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REVIEW

Cannabis in Eurasia: origin of human use and Bronze Age trans-continental connections

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Abstract A systematic review of archaeological and palaeoenvironmental records of cannabis (fibres, pollen, achenes and imprints of achenes) reveals its complex history in Eurasia. A multiregional origin of human use of the plant is proposed, considering the more or less contemporaneous appearance of cannabis records in two distal parts (Europe and East Asia) of the continent. A marked increase in cannabis achene records from East Asia between ca. 5,000 and 4,000 cal BP might be associated with the establishment of a trans-Eurasian exchange/migration network through the steppe zone, influenced by the more intensive exploitation of cannabis achenes popular in Eastern Europe pastoralist communities. The role of the Hexi Corridor region as a hub for an East Asian spread of domesticated plants, animals and cultural elements originally from Southwest Asia and Europe is highlighted. More systematic, interdisciplinary and well-dated data, especially from South Russia and Central Asia, are necessary to address the unresolved issues in understanding the complex history of human cannabis utilisation.

Keywords Hemp · Marijuana · Holocene · Indo-European cultures · Neolithic · Early agriculture

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Introduction

Cannabis is a versatile plant, used either as a medicament, hallucinogen, raw fibre material for ropes and textiles, or as a food source (seeds and oil) (Warf 2014). It is regarded as one of the world's oldest cultivated plants (Russo 2007) and an element of the ethnological myths and social identity of many traditional societies (e.g. Ullah et al. 2013). Despite a large volume of information on the botany, agriculture or medical application of the plant (e.g. Borgelt et al. 2013), the history of cannabis remains poorly understood.

There are different hypotheses on the origin of cannabis domestication, of which the two most frequently cited either refer to China (e.g. Chang 1986; Crawford 2006) or Central Asia (e.g. Vavilov 1992) as the domestication centre. The China hypothesis is largely based on early written records (Li 1974b), whereas the Central Asia hypothesis considers Central Asia as a biodiversity centre of cannabis and thus a possible domestication centre. However, both hypotheses lack a systematic test based on available archaeological evidence. That the domestication centre of a crop does not necessarily match its modern centre of biodiversity has been documented in earlier studies. For example, the Yunnan-Assam region (Fig. 1), the modern biodiversity centre of Asian rice (*Oryza sativa*) (Zeng et al. 2007), was for a long time believed to be the domestication centre of rice (Chang 1976). However, this hypothesis has been largely refuted by archaeological evidence for domestication activities from the middle and lower reaches of the Yangtze River (Fuller 2011). Thus, a systematic compilation of early records of cannabis becomes an important and reasonable approach in response to a growing interest in understanding cannabis and its early domestication history (e.g. Booth 2003; Clarke and Merlin 2013; Small 2015).

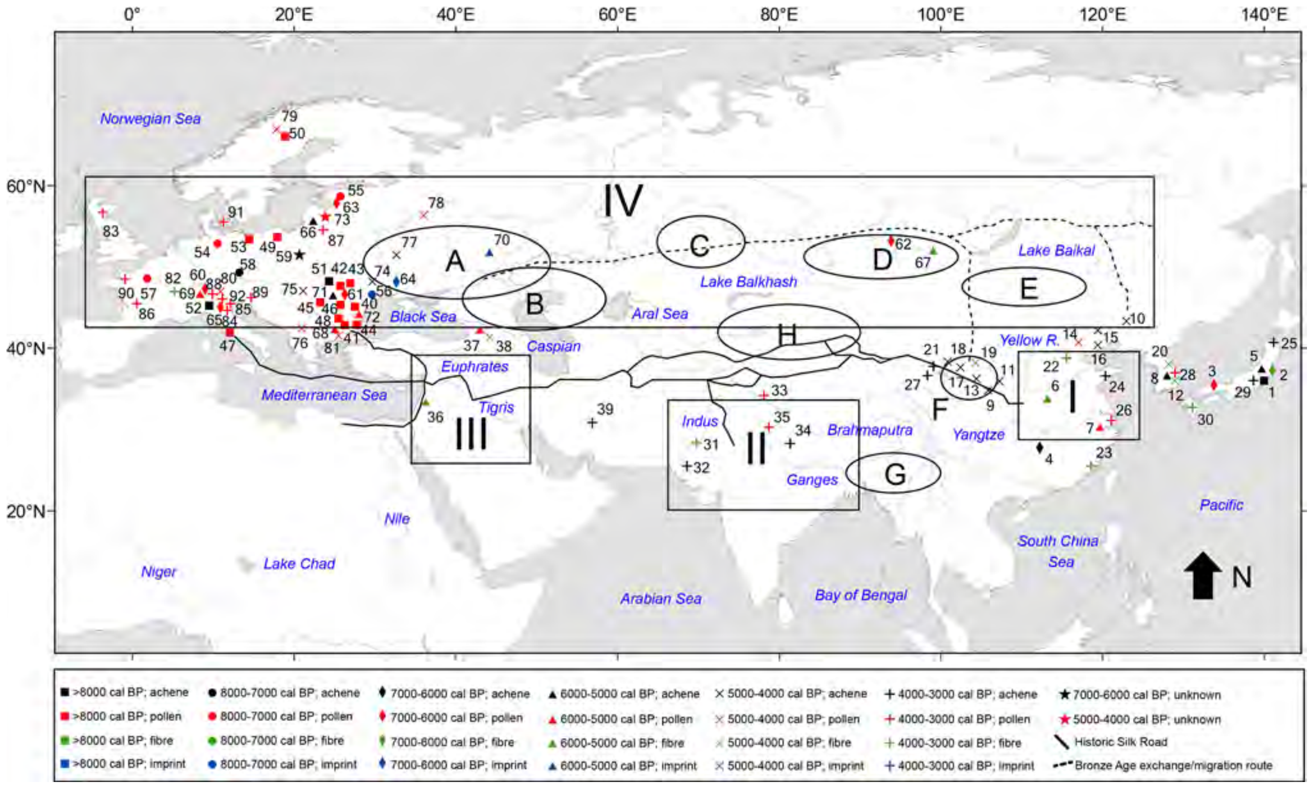

Fig. 1 Map of sites/areas or cultures in Eurasia with early (older than ca. 3,000 cal BP) cannabis remains; for numbers see Table 1. I—heartland of ancient East Asian civilisation, II—heartland of ancient South Asian civilisation, III—heartland of ancient Southwest Asian civilisation, IV—heartland of mid-latitude Eurasia. A—possible homeland of the Yamnaya Culture, B—possible homeland of the Scythians, C—possible homeland of the Botai Culture, D—Altai Mountains region, E—homeland of the Xiongnu tribes, F—Hexi Corridor region, G—Yunnan-Assam region, H—Xinjiang. The historic Silk Road and the Bronze Age trans-Eurasian exchange/migration route are shown, respectively, in *solid* and *dashed lines*. Equidistant Cylindrical Projection is used for the map

This paper reviews archaeological and palaeoenvironmental case studies related to early cannabis remains in Eurasia, in order to trace the origin of its use by humans and to shed further light on related environmental and cultural contexts. These remains mainly include four different types: fibres, pollen, achenes or imprints of achenes on archaeological artefacts. We follow Small (2015, p. 191) using 'cannabis' as a vernacular abstraction when referring to the plant in general and '*Cannabis*' as the genus name when referring to the binomial nomenclature.

Botany and ecology of cannabis

Cannabis plants are generally considered as one genus, *Cannabis*, family Cannabaceae, order Urticales (Kuddus et al. 2013). Previously, plants of Cannabaceae were included in the family of Moraceae or Urticaceae, but now are considered as taxa of a separate family based upon accumulating genetic and morphological evidence (Gautam et al. 2013). *Cannabis* and *Humulus* are the two acknowledged genera of Cannabaceae, although ongoing studies suggest moving some subfamilies previously under Ulmaceae to Cannabaceae (e.g. Yang et al. 2013).

The taxonomic differentiation within the genus *Cannabis* is under ongoing debate (Laursen 2015). Based on genetic variations, some authors propose a multitypic genus with at least two putative species, *C. sativa* and *C. indica* (possibly supplemented by *C. ruderalis* and *C. chinensis*) (e.g. Hillig 2005; Salentijn et al. 2015), while other authors propose a single species *C. sativa* with the genetic variation explained by differences on subspecies- and variety-levels or on a biotype-level of putative taxa (e.g. de Meijer et al. 2003). Both proposals, however, reveal problems in excluding hybridisation of different taxa and/or determining an adequate size of sample (Small 2015). Notwithstanding the difficulty in nomenclature or in defining species, genetic differentiation is almost certain between the hemp-type fibre cannabis (low in the principal psychoactive constituent delta-9-tetrahydrocannabinol (THC) and mostly used for fibre production) and marijuana-type cannabis (rich in THC and mostly used for drug intoxication) and between European hemp and East Asian hemp (Hillig 2005).

Table 1 Records of early (older than ca. 3,000 cal BP) cannabis remains from Eurasia

Region	Site, area or culture	Site no	Remain type	Estimated age (cal BP)[a]	References
E Asia	Okinoshima	1	Achene	10,200	Okazaki et al. (2011)
	Torihama	2	Fibre	7,000	Nunome (1992)
	Ubuka Bog	3	*C.*-type pollen	7,000–5,000	Crawford and Takamiya (1990)
	Chengtoushan	4	Achene	6,400–5,300	Yin (2003)
	Matsugasaki and Torihama	5	Achene	6,000–5,200	Matsui and Kanehara (2006)
	Qingtai	6	Fibre	5,500	Zhang and Gao (1999)
	Pingwang	7	*C.*-type pollen	5,500	Innes et al. (2014)
	Daecheon-ni	8	Achene	5,200	Shin et al. (2012)
	Haminmangha	9	Achene	5,000	Sun (2014)
	Yanggua	10	Achene	5,000	Zhou et al. (2011)
	Buziping	11	Achene	5,000	Jia et al. (2012)
	Goongsan	12	Fibre	5,000	Clarke (2006)
	Linjia	13	Achene	5,000–4,700	Institute of Botany, Northwest Normal University and Gansu Provincial Museum (1984)
	Taishizhuang	14	*C.*-type pollen	4,400	Tarasov et al. (2006)
	Erdaojingzi	15	Achene	4,300–3,600	Sun (2014)
	Shangtaizi	16	Achene	4,300–3,600	Sun (2014)
	Jinchankou	17	Achene	4,200–3,700	Yang (2014)
	Lajia	18	Achene	4,200–3,500	Zhang (2013)
	Tahozhuang	19	Fibre	4,150–3,780	Kühn (1987)
	Gojoseon	20	Fibre	4,100	Clarke (2006)
	Ejia, Xinjia, Qingquanhantai	21	Achene	4,000–3,600	Zhang (2012)
	Taixicun	22	Fibre	3,600–3,000	Gao et al. (1979)
	Wuyi Mountains	23	Fibre	3,600–3,000	Li (1984)
	Daxinzhuang	24	Achene	3,600–3,000	Chen (2007)
	Shimoyakebe	25	Achene	3,400	Crawford (2011)
	Chuodun	26	*C.*-type pollen	3,400	Long et al. (2014)
	Erfang, Lamafeng, Baojia, Wenjiagou, Zhongchuannongchang	27	Achene	3,300–3,000	Zhang (2012)
	Seonam-dong	28	*C.*-type pollen	3,100–400	Park et al. (2013)
	Kazahari	29	Achene	3,000	D'Andrea (1995)
	Yoshinogari	30	Fibre	3,000–1,700	Hudson and Barnes (1991)
S Asia	Indus Valley	31	Fibre	4,000	Lawler (2009)
	Indus Valley	32	Achene	3,600–3,300	Fuller and Boivin (2009)
	Tso Moriri	33	*C.*-type pollen	3,500	Leipe et al. (2014)
	Senuwar	34	Achene	3,300–2,600	Fuller (2008)
	Badanital	35	*C.*-type pollen	3,100	Demske et al. (2016)

Table 1 continued

Region	Site, area or culture	Site no	Remain type	Estimated age (cal BP)[a]	References
SW Asia	Christmas Cave	36	Fibre	5,600	Murphy et al. (2011)
	Ispani-II	37	*C.*-type pollen	5,600–4,500	Connor et al. (2007)
	Bedeni	38	Fibre	4,500	Kvavadze et al. (2015)
	Gonur depe	39	Achene	4,000–3,500	Sarianidi (1994)
MEA	Romania	40	*C.*-type pollen	>11,500	Feurdean et al. (2013)
	Lake Ribno Banderishko	41	*C.*-type pollen	>11,200	Tonkov et al. (2002)
	Lake Buhăiescu Mare	42	*C.*-type pollen	11,000	Geantă et al. (2014)
	Steregoiu and Preluca Tiganului	43	*C.*-type pollen	11,000	Feurdean and Astalos (2005)
	GGC 18	44	*C.*-type pollen	11,000–9,000	Filipova-Marinova et al. (2013)
	Lake Dalgoto	45	*C.*-type pollen	10,200–8,500	Stefanova and Ammann (2003)
	IC Ponor I	46	*C.*-type pollen	10,000	Bodnariuc et al. (2002)
	Rome	47	*C.*-type pollen	10,000	Mercuri et al. (2002)
	Lake Trilistnika	48	*C.*-type pollen	9,900	Tonkov et al. (2008b)
	Bory Tucholskie	49	*C.*-type pollen	9,000–7,300	Miotk-Szpiganowicz (1992)
	Dumpokjauratj	50	*C.*-type pollen	8,700–8,400	Hörnberg et al. (2005)
	Frumusica	51	Achene	8,600–5,500	Willerding (1970)
	Thayngen-Weier	52	Achene	8,600–5,500	Willerding (1970)
	Wolin II	53	*C.*-type pollen	8,200	Latalowa (1999)
	Großer Eutiner See	54	*C.*-type pollen	8,000	Wieckowska et al. (2012)
	Akali	55	*C.*-type pollen	7,600	Poska and Saarse (2006)
	Dancheny 1	56	Imprint	7,500–6,500	Pashkevich (2003) and Yanushevich (1989)
	Quai-Branly	57	*C.*-type pollen	7,500–5,500	Chaussé et al. (2008)
	Bandkeramik	58	Achene	7,400–6,900	Willerding (1970)
	Bylony, C-Europe	59	Unknown	7,000	Kabelik et al. (1960)
	Emines	60	*C.*-type pollen	7,000	Berthel et al. (2012)
	Tăul Mare–Bardău	61	*C.*-type pollen	7,000–6,000	Fărcaş et al. (2013)
	Lugovoe Mire	62	*C.*-type pollen	7,000–5,800	Blyakharchuk and Chernova (2013)
	Lakes Plaani, Verijärv and Lasva	63	*C.*-type pollen	6,900–3,800	Niinemets and Saarse (2009)
	Ukraine	64	Imprint	6,500–5,500	Merlin (2003)

Table 1 continued

Region	Site, area or culture	Site no	Remain type	Estimated age (cal BP)[a]	References
	Lago della Costa	65	*C.*-type pollen	6,400–4,400	Kaltenrieder et al. (2010)
	Šventoji	66	Achene	6,000	Stančikaitė et al. (2009)
	Western Sayan Mountains	67	Fibre	6,000–5,000	Blyakharchuk and Chernova (2013)
	Varna Lake	68	*C.*-type pollen	5,800–5,500	Filipova-Marinova et al. (2015)
	Egelsee	69	*C.*-type pollen	5,700	Wehrli et al. (2007)
	Mikhailovka 3	70	Imprint	5,600–4,300	Pashkevich (2003)
	Romania	71	Achene	5,300–4,300	Anthony (2007) and Merlin 2003)
	Durankulak-2	72	*C.*-type pollen	>5,300	Marinova (2003)
	Zvejnieki	73	Unknown	5,000	Gronenborn (2003)
	Gurbanesti	74	Achene	5,000–4,000	Sherratt (1991)
	North Caucasus Mountains	75	Achene	5,000–4,000	Ecsedy (1979)
	Nisi Fen	76	*C.*-type pollen	5,000–4,000	Lawson et al. (2005)
	Vinogradnyi Sad	77	Achene	5,000–3,000	Pashkevych (2012)
	ZBS	78	*C.*-type pollen	4,600–4,400	Krenke et al. (2013)
	Stjeäddjiejávvrie	79	*C.*-type pollen	4,500	Hörnberg et al. (2015)
	RF 93-30	80	*C.*-type pollen	4,200	Mercuri et al. (2012)
	Straldzha mire	81	*C.*-type pollen	4,200–2,800	Tonkov et al. (2008a)
	Provence	82	Fibre	4,000	Barber (1991)
	Black Loch	83	*C.*-type pollen	4,000	Edwards and Whittington (2000)
	Terramaras	84	*C.*-type pollen	3,600–3,200	Mercuri et al. (2006)
	Po Plain	85	*C.*-type pollen	3,600–3,100	Fleming and Clarke (1998) and Mercuri et al. (2015)
	Oudon	86	*C.*-type pollen	3,500	Cyprien et al. (2004)
	Lake Pelesa	87	*C.*-type pollen	3,500	Stančikaite et al. (2002)
	Neugrundmoor	88	*C.*-type pollen	3,500	Wehrli et al. (2010)
	Mlaka	89	*C.*-type pollen	3,200	Andrič (2007)
	GL3	90	*C.*-type pollen	3,200–2,700	Fernane et al. (2015)
	Gundsømagle Sø	91	*C.*-type pollen	3,100	Rasmussen and Anderson (2005)
	Fuorn Valley	92	*C.*-type pollen	3,000	Stähli et al. (2006)

MEA Mid-latitude Eurasia, *E Asia* East Asia, *S Asia* South Asia, *SW Asia* Southwest Asia, *C.*-type pollen *Cannabis*-type pollen

[a] The age was estimated either from direct radiometric dating or established chronology for the archaeological sequence the remains are associated with

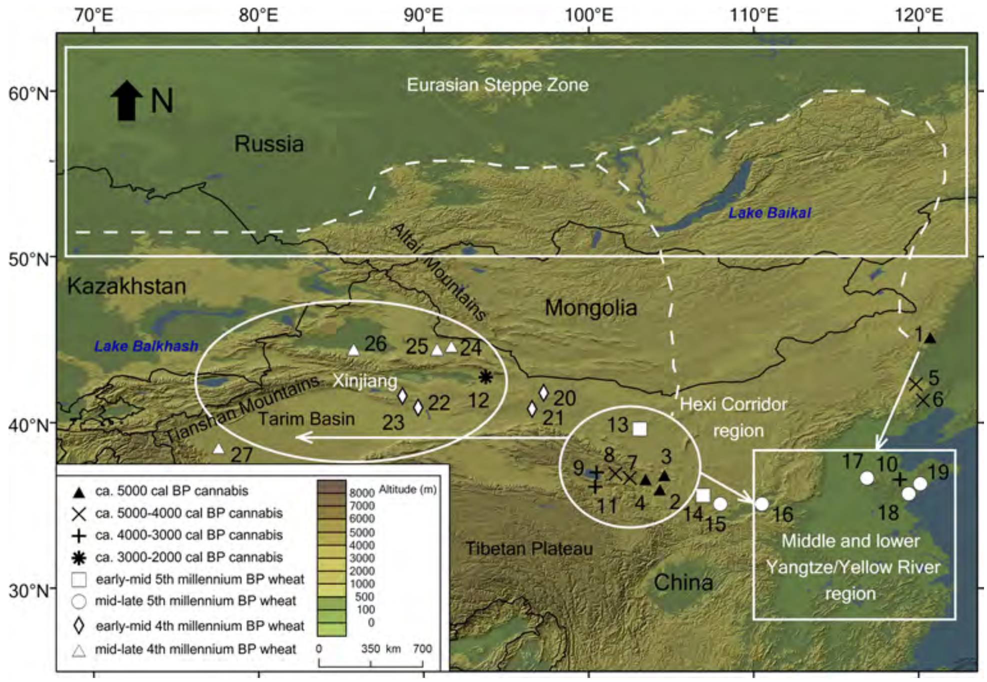

Fig. 2 Temporal and spatial distribution of cannabis achenes (ca. 5,000–2,000 cal BP) and wheat (ca. 5,000–3,000 cal BP) records in North China and adjacent regions. Sites with cannabis remains: 1 Haminmangha, 2 Yanggua, 3 Buziping, 4 Linjia, 5 Erdaojingzi, 6 Shangtaizi, 7 Jinchankou, 8 Lajia, 9 Ejia, Xinjia, Qingquanhantai, 10 Daxinzhuang, 11 Erfang, Lamafeng, Baojia, Wenjiagou, Zhongchuannongchang, 12 Yanghai. Information about sites 1-11 can be found in Table 1 and Fig. 1, and information about site 12 can be found in Jiang et al. (2006). Sites with early wheat remains: 13 Donghuishan, 14 Xishanping, 15 Zhouyuan, 16 Zhaojialai, 17 Jiaochangpu, 18 Liangchengzhen, 19 Zhaojiazhuang, 20 Huoshiliang, 21 Ganggangwa, 22 Xiaohe, 23 Gumugou, 24 Luanzagangzi, 25 Sidaogou, 26 Xintala, 27 Wupaer. The sites with wheat remains are based on Betts et al. (2014). Possible Bronze Age trans-Eurasian exchange/migration routes through the Eurasian steppe and possible dispersal directions of western (Southwest Asia and Europe) cultural elements within China are shown in dashed lines and arrowed lines, respectively. The topographic base map was generated from ETOPO1 Global Relief Model data (Amante and Eakins 2009). National boundaries were drawn from Natural Earth vector data v2.0 (http://www.naturalearthdata.com). Equidistant Cylindrical Projection is used for the map, in which the scale is true along the meridians

Cannabis is an annual herb growing during the warm season (Raman 1998). The plant is heliotropic and flowering is critically controlled by the length of the photoperiod (Booth 2003). Growing on almost any type of soil, it is most productive on nutrient-rich ground (Angelini et al. 2014). As a nitrophilous plant (Small et al. 2003), cannabis is closely associated with intentionally or unintentionally manured soils near human settlements subjected to organic wastes (Clarke and Merlin 2013). In general, this ruderal plant is considered as one of man's camp followers in prehistoric time, appearing quickly along roadsides, in dump heaps, and/or on the edges of fields after establishment of settlements (Schultes et al. 1974).

Data sources and criteria of evaluation

A list of early cannabis records was compiled from published sources specifying the location where the remains were recovered, types of remains, and their approximate age. Radiocarbon dates were directly cited with the determined age, while relative ages (e.g. associated with an archaeological culture) referred to the chronology of the given culture. All age information was harmonised with the unit of calendar years before present (cal BP), where 'present' is conventionally taken as AD 1950.

Only records having an age older than ca. 3,000 cal BP were selected for our database. The critical value of 3,000 cal BP was chosen because the period between ca. 3,200 and 2,500 cal BP marks the approximate start of the Iron Age and documented contacts across Eurasia (Smith 2014). The pre-Iron Age millennia are of high relevance for understanding the origin of cannabis utilisation. Accordingly, the records were grouped into time intervals: >ca. 8,000 cal BP, ca. 8,000–7,000 cal BP, ca. 7,000–6,000 cal BP, ca. 6,000–5,000 cal BP, ca. 5,000–4,000 cal BP and ca. 4,000–3,000 cal BP. In the compilation process, we followed data interpretation in the original references. For example, pollen from the Banpo Site in China, which was exclusively assigned to *Humulus* in the original archaeological report (Zhou 1963), but hypothetically interpreted as *Cannabis* in a widely cited secondary reference (Li

1974a). In this case we did not accept the interpretation of the secondary reference in our database.

We separated four geographical regions in Eurasia to trace the ancient spatial distribution of the plant. These are East Asia (including China, North Korea, South Korea and Japan), South Asia (including India, Pakistan, Nepal, Bangladesh, Bhutan and Sri Lanka), Southwest Asia (including Iraq, Syria, Lebanon, Turkey, Jordan, Georgia, Azerbaijan, Iran, Armenia and Azerbaijan) and mid-latitude Eurasia (including Europe, Russia, Mongolia, Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan and Afghanistan).

Four major types of cannabis remains were distinguished in the database: cannabis achenes, hemp fibres (e.g. for ropes or textiles), pollen assigned to *Cannabis*-type, and imprints of achenes on archaeological artefacts. The differentiation allows consideration of the relative merits and weaknesses of these different remains in indicating human use (see Fleming and Clarke 1998). In general, cannabis achenes can be accurately identified to the genus level, so achenes recovered from an archaeological context were tentatively considered as potential evidence for human exploitation of cannabis achenes at the site (Bouby 2002). Hemp fibres directly indicate use of cannabis (Ryder 1999), but ambiguity exists in accurately distinguishing these remains from other fibre remains (especially after several millennia of degradation) (Haugan and Holst 2014). Imprints of cannabis achenes on ceramics are evidence for a more intensive human use of cannabis achenes than a few sieved cannabis grains obtained by floatation. However, cord imprints on ceramics with linear decorative patterns that are often assigned to hemp were not accepted in the database, because distinguishing different fibre traces based only on morphological features is particularly unreliable (Bergfjord and Holst 2010).

Lastly, appearance of pollen assigned to *Cannabis* is seen as an indicator of local growth of cannabis plants near the study site (Godwin 1967), though pollen grains can be transported over long distances in certain circumstances (Moore et al. 1991). The fact that *Humulus* pollen morphologically resembles that of *Cannabis* may lead to erroneous identification, although some authors (Dörfler 1990; Fleming and Clarke 1998; Mercuri et al. 2002; Punt and Malotaux 1984) propose criteria for distinguishing between the two. Furthermore, pollen records do not explicitly allow the identification of past human use of cannabis, since plants might have grown spontaneously. However, if a sudden and strong increase in percentages of cannabis pollen is observed in a pollen diagram, the increase is more likely to be due to human activities, such as retting hemp for fibre production (Demske et al. 2016; Lavrieux et al. 2013; Mercuri et al. 2002). A unique advantage of palynological evidence of anemophilous cannabis is the often excellent preservation of its pollen grains in sediment records. Preservation of macrofossils in sediments, in general, is less often recorded (Birks 2001).

Results

Table 1 lists published cannabis records (older than ca. 3,000 cal BP) across Eurasia while Fig. 1 illustrates their location, with records of different ages indicated with different symbols. Records associated with an estimated age range were indicated according to the upper (older) boundary of that age range.

Eastern Europe, notably the region north and west of the Black Sea, has a high frequency of records of fossil *Cannabis*-type pollen (site numbers 40, 41, 42, 43, 44, 45, 46 and 48) older than ca. 8,000 cal BP, and at least one achene record (site number 51) of the same age. Western Europe and Central Europe has five pollen and achene records (site numbers 47, 49, 50, 52 and 53) older than ca. 8,000 cal BP. A record of achenes (site number 1) also appears in East Asia from ca. 10,000 cal BP.

A continuous series of achene or ceramic imprint records is found in Europe from ca. 8,000–7,000 cal BP (site numbers 56 and 58) through ca. 7,000–6,000 cal BP (site number 64) to ca. 6,000–5,000 cal BP (site numbers 66, 70 and 71). In East Asia, there are also some records of cannabis achenes (site numbers 4, 5 and 8) but also hemp fibre (site numbers 2 and 6) throughout the period between ca. 7,000 and 5,000 cal BP. A marked increase in achene records, however, only takes place in the millennium ca. 5,000–4,000 cal BP. From a total of eight sites or site clusters in East Asia (site numbers 9, 10, 11, 13, 15, 16, 17 and 18) cannabis achenes dating to this millennium were reported.

Outside of Europe and East Asia, records are scattered and appear relatively late in time. Southwest Asia has two geographically isolated records of hemp fibre (site numbers 36 and 38), of which one dates to ca. 6,000–5,000 cal BP and the other to ca. 5,000–4,000 cal BP, and only one record of cannabis achenes (site number 39) dating to ca. 4,000–3,000 cal BP. *Cannabis* records did not appear in records from South Asia until ca. 4,000–3,000 cal BP.

Analysis and discussion

Scythians in the mid-fifth century BC (ca. 2,500 cal BP) were described by the contemporaneous Greek historian Herodotus as consuming cannabis by inhaling its smoke in rituals (Warf 2014). Scythians was a general term at that time referring to nomads who inhabited the area stretching from present-day Ukraine to Central Asia (González-Ruiz et al. 2012). Herodotus' record seems to be amongst the earliest texts from Europe describing the use of cannabis (Wills 1998). Excavations carried out in the eastern part of Scythia (i.e. Central Asia) provide evidence supporting his description. Archaeological sites such as Pazyryk Frozen Tombs in the Altai Mountains (Fig. 1; van Noten and Polosmak 1995) and Iron Age burial sites at Yanghai in the Turpan Depression (Fig. 2; Jiang et al. 2006) recovered fur bags or bowls containing cannabis remains dated to ca. 2,500 cal BP. Being of similar age, the earliest written Chinese record concerning cannabis growth and use in the eastern part of Eurasia can be found in the Shi Jing, a collection of poems finalised in the sixth century BC (ca. 2,600 cal BP) (Li 1974a). Texts from Southwest Asia, South Asia and Egypt, quoted as 3,500–4,000 years old (Russo 2007), were suggested as even earlier records of medical uses of cannabis, but the reliability of these records is questionable (Wills 1998).

According to the collected data, all these written records are late reflections of a much earlier tradition of cannabis use across Eurasia, dating back to the early Holocene or even earlier periods. On one hand, cannabis seems to have grown as a component of natural vegetation across the entire continent at least since the early Holocene, represented by pollen and achene records appearing older than ca. 8,000 cal BP from both Europe and East Asia, a plant resource ready to be used by humans. The scarcity of cannabis pollen records predating ca. 8,000 cal BP from East Asia and other regions outside Europe might be due to the fact that Europe has been more thoroughly studied through pollen analysis (Grimm et al. 2007) and that the genus *Cannabis* was placed in different taxonomic groups depending on the flora to which the authors referred. For example, in previous Chinese standard floras (Editorial Board of 'Flora of China' of Chinese Academy of Sciences 1959–2004), *Cannabis* was listed as a genus of the Moraceae family (sensu Engler). Accordingly, some palynologists in China enumerated *Cannabis* pollen as unspecified Moraceae-type pollen (Wang et al. 1995). On the other hand, the three archaeological sites (site numbers 1, 52 and 53) with achene remains provide more direct evidence of human use of cannabis in both Europe and East Asia during the early Holocene. In light of the availability of the cannabis plant resource and contemporaneous records of cannabis achenes in the two distal parts of the continent, a multiregional origin of cannabis exploitation in Eurasia is, at least on a Holocene scale, more likely than a single-region origin (e.g. China) proposed in some conventional hypotheses. At least two centres, Europe and East Asia, appear as origins based on our compiled dataset. Prior to the Holocene, however, a more constrained centre of natural distribution of *Cannabis* remains possible.

In the cannabis exploitation history of Europe, there seems to be a long tradition of using cannabis achenes, which is reflected by the continuous series of achene or ceramic imprint records in combination with a few hemp fibre records. How achenes were exploited by prehistoric people cannot be clarified based on the present dataset. Archaeologists suggest that the practice of inhaling cannabis smoke might have appeared in Eastern Europe during the Yamnaya Culture (ca. 5,500/5,300–4,500/4,300 cal BP; Milisauskas and Kruk 2011; Anthony 2007) or even earlier (Balter and Gibbons 2015). The Yamnaya Culture originally occupied the region north of the Black Sea and is thought to be one of the most likely candidates for suggested Proto-Indo-European ancestors (Haak et al. 2015). Their westward migration is believed to have had influences on large parts of Europe linguistically and genetically (Haak et al. 2015). It is suggested that at this time cannabis was one of the key trade goods in the East European steppe and that smoking for psychoactive purposes became a ritual practice (Sherratt 2003). While achenes are not highly psychoactive, bracts attached to them contain the highest content of THC (Jiang et al. 2006). Thus, achene finds can be associated with the consumption of cannabis as a hallucinogen, as e.g. shown in a study of an Iron Age tomb in Central Asia (Russo et al. 2008). The westward migration of the Yamnaya people further spread the practice of cannabis smoking in Europe. One example for this is the record of a clay vessel with carbonised achenes and signs of cannabis burning from a tomb in Romania (site number 71).

Although more or less continuous cannabis records are reported from East Asia prior to ca. 5,000 cal BP, they are scattered in space and time. The marked increase in cannabis records in East Asia, notably achene records, between ca. 5,000 and 4,000 cal BP, might indicate a change in utilisation at that time. At least in one (Linjia, site number 13) of the eight sites or site clusters from which cannabis records date to this age, achenes appear to have been of high value as they are found to have been collectively stored in a clay pot (Institute of Botany in Northwest Normal University and Gansu Provincial Museum 1984). All the eight sites or site clusters are located in western or northern borderlands of China that are at similar distances from the eastern part of the Eurasian steppe and from the ancient (agri-)cultural centres in East Asia (the middle and lower reaches of the Yangtze and Yellow Rivers) (e.g. Zhao 2011), in particular the Hexi Corridor region and Northeast China. In the Hexi Corridor region, the oldest remains of wheat (*Triticum* spp.) in China were also found. This crop is considered to be of Southwest Asian origin and was first introduced to East Asia around ca. 5,000 cal BP or immediately after. Betts et al. (2014) cite an age of directly-dated carbonised wheat grains at the Donghuishan Site (Hexi Corridor region) as old as ca. 5,300–3,900 cal BP. Fig. 2 shows records of earliest wheat from northern China as compiled in Betts et al. (2014) and cannabis achene remains dating to ca. 5,000–2,000 cal BP. The radial distance from the Hexi Corridor region of early cannabis and wheat records is increasing over time.

A possible explanation for such a distribution pattern is that the Hexi Corridor region might have acted as a gateway through which the ancient exchange/migration network in Eurasia stretched to the heartland of the Chinese civilisation located further southeast. Although the Hexi Corridor was an easy passage later followed by the historical Silk Road, which accounted for much of the trade in Eurasian written history, the Silk Road itself was not firmly established until the second century BC (ca. 2,200 cal BP), when the Chinese Emperor Han Wu attempted to defeat the nomadic Xiongnu (living in the eastern part of the Eurasian steppe) through allying with political powers and seeking to obtain horses in Central Asia (Xie et al. 2007). However, available archaeological evidence (Warburton 2011) supports the hypothesis that connections between East Asia and Southwest Asia/Europe were already established since the late Neolithic or the early Bronze Age (e.g. Anthony 2007). The third millennium BC (ca. 5,000–4,000 cal BP) seems to have been the key period for firm establishment of this connection. Pastoralists, particularly the Yamnaya and their eastern neighbours (e.g. the Botai), living on the Eurasian steppe at that time, played an important role in this exchange/migration network. It is believed that these people domesticated wild horses (*Equus ferus*) (Levine 1999), probably from ca. 6,000 and 5,000 cal BP (Bendrey 2014), and were able to travel long distances across the relatively flat steppe zone (Frachetti 2011). It might have been this domesticated horse-based mobility—much enhanced compared to other agricultural societies located in the southern part of the continent—that enabled these populations to become a key promoter in the early exchange/migration network connecting far distant parts of the continent (Boivin et al. 2012), comparable to the merchants of the Silk Road several millennia later. Recent genetic evidence suggests that the Yamnaya population not only spread westwards to the heartland of Europe, but also migrated to Central Asia (e.g. Altai region) and later to Mongolia and northern China, suggesting a dynamic mobility throughout the entire Eurasian steppe zone during the Bronze Age (Allentoft et al. 2015). This mobility might have also facilitated the spread of bronze-making technology throughout Eurasia, contributing to the formation of the Bronze Age World System across the continent and to fundamental societal changes towards the end of the third millennium BC (ca. 5,000–4,000 cal BP) (Warburton 2011). In China, the utilisation of bronze, horses and new cereal crops, probably introduced via the network, changed the mode of warfare, which resulted in the establishment of the first dynastic states in the middle Yellow River region (Yi 2014). Interestingly, the first appearance of bronze artefacts in China was also in the Hexi Corridor region: the Qijia Culture, which was a representative archaeological culture in the region at the time, is famous for its early bronze mirrors, knives, rings and spears (Yi 2014). Also, the first bone remains of the domesticated form of horse (*Equus ferus* ssp. *caballus*) in China are associated with Qijia Culture sites (Yuan 2010).

The above-mentioned ancient exchange network is termed the 'Bronze Road' by some authors (e.g. Liu and Li 2014 p. 79), as bronze might have been a key object of trade. Nonetheless, the transfer of plants and plant utilisation techniques may also have played an important role in this trade network (Lightfoot et al. 2013). The multiple usability of cannabis makes it an ideal candidate for being a 'cash crop before cash', a plant that is cultivated primarily for exchange purposes (Sherratt 1999, p. 16), even if the ritual obsession of cannabis smoking in East Europe and the potential role of hemp-made rope in the first horse reins (Merlin 2003) are not emphasized. The marked increase in cannabis achene remains at ca. 5,000–4,000 cal BP (site numbers 9, 10, 11, 13, 15, 16, 17 and 18) in distal parts of East Asia, in particular the Hexi Corridor and Northeast China, may be interpreted as evidence for the increased importance of the plant in the exchange network established during the early Bronze Age. Firm archaeobotanical evidence of cannabis appearing at archaeological sites in areas such as South Asia (e.g. site number 34) during ca. 4,000–3,000 cal BP (e.g. Stevens et al. 2016) could be associated with a further expansion of the network.

This ancient exchange/migration network might have passed largely through the Eurasian steppe in the earliest stage, differing from the historical Silk Road to the south (Christian 2000) (Fig. 1). The difference could partly be due to the lower degree of landscape complexity in the steppe zone. Extreme environments (i.e. arid deserts and precipitous mountainous terrain) along the Silk Road (Fig. 2) could have hindered early exchange activities of people who were probably less well equipped compared with their later counterparts of the historical period (Liu and Li 2014). The steppe route of the Bronze Road (Christian 2000) might also explain the relatively late appearance of cannabis remains (from ca. 3,000–2,000 cal BP) (e.g. Jiang et al. 2006) and Southwest Asian crops such as wheat (from ca. 4,000–3,000 cal BP) (e.g. Dodson et al. 2013) in Xinjiang (Fig. 1). This indicates that the Hexi Corridor region was probably the central hub in China from which introduced plants and cultural elements from Southwest Asia/Europe were further diffused south-eastwards and westwards.

The fact that traits like smoking cannabis or using its achenes as funerary objects are closely related to Indo-European cultures may also facilitate the reconstruction of migrations of Proto-Indo-European populations. The Scythians were likely an Indo-European population (Ning et al. 2015). There is strong evidence of ritual/medicinal use of cannabis dating to ca. 2,500 cal BP from the burial site at Yanghai, Tarim Basin, Northwest China (Jiang et al. 2006). Several anatomical features of the skulls recovered from the site show more similarities to those of European populations than to East Asian features (Yang et al. 2010). Even clearer European anatomical and genetic features are observed in populations in the Tarim Basin dating to ca. 4,000 cal BP (Li et al. 2010), for example at the Xiaohe and Gumugou burial sites (Fig. 2). These people possibly spoke Tocharian (extinct today), which was a western branch of the Indo-European language family (Jia and Betts 2010; Li and Li 2011). Hypothesizing that ritual burning of cannabis was an important Indo-European tradition, cannabis remains may be regarded as a valuable palaeobotanical proxy for the reconstruction of migration activities of Proto-Indo-European people across Eurasia, which are still poorly understood (Bouckaert et al. 2012).

We found only three spatially scattered cannabis records (site numbers 62, 67 and 70) from the large area of South Russia and Central Asia published in international literature. The scarcity is partly due to the current focus in archaeobotany on regions such as Europe and East Asia, leaving large parts of the Eurasian steppe and adjacent regions to its south understudied (Outram et al. 2012). This outlines the need for more high-resolution, interdisciplinary and well-dated data from the Eurasian steppe to strengthen or to falsify our hypothesis that cannabis was closely associated with the Bronze Age trans-continental exchange. One promising method in studying ancient cannabis remains appears to be the analysis of phytochemical and genetic features, as it may allow for identifying the genetic type of the remains and their possible utilisation (Russo et al. 2008). The results can be correlated with modern phylogenetic-biogeographical relations of different putative taxa of cannabis.

Conclusion

In light of archaeobotanical and palynological records of cannabis available to date, the history of human use of this plant remains a complex and unresolved issue. More well-dated data, especially from the Eurasian steppe zone, are called for to address open questions. Existing evidence, however, suggests that a multiregional origin of cannabis utilisation in different parts of Eurasia is more likely than a single-region origin as argued for in some conventional hypotheses. It appears that at least Europe and East Asia were two independent centres of early cannabis use. Additional domestication centres cannot be ruled out, since other regions in Eurasia still lack systematic archaeobotanical investigations. There seems to be a continuous emphasis on exploiting cannabis achenes in Europe from the early Holocene. This practice might have also influenced how cannabis was used in East Asia since the onset of the Bronze Age exchange/migration network across Eurasia (ca. 5,000–4,000 cal BP).

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