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ORIGINAL ARTICLE

# *Cannabis* utilization and diffusion patterns in prehistoric Europe: a critical analysis of archaeological evidence

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**Abstract** Archaeological evidence of *Cannabis sativa* is comprised of textiles, cordage, fibre and seeds, or pottery impressions of those materials, as well as pseudoliths and phytoliths (pollen is not addressed here). Previous summaries of this evidence connect hemp with Bronze and Iron Age cultures in Europe. This study improves upon earlier summaries by: (1) accessing a larger database; (2) relying on original studies instead of secondary sources; (3) stratifying evidence by its relative robustness or validity. We coupled digital text-searching engines with internet archives of machine-readable texts, augmented by citation tracking of retrieved articles. The database was large, so we limited retrieval to studies that predated 27 BCE for west-central Europe, and pre-CE 400 for eastern Europe. Validity of evidence was scaled, from less robust (e.g., pottery impressions of fibre) to more robust (e.g. microscopic analysis of seeds). Archaeological sites were mapped using ArcGIS 10.3. The search retrieved 136 studies, a yield four-fold greater than previous summaries when parsed to our geographic/time constraints. Only 12.5% of studies came from secondary literature. No robust evidence supports claims of Neolithic hemp usage. One Copper Age site in southeastern Europe shows robust evidence (from the Gumelniţa-Varna culture). More robust evidence appears during the Bronze Age in southeastern Europe (Yamnaya and Catacomb cultures). An Iron Age steppe culture, the Scythians, likely introduced hemp cultivation to Celtic, Slavic and Finno-Ugric cultures. The results correlate with a recent palynology study of fossil pollen in Europe. We discuss possible autochthonous domestication of *Cannabis* in Europe.

**Keywords** *Cannabis sativa* · Hemp · Catacomb culture · Gumelniţa culture · Yamnaya culture · Scythians

## Introduction

Debates swirl around hemp, *Cannabis sativa* L., regarding its taxonomic status, centre of origin and history of domestication. Most taxonomists recognize one species, with two subspecies. Others elevate the segregates to the rank of species—*C. sativa* L. and *C. indica* Lam., and sometimes add *Cannabis ruderalis* Jan. The centre of origin of the genus is considered Central Asia, although some scholars offer East Asia or Europe. *Cannabis* was utilized for three commodities—bast fibre (for cordage and textiles), seed (food, seed oil), and flowering tops (medicinal and psychoactive drugs). Speculations regarding the domestication and diffusion patterns of *C. sativa* date back to Ibn Wahshīyah in CE 904. From his viewpoint in present-day Iraq, *šāhdānaj* came from India and perhaps China (Hämeen-Anttila 2006).

New discoveries affirm the antiquity of *Cannabis* use in East Asia. *Cannabis* seeds recovered from a site associated with the Jōmon culture in Japan date to 8000 cal BCE (Kudo et al. 2009). In northern China, Zhou et al. (2011) recovered seeds at a site associated with the Yǎngsháo culture

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(5000–3000 BCE). Seeds from the Jōmon and Yǎngsháo sites show traits of domestication (e.g. seed enlargement, loss of abscission zone). Traits of domestication arise centuries after plants have been brought into cultivation (Colledge 2002). Pottery impressions of cord or textiles in Yǎngsháo pottery have been identified as hemp (Andersson 1923). In southern China, hemp rope and cloth recovered from a Liángzhǔ site dates to 3000 cal BCE (Zhou 1985).

Most scholars concur with de Candolle (1883), the founder of biogeography, who hypothesized a centre of origin in Central Asia, and conveyance to Europe during the late Bronze Age, ca. 1500 BCE. A minority disagree with this hypothesis. Thiébaut de Berneaud (1835) stridently proposed a *Cannabis* centre of origin in Europe rather than Asia, "If one were to believe the majority of botanists and agronomists, hemp is native to High Asia, but their assertion is nothing but a falsehood of servile copyists".

Virchow (1897) questioned whether *Cannabis* was domesticated independently by Europeans or imported from Asia. Several 20th century archaeobotanists proposed autochthonous domestication in Europe during the Neolithic era (e.g. Tempír 1963; Willerding 1970; Opravil 1983; and citations therein). However, Körber-Grohne (1967, 1985, 1988) critiqued and dismissed all six reports of Neolithic cultivation in central Europe.

Unfortunately, the archaeology of hemp has been biased by cultural chauvinism. People naturally seek "we-were-first" status. Researchers may exaggerate the age of artifacts, or overinterpret their findings. For example, new-age chauvinists have buttressed claims of pre-Columbian, trans-Atlantic trade by finding hashish "alkaloids" in Peruvian mummies (Parsche et al. 1993). Langlie et al. (2014) call for researchers to restrain their agendas and historical conjectures. They emphasize that new research on a crop plant does not always push the date of its domestication deeper into the past—sometimes the antiquity of a crop gets shortened rather than lengthened.

Archaeobotanical evidence consists of cordage, textiles and seeds, or pottery impressions of those materials, as well as pseudoliths, phytoliths (cystolithic trichomes), wood charcoal and pollen. Various types of evidence may give rise to contradictory interpretations; they must be pieced together with logic and probability. For example a study of pottery impressions may report hundreds of seeds from several crop plants, yet only one hemp seed. Probability suggests a misidentification occurred, or a taphonomic process was involved, i.e. a disturbance of soil, causing the downward percolation of a seed or pottery shard to a deeper stratigraphic level.

The validity of inferences made from various types of evidence varies in its robustness. The earliest evidence of hemp in China is not very robust. It consists of pottery impressions of cordage or textiles. Inferring the plant source that made those impressions has a subjective element. Abel (1980) assumed that cord marks in Taiwanese pottery came from hemp, "the earliest record of man's use of cannabis". Abel cited photographs of Yuánshān culture pottery by Chang (1968). The "cord marks" in Chang's photograph look like incised marks, not cord marks.

Abel dated Chang's find to 10000 BCE. Tarling (1992) stated that $^{14}C$ dates in Taiwan are unreliable, and estimated the Yuánshān culture began *ca*. 2000 BCE, not 10000 BCE. Abel also interpreted cylindrical stones as tools for beating hemp; he reasoned that hemp was the primary source of plant fibre in prehistoric China. However, Taiwan was inhabited by Austronesian people in 2000 BCE, not by Chinese people. Their descendants—Taiwanese aborigines, Polynesians, Micronesians, Melanesians—obtained bast fibre from a native Taiwanese tree, the paper mulberry, *Broussonetia papyrifera*. Therefore, we interpret the stones as tools for making *tapa* cloth from *B. papyrifera*. Similiarly, Barber (1991) commented upon Yǎngsháo pottery impressions illustrated by Andersson (1923), "the fibres are too coarse to have been silk; no other fibre-producing source is known to have existed in northern China". Kuhn (1988) presented a list of 14 other plants utilized for making cord impressions in Chinese pottery.

Hemp fibre, never mind its pottery impressions, cannot easily be differentiated from other plant fibres. Herodotus (Strassler 2007) wrote about difficulties telling apart hemp cloth from linen (made of flax, *Linum usitatissimum* L.). Hemp and flax fibres derive from bast fibres, which are phloem (sap-conducting) cells in stalks. The microscopic differentiation of hemp and flax fibres has been an elusive goal for over 150 years. Körber-Grohne (1967, 1985, 1988) pioneered new methods for identifying hemp fibres. She visualized unique cell wall markings in hemp fibre using polarized light microscopy, as well as unique calcium crystals, and epidermal tissues in crudely-processed fibres.

Seeds (achenes) are easier to distinguish. The identification of Jōmon seeds from 8000 cal BCE was based on microscopic comparisons with modern seeds of *C. sativa, Humulus lupulus* L., and *H. japonicus* Siebold & Zucc. (Kudo et al. 2009). The published photographs indicate a good morphological basis for identification. Other archaeologists are not so confident regarding identification: Lempiäinen (1995) recovered 151 Cannabaceae seeds from a Russian site; she identified 53 as *Cannabis*, 13 as *Humulus*, and relegated the rest to a gray zone of *Cannabis*/*Humulus*.

Seed impressions in pottery have been identified by the archaeological context in which they were found, rather than microscopic analysis. For example, Sarianidi (1998) found impressions in Turkmenistan pottery that he identified as hemp seeds. Bakels (2003) microscopically examined the material, and asserted the impressions were too small and the wrong shape for *Cannabis* seed. Ukrainian and Russian

archaeologists have taken the analysis of pottery seed impressions to a high art. They fill cavities of seed impressions with Plasticine to obtain a cast. They compare the cast with modern seeds, in terms of size, shape, and even surface texture. Gorbanenko (2013) provided photomicrographs of Plasticine casts, and the hemp casts look exactly like hemp seeds. Mottling from a persistent perianth can even be seen.

Archaeobotanical evidence of hemp in Europe has been summarized by Tempír (1963), Willerding (1970), Opravil (1983), Körber-Grohne (1967, 1985, 1988) and Dörfler (1990), plus two new pan-Eurasian summaries (Clarke and Merlin 2013; Long et al. 2017). The purpose of this study was to update these summaries, by accessing a larger database, made available through internet search engines. We focused upon primary literature (rather than secondary sources), and stratified evidence by its validity.

This study is limited to "macroscopic" evidence. Microscopic evidence (subfossil pollen) will be synthesized and presented in a subsequent publication. Combining macroscopic and microscopic evidence was unwieldy for a single journal publication, although it has been combined in a book (Clarke and Merlin 2013) and in a project with less dense sampling (Long et al. 2017).

## Methods

The following databases were searched through June 2016: Web of Science, PubMed, Google Scholar, a database by Helmut Kroll (http://www.archaeobotany.de) and the search engines of individual archaeology-related journals. This was supplemented with citation tracking of retrieved publications. Our search identified *hundreds* of studies. Therefore we placed age constraints on literature that was included in this study. Because the Romans spread hemp cultivation throughout most of their conquered territories (Dörfler 1990), we limited evidence in west-central Europe to dates preceding the start of the Roman Empire (pre-27 BCE). In eastern Europe beyond the Roman Empire (> 17°E meridian), temporal patterns of diffusion were delayed until the Migration Period. So in eastern Europe we used the beginning of the Migration Period (400 CE) as *terminus ante quem*.

We also constrained the subjective element in archaeological inference. The validity of inferences from archaeobotanical evidence is elaborated at length in Online Resource 1. The robustness (validity) of archaeobotanical evidence was dichotomized: (1) less robust: pottery impressions of fibre, pottery impressions of seeds not examined with Plasticine casts, and other materials (pseudomorphs, cordage, textiles, seeds) not subjected to forensic (microscopic) analysis; (2) more robust: Plasticine cast analysis of pottery seed impressions, and other materials (pseudomorphs, cordage, textiles, seeds, cystolith trichomes) subjected to forensic analysis.

The latitude and longitude of each archaeological site was plotted, using geographic information system (GIS) software, ArcGIS 10.3. The results of this systematic search are presented in a narrative review, structured from an historical and cultural perspective. That is to say, we present evidence within the archaeological context in which it was found, beginning with the Neolithic era, through the Copper, Bronze, and Iron Ages.

## Results and discussion

The search strategy yielded 136 studies within geographical constraints (continental Europe) and age constraints (pre-27 BCE for ≤ 17°E, and pre-400 CE for > 17°E). The yield included 119 primary source articles; we used 17 secondary sources when original studies could not be traced or located. The search was aided by digital text-searching engines, coupled with Unicode, and today's internet archive of machine-readable texts.

Previous reviews yielded fewer studies, and a higher percentage of secondary sources: Tempír (1963) 5 primary and 2 secondary sources; Willerding (1970) 6 and 2; Opravil (1983) 9 and 2; Körber-Grohne (1967, 1985) 8 and 3; Dörfler (1990) 20 and 5 (numbers parsed to match our temporal constraints). Two pan-Eurasian reviews, when parsed to our geographical and temporal constraints, yielded: Long et al. (2017) 3 primary and 12 secondary sources (two secondary sources referred to one primary study); Clarke and Merlin (2013) 34 primary and 27 secondary sources (they included several primary sources published in conference proceedings not available to us).

The 136 studies are tabulated in Online Resource 2. Each study is labelled with an accession number and full bibliographical citation, with information regarding its location, type of evidence, associated archaeological culture, and details regarding data validity. Secondary analyses of the original studies by subsequent archaeologists are also documented. Study accession numbers will be cited below, rather than full bibliographical citations. This method improved narrative flow, and prevented the references section from swelling to 200 entries. Interested scholars may find it troublesome to refer back to Online Resource 2 for bibliographical citations, which we regret.

Locations of the 136 studies, plotted on a map of Europe, appear in Fig. 1. Locations of the 136 studies are also provided in an interactive map, available at http://arcg.is/2k8UX05. Interactive functionalities include site queries (click on each individual site to obtain its accession number),

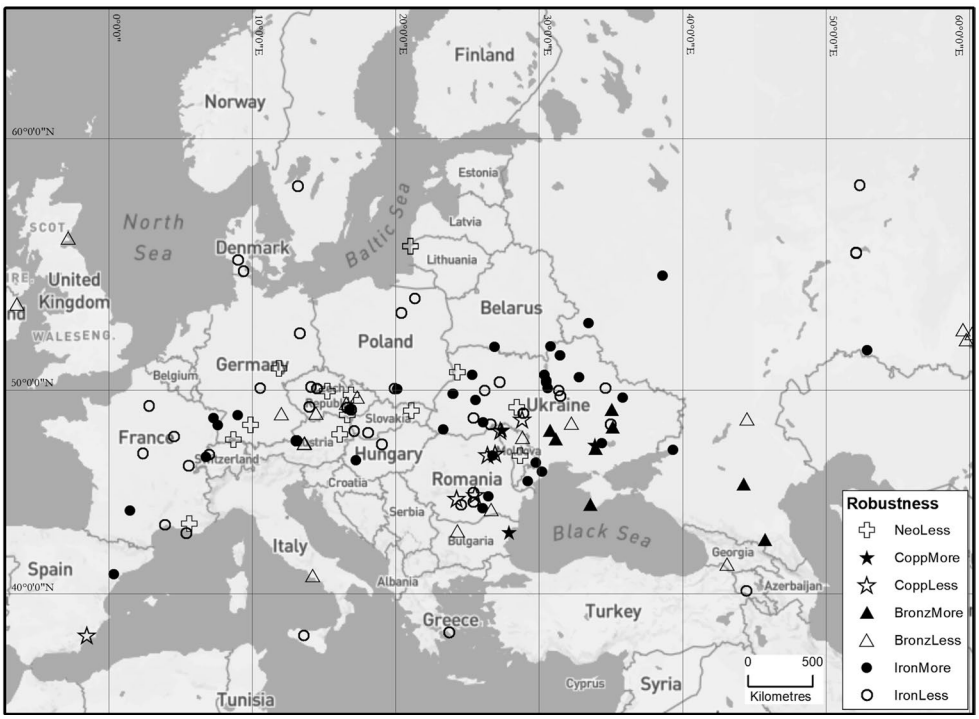


**Fig. 1** Locations of 136 studies, plotted on a map of Europe. Symbology for each site indicates its relative age (Neolithic, Copper, Bronze, Iron ages), and the relative validity of its evidence (more robust, less robust)

pan and zoom, and changing the basemap (for topography, vegetation type, etc.).

## Neolithic

The earliest evidence of fibre attributed to hemp predates the Neolithic, and is associated with the Gravettian culture, 25000 BCE, designated herein as study #1. (Study numbers refer to tabulated data in Online Resource 2, and site numbers in http://arcg.is/2k8UX05.) The evidence consists of low-resolution pottery impressions of woven netting, found in the Czech Republic. Other archaeologists attribute the impressions to nettles (*Urtica* sp.) or milkweed (*Asclepias* sp.).

Neolithic archaeobotanical remains of any kind are relatively hard to find, and less abundant than younger evidence. Nevertheless, the few reports of Neolithic hemp consisted of less robust evidence. They included superficially-analysed pottery impressions (study #13), cordage that superficially resembled hemp (#3, 5), studies marred by dating errors or taphonomy (#4, 6) and poorly-documented evidence appearing in secondary sources (#2, 9, 14).

For example, a study at Šventoji in Lithuania (#10) recovered a piece of string identified as hemp. A photograph shows the string in remarkably good condition: a two-ply twist of bast fibre. No method of fibre identification was described. The same researcher (#11) also reported seeds of "*Cannabis ruderalis* Jan., *C. sativa* L., and *C. sativa* var. *indica* Lam". This is overstatement; *C. sativa* and *C. indica* seeds are difficult or impossible to differentiate, even in fresh material, by *Cannabis* specialists (Small 1975). A subsequent analysis identified the seeds as either *C. sativa* or *Humulus lupulus* (#12).

Körber-Grohne (1967, 1985, 1988) and Dörfler (1990) previously deconstructed the evidence in studies #3, 4, 5 and 6. Nevertheless, these studies, or secondary sources based on these studies, were cited in recent summaries (Clarke and Merlin 2013; Long et al. 2017). Even Körber-Grohne got tripped up by secondary sources; she critiqued data in two secondary sources that actually derived from the same primary source (see notes in study #3).

Two studies of the Linearbandkeramik culture (LBK) identified pottery seed impressions as *Cannabis* (studies #7, 8). The LBK originated in Central Europe, but the late-LBK expanded southeast into the Prut and Dniester river basins. The Dănceni I site in Moldova (#7) dates to ca. 5500–5000 BCE. This would make it the oldest archaeological find of *Cannabis* in Europe, and second oldest world-wide—if it is valid. Probability enters the equation: study #7 reported nine *Cannabis* seeds out of 247 total seed impressions. The Zimne site in Ukraine (study #8), ca. 5000 BCE, reported one solitary *Cannabis* seed out of 54 total seed impressions at eight LBK sites.

Does this represent autochthonous domestication of *Cannabis* in Europe, separate from its domestication in East Asia? This question also concerns common millet, *Panicum miliaceum* L., domesticated in China by 8350–6750 BCE (Lu et al. 2009). Hunt et al. (2008) catalogued records of *P. miliaceum* in Europe that predated 5000 BCE. Many LBK-associated records in Germany were based on solitary

seeds, with questionable identification and dating. Motuzaite-Motuzeviciute et al. (2013) subjected German LBK seeds to rigorous AMS radiocarbon dating, and the oldest ones dated to 1500–1386 BC. The authors suggested millet reached Europe by the Middle Bronze Age.

Motuzaite-Motuzeviciute et al. (2013) also questioned the reliability of pottery seed impressions. They specifically questioned the dating of pottery typologies and the correct identification of seed impressions in study #7. They quote the author saying the seed impressions at the Dănceni site were not very clear, and she too questioned their proper identification. It is worth noting that LBK artifacts at Dănceni are overlaid by remains of the Chernyakhov culture (second-5th centuries CE), which shows evidence of *Cannabis* (studies #112, 113). Perhaps pottery fragments got mixed by taphonomic processes.

We conclude that Neolithic Europeans did not cultivate or domesticate hemp. It is possible that wild harvesting occurred, but at a small scale invisible to the archaeological record. Surveys of Neolithic agriculture in Europe do not report evidence of *Cannabis* (Cârciumaru 1996; Gyulai 2001; Bogaard 2004; Colledge et al. 2004; Kreuz et al. 2005; Conolly et al. 2008). Neolithic Europeans cultivated flax, *Linum usitatissimum* L., for fibre and seed oil.

### Copper (Chalcolithic, Eneolithic) Age

Pottery seed impressions identified as *Cannabis* at two sites in Moldova (studies #16, 17) are associated with the Cucuteni–Tripolye (C–T) culture. The two sites date to C–T *phase B*, 4600–3600 BCE. Probability enters the equation again: study #16 reported one *Cannabis* seed out of 232 seed impressions, and study #17 reported two *Cannabis* seeds out of 54 seed impressions. The author of #16 and #17 reports no *Cannabis* at 15 other C–T *phase B* sites, or at 22 C–T *phase A* sites, or at 34 C–T *phase C* sites—all in Moldova and Ukraine. Stevens et al. (2016) questioned the reliability of pottery seed impressions by this researcher. Study #7 included three C–T sites in Moldova and Ukraine and reported no *Cannabis* seeds.

Hemp seeds found at a C–T site in Romania were misidentified (see notes in study #18). A secondary source, which reported *Cannabis* seeds without provenance (#19) likely referred to #18. A survey of C–T archaeobotanical findings by Cârciumaru (1996) reported no *Cannabis* at a dozen C–T sites in Romania; he did report flax seeds.

*Cannabis* seeds have been reported from two sites associated with the Gumelniţa culture in Romania (#21, 22). The Gumelniţa culture was located south of the C–T culture, with contemporaneous dates. The first study identified charred hemp seeds, along with wheat and millet, in an intact Gumelniţa-style vessel. The second study also found charred hemp seeds, at a site identified as Gumelniţa phase A2. Neither study described their identification methods, or provided morphological data, or radiocarbon dating.

The Gumelniţa is aggregated with the Varna culture by some archaeologists. A Varna site dated 4200 BCE yielded fibres preserved in the patina of a copper object (#23). Polarized light photomicrographs of the fibres are more suggestive of hemp than flax (25 µm diam., prominent distinct dislocation nodes and cross-markings). Two recent pan-Eurasian reviews did not mention the Gumelniţa–Varna culture (Clarke and Merlin 2013; Long et al. 2017), although the latter did cite a fossil pollen study at Lake Varna.

### Bronze Age

The best evidence from the Bronze Age arises in southeastern Europe. A site associated with the Repin culture (3400–3200 BCE) identified one hemp seed impression out of seven total pottery seed impressions (#26). The reliability of pottery seed impressions in this publication has been questioned (Stevens et al. 2016). Three sites in Ukraine associated with the Yamnaya culture (3500–2300 BCE) yielded pottery seed impressions, subjected to Plasticine analysis (#28–30). The ratio of hemp seed to total seed impressions was high, from 1-in-7 to 1-in-16.

A Yamnaya site at Gurbăneşti in Romania recovered hemp seed, ash, charcoal, and a lump of yellow clay, as well as pottery with cord impressions (#31). The author imaginatively interpreted the clay lump as a *cuptoare-pipă*, "stove-pipe." Another Yamnaya site in Ukraine yielded textile fragments identified as hemp or flax (#32). Others have identified the Yamnaya culture as a likely candidate for *Cannabis* domestication (Clarke and Merlin 2013; Long et al. 2017).

Yamnaya burials contain clay censers, which are low-pedestalled dishes, bowls, or braziers. Some censers contain ashes with burnt surfaces, "presumed to be used in rituals involving some narcotic substance such as hemp" (see also Ecsedy 1979; Sherratt 1991; Mallory and Adams 1997). These secondary sources reference the aforementioned Gurbăneşti study, which actually unearthed a lump of yellow clay—*not* a censer or brazier. This reinterpretation in secondary sources highlights the importance of accessing primary source articles.

The Catacomb culture (2800–2200 BCE) evolved out of the Yamnaya culture. Cystolithic trichomes (as well as *Cannabis* pollen) were recovered from a Catacomb grave in southern Russia, with good photomicrograph evidence (#33). The authors nominated the Catacomb people as the first to employ psychotropic *Cannabis*. A Bronze Age burial at Gatyn Calais in the North Caucasus, possibly a Catacomb grave, contained *Cannabis* seeds in a vessel (#34). An inventory of Catacomb pottery (#35) reported soot or charcoal in many censers, with pottery

ornamented by cord impressions. The author presumed hemp was burned in the censers, and she named hemp as the most likely candidate for the cord impressions. Several Bronze Age cultures following the Catacomb also evince *Cannabis* usage (#36–44).

Bronze Age evidence in west-central Europe was less robust. It included superficially-analysed pottery impressions (#45), the fragment of a single seed (#46), possibly misidentified fibre (see note in #47), pottery identified as a clay pipe for smoking hemp (#48), and cordage that superficially resembled hemp (#49, 50). Many scholars associate the Hallstatt culture with hemp, but during its Bronze Age phase (Hallstatt A and B, 1250–800 BCE), the evidence is limited to cordage and cloth that superficially resembled hemp (#51, 52), and one seed labelled with a question mark (#53).

By the Middle Bronze Age, evidence of autochthonous plant domestication in Europe becomes complicated, due to nascent contact and exchange between Europe and China. The "Silk Road" did not yet exist, but indirect connections linked Europe and China. We previously mentioned *Panicum miliaceum*, a Chinese domesticate that reached Europe by the Middle Bronze Age. Spengler et al. (2014) credit migratory livestock herders with the transport of *Panicum* beyond China. They recovered *Panicum* seeds in Central Asia (at Begash in Kazakhstan) dating 2460–2190 BCE.

The earliest wheat (*Triticum* spp.), a western domesticate, was also unearthed at Begash (Spengler et al. 2014). Long et al. (2017) highlighted the eastern spread of wheat, which arrived in China by 2500–2400 BCE (Boivin et al. 2012). Mei et al. (2012) document a suite of European bronze technologies arriving in western China (Gānsù-Qīnghǎi) by 2500 BC. The earliest evidence of *Cannabis* in Central Asia dates to 1750 BCE in western Xīnjiāng—a fossil pollen study with a surge in *Cannabis* pollen suggestive of cultivation (Lia et al. 2011). In this case, a culture with European roots may be responsible: the Andronovo culture reached Xīnjiāng by 1800 BCE (Mei and Shell 1999).

If we choose 2500 BCE as the latest possible date for autochthonous domestication in Europe, then six earlier sites with more robust evidence (#17, 23, 26, 28–30) support the hypothesis of autochthonous domestication. Vavilov (1926) would have agreed, "it is probable that the cultivation of hemp arose simultaneously and independently in several places". Consistent with the autochthonous hypothesis, Clarke (2010a, b) documented that Asian methods of textile production were distinct from European methods in regards to fibre extraction, spinning, and weaving. A genetic study of *Cannabis* population structure might provide a definitive answer to the question of one or more domestication events.

## Iron Age

Once again, the oldest evidence arises in southeastern Europe where the Scythians migrated to the Pontic steppe from Central Asia. Twelve Scythian sites have yielded seeds or fabric, located in Ukraine, Russia, and Moldova (#54–66). At the dawn of European history, Herodotus documented the Scythians cultivating *κάνναβις*.

Sites associated with two Iron Age Celtic cultures—Hallstatt (phases C and D, 800–475 BCE) and La Tène (475–50 BCE)—have yielded fabric or seed, in Germany, Austria, Switzerland, France, Hungary, Czech Republic, Slovakia and Romania (#67–98). This plethora of Celtic data partially reflects the density of archaeologists in these countries. Many authors allude to the Celts as Iron Age "Johnny hempseeds". Pezron (1703) proposed that the Celtic word *canab* was loaned into other languages—Greek *κάνναβις*, Latin *cannabis* and German *kennep*. Thiébaut de Berneaud (1835) reconstructed **kanab* as the Proto-Celtic word for hemp, and argued that the word subsequently spread to all the languages of Europe. Hehn and Stallybrass (1885) stated that hemp cultivation "travelled along the great chain of Celtic nations that already stretched from Gaul to Pannonia and the Hæmus". Kerr (1877) deduced that the Celts "brought the plant to Marseilles from Thrace".

Rather than the Celts, we credit the Scythians for the spread of *Cannabis* cultivation in western and central Europe. Scythian evidence predates Celtic evidence. The Scythians inherited a hemp history in southeastern Europe, from earlier Bronze/Iron cultures (studies #43, 44), dating back perhaps to the Copper Age (#16–24). The Celts originated in central Europe, a region that lacks robust evidence prior to the Iron Age.

The Scythians impacted on the Celts by the 7th and 6th centuries BCE. If we consider 550 BCE as the *terminus post quem* for Scythian contact, only one Celtic site with robust evidence precedes that date (#67), out of 35 sites in total. The Scythians also impacted on proto-Slavic cultures by the 7th–6th century BCE. The oldest Slavic sites (#99–101) are associated with the Przeworsk culture (200 BCE–CE 400). Pottery seed impressions have been found at six sites (#102–107) associated with the Zarubintsy culture (3rd century BC–2nd century AD). More evidence appears at later Slavic sites (#108–116).

The Scythians also impacted on Finno-Ugric cultures. People of the Dyakovo and Ananyino cultures lived in fortified settlements, and their art reflects Scythian influences (Koryakova and Epimakhov 2007). Their descendants include the Volga Finns, whose languages have words for hemp likely borrowed from the Scythians (Gordeev and Galkin 1985). Four sites associated with the Dyakovo and Ananyino culture have yielded seeds (#117–120).

Lastly, the Scythians impacted on the Thracians. Herodotus said the Scythians cultivated *κάνναβις*, and the Thracians made clothing from it. The oldest Thracian evidence dates to the 3rd/2nd centuries BC (#121–122); other evidence was more recent (#123–127). Evidence from other European cultures not directly impacted on by the Scythians appeared even later, from the West Baltic Barrow culture (#128), Jastorf culture (#129–131) and Wielbark culture (#132, 133). Three sites in Greece and Italy precede Herodotus, but the evidence is not robust (#134–136).

## Conclusions

Neolithic LBK sites have yielded pottery seed impressions reported as hemp seeds, but probability suggests misidentifications, or taphonomic processes were involved. One solitary Copper Age site provided robust evidence of hemp fibre usage. Turning to the Bronze Age, several cultures show robust evidence, the earliest being the Yamnaya culture. Material culture during the Bronze Age would have benefited from fibre hemp. Overman (1852) links metallurgy with a need for rope—for securing mine structures, hoisting and transport. Our analysis suggests the Scythians introduced *Cannabis* to Celtic, Slavic and Finno-Ugric cultures. Our next study will corroborate these results with linguistic data, by examining European cognates for hemp in Indo-European, Finno-Ugric, Caucasus and Semitic language families.

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## References

Abel EL (1980) Marijuana: the first 12,000 years. Plenum Press, New York

Andersson JG (1923) An early Chinese culture. Bull Geol Surv China 5:1–68

Anthony DW (2007) The horse, the wheel, and language. Princeton University Press, Princeton

Bakels CC (2003) The contents of ceramic vessels in the Bactria–Margiana Archaeological Complex, Turkmenistan. Electronic J Vedic Studies 9:1c

Barber EJW (1991) Prehistoric textiles: the development of cloth in the Neolithic and Bronzes Ages. Princeton University Press, Princeton

Bogaard A (2004) Neolithic farming in central Europe. Routledge, London

Boivin N, Fuller DQ, Crowther A (2012) Old World globalization and the Columbian exchange: comparison and contrast. World Archaeol 44:452–469

Cârciumaru M (1996) Paleoetnobotanica. Studii în preistoria şi protoistoria României. Editura Glasul Bucovinei, Iaşi

Chang KC (1968) The Archaeology of Ancient China. Yale University Press, New Haven

Clarke RC (2010a) Traditional fiber hemp (Cannabis) production, processing, yarn making, and weaving strategies—functional constraints and regional responses, part 1. J Nat Fibers 7:118–153

Clarke RC (2010b) Traditional fiber hemp (Cannabis) production, processing, yarn making, and weaving strategies—functional constraints and regional responses, part 2. J Nat Fibers 7:229–250

Clarke RC, Merlin MD (2013) Cannabis evolution and ethnobotany. University of California Press, Berkeley

Colledge S (2002) Identifying pre-domestication cultivation in the archaeobotanical record using multivariate analysis presenting the case for quantification. In: Cappers RTJ, Bottema S (eds) The dawn of farming in the near East. Ex Oriente, Berlin, pp 141–152

Colledge S, Conolly J, Shennan S (2004) Archaeobotanical evidence for the spread of farming in the Eastern Mediterranean. Curr Anthropol 45(Suppl 4):S35–S58

Conolly J, Colledge S, Shennan S (2008) Founder effect, drift, and adaptive change in domestic crop use in early Neolithic Europe. J Archaeol Sci 35:2,797–2,804

De Candolle AP (1883) Origine des Plantes Cultivées. Baillière, Paris

Dörfler W (1990) Die Geschichte des Hanfanbaus in Mitteleuropa aufgrund palynologischer Untersuchungen und von Großrestnachweisen. Prähistorische Zeitschrift 65:218–244

Ecsedy I (1979) The people of the pit-grave kurgans in eastern Hungary. Fontes Archaeologici Hungariae, Akadémiai Kiadó, Budapest

Gorbanenko SA (2013) Палеоэтноботанические материалы с животинного городища (по отпечаткам на изделиях из глины. Древности 12:273–282

Gordeev FI, Galkin IS (1985) Историческое развитие лексики марийского языка.Yoshkar-Ola, Russia

Gyulai F (2001) Historical plant-biodiversity in the Carpathian basin. http://public-repository.epoch-net.org/publications/BORITO/063-072.pdf. Accessed 2016

Hämeen-Anttila J (2006) The last pagans of Iraq: Ibn Wahshīyah and his Nabatean Agriculture. Brill Academic Publishers, Leiden

Hehn V, Stallybrass JS (1885) The wanderings of plants and animals from their first home. Swan Sonnenschein & Co., London

Hunt HCV, Vander Linden M, Liu XY et al (2008) Millets across Eurasia: chronology and context of early records of the genera *Panicum* and *Setaria* from archaeological sites in the Old World. Veget Hist Archaeobot 17:5–18

Kerr HC (1877) Report of the cultivation of, and trade in, ganja in Bengal. Br Parliam Papers 66:94–154

Körber-Grohne U (1967) Geobotanische Untersuchungen auf der Feddersen Wierde. Steiner, Wiesbaden

Körber-Grohne U (1985) Die biologischen Reste aus dem hallstattzeitlichen Fürstengrab von Hochdorf, Gemeinde Eberdingen (Kreis Ludwigsburg). In: Küster H, Körber-Grohne U, Krausse D (eds) Hochdorf 1. Forsch Ber Vor- Frühgesch Bad-Württ 19. Theiss, Stuttgart, pp 87–162

Körber-Grohne U (1988) Microscopic methods for identification of plant fibers and animal hairs from the prince's tomb of Hochdorf, SW Germany. J Archaeol Sci 15:73–82

Koryakova L, Epimakhov AV (2007) The Urals and Western Siberia in the Bronze and Iron Ages. Cambridge University Press, Cambridge

Kreuz A, Marinova E, Schäfer E, Wiethold J (2005) A comparison of early Neolithic crop and weed assemblages from the Linearbandkeramik and the Bulgarian Neolithic cultures: differences and similarities. Veget Hist Archaeobot 14:237–258

Kudo Y, Kobayashi M, Momohara A et al (2009) Radiocarbon dating of fossil hemp fruits in the earliest Jomon period. Shokuseishi kenkyū 17:27–32

Kuhn D (1988) Textile technology. In: Needham J, Wang L (eds) Science and civilisation in China, vol 5, Part 9. Cambridge University Press, Cambridge

Langlie BS, Mueller NG, Spengler RN, Fritz GL (2014) Agricultural origins from the ground up: archaeological approaches to plant domestication. Am J Bot 101:1,601–1,617

Lempiäinen T (1995) Medieval plant remains from the fortress of Käkisalmi, Karelia (Russia). Fennoscand Archaeol 12:83–94

Lia XQ, Zhao KL, Dodson J, Zhou XY (2011) Moisture dynamics in central Asia for the last 15 kyr: new evidence from Yili Valley, Xinjiang, NW China. Quat Sci Rev 30:3,457–3,466

Long TW, Wagner M, Demske D et al (2017) Cannabis in Eurasia: origin of human use and Bronze Age trans-continental connections. Veget Hist Archaeobot 26:245–258

Lu H, Zhang J, Liu KB et al. (2009) Earliest domestication of common millet (*Panicum miliaceum*) in East Asia extended to 10,000 years ago. Proc Natl Acad Sci USA 106:7,367–7,372

Mallory JP, Adams DQ (1997) Encyclopedia of Indo-European culture. Fitzroy Dearborn, London

Mei JJ, Shell C (1999) The existence of Andronovo cultural influence in Xinjiang during the 2nd millennium BC. Antiquity 73:570–578

Mei JJ, Wu JW, Chen KL et al (2012) Recent research on early bronze metallurgy in northwest China. In: Jett P (ed) Scientific research on ancient asian metallurgy. Freer Gallery of Arts, Washington DC, pp 37–46

Motuzaite-Matuzeviciute G, Staff RA, Hunt HV et al. (2013) The early chronology of broomcorn millet (*Panicum miliaceum*) in Europe. Antiquity 87:1,073–1,085

Opravil E (1983) Z historie šíření konopě seté (*Cannabis sativa* L.). Archeologické Rozhledy 35:206–213

Overman F (1852) A treatise on metallurgy. D. Appleton & Co., New York

Parsche F, Balabanova S, Pirsig W (1993) Drugs in ancient populations. Lancet 341:503

Pezron PY (1703) Antiquité de la nation, et de langue des celtes. Jean Boudot, Paris

Sarianidi VI (1998) Margiana and protozoroastrism. Kapon Editions, Athens

Sherratt AG (1991) Sacred and profane substances: the ritual of narcotics in later Neolithic Europe. In: Garwood P, Jennings D, Skeates R, Toms J (eds) Sacred and profane. Oxford Committee for Archaeology, Oxford, pp 50–64

Small E (1975) Morphological variation of achenes of Cannabis. Can J Bot 53:978–987

Spengler RN, Frachetti MD, Doumani P et al (2014) Early agriculture and crop transmission among Bronze Age mobile pastoralists of Central Eurasia. Proc R Soc B Biol Sci 281:20133382

Stevens CJ, Murphy C, Roberts R et al. (2016) Between China and South Asia: a Middle Asian corridor of crop dispersal and agricultural innovation in the Bronze Age. Holocene 26:1,541–1,555

Strassler RB (ed) (2007) The landmark Herodotus: the Histories (transl. by Andrea L. Purvis). Pantheon Books, New York

Tarling N (1992) The Cambridge History of Southeast Asia. Cambridge University Press, Cambridge

Tempír Z (1963) Nejstarši doklady o počátcich pěstováni konopí u Europě. Len a Konopi 3:73–80

Thiébaut de Berneaud A (1835) Chanvre. In: Guérin-Méneville FE (ed) Dictionnaire pittorosque d'histoire naturelle et des phénomènes de la nature, Tome 2. De Cosson, Paris, pp 87–89

Vavilov NI (1926) The origin of the cultivation of "primary" crops, in particular cultivated hemp. Труды по прикладной ботанике, генетике и селекции 16:221–233

Virchow R (1897) Pflanzenreste in vorgeschichtlichen Gefäßen. Verhandlungen der Berliner Gesellschaft für Anthropologie. Ethnologie Urgeschichte 5:225

Willerding U (1970) Vor- und frühgeschichtliche Kulterpflanzenfunde in Mitteleuropa. Neue Ausgrabungen Forschungen in Niedersachsen 5:287–375

Zhou KM (1985) Revelations of the excavation of the silk tabby remnant from Qianshanyang. In: Dien AE, Riegel JK, Price NT (eds) Chinese archaeological abstracts, 2: Prehistoric to Western Zhou. Momumenta archaeological 9. Institute of Archaeology, University of California, Los Angeles, pp 74–77

Zhou XY, Li XQ, Zhao KL, Dodson J, Sun N, Yang Q (2011) Early agricultural development and environmental effects in the Neolithic Longdong basin (eastern Gansu). Chin Sci Bull 56:762–771