal Network Disruption. Scientific Reports, [online] 4(1). doi:https://doi.org/10.1038/srep04238.

[16] BBC News (2025). ‘Largest ever’ cannabis farm found in former Kirkcaldy college campus. BBC News. [online] 1 Jul. Available at: https://www.bbc.co.uk/news/articles/cr799d98vk3o [Accessed 27 Nov. 2025].

[17] Reed, K. (2024). Network theory | EBSCO. [online] EBSCO Information Services, Inc. | www.ebsco.com. Available at: https://www.ebsco.com/research-starters/physics/network-theory [Accessed 28 Nov. 2025].

The challenges of Law Enforcement

LEAs face complex challenges when utilising DNA analysis and forensic botany in efforts to disrupt the illegal trade of cannabis. A fundamental issue stems from the fact that industrial hemp and marijuana are identical varieties of C. Sativa making visual differentiation impossible. While DNA analysis can identify the species, it cannot determine the crucial THC content. This limitation means that DNA analysis alone is insufficient for distinguishing between legal and illegal cannabis, forcing investigators to rely on chemical analysis alongside botanical examination. This is not the only challenge faced as practical implementation also poses significant issues for law enforcement.

Obstacles such as limited access to specialised equipment capable of performing both DNA and chemical analysis, can create resource constraints, while the high cost of maintaining dual-capacity laboratories forces difficult budget decisions. Furthermore, the need for trained personnel in both forensic botany and chemical analysis creates staffing challenges. Time sensitivity also plays a critical role, as analysis must be completed quickly to maintain investigation momentum while preventing sample degradation that could affect test accuracy.

An example of indirect physical challenges posed can be seen through the lens of local geopolitical factors, especially when considering the open borders within the Schengen area. The absence of systematic border controls allows traffickers to move freely throughout much of Europe, creating a vast, interconnected network where illegal cannabis can flow relatively unimpeded. This freedom of movement makes tracking and intercepting shipments extremely challenging, as smugglers can exploit the lack of checkpoints to transport goods across multiple jurisdictions without detection, particularly when combined with the limitations of forensic botany as an evidentiary tool.

Furthermore, emerging developments continue to reshape these challenges, with industrial hemp now legally grown in many countries[18], advances in hemp microbiome research may create new identification challenges. The increasing sophistication in legal hemp cultivation methods and potential for genetic modification could further complicate traditional identification methods. International cooperation becomes increasingly important as different jurisdictions establish varying analytical standards, requiring careful coordination across borders to handle evidence and share intelligence effectively. However issues do not end with at the analysis stage as the LEAs must now present their evidence to the court. Forensic botany (as most forms of DNA science) still remains an emerging field, rather than a

[18] Brant, E. (2014). Where in the world can you legally smoke cannabis? BBC News. [online] 30 Oct. Available at: https://www.bbc.co.uk/news/newsbeat-29834450 [Accessed 26 Nov. 2025].

fully established science in, and of, its own right[19]. This lack of acceptance allows for significant hurdles in court proceedings.

To achieve a lawful conviction, prosecutors must demonstrate beyond reasonable doubt that the seized material meets the statutory definition of an illicit drug, which hinges on its measured THC content. DNA based methods can clarify a plant's genetic identity (its species, varietal lineage, or potential links to particular cultivation sources) but they cannot determine the actual THC concentration that legally distinguishes industrial hemp from criminalised high THC cannabis. Because this metric is central to the legal definition of the offence, genetic evidence alone cannot establish that the material is a controlled substance; instead, it can only contribute contextual or associative information about origin and distribution networks. Consequently, it remains subordinate to chemical analysis, which is the only technique capable of generating the quantitative THC measurements required to satisfy the legal burden of proof.

Given that samples of industrial hemp and illicit marijuana are frequently indistinguishable in both appearance and genetic composition, law-enforcement could confiscate a lawful hemp sample, sequence it, and still find it matching the genetic profile of a known trafficking group. If the accompanying chemical analysis is absent, compromised, or successfully challenged, the genetic match (however strong) holds no legal weight, as there is no evidence that the linked material qualifies as a prohibited drug. For this reason, forensic botany cannot serve as the primary basis for classifying a cannabis sample in legal proceedings. Its value lies in generating investigative intelligence, such as mapping supply networks or demonstrating source relationships, which must ultimately be corroborated by definitive chemical assessment of THC content.

This combination of factors creates a highly challenging operational environment that significantly undermines effective law-enforcement responses to illicit cannabis trafficking. Traffickers are able to exploit the freedom of movement within the Schengen Area while simultaneously capitalising on the limitations that continue to constrain forensic botany efforts, particularly in distinguishing legal from illegal varieties. Prosecutors, meanwhile, must meet stringent standards, making it more difficult to construct cases that are both scientifically robust and legally sustainable. These pressures showcase why traditional forensic botany alone is insufficient and must be supplemented by advanced profiling, rigorous documentation, and strengthened international cooperation mechanisms. This is why forensic botany, while effective as a tool, must always be supporting other forms of intelligence and investigatory science. A comprehensive, multi-disciplinary approach allows

[19] Roth, J. and others (2021). Application of a Forensic DNA Extraction System for Cannabis sativa Seed Identification. Journal of Biomolecular Techniques : JBT, [online] 32(4), p.3fc1f5fe.3e117784. doi:https://doi.org/10.7171/3fc1f5fe.3e117784.

LEAs to address the challenges posed, ensuring that investigations remain methodologically sound, compliant with evolving regulations, and capable of withstanding scrutiny in global and regional legal contexts.

Conclusion

Cannabis remains a controlled substance throughout much of the world. With the global illicit trade of narcotics being worth fivefold that of some nations, it is ever so important for governments to enforce the laws. Controlling the import/export and cultivation of cannabis is becoming more and more difficult as hybridisation and cloning allow for more genetically robust crops. This allows for forensic botany to provide high-value investigative insights by leveraging non-nuclear DNA markers, such as cpDNA and mtDNA to establish maternal lineage. Law enforcement agencies can then apply network theory to visualise and prioritise criminal nodes like "super-producers.", and utilise independent intelligence to apply disruptive techniques on specific targets with high node centrality. However, there are limitations to the use of DNA analysis, primarily DNA analysis does not indicate the actual content of psychoactive metabolites within a sample which is required for prosecution within certain jurisdictions where it is legal to grow industrial hemp.

Furthermore there are logistical constraints present within enforcing laws on the illegal importation of any substance, not just cannabis. Within European contexts, this can be seen through the openness of the borders within the Shengen Area. As some Schengen areas begin to decriminalise and legalise cannabis (be it hemp or marijuana), this will begin to flow into neighbouring countries. This allows for the conclusion that the forensic DNA analysis of Cannabis (while limited in some aspects) can effectively and significantly assist policing efforts in disrupting the illegal trade, especially when backing more robust investigatory methods and intelligence gathering techniques.

SECTION 2:

Annex and Accreditation.

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