

Unveiling the Botanical Versatility of *Cannabis sativa*: A Modern Perspective on Medicinal and Industrial Applications

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Abstract

Cannabis sativa is a highly versatile plant species with a long history of use in medicine, industry, and culture. Once stigmatized due to its psychoactive properties, the plant is now being re-evaluated for its broad applications in health and sustainable development. Its rich phytochemical profile, particularly cannabinoids such as tetrahydrocannabinol (THC) and cannabidiol (CBD), underpins its therapeutic potential. Research has demonstrated its efficacy in managing epilepsy, chronic pain, chemotherapy-induced nausea, anxiety, and other neurological and psychological disorders. At the same time, industrial hemp varieties of *Cannabis sativa*, characterized by low THC content, have emerged as valuable resources in textiles, construction, nutrition, and renewable energy. Hemp fibers are durable and eco-friendly, hempcrete is an innovative green building material, and hemp seeds provide highly nutritious food products. *Cannabis sativa* contributes to environmental sustainability through carbon sequestration, soil restoration, and phytoremediation of contaminated sites, significant challenges remain, particularly inconsistent regulatory frameworks, legal restrictions, and the need for robust clinical trials to validate medicinal claims. Looking ahead, biotechnology and genomics offer pathways to develop specialized cultivars optimized for medical and industrial purposes, aligning with global goals of sustainability and climate resilience. This modern perspective highlights *Cannabis sativa* not only as a source of therapeutic compounds but also as a driver of green innovation and sustainable livelihoods.

Keywords: *Cannabis sativa*, Hemp, Medicinal Plants, Industrial Applications, Biodiversity, Sustainability, Cannabinoids

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Graphical abstract of *cannabis sativa*-Medical and Industrial applications

Introduction

Cannabis sativa, one of the oldest domesticated plants known to humanity, occupies a unique position at the intersection of medicine, industry, and culture. With archaeological evidence tracing its use back thousands of years in Asia, this plant has been valued historically for its fiber, seeds, and therapeutic properties [1]. While the psychoactive effects of its primary cannabinoid, tetrahydrocannabinol (THC), led to widespread stigmatization and restrictive legislation during much of the 20th century, a resurgence of scientific inquiry has revealed the extraordinary versatility of *Cannabis sativa*. Today, it is increasingly recognized not merely as a recreational substance but as a botanical resource of immense medicinal, nutritional, and industrial importance.

The growing interest in *Cannabis sativa* stems largely from its diverse phytochemical profile, which includes cannabinoids, terpenes, and flavonoids. Among these, cannabidiol (CBD) and THC have been the most extensively studied. Unlike THC, CBD is non-psychoactive and has been shown to exhibit a wide range of pharmacological effects, from anti-inflammatory and anxiolytic properties to anticonvulsant and neuroprotective functions. Clinical trials and patient experiences underscore its therapeutic promise in managing conditions such as epilepsy, multiple sclerosis, chronic pain, and anxiety disorders [2]. In many countries, medical cannabis programs now provide regulated access to cannabinoid-based therapies, reflecting a shift toward evidence-based policymaking. Equally significant is the industrial potential of hemp, a variety of *Cannabis sativa* characterized by its low THC content. Hemp cultivation requires fewer chemical inputs than conventional crops and contributes to sustainable farming practices. Its strong, lightweight fibers are used in textiles, rope, paper, and increasingly in eco-friendly building materials such as hempcrete. Meanwhile, hemp seeds are rich in essential fatty acids, proteins, and minerals, making them a valuable dietary supplement [3]. In the context of global climate change, hemp has also attracted attention for its environmental benefits: it sequesters carbon dioxide efficiently, enriches soil fertility, and is capable of phytoremediation, helping to restore polluted environments, the utilization of *Cannabis sativa* remains complicated by legal, social, and scientific challenges. Inconsistent regulations across different regions create barriers to research, cultivation, and commercialization. In many countries, cannabis is still classified as a controlled substance, restricting scientific exploration and limiting access for patients who could benefit from its medicinal properties [4], while anecdotal evidence is abundant, rigorous clinical trials are still needed to establish standardized treatments and dosages, ensuring safety and efficacy. Public perception also remains divided, with lingering stigma and misconceptions slowing down broader acceptance of cannabis-based products, the global landscape is changing. Many nations are revisiting their *cannabis* policies, opening pathways for innovation in medicine, agriculture, and industry [5]. Advances in biotechnology and genomics now enable the development of specialized cannabis cultivars with targeted cannabinoid profiles, designed for specific therapeutic or industrial applications. At the same time, the rise of sustainable development agendas positions hemp as a promising crop for addressing environmental and economic challenges. This dual role of *Cannabis sativa*—as both a medicinal resource and an industrial raw material—illustrates its capacity to contribute to human well-being and planetary health, *Cannabis sativa* from a modern perspective, highlighting its potential to transform healthcare, promote sustainable agriculture, and drive green innovation. By examining its medicinal applications, industrial uses, environmental contributions, and the challenges it faces, the discussion aims to shed light

on the evolving role of cannabis in contemporary society [6]. Ultimately, the goal is to reframe *Cannabis sativa* not as a controversial plant of the past but as a key resource for building a healthier, more sustainable future.

Botanical Characteristics of *Cannabis sativa*

Cannabis sativa is an annual, dioecious, and flowering plant belonging to the family Cannabaceae. It is one of the most morphologically and chemically diverse species in the plant kingdom, reflecting centuries of human cultivation and natural adaptation. The plant is easily recognizable by its distinctive palmate leaves, typically composed of five to nine serrated leaflets, which maximize surface area for photosynthesis. Another notable feature is the presence of glandular trichomes, microscopic hair-like structures located primarily on the female inflorescences. These trichomes secrete a sticky resin that contains cannabinoids, terpenes, and flavonoids—the bioactive compounds responsible for the plant's medicinal and psychoactive properties [7]. One of the remarkable traits of *Cannabis sativa* is its adaptability. It grows successfully in a wide range of climatic zones and soil conditions, from temperate regions of Europe to tropical zones of Asia, demonstrating resilience and versatility. The plant exhibits rapid growth, with heights ranging from one to six meters depending on the variety and environmental conditions. Its deep taproot system supports stability and efficient nutrient uptake, while its robust stems provide valuable fiber for industrial purposes. *Cannabis sativa* is broadly divided into two main categories based on its tetrahydrocannabinol (THC) content [8]. The first category, hemp, contains less than 0.3% THC and is primarily cultivated for industrial and nutritional purposes. Hemp varieties are prized for their long, strong fibers used in textiles, ropes, and eco-friendly construction materials, as well as their seeds, which are rich in protein and essential fatty acids. Hemp oil, derived from seeds, is also valued in food and cosmetic industries. The second category, commonly referred to as marijuana, contains higher levels of THC, often exceeding 0.3%, and is cultivated for its psychoactive effects and medicinal applications [9]. These varieties are the primary source of cannabinoid-based therapies and recreational products. This distinction between hemp and marijuana has shaped both legal frameworks and scientific approaches to cannabis research. While hemp is increasingly accepted as an agricultural commodity, marijuana remains regulated in many regions due to its psychoactive properties. Understanding these botanical characteristics is essential for harnessing the full potential of *Cannabis sativa*—whether as a sustainable industrial crop or as a source of therapeutic compounds.

Medicinal Applications of *Cannabis sativa*

Cannabis sativa has gained significant attention in recent decades for its medicinal properties, primarily attributed to its diverse phytochemical profile.

The plant contains more than 100 identified cannabinoids, along with terpenes and flavonoids, which collectively contribute to its therapeutic effects. Among these, tetrahydrocannabinol (THC) and cannabidiol (CBD) are the most extensively studied [10]. THC is psychoactive, responsible for the characteristic “high” associated with cannabis use, yet it also exhibits notable medicinal properties, including pain relief, appetite stimulation, and anti-nausea effects. In contrast, CBD is non-psychoactive and has demonstrated efficacy in managing neurological, inflammatory, and psychiatric disorders, making it especially appealing for therapeutic applications where psychoactivity is undesirable.

Cannabinoids and Therapeutic Potential

THC has been successfully used in managing chronic pain conditions, particularly where traditional analgesics are less effective. It is also utilized in stimulating appetite among patients with HIV/AIDS or those undergoing chemotherapy. CBD, meanwhile, has been clinically validated in the treatment of epilepsy, most prominently through the U.S. FDA-approved drug Epidiolex [11]. Beyond epilepsy, CBD exhibits neuroprotective and anxiolytic properties, offering potential in treating Alzheimer's disease, Parkinson's disease, anxiety, and post-traumatic stress disorder (PTSD).

Evidence-Based Medical Uses

Cannabis-derived medicines are increasingly being integrated into healthcare for targeted uses.

Table 1: Medicinal Applications of Cannabis sativa

Therapeutic Area	Key Compounds Involved	Evidence/Applications
Neurological Disorders	CBD	FDA-approved drug <i>Epidiolex</i> for epilepsy; ongoing trials for Parkinson's and Alzheimer's
Chronic Pain Management	THC, CBD	Used in palliative care; reduces chemotherapy-induced nausea and cancer-related pain
Mental Health	CBD, THC	Promising results for anxiety, PTSD, depression, and insomnia (requires more studies)
Inflammation & Autoimmune	CBD	Anti-inflammatory effects explored in arthritis and multiple sclerosis
Appetite Stimulation	THC	Prescribed to improve appetite in HIV/AIDS and cancer patients

Table 2: Industrial Applications of Hemp (Low-THC Cannabis sativa)

Sector	Products/Uses	Sustainability Benefits
Fiber& Textiles	Clothing, ropes, composites	Durable, biodegradable, lower water use than cotton
Construction	Hempcrete, insulation panels	Carbon sequestration, energy efficiency, biodegradable
Food & Nutrition	Hemp seeds, oil, protein powders	High in omega-3 & omega-6, plant-based protein, nutrient-rich
Bioenergy	Bioethanol, biodiesel	Renewable alternative to fossil fuels
Bioplastics	Packaging, automotive parts	Biodegradable, reduces reliance on petroleum-based plastics
Environmental Uses	Soil phytoremediation, crop rotation	Removes pollutants, restores soil health, reduces herbicides

Industrial Applications of Cannabis sativa

Beyond its medicinal potential, *Cannabis sativa*—particularly its hemp variety—offers a wide range of industrial applications that make it a cornerstone of sustainable development. With its versatility, rapid growth cycle, and minimal ecological footprint, hemp provides eco-friendly alternatives across textiles, construction, nutrition, and renewable energy sectors [14].

Fiber and Textiles

Hemp has been used as a fiber source for thousands of years, valued for its strength, durability, and resistance to pests and mold. Compared to cotton, hemp requires significantly less

In neurological disorders, CBD formulations have reduced seizure frequency in treatment-resistant epilepsy. In chronic pain and cancer care, cannabis-based therapies alleviate cancer-related pain, reduce chemotherapy-induced nausea, and improve overall quality of life. In mental health, emerging studies highlight the role of cannabinoids in reducing anxiety, improving sleep quality, and supporting PTSD management [12]. These developments position *Cannabis sativa* as a complementary therapy in multiple domains of medicine.

Challenges in Medical Use

Several barriers hinder the widespread acceptance of cannabis-based treatments. Regulatory restrictions vary across countries, creating obstacles for research and standardization. Product quality is another concern, as cannabinoid concentrations can vary widely, leading to inconsistent therapeutic outcomes [13]. Moreover, while preclinical and small-scale clinical studies are encouraging, large-scale randomized clinical trials remain limited, preventing definitive conclusions about long-term safety and efficacy. Addressing these challenges requires harmonized policies, investment in rigorous scientific research, and standardization of cultivation and extraction methods to ensure reliability.*Cannabis sativa* represents a valuable resource for modern medicine, offering therapeutic solutions for neurological, oncological, and psychiatric conditions, realizing its full potential depends on overcoming scientific, regulatory, and ethical challenges to establish cannabis as a credible and safe component of evidence-based healthcare.

water and fewer pesticides, making it a more sustainable crop. Its long, sturdy fibers are used in the production of ropes, sails, carpets, and increasingly, in modern clothing as a substitute for cotton and synthetic fabrics [15]. The resurgence of interest in eco-conscious fashion has renewed global demand for hemp-based textiles, promoting both environmental sustainability and innovation in fabric technology.

Construction Materials

One of the most innovative applications of hemp is in the construction sector. Hempcrete, a composite material made from hemp hurds mixed with lime, is emerging as a

sustainable alternative to conventional building materials. It is lightweight, fire-resistant, and provides excellent thermal and acoustic insulation [16]. Moreover, hempcrete is carbon-negative—it absorbs more carbon dioxide during growth and curing than it emits—making it an effective tool in reducing the carbon footprint of the construction industry. Its biodegradability also ensures minimal environmental impact at the end of its lifecycle.

Food and Nutrition

Hemp seeds are a powerhouse of nutrition, containing all essential amino acids, making them a complete plant-based protein source. They are also rich in omega-3 and omega-6 fatty acids in an ideal ratio, alongside vitamins E, B-complex, magnesium, and iron. These seeds are consumed raw or processed into hemp oil, flour, protein powders, and plant-based dairy substitutes. Hemp oil, in particular, is prized for its heart-healthy properties and use in dietary supplements [17]. The growing demand for functional foods and plant-based proteins has significantly boosted hemp's role in global nutrition markets.

Biofuels and Bioplastics

Hemp biomass is increasingly recognized as a renewable energy resource. It can be converted into bioethanol and biodiesel, reducing dependency on fossil fuels. Additionally, hemp cellulose serves as a raw material for bioplastics, offering biodegradable alternatives to conventional plastics [18]. These innovations not only provide renewable energy and packaging solutions but also contribute to addressing global issues such as climate change and plastic pollution.

Environmental Benefits

Cannabis sativa, particularly in its hemp form, provides significant environmental advantages that support sustainable agriculture and ecological health. One of its most notable features is its rapid growth cycle, which allows the plant to outcompete weeds naturally, thereby reducing the need for herbicides and other chemical inputs. This makes hemp cultivation a low-impact and environmentally friendly alternative compared to many conventional crops [16]. The plant's deep and fibrous root system plays a crucial role in improving soil structure. These roots penetrate compacted layers, enhance aeration, and increase water infiltration, which helps in maintaining soil fertility and preventing erosion. Hemp's ability to restore degraded soils also makes it an ideal candidate for crop rotation systems, contributing to long-term agricultural sustainability. *Cannabis sativa* functions as a phytoremediator—a plant capable of absorbing and sequestering heavy metals, toxins, and pollutants from contaminated soils. This property has been demonstrated in sites polluted by industrial activities, where hemp successfully extracts cadmium, lead, and other harmful substances. By cleaning up contaminated land while simultaneously producing valuable biomass, hemp embodies the principle of circular sustainability [15].

Additionally, hemp's high rate of carbon dioxide absorption during growth further enhances its role in mitigating climate change.

Regulatory Landscape and Challenges

Despite its broad utility and environmental benefits, *Cannabis sativa* remains subject to complex legal and regulatory barriers worldwide. The primary challenge arises from its association with psychoactive cannabis (marijuana), which contains higher levels of tetrahydrocannabinol (THC). Industrial hemp, in contrast, has very low THC concentrations (typically less than 0.3%), yet its legal status often remains entangled with restrictive narcotics regulations [12]. In many regions, hemp cultivation is legal but governed by stringent rules regarding THC thresholds, licensing, and monitoring. For example, while some countries allow cultivation up to 0.3% THC, others set stricter limits, creating inconsistencies that complicate international trade and market development. This lack of harmonization discourages investment and limits the global integration of hemp-based industries, regulatory uncertainty hinders research into the plant's full potential. Strict controls often delay scientific studies, clinical trials, and product development, slowing progress in both medicinal and industrial sectors. In addition, consumer safety and product standardization remain challenges, as inconsistent regulations lead to variable product quality in global markets [13]. To unlock the full potential of *Cannabis sativa*, a science-based, harmonized regulatory framework is essential. Such a framework should distinguish clearly between industrial hemp and psychoactive cannabis, ensure fair trade, and promote research and innovation while safeguarding public health. Addressing these challenges would allow hemp to emerge as a key resource in advancing sustainable agriculture, renewable industries, and global environmental health.

Future Prospects

The future of *Cannabis sativa* lies in integrated research, innovation, and policy reforms. Advances in biotechnology, genomics, and precision breeding may lead to the development of specialized cultivars tailored for medicine, nutrition, or industry. At the same time, global acceptance of cannabis-based therapies is expected to expand as more evidence emerges from clinical studies [17], its role in promoting sustainable industries aligns with global efforts to combat climate change and achieve the United Nations Sustainable Development Goals (SDGs).

Conclusion

Cannabis sativa stands as a remarkable example of botanical versatility, bridging multiple domains of human advancement—medicine, industry, and environmental sustainability. Its dual identity as both hemp and marijuana demonstrates the breadth of its applications, ranging from life-saving therapies to eco-friendly industrial innovations.

In medicine, cannabinoids such as THC and CBD are reshaping treatments for chronic pain, neurological disorders, and mental health conditions. Meanwhile, hemp's industrial uses—from textiles and construction materials to biofuels and nutrition—highlight its role as a renewable and sustainable resource for the future. Equally significant are the plant's environmental contributions. Through rapid growth, soil restoration, phytoremediation, and high carbon sequestration, *Cannabis sativa* offers solutions to some of the most pressing ecological challenges of our time, including climate change, soil degradation, and plastic pollution. Its adaptability across climates further reinforces its value as a crop that can strengthen both local livelihoods and global sustainability goals, however, *Cannabis sativa* continues to face regulatory hurdles rooted in historical stigma and inconsistent legal frameworks. These restrictions not only constrain research but also hinder large-scale adoption of hemp-based innovations. Overcoming these barriers requires harmonized, science-based policies that clearly differentiate between industrial hemp and psychoactive cannabis, while encouraging responsible cultivation, fair trade, and rigorous product standards, evidence-based perspective, societies can unlock the full potential of *Cannabis sativa* as a cornerstone of sustainable development. In doing so, humanity will not only benefit from its medicinal and industrial promise but also secure a greener, healthier, and more resilient future.

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