

An Analysis of Cannabis: Determining the Origin of the Superlative Weed

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WRITER'S COMMENT: *In the class Plant Biology 143 (the Evolution of Crop Plants), I was prompted to write an up-to-date account of what was known about the evolution of a specific crop plant for the term paper. The unique and complex evolutionary history of Cannabis sativa piqued my interest for many reasons; ergo, I decided to write my paper on this plant. My ambition while writing this paper was to provide an in depth technical review of the origin and domestication of Cannabis sativa that would still be enjoyable and informative for an uninitiated audience.*

INSTRUCTOR'S COMMENT: *PLB143, Evolution of Crop Plants, studies the history of plant domestication and evolution over the last 10,000 years. Agriculture began independently in multiple parts of the globe and the profound effects it had on civilization can be studied by examining the spread of plant material and culture, which traveled together through migration and trade. By evaluating a range of evidence from genetic data to archeological remains we start to understand how early cultivation of plants coupled with conscious and unconscious selection changed crops, making them adapted to human needs and less fit for the wild. The term paper gives students an opportunity to thoroughly research a crop of their interest and evaluate different sources of evidence to find its most likely origin of domestication. The evidence can be contradictory and contain holes. Maisie did a thorough job with her research and wrote an engaging and clear paper full of fascinating facts, which make her paper a pleasure to read.*

—Sarah Dohle, Plant Sciences Department

Abstract:

Cannabis, marijuana, dope, hemp, pot, reefer, grass, weed, ganja—so many terms refer to this same plant, *Cannabis sativa* L., but how much do people really know about it and its origins? One of the most versatile plants known to man, *Cannabis* is grown in modern times mainly for its psychoactive resin, useful fiber, and nutritious seed (Decorte, Potter, and Bouchard 223). A respectable amount of evidence indicates that the original area of speciation and growth of the plant was in Central Asia (Hillig 161; Potter; Clarke and Merlin 22) in the upland valleys of the Tian Shan (a system of mountain ranges located in Central Asia) or Altai Mountains, where the first uses and domestication of *Cannabis* are also thought to have originated after the Pleistocene (Clarke and Merlin 24). This paper describes *Cannabis*'s significance as well as the different archaeological, historical, linguistic, botanical, paleobotanical, and genetic evidence to support the claimed origin. Also discussed is the evidence of human selection pressure (domestication syndrome) on *Cannabis sativa* L.

Introduction:

Throughout the ages, [*Cannabis*] has been extolled as one of man's greatest benefactors—and cursed as one of his greatest scourges. [*Cannabis*] is undoubtedly an herb that has been many things to many people. Armies and navies have used it to make war, men and women to make love. Hunters and fishermen have snared the most ferocious creatures, from the tiger to the shark, in its herculean weave. Fashion designers have dressed the most elegant women in its supple knit. Hangmen have snapped the necks of thieves and murderers with its fiber. Obstetricians have eased the pain of childbirth with its leaves. Farmers have crushed its seeds and used the oil within to light their lamps. Mourners have thrown its seeds into blazing fires and have had their sorrow transformed into blissful ecstasy by the fumes that filled the air. (Abel ix)

As so eloquently expressed by Ernest Abel, the versatility of value of *Cannabis* is virtually unrivaled in the plant kingdom. *Cannabis* has the unique quality to quench mankind's multiple desires—fulfilling a spiritual desire with its psychotropic effects as well as providing entirely physical desires with material and sustenance (Pollan). These virtues caused humans

to begin the cultivation of *Cannabis* and consequently catapult this plant around the world. The inherently weedy and aggressive nature of *Cannabis* is undoubtedly a contributing factor to the plant's expansion.

In the eighteenth century, the Swedish botanist Carl Linnaeus gave this plant its full botanical nomenclature, *Cannabis sativa* (Booth 2). Controversy existed regarding the taxonomy of the genus *Cannabis* for decades. While some scholars argued that *Cannabis* is a monotypic genus containing just one species (*Cannabis sativa* L.), most scholars today agree that *Cannabis* is polytypic, containing distinct species including *C. sativa* L., *C. indica*, and *C. ruderalis* (Hillig 161; Clarke and Merlin 17). Although at times the speciation debate is still convoluted due to the easy hybridization as well as natural history of *Cannabis*, for the purpose of this paper, emphasis will be on one species, *Cannabis sativa* L. (*C. sativa*), or Narrow-leaf hemp, which is the most widespread (Booth 3).

C. sativa is a rapidly growing, highly adaptable, annual herbaceous species spread widely around the world (Abel ix). Iconically, *Cannabis*'s leaves are palmately compound (digitate) with serrate leaflets (Kubitzki 204). Standing erect *C. sativa* can grow up to 5 meters (16 feet) tall in its four to six month season of growth (Clarke and Merlin 325). It is an assertive plant that can grow up to 15 centimeters (~6 inches) a day if given an ideal location in loamy soil under direct sunlight with adequate moisture that can easily shade out competitors (Booth 3). Under strenuous conditions for most other plants, *C. sativa* can thrive; it can tolerate poor, sandy soils as well as elevations up to 8000 ft. (Booth 3).

Different varieties of *Cannabis* are grown based on the desires of the grower. *Cannabis sativa* has been specially domesticated to enhance the production of three main plant parts: the bast (phloem) fiber in the stem, the oil and nutritious content in the “seeds” (achenes), and the psychotropic Tetrahydrocannabinol (and other cannabinoids) with the highest concentration in the female flowers (Small and Marcus). Historically, hemp, the variety grown for its low psychoactive component, was grown for industrial applications, such as paper, textiles, and cordage but today has gained immense popularity for a variety of “products including health foods, organic body care, clothing, construction materials, biofuels, plastic composites and more” (Yonavjak). *C. sativa* has been touted as useful for 25,000 products “ranging from dynamite to Cellophane” (Small and Marcus). Nutritionally, the seeds of *C. sativa* are a vegetarian source of omega-3 fatty acids, are a complete source of

protein (they contain all of the essential amino acids), and are also a potent source of multiple essential minerals, including magnesium, phosphorus, iron, and zinc (Corleone). In the U.S., most hemp product is imported from countries with more relaxed Cannabis laws such as Canada, yet the hemp industry seems to be growing despite this—in 2012 the U.S. hemp industry was valued at an estimated \$500 million in annual retail sales (Yonavjak). The final 2014 Farm Bill included fifteen US states (California, Colorado, Hawaii, Indiana, Kentucky, Maine, Montana, Nebraska, North Dakota, Oregon, South Carolina, Tennessee, Utah, Vermont, and West Virginia) that now have laws legalizing industrial hemp production, as well as allowing universities and agricultural departments to grow and study it (Henricks).

Today the act of growing and selling psychoactive *C. sativa* is nearly universally illegal, despite the longstanding history between humans and *Cannabis* (Clarke and Merlin 9). In spite of illegality, people around the world still risk growing marijuana (the common term for relatively psychoactive varieties of *Cannabis*). In a study from 2006, marijuana production was estimated to have a value of \$35.8 billion, exceeding the value of corn (\$23.3 billion) and wheat (\$7.5 billion) combined (Venkataraman). The United Nations Office on Drugs and Crime's 2013 World Drug Report states, "*Cannabis* is produced in virtually every country of the world, making it the most widely illicitly produced and consumed drug plant" (United Nations 24). Despite efforts on behalf of law enforcement, today *C. sativa* thrives due to clandestine human cultivation and unrelenting self-propagation in vast stretches of the world. *Cannabis sativa* has naturalized populations in 48 of the 50 United States as well as 6 of the 13 Canadian provinces and is even a state-listed "Noxious Weed" in Illinois, Minnesota, Missouri, Pennsylvania, and West Virginia (USDA, NRCS).

But do we in fact know where *Cannabis* originated? The fact that *C. sativa* was among the first plants to be cultivated and diffused by humans, coupled with *C. sativa*'s propensity to escape cultivation and become feral in an extensive number of environmental conditions, has made the determination of a geographic origin a difficult task (Clarke and Merlin 36). Despite these complications, there has been commendable progress in identifying the whereabouts of *C. sativa*'s putative progenitors. This paper will focus on the current evidence illuminating the historical background of *Cannabis sativa*.

Results and Discussion:

The area of origin and domestication of *Cannabis sativa* is widely believed to be in Central Asia (Hillig 161; Potter; Clarke and Merlin 22). Specifically, it is believed to have originated in the upland valleys of the Tian Shan (a system of mountain ranges located in Central Asia) or Altai Mountains, where the first uses and cultivation of *C. sativa* are also thought to have originated (Clarke and Merlin 22). *C. sativa* speciation occurred during the early Pleistocene, and domestication occurred more than a few million years later in the same region (Clarke and Merlin 24). The following paragraphs discuss the different archaeological, historical, linguistic, botanical, paleobotanical, and genetic evidences to support this claim, as well as the evidence of human selection pressure (domestication syndrome) on *Cannabis sativa*.

The human relationship with *C. sativa* is longstanding; it is thought to be one of the first plants domesticated by man (Booth 3). Over time, humans have exerted evolutionary pressure on *C. sativa*, resulting in adaptation to the human environment, a phenomenon referred to as the domestication syndrome. It is important to identify traits of domestication while studying the evolution of *C. sativa* to aid in pinpointing the origin of domestication by differentiating truly wild populations from feral populations. *C. sativa* fruits are achenes (botanically simple), are dry, and do not open at maturity (indehiscent) (Kubitzki 204). One study in the early seventies discovered that “domesticated plants have large achenes which usually lack an adhering, patterned perianth and also lack an elongated base,” or what was called “domesticated achene syndrome,” which differed from achenes of uncultivated plants, which are much more variable (Small 978). The differences between the cultigens and the wild races of *C. sativa* achenes can be explained by the human selective pressure (or lack thereof); in the wild plants, the “small size of fruits would be advantageous to a wild or weedy biotype in that frequently such plants are forced to reproduce in extremely inhospitable circumstances, which dwarf the plants and minimize the energy reserves available to form propagules” (Small 985). The wild races have characteristics such as attenuated achene bases that facilitate disarticulation and dissemination that would be selected for in nature as well as a “marbling” feature of the perianth that may “provide camouflage against herbivorous rodents, birds, and insects, and thus would be of selective value in nature” (Small 985). Since these features are not advantageous in cultivation, the selection

pressure has relaxed, and thus in domesticated *C. sativa* we see large, persistent achenes instead of small, easily dislodged achenes (Small 986).

In 2003, a formal excavation of a shaman tomb in the Yanghai Tombs near Turpan, Xinjiang-Uighur Autonomous Region, China, revealed the oldest evidence of *C. sativa* cultivated specifically for its psychoactive components (Russo et al 4171). 789 grams (1.7 pounds) of potent *C. sativa* was found near the head and foot of the shaman's bier within a wooden bowl and large leather basket (Russo et al 4173). The *C. sativa* had been pounded and the wooden bowl worn smooth, evidently from use as a mortar (Russo et al 4173). It was dated to 2700 years BCE, based on the age of artifacts around it as well as tree ring data (dendrochronology) in China (Russo et al 4173). The *C. sativa* had relatively large achenes, their color was light with some striations, and they had rough, non-concave fruit attachment; all these traits are clear markers of domestication (Russo et al 4175; Small). Other archaeological evidence comes from a postglacial fishing site from 12,000 BCE in southern China; cord-impressed pottery was found with hemp likely being the cordage used (Chang; Clarke and Merlin 65). Carbonized hemp seed was found on a house floor within pottery in an ancient western Yangshao site in northwestern China dated to 5500 to 4500 BCE (Clarke and Merlin 138).

There are voluminous ancient texts and historical references to *C. sativa* throughout Central Asia; “from a historical vantage, *Cannabis* has been found in China since Neolithic times, about 6,000 years ago, with a continuous record of cultivation down to the present” (Li “An archaeological” 437). According to classic Chinese literature, Shen Nung (ca. 2800 BCE), a celebrated herbalist and patron divinity (whose name literally means “Divine Farmer”), was the first to instruct his people to cultivate hemp, and he also prescribed it for medicinal purposes (Henricks; Russo 1; Clarke and Merlin 138). One of Confucius's “Five Classics,” from the second century, titled “Li Chi” (“Record of Rites”), refers to *C. sativa* many times, from proper etiquette for ritual *C. sativa* use to wearing appropriate hemp mourning clothes (Clarke and Merlin 138). As Hui-Lin Li once marveled, “detailed instructions on the cultivation of hemp as both a fiber and a grain crop were given in the most ancient works on agriculture in existence” (Li “The Origin” 295). Relevantly, the oldest paper known to man was made out of hemp, discovered in 1957 within a grave in Shensi province (near Xian, China); it was dated to 104-87 BCE (Li “The Origin” 294).

Due to the uniformity and continuity of the unique written Chinese language, its “monosyllabic characters can be traced back continuously for thousands of years to the early ideograms from which they were derived...the oldest documents can thus be read or deciphered” (Li “The Origin” 300). Therefore, linguistic evidence of the origin of *C. sativa* in Central Asia is strong. The same “nonphonetic, ideographic written language can be used and understood in every part of the vast country” of China (Li “The Origin” 300). The use of *C. sativa* as fiber is thought to be its original and primary use, and there is substantial linguistic evidence for this. The character for hemp today is a relic from the past; the character *ma*, in the ancient *chuan* script, was “derived from ideographic components representing fibers hanging on a rack and placed under a roof shack” (Li “The Origin” 294). Thus, the character for fiber was literally depicting early hemp utilization. Today hemp is known as *ta-ma* (great *ma*) because *ma* is now the generic name for fiber (Li “The Origin” 294; Pollan 157).

A number of clues regarding the origin of *C. sativa* can be found when considering the plant’s own biology (such as abiotic tolerances, reproductive strategies, and breeding system). Since certain aspects of plant growth can only function in certain environments, studying these aspects can give us insight into the geographic region of the evolution of *Cannabis*. Because *C. sativa* is an annual autumn-flowering, short-day photoperiod plant that cannot tolerate frost, we can infer that it had to evolve in a high temperate latitude with shortened seasons (Clarke and Merlin 357). Central Asia fits these criteria. Thorough paleoclimate reconstructions have also been matched with *C. sativa*’s ecological requirements, all which are indicative of its origin in Central Asia (Clarke and Merlin 341). There has been an abundance of paleobotanical evidence including seeds, fibers, fiber and seed impressions, pollen grains, trichomes, carbonized remains, and cannabinoid compounds recovered from Central Asia as well (Clarke and Merlin 61). The oldest of this comes from Northern Central Asia, where pollen was found dating back to 100,000 to 120,000 BCE (Clarke and Merlin 72). *C. sativa* plants are anemophilous, which means they are wind pollinated, which is a relatively rare form of pollination (Clarke and Merlin 353). Pollen can travel an astounding distance; *Cannabis* pollen has been documented to have the ability to travel across the Mediterranean from North Africa to southern Spain (Simons). This trait is correlated with growing in dense

populations in open habitats within temperate climates; because Central Asia is relatively arid, this reproductive strategy is thought to have evolved to persist when the streams and lakes would have been at times separated on the vast continent (Clarke and Merlin 357).

In 2003, a genetic study of *Cannabis* speciation analyzed a “diverse collection of 157 *Cannabis* accessions of known geographic origin... obtained from breeders, researchers, genebanks, and law enforcement agencies” (Hillig 163). The study concluded with the allozyme data that *Cannabis* is derived from two major gene pools in Central Asia (Hillig 170). One would expect the gene pool of a cultivated taxon to contain a subset of the alleles present in the ancestral gene pool, but, “in the case of *Cannabis*, the available evidence is insufficient to make an accurate determination of progenitor–derivative relationships” (Hillig 178). As the Russian botanist Nikolai Vavilov postulated in 1926, indigenous and cultivated landraces may have followed human migration thriving on disturbed areas; it is for this reason that modern genetics of *C. sativa* is convoluted because the “weedy populations of Europe may represent the aboriginal gene pool into which individuals that have escaped from cultivation have merged” (Hillig 178). To establish more exact data on the geographic origin, additional genetic research needs to be completed on deciphering the true wild populations from feral populations or cultivars that simply escaped cultivation and became naturalized (Clarke and Merlin 23).

Recommended Research:

Unfortunately, because illicit *Cannabis* use is a multibillion-dollar industry, much genetic research has been focused on the forensic capabilities of *Cannabis* genetics (such as differentiating between whether it was grown indoors or outdoors, psychoactive strain or nonpsychoactive strain etc.) rather than the evolutionary aspects. The same is true for paper pulp production; genetic research has been completed to advance the knowledge of relevant hemp traits for paper production within the germplasm (De Meijer and Keixer 41). Thus, there have been many genetic studies on *Cannabis* including randomly amplified polymorphic DNA studies (RAPD) (Faeti, Mandolino, and Ranalli 367), microsatellites (Gilmore and Peakall 105; Hsieh et al. 1) and amplified fragment length polymorphisms (AFLP) (Piluzza et al. 2331; Datwyler and Weiblen 371), which are all beneficial and pave the way for more geographical origin research, but the necessary funding and motivation need to be amplified.

Overall, *C. sativa* is an extremely difficult plant to identify the geographic origin of because of centuries of genetic material exchange between vast locations via humankind, but decades of studies have narrowed it down quite well (Clarke and Merlin 23). The progenitor–derivative relationships within *Cannabis* are yet to be well understood, and, until an extensive amount of additional sampling and subsequent genetic analysis on introgressive hybridization is completed, the precise *Cannabis* genetic–geographic data will remain unsettled (Hillig 178). More archeological investigation in Central Asia for evidence of early cultivation of *Cannabis* would also be extremely valuable for this topic. Until then, contemporary science has reasonable amount of data on *Cannabis* evolution that is awaiting augmentation.

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*An Analysis of Cannabis:
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