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The long history of *Cannabis* and its cultivation by the Romans in central Italy, shown by pollen records from Lago Albano and Lago di Nemi

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Abstract. The cores from the Albano and Nemi lakes, near Rome, were studied within the European Union funded PALICLAS project and provided high resolution records of the Late-glacial and Holocene. Pollen evidence of increasing human influence on vegetation was recorded in the Holocene parts of both diagrams, and the *Cannabis* (hemp) curve was one of the major signs. In this paper we present unambiguous pollen evidence from the Cannabaceae records for the cultivation of hemp in central Italy by the Romans. The oldest records of *Cannabis* and *Humulus* (hop) date from to the Late-glacial. Hop pollen values rise during the mid Holocene, while hemp pollen becomes more abundant from ca. 3000 cal B.P. onwards. The highest earliest hemp peak (21%) is dated to the 1st century A.D. This '*Cannabis* phase', with the abrupt rise of hemp pollen soon after the rise of cultivated trees (*Castanea, Juglans* and *Olea*) is associated with the increase in cereals and ruderal plants. This unambiguous proof of cultivation by Romans around 2000 B.P. occurs as well as a long lasting pre-Roman presence of hemp in the area, which is natural and possibly also anthropogenic. Subsequent clear episodes of cultivation in the medieval period were found.

Key words: *Cannabis* – *Humulus* – Pollen analysis - Cultivation - Italian crater lakes – Late-glacial/Holocene – Roman period

Introduction

The present study was carried out as part of the EU-funded research project PALICLAS (1994-1996; co-ordinator Frank Oldfield), which aimed to study the ecosystem response to both climatic and human forcing in Italy during the last 25,000-30,000 years. The project focussed on sediment cores from the central Adriatic and crater lakes in central Italy. The cores provide high resolution records of the late Pleistocene and Holocene periods and detailed palaeoclimatic reconstructions were inferred from multiproxy data (Guilizzoni and Oldfield 1996; Lowe et al. 1996a; Lami et al. 1997; Aritzegui et al. 2000, 2001; Guilizzoni et al. 2002). Evidence of human impact has been recognised in the Holocene sequences and the pollen data include a number of records attributable to human influence, which increase towards the late Holocene. The hemp pollen curve was one of them (Lowe et al. 1996b; Accorsi et al. 1998b).

This paper focuses on the Late-glacial and Holocene *Cannabis* pollen recorded in two lake cores from Lazio region, Lago Albano and Lago di Nemi, and it particularly intends to show the most ancient unambiguous pollen evidence of the cultivation of hemp in central Italy, dated to Roman times. The topic is outlined in a general discussion of Cannabaceae pollen records, since most published diagrams report this level of identification.

The family of Cannabaceae includes two genera, *Cannabis* and *Humulus*. They are both considered native in the northern hemisphere, the first in Asia, the second also in Europe, but their origins are still uncertain (Simmonds 1976; Zohary and Hopf 1994; Heywood and Zohary 1995). The genus *Cannabis* is monospecific according to the majority of authors, with two subspecies and two varieties (Royal Botanic Gardens Kew 1997). The genus *Humulus* includes two or three species, depending on the authors (Royal Botanic Gardens Kew 1997; Pignatti 1982). *Cannabis sativa* L. (hemp) and *Humulus lupulus* L. (hop) are well-known crops. Hemp is commonly found all over the world as a cultivated plant but it is also known as a weed or wild plant. Populations of *C. sativa* which appear to grow wild, though probably not fully primary, are present in the Caspian basin, Afghanistan, the Himalayas and other central Asian territories (Small and Cronquist 1976). Hop is cultivated all over the world and is also largely spread as a wild plant in the temperate zone of the northern hemisphere (Simmonds 1976). In Italy, hemp is cultivated and also grows as a weed; hop grew wild in wet woods, more commonly in the north, and is also cultivated. Exotic *Humulus* species are cultivated as ornamentals (Pignatti 1982).

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Historical background of hemp and hop

Hemp is a multiple-use plant. It provides fibre which is useful in textile production, fruits that can be eaten or from which oil can be extracted and put to various uses, and a resin which is useful as a medicine and narcotic (Simmonds 1976; Bandini Mazzanti and Forlani 1981; Schultes and Hofmann 1992; Pate 1994). It has had a long history as a cultivated plant which started quite early in central Asia.

Although hemp may have been cultivated as long as 10,000 years ago (Abel 1980; Lester and Bakalar 1993), the early cultural and linguistic evidence of its use for fibre in China goes back to at least 2500 B.C. (Li 1974 in Zohary and Hopf 1994, p 126; Harlan 1995).

For the 1st millennium B.C., hemp cultivation is documented by archaeobotany, in the Near East, Greece and in general in the Mediterranean basin; in Anatolia, hemp fabrics dated to the 8th century B.C. are known (Zohary and Hopf 1994).

In Europe, although hemp has been found as early as the 7th-4th millennium B.C. in Romania (Comsa 1996 in Kroll 1999) and pollen evidence points to the possibility of its cultivation from the Bronze Age or even Neolithic (see discussion), the earliest fruits recorded date back to the end of the 1st millennium B.C. in the Iron Age in Poland, Romania, and the Ukraine (Wasylikowa et al. in van Zeist et al. 1991, p 213) followed by several findings in various other European countries (van Zeist et al. 1991; for reviews see Dörfler 1990 and Kroll 1996, 1997, 1998, 1999, 2000). Although records are sometimes scarce, use of hemp can be reliably inferred from the archaeological contexts (van Zeist et al. 1991; Behre 1986). The expansion of hemp growing to Europe in the 1st millennium B.C. is also mentioned by classical writers. It is thought to have been used by the Scythians in at least 500 B.C. (Herodotus, *Histories,* 1.4) and it is known that the fibre crop spread to Italy and Sicily in about 120 B.C. (as quoted in a fragment by Lucilius Gaius, 180-103? B.C.). Finally, important finds of charred and uncharred hemp fruits are present in the archaeological collections from Pompeii and the surrounding area from A.D. 79 (M. Borgongino pers. comm.; Pagano 1997), confirming their use in Roman times.

Hop provides oil, fibre, and medicine but it does not have such a long history as hemp. Its major use, for example as an additive in brewing, started in Europe from the early Middle Ages onwards, and its cultivation began in the 9th century A.D. (Behre 1999).

Uses of hemp and hop by Romans

Both hemp and hop were used by the Romans. Hemp was well-known as a fibre and medicinal plant. Among Latin writers, Lucilius Gaius firstly mentioned its use as fibre at ca. 120 B.C., Pliny the Elder (A.D. 23?-79) outlined the preparation and grades of hemp fibre (*Hist. nat.*, 1.19, c. 9). Varro (*De re rustica*, 1.2, c. 23) and Columella (*De re rustica*, 1.2, c. 10) listed hemp among the plants used to make ropes and mats. The latter author also indicated the best season and technique for sowing. Cato, Dioscorides and Palladio mentioned the crop too (Targioni Tozzetti 1896). Initially, in the 3rd century B.C., Rome imported fibre for ropes and sails from Gaul (Schultes and Hofmann 1992). Then, during the Roman Empire, hemp was also cultivated in Italy, especially in the north (Bandini Mazzanti et al. in press). Romans knew its efficacy as a medicine, especially for treating earache (Abel 1980; Dörfler 1990). Romans are not thought to have generally taken *Cannabis* as a drug, but they were aware of its psychoactive properties. In fact, Galen (about 200 A.D.) wrote that it was sometimes given to guests to promote hilarity and enjoyment. On the other hand, the psychoactive properties of hemp must have already been well-known by the Greeks, considering that Herodotus (440 B.C.) described the use of burnt fruits for excitation during funeral rituals by the Scythians and Democritus (460-390 B.C.) wrote that hemp was occasionally drunk with wine and myrrh to produce visionary states (Schultes and Hofmann 1992).

Humulus was also known to the Romans, who ate its young shoots like asparagus (Duke 1979). Pliny the Elder also mentioned the hop as a garden plant, but its use in brewing was not known then (Behre 1999).

The study area

Geography, climate and vegetation

The Lago Albano (41°45'N, 12°40'E) and the Lago di Nemi (41°43'N, 12°42'E) are located in the Albano Hills, ca. 25 km south-east of Rome, and they have formed in adjacent craters within the same volcanic complex (Fig. 1). The surface of Lago Albano is at 293 m asl and covers an area of 6 km^2; Lago di Nemi is at 320 m asl and covers an area of 1.8 km^2. Both lakes are hydrologically closed basins and receive water from underground springs and mainly from atmospheric precipitation.

The climate is sub-oceanic due to the influence of the Tyrrhenian sea, and it is a transitional type between the Mediterranean and the central European climate (Blasi 1994). The mean annual temperature is between 13° and 14°C, and the mean annual precipitation is between 700 and 900 mm, and up to 1200 mm on mountains (Pignatti 1994).

The vegetation consists of evergreen woodland, the *Orno-Quercetum ilicis* community which is dominated by *Quercus ilex* L. (holly oak), covering the Alban Hills on the lower as well as the highest points in the area (949 m asl on Monte Cavo; Pignatti 1994), alternating with deciduous oak woods containing *Quercus cerris* L., *Q. petraea* (Mattuschka) Liebl., *Q. pubescens* Willd., *Corylus avellana* L., *Carpinus betulus* L., depending on the drainage and available moisture in the soil (Blasi 1994; Blasi et al. 1995). Extrazonal beech woods growing in the area are evidence of past interglacial vegetation (Follieri et al. 1988) preserved during the last glacial in the Lazio region (Follieri et al. 1998). Cultivated chestnut woods, replacing deciduous oak wood, together with olive groves, characterise the cultural landscape of the area.

Historical background in Roman times

In the investigation area, there is no evidence of hemp cultivation in Roman times, nor before, as far as we know. Anyway, that area, which lies in the Castelli Romani region, is a land rich in history, especially that related to Romans. The little town of Albano was probably the mythical 'Albalonga', thought to be the Latin homeland. Many peoples, including the Etruscans, lived in the territory when Rome was founded (at 753 B.C. according to Varro, or between 875 and 729 according to other Roman writers). The two lakes of Nemi and Albano are especially known because the Romans used them to perform the 'naumachie', representations of naval battles, and they were surrounded by important *villae*. Ancient artificial underground outflows were dug by the Romans in the two lakes in the 4th century B.C. (Burri 1998). This testifies the intense use of the area.

Pollen records of Cannabaceae from Latium

Very little hemp and Cannabaceae pollen is present in pollen diagrams published so far from the area of Latium (Fig. 2). At Lago di Vico (Fig. 1), a discontinuous Cannabaceae curve was traced from the late Pleistocene (87±7 ka; Magri and Sadori 1999) and from the Late-glacial (Frank 1969). The earliest record of *Cannabis sativa* was found at Lago di Martignano in the zone between 7310±940 and 4225±1290 uncal B.P. (Kelly and Huntley 1991). No records of Cannabaceae were shown in the pollen diagrams from Valle di Castiglione (Alessio et al. 1986; Follieri et al. 1988) and Lagaccione (Magri 1999).

Materials and methods

A seismic survey (3.5 kHz) was carried out to identify a range of sites for coring in the Albano and Nemi lakes (Lami et al. 1996). Core PALB94-1E, 1400 cm long, was collected from Lago Albano at a water depth of 70 m and core PNEM94-1B, 915 cm long, was collected from Lago di Nemi at a water depth of 30 m. Lithological descriptions were given by Chondrogianni et al. (1996). Subsampling for pollen analysis was carried out at average intervals of about 10 cm.

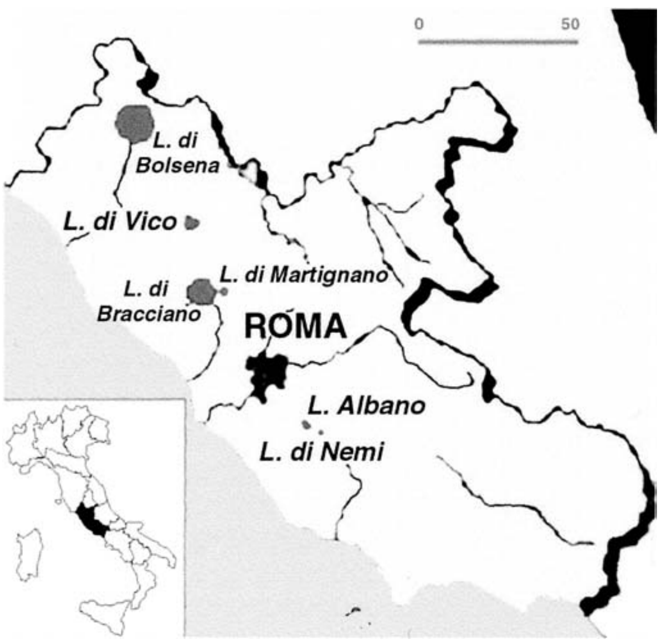

Fig. 1. Location map of Lago Albano and Lago di Nemi in Latium (central Italy)

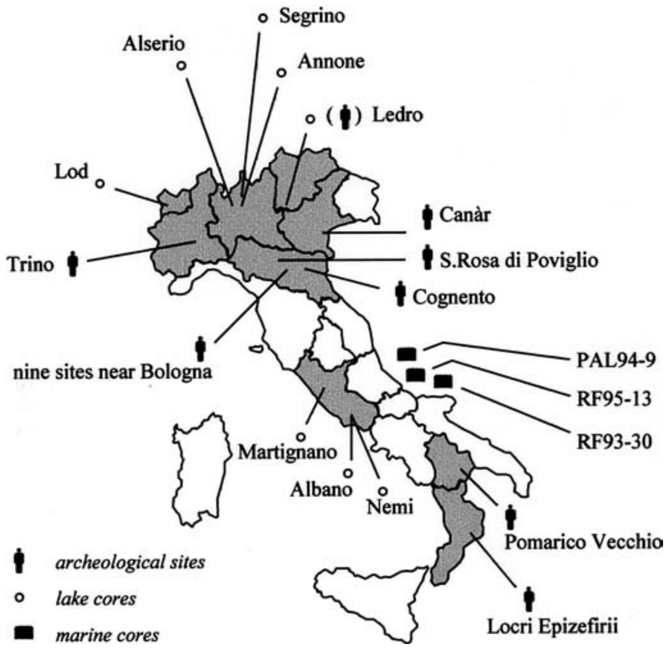

Fig. 2. Hemp pollen records in Italy: map of the sites quoted in the paper (chronology and references in the text)

Chronology

The chronology of the lake cores studied within the PALICLAS project was based on correlations between combined results of AMS radiocarbon dating, Potassium/Argon dating, tephra and palaeomagnetic analyses of all cores besides varve counting and biostratigraphical data (for further details, see also Olfield 1996; Guilizzoni et al. 2002).

The two lake cores involved here were not radiocarbon dated because macrofossils were extremely rare and the sediments were only occasionally calcareous (Chondrogianni et al. 1996). Their age-depth scales were assessed by Stephen Juggins and Piero Guilizzoni (pers. comm.). They used correlations with a core from Albano (PALB94-3A with four ^{14}C dates calibrated according to Stuiver and Reimer 1993), and by stratigraphical, palaeomagnetic, geomagnetic data and the 'Avellino' tephra, which is present in all three cores (Calanchi et al. 1996); moreover, detailed correlations between the Albano and Nemi cores were obtained from high-resolution magnetic susceptibility measurements, planktonic diatom and Cladocera analyses, pigment data, tephra layers and pollen stratigraphy. In these age-depth scales the beginning of the Holocene is at ca. 11,300 cal B.P., midway between the date assessed for northern central Europe (11,500 cal B.P.; Litt et al. 2001) and that assessed for the Mediterranean area at the Lago Grande di Monticchio (11,200 cal B.P.; Allen et al. 2002). The age scales have already been applied to multi-proxy studies of these cores (Aritzegui et al. 2000; Guilizzoni et al. 2002).

In core PALB94-1E from Albano, a hiatus representing ca. 2500 years was identified in the Holocene interval based on magnetic susceptibility, pollen and other biological data. It was not a coring artefact, but the determining cause is still under investigation (Oldfield 1996). The hiatus is thought to affect the part of the core between around 6500 and 4260 cal B.P.

The core from Lago Albano dates back to the full Glacial, and the Lago di Nemi core spans the Holocene entirely, touching the Late-glacial.

Laboratory analyses

A total of 161 subsamples were analysed for pollen in our laboratory: 74 of these were subsamples taken from 669 cm to the top of PALB91-1E/Albano core (which are mainly of Holocene age, with the lower samples touching the late Pleistocene; for the late Pleistocene part see Lowe et al. 1996a, 1996b), and 87 subsamples taken from the whole PNEM94-1B/Nemi core (mainly dated to the Holocene with the lower samples touching the Late-glacial). Subsamples were prepared for counting using tetra-Na-pyrophosphate, HCl 10%, acetolysis, heavy liquid separation (Na-metatungstate hydrate), HF 40% and ethanol (Lowe et al. 1996b). The pollen slides were mounted with glycerol jelly. *Lycopodium* spores were added to calculate pollen concentrations. Pollen identification was based on reference specimens together with relevant keys and atlases. The identification of cereal pollen was based mainly on the criteria in Andersen (1979) with the correction factor for glycerol jelly (Fægri et al. 1989).

Identification of Cannabis *and* Humulus *pollen*

Cannabis and *Humulus* have very similar pollen grains. They are included in the *Humulus lupulus*-type by Punt and Malotaux (1984) and in the *Cannabis*-type by Moore et al. (1991). Morphological differences, based on exine, pore protrusion and grain size, allow us to differentiate between the two genera with a light microscope (Whittington and Gordon 1986; Whittington and Edwards 1989; Punt and Malotaux 1984; Accorsi et al. 1986; De Leonardis et al. 1986; Moore et al. 1991; for a review see also Dörfler 1990). Most literature concerns *Cannabis sativa* and *Humulus lupulus*. No information could be found on the other *Humulus* species.

We carried out morphological observations (at 1000x) on fossil pollen of Cannabaceae recorded in both cores as well as on reference pollen of hemp and hop collected from various specimens, treated with acetolysis and mounted in glycerol jelly. The size of grains, the number of pores, and the pore protrusion were observed. Measurements on recent pollen present in *Cannabis* resin were also considered (Gabrielli 1996). Based on pollen literature, investigations on fossil/recent pollen and current distribution of plants, we concluded that the pollen in our cores can be reliably attributed to either hemp or hop. Hereafter, for the sake of brevity, *Cannabis sativa* is indicated as *Cannabis* and *Humulus lupulus* as *Humulus*.

All data indicate that both plants have prevalently triporate pollen (rarely with 4 or 2 pores) and that hemp pollen is almost always with non-raised or inrolled pores, possibly due to the preparation process (French and Moore 1986). They also stress the potential for using grain size as a character in the identification of *Cannabis* pollen within Cannabaceae, since its pollen is usually larger than that of *Humulus*. This seems the most reliable way to separate hop and hemp pollen during routine analyses.

Taking into account the overlap in their size, we divided fossil pollen into the following three categories:

1) *Humulus*: up to 25 μm;
2) *Cannabis /Humulus*: between > 25 and 28 μm;
3) *Cannabis*: > 28 μm (the maximum size observed in these cores was 37 μm, in Lago di Nemi).

As *Cannabis* pollen is sometimes less than 28 μm (see for example Punt and Malotaux 1984; De Leonardis et al. 1986; Whittington and Gordon 1986), it may have been under-estimated in our counts.

Pollen diagrams

A mean of about 600 land pollen grains was counted in each sample. Percentages were calculated according to the standard assessed within the PALICLAS project, in which the pollen sum included total land pollen (TLP), which however excluded *Pinus* (Lowe et al. 1996b). Pollen zones and phases were correlated and labelled in the same way in both cores (Figs. 3,4) using the same terms as the first version (Lowe et al. 1996b), which must not be confused with the commonly used zones of Firbas north of the Alps.

In the diagrams (Figs. 5,6,7), the curve of wild anthropogenic indicators (*sensu* Behre 1986) includes the following pollen types of synanthropic plants (Moore et al. 1991): *Asphodelus, Centaurea cyanus, Centaurea nigra* type, *Cirsium, Convolvulus arvensis, Cuscuta europaea* type, *Galium* type, *Linum*

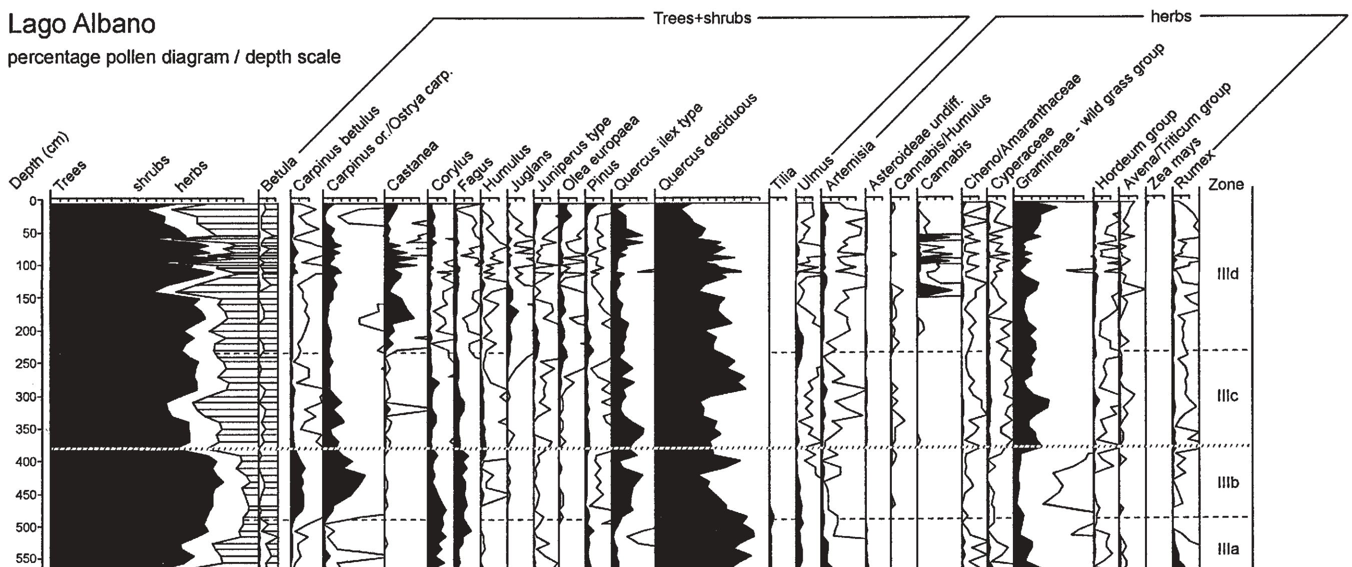

Fig. 3. Percentage pollen diagram of core PALB94-1E / Albano - depth scale, selected taxa only. Pollen sum = TLP, *Pinus* excluded. The pattern line in the PALB94-1E signs a chronological hiatus

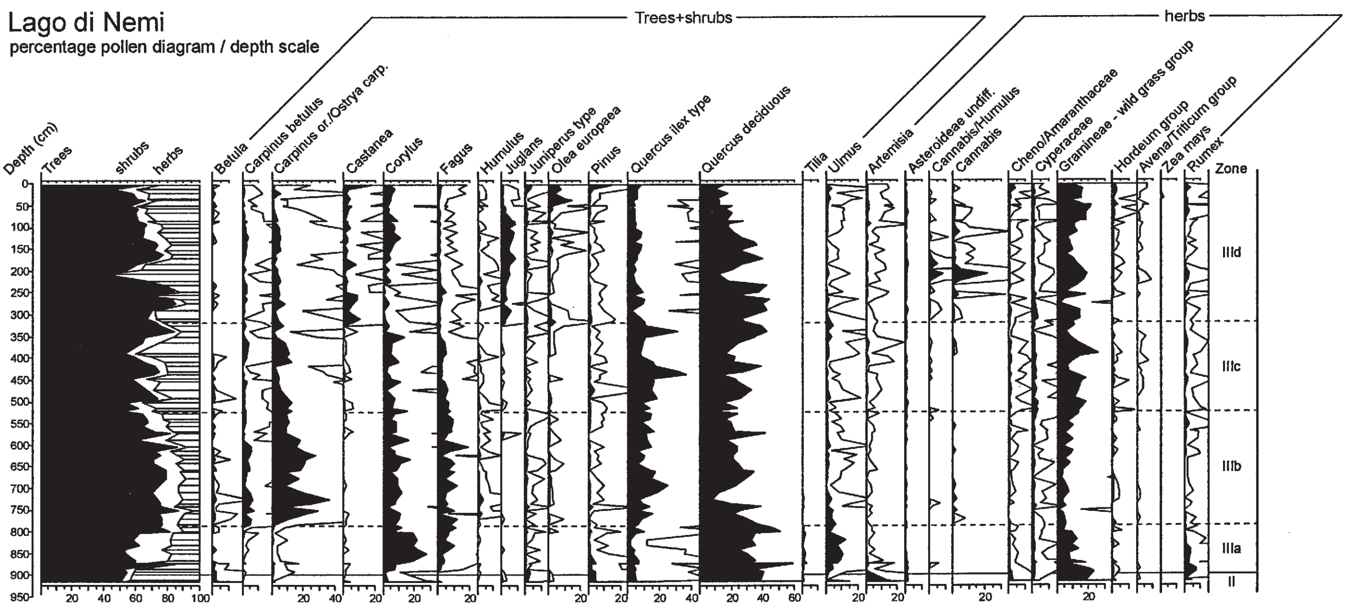

Fig. 4. Percentage pollen diagram of core PNEM94-1B / Nemi - depth scale, selected taxa only. Pollen sum = TLP, *Pinus* excluded

catharthicum type, *Mercurialis, Plantago coronopus, P. lanceolata* type, *P. major, P. maritima* type, *P. media, Papaver rhoeas* type, *Sanguisorba minor, Scleranthus, Spergula* type and *Urtica dioica* type.

Plants were named using *Flora d'Italia* (Pignatti 1982) and *Flora Europaea* (Tutin et al. 1964-1980). The pollen diagrams were drawn using TILIA.GRAPH by Grimm (1991-1993).

Results

Cannabaceae records

Cannabis pollen is quite frequent in both lake cores, in 31% of samples in Albano and 33% of samples in Nemi. Likewise, *Cannabis/Humulus* is present in 32% and 27% of samples respectively, while *Humulus* is present in 74% and 71% of samples respectively. Altogether, Cannabaceae are present in 78% of samples from Albano and 82% from Nemi.

In the Albano core (Figs. 3,5,7a), Cannabaceae are recorded from the Late-glacial (*Cannabis/Humulus* at 664 cm depth - ca.13,700 cal B.P.; *Cannabis* and *Humulus* in the next sample, ca. 13,400 cal B.P) and becomes almost continuous from 467.0 cm - ca. 8700 cal B.P. onwards. *Cannabis* reaches its maximum (20%; 18,400 pollen/cm^3) at 140 cm - ca. 1760 cal B.P, and two other peaks follow at ca. 1170 cal B.P. (18.5%; 10,700 pollen/cm^3) and at ca. 730 cal B.P. (18.5%; 6100 pollen/cm^3). *Humulus* has its maximum (3%) at ca. 6550 cal B.P. *Cannabis/Humulus* has always low values (< 1%).

In the Nemi core (Figs. 4,6,7b), Cannabaceae are recorded from the base of the Holocene (*Humulus* at 893 cm - ca. 11,200 cal B.P.) and becomes almost continuous from 782 cm - ca. 9000 cal B.P. onwards. *Cannabis* reaches its maximum (21%; 31 800 p/cm^3) at 208.5 m - ca. 1900 cal B.P. and has two subsequent low peaks (5 and 4%, 2800 and 2900 p/cm^3) at ca. 1790 and ca. 1000 cal B.P. *Humulus* has its maximum (4%) at ca. 8200 cal B.P., and *Cannabis/Humulus* peaks (8%) at ca. 1900 cal B.P.

Pollen Zones

A brief description of the flora and vegetation interpreted from pollen diagrams is given below with chronology and pollen zones. The key features are considered, especially Cannabaceae and also evidence of human impact helpful for the discussion. According to multiproxy data (see Guilizzoni and Oldfield 1996; Lowe et al. 1996b; Aritzegui et al. 2001; Guilizzoni et al. 2002, for analytical descriptions) Pollen Zone I represents the late Pleistocene, Zone II corresponds to the Late-glacial and Zone III to the Holocene. Note that Zone I, present here only in Albano, actually is the top (studied in detail) of the Zone I fully studied by Lowe et al. (1996). In Zone III, the most reliable pollen evidence suggesting human impact on the environment comes from the increase in cereal groups, weeds and cultivated woody plants as well as from the decrease in natural woodland.

Core PALB94-1E / Albano

The mean pollen concentration of terrestrial plants was 130,000 pollen grains/cm^3 per sample and about 45,000 pollen grains were counted altogether. The pollen diagram is divided into three pollen assemblage zones and six subzones.

PAZ I - Late Pleistocene 678-669 cm; ca. 14,000-13,860 cal B.P.

Cannabaceae are absent (and also absent in the lower Late Pleistocene part of the Zone I, J. Lowe pers. comm.). High percentages of herb pollen (ca. 80%), mainly *Artemisia*, Asteroideae undiff., Chenopodiaceae/Amaranthaceae, Gramineae, Cyperaceae and *Rumex* are present; possibly *Artemisia* and Chenopodiaceae also include shrubs. Among trees and shrubs only deciduous *Quercus*, *Pinus*, *Juniperus* and *Corylus* have significant values. *Hordeum* and *Avena/Triticum* groups (hereafter 'cereals') are present.

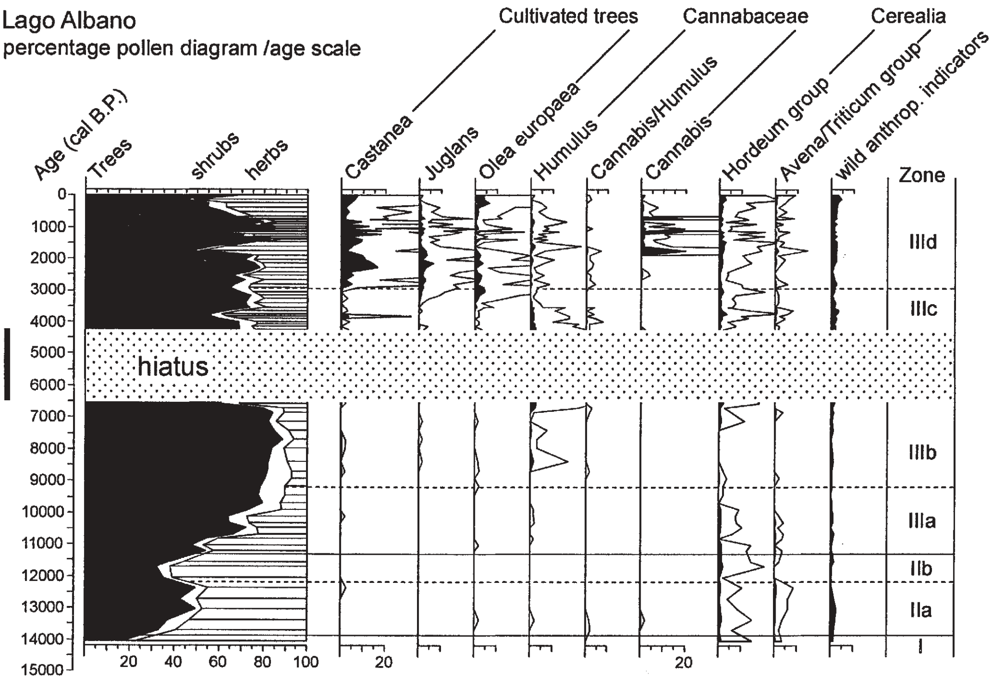

Fig. 5. Percentage pollen diagram of PALB94-1E / Albano, age scale, selected taxa only. Pollen sum = TLP, *Pinus* excluded ('cultivated trees' means 'possibly or surely cultivated trees'). The pattern line in the PALB94-1E signs a chronological hiatus

PAZ II, subzones IIa, IIb - Late-glacial 669-588 cm; around 13,860-11,300 cal B.P.

Cannabaceae (all the three pollen types) appear at the base of this zone. This is a transitional zone between the herb-dominated PAZ I and the deciduous tree dominated PAZ III. Among trees and shrubs (30-55%), *Juniperus* and *Pinus* values remain constant while deciduous *Quercus* increases. Among herbs, *Artemisia* is still well-represented (10-20%) while Gramineae decrease. Cereals and wild anthropogenic indicators increase slightly.

Subzone II a (669-620 cm; around 13,860-12,200 cal B.P.)

Cannabis is firstly recorded at 13,400 cal B.P. *Humulus* and *Cannabis/Humulus* are also present. Trees/shrubs increase, mainly deciduous *Quercus*, *Ulmus*, and *Tilia*, the latter reaching its maximum here. *Castanea* and *Olea* are present.

Subzone II b (620-588 cm; around 12,200-11,300 cal B.P.)

Artemisia and Chenopodiaceae/Amaranthaceae reach their maxima, also *Betula*; deciduous *Quercus*, *Ulmus* and *Tilia* decrease strongly.

PAZ III, subzones IIIa, IIIb, IIIc, IIId - Holocene 588-2 cm; from around 11,300 cal B.P. to present.

Cannabaceae are quite frequent, abundant in the second half of the zone. The zone is characterised by high tree and shrub pollen values (up to 90%), mainly deciduous *Quercus* accompanied by many other deciduous broad-leaved trees; *Quercus ilex* type increases; *Artemisia* decreases significantly. Cereals and cultivated/cultivable trees (hereafter 'cultivated') increase towards the top.

Subzone IIIa (588-490 cm; around 11,300-9200 cal B.P.)

Humulus is sporadic. Trees and shrubs increase (deciduous *Quercus, Corylus, Fagus, Tilia, Ulmus* and *Q. ilex* type). *Artemisia* and wild Gramineae decrease. Cereals and wild anthropogenic indicator values remain constant.

Subzone IIIb (490-380 cm; around 9200-6500 cal B.P.)

Humulus records become continuous and reach their maximum (3%). *Cannabis/Humulus* is sporadic. Deciduous *Quercus* decreases; *Carpinus betulus*, *Carpinus orientalis/Ostrya carpinifolia* and *Quercus ilex* type increase notably; *Olea* and *Castanea*, already recorded in the previous subzone, are joined by *Juglans*; cereals become more discontinuous.

Hiatus (ca. 6500-4260 cal B.P.)

Subzone IIIc (370-235 cm; around 4260-2950 cal B.P.)

Cannabis is present again at 4250 cal. B.P.; *Cannabis/Humulus* and mainly *Humulus* are frequent. There is clear evidence of human activities: *Olea, Juglans* and wild anthropogenic indicators increase in both percentage and concentration. *Castanea* and cereal values remain constant. Short cycles of woodland regrowth and further clearance episodes occurred. Note that *Humulus* seems to increase especially during the woodland clearance phases, when cereal maxima and wild anthropogenic indicators generally increase.

Subzone IIId (235-0 cm; around 2950 cal B.P. - present)

This includes the "*Cannabis*-phase", in which there is a notable increase in hemp pollen in a context of evident human impact on local vegetation. *Castanea, Juglans* and *Olea* first increase significantly at around 3000 cal B.P., then *Cannabis* has three brief peaks, spaced ca. 500 years from each other (ca. 20%, at ca. 1760 cal B.P., ca. 1170 cal B.P. and ca. 730 cal B.P. respectively) and a subsequent sudden decrease (from ca. 660 cal B.P. onwards). One of the *Cannabis/Humulus* highest values (0.7%) coincided with the earliest *Cannabis* peak. *Humulus* maintained a continuous curve. At the top of the zone Cannabaceae become insignificant while cereals (including a *Zea mays* record), *Olea* and other cultivated and wild anthropogenic indicators increase further.

Core PNEM94-1B / Nemi

The mean pollen concentration of terrestrial plants was 170,000 pollen grains/cm^3 per sample, and about 49,000 pollen grains were counted altogether. The pollen diagram was divided into two pollen assemblage zones and four subzones.

PAZ II - Late-glacial 914.5-900 cm; around 11,600-11,300 cal B.P.

Cannabaceae are absent. The tree and shrub records (55%) mainly consist of deciduous *Quercus* (35%), accompanied by *Pinus*, *Juniperus* and *Betula*, each around 3-5%; *Artemisia* and Gramineae are around 15-20%, followed by low Chenopodiaceae/ Amaranthaceae, *Rumex* and Asteroideae undiff. *Olea*, *Castanea* and *Juglans* are present as well as cereals and wild anthropogenic indicators.

PAZ III, subzones IIIa, IIIb, IIIc, IIId - Holocene 900-0 cm; from around 11,300 cal B.P. to present

Cannabaceae, initially sporadic, become very frequent and increases towards the top of the zone. The zone is characterised by high percentages of trees and shrubs (usually 70-90%), mainly represented by deciduous *Quercus,* and many other deciduous broadleaved trees such as *Corylus, Carpinus betulus, Carpinus orientalis/Ostrya carpinifolia, Fagus, Ulmus. Quercus ilex* type is continuous. *Betula, Juniperus* are low. *Artemisia,* Gramineae and Chenopodiaceae/Amaranthaceae decrease significantly.

Subzone IIIa (900-785 cm; around 11,300-9040 cal B.P.)

Cannabis/Humulus and *Humulus* are rare. Trees and shrubs increase, mainly due to deciduous oaks, and *Corylus, Tilia* and *Ulmus* which peak here. *Olea, Castanea* and *Juglans*, together with cereals and wild anthropogenic indicators are still low.

Subzone IIIb (785-524 cm; around 9040-5200 cal B.P.)

Cannabis is first recorded at 8800 cal B.P. (0.7%), and some other records are present. *Cannabis/Humulus* is still sporadic. *Humulus* is almost continuous and reaches its maximum (4%). Trees and shrubs (80-90%) reach their maximum; *Quercus ilex* type, *Carpinus betulus, Carpinus orientalis/Ostrya carpinifolia* increase. *Olea,* cereals and wild anthropogenic indicators become more continuous.

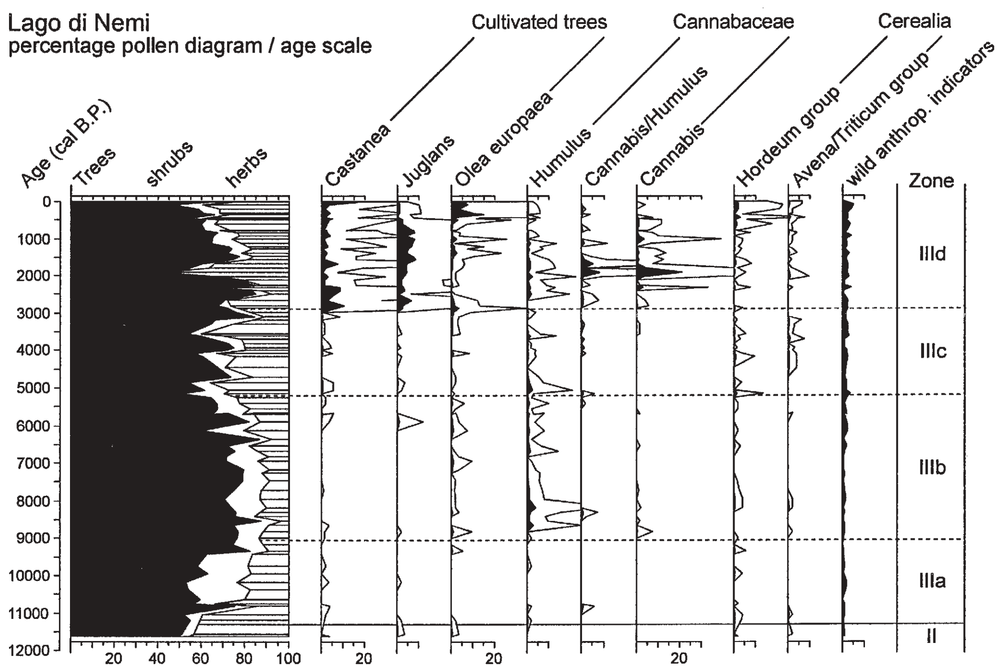

Fig. 6. Percentage pollen diagram of PNEM94-1B / Nemi, age scale, selected taxa only. Pollen sum = TLP, *Pinus* excluded ('cultivated trees' means 'possibly or surely cultivated trees')

Subzone IIIc (524-320 cm; around 5200-2900 cal B.P.)

Cannabis and *Cannabis/Humulus* are still sporadic. *Humulus* has low peaks (up to 2%) mainly in episodes of woodland clearance, which can be recognised in the subzone. Trees and shrubs decrease a little (75%), but *Castanea* and *Juglans* become more frequent, and *Olea* records remain constant. Gramineae, cereals and wild anthropogenic indicators increase a little.

Subzone IIId (320-0 cm; around 2900 cal B.P.-present)

This includes the "*Cannabis* phase". There is a first notable increase in *Castanea, Juglans* and *Olea*, clearly cultivated. Then, *Cannabis* reaches its maximum (21%) at 1900 cal B.P. coinciding with the *Cannabis/Humulus* maximum (8%). Subsequently, hemp rapidly decreases (to 5%) and likewise the main deciduous trees (*Quercus, Carpinus orientalis/Ostrya*). Gramineae and cereals increase. At the top of the sequence, Cannabaceae become insignificant while there are further increases in *Olea*, cereals (including a *Zea mays* record) and other cultivated and wild anthropogenic indicators.

Discussion

The two pollen diagrams correlate with each other. The hemp pollen curves, together with the other Cannabaceae records, have very similar trends in both the cores and provide new information on the history of hemp in Italy.

The long history of the hemp family and hemp in Italy

a) between ca. 13,900 and 12,200 cal B.P. In our cores, the most ancient Cannabaceae records are in PAZ IIa (Lago Albano), between ca. 13,900 and 12,200 cal B.P. In this subzone all three pollen types are recorded. The first is actually *Cannabis/Humulus*, observed in the base sample, followed immediately by *Cannabis* and *Humulus* (in the next samples, ca. 13,500 cal B.P.). These pollen records suggest that their parent plants lived in the area or in the surroundings. At that time, pollen assemblages indicate an open plant landscape sustained mainly by *Artemisia* and Chenopodiaceae/Amaranthaceae, and more or less densely wooded by *Pinus* and *Juniperus*, in which deciduous oaks were beginning to spread. With regard to hemp, the record could suggest the presence of wild plants in the area even if caution is recommended because only one pollen grain was recorded.

Among the other published Cannabaceae records in pollen diagrams covering the Late-glacial period in Mediterranean Italy, some have a similar age: 1) in the central Adriatic Sea core RF95-13 spanning from the Younger Dryas to the early Holocene (Mercuri et al. 2001 and unpublished data), *Humulus* has been found since ca. 12,800 cal B.P., and *Cannabis* somewhat later, at ca. 11,000 cal B.P. 2) in southern Italy, at Lago Grande di Monticchio, Cannabaceae (included in the arboreal sum), was recorded at 12,000 cal B.P. (Huntley et al. 1996); 3) in central Italy, at Lago di Vico, Cannabaceae (included in the herb sum) and some *Humulus* records were found in the period ranging from Younger Dryas to the late Holocene (respectively, zone V1-18 in Magri and Sadori 1999, and zones F - G in Frank 1969).

b) *between ca. 9000 and 7000 cal B.P.* With the transition to the Holocene in the Mediterranean area, the open, lightly wooded Late-glacial vegetation described above was rapidly replaced by deciduous woods, mainly dominated by oaks (see, for example, Hooghiemstra et al. 1992; Bottema 1995; Rossignol-Strick 1995; Lowe et al. 1996a, 1996b; Magri and Sadori 1999 and references therein; Ramrath et al. 2000).

In our cores, Cannabaceae become continuous between ca. 9000 and 7000 cal B.P., during the early to middle Holocene (PAZ IIIb of both cores).The records of deciduous broadleaved trees such as oaks and other trees and shrubs such as *Corylus, Fagus, Ulmus* and *Tilia* indicate the development of a well-developed woodland which was either already widespread or was spreading at that time (*Carpinus orientalis/Ostrya*, *Carpinus betulus*). Only a temporary interruption in woodland development was observed in the Nemi diagram (Fig. 6), mainly the result of a short, dry and cool climatic episode at about 8500-7500 cal B.P., which is a low productivity phase within the high productivity period of sapropel formation between 9500 and 6000 cal B.P. (Aritzegui et al. 2000). In this period, *Humulus* is prevalent among Cannabaceae while *Cannabis* and *Cannabis/Humulus* are sporadic. As far as hop is concerned, its expansion seems to have occurred when the woodland was at its maximum, or more precisely when *Carpinus betulus* (hornbeam) increased and oaks decreased, either from natural causes or due to human activity.

A similar rise in hop pollen within a *Carpinus* phase of woodland regrowth was observed in the central Adriatic sea cores PAL94-8 and PAL94-9 (Lowe et al. 1996b, and unpublished data). With regard to hemp, the rare records in our cores continue to suggest the presence of wild plants in the area, as in the previous period.

c) *between ca. 7000 and 3000 cal B.P.* Between ca. 7000 and 3000 cal B.P., in PAZIIIb and PAZIIIc of both cores, Cannabaceae and other anthropogenic indicators increase. After the above mentioned full development of the deciduous woodland, tree cover decreased more or less gradually. Cereals and wild anthropogenic indicators became more frequent, suggesting an increase in human activities in the area. This is in accordance with the large number of settlements established before and by this age in Italy (Guidi and Piperno 1992). In our cores, the pollen record suggests that human activities contributed to limiting natural tree cover from the beginning of the time covered. In this scenario, *Cannabis* and *Cannabis/Humulus* were still sporadic, and the low *Humulus* peaks mainly occur during episodes of woodland clearance. In PAZIIIc, these small hop peaks are accompanied by high cereal values, mainly *Hordeum* group, and wild anthropogenic indicators. The hop pollen trend in our spectra could look like that of a crop, but there is not enough evidence to be able to say whether it was being grown then, and its low percentages in our spectra (always < 3%) indicate that the expansion of this liana was naturally favoured within woodland clearings. So too for hemp: although pollen suggests that hemp

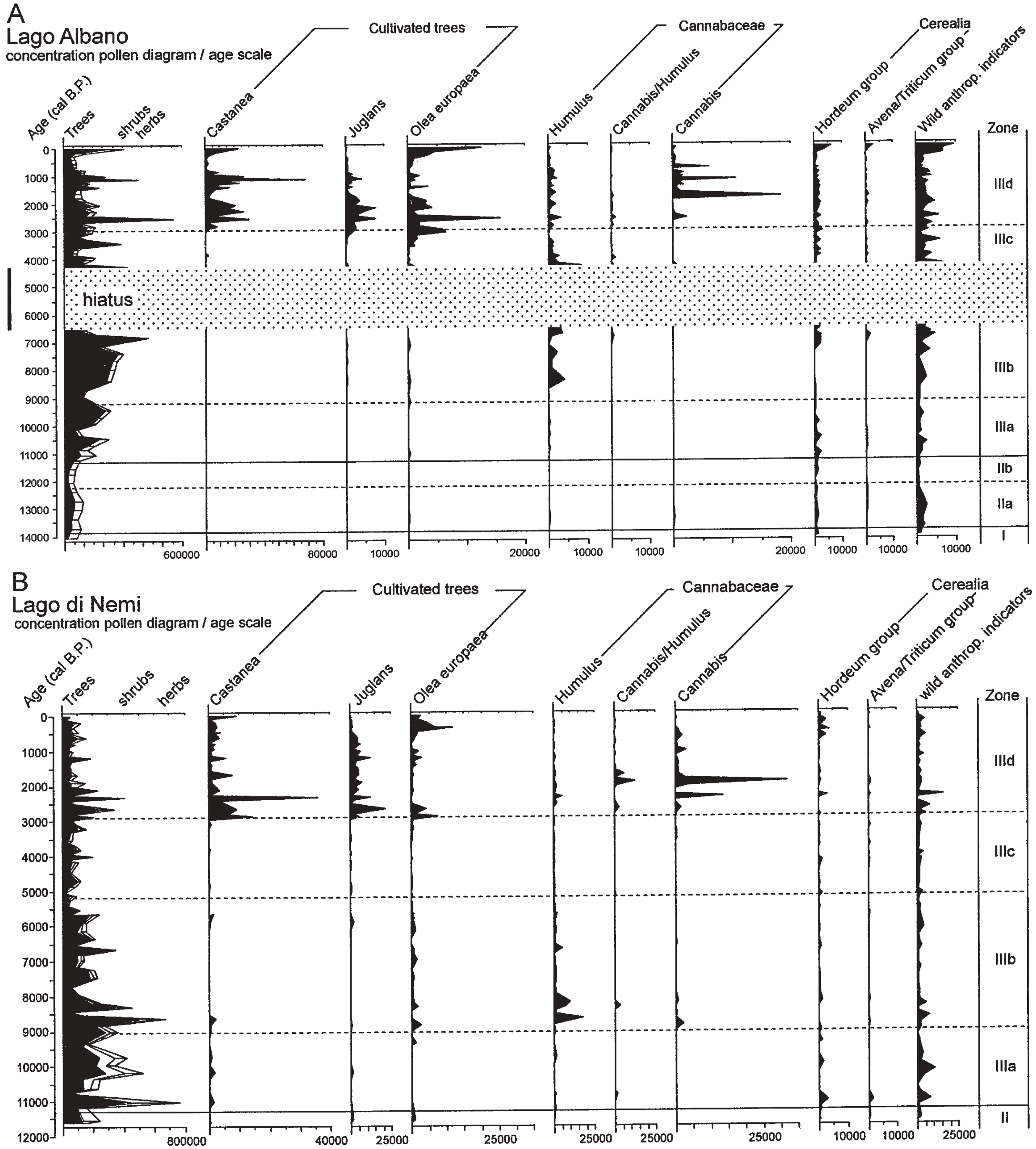

Fig. 7. Concentration pollen diagrams (grains/cm^3) of the two cores PALB94-1E / Albano (7A) and PNEM94-1B / Nemi (7B), age scale, selected taxa only ('cultivated trees' means 'possibly or surely cultivated trees')

continued to grow in the area, there is no clear proof of its cultivation despite the high number of human settlements, as mentioned earlier.

During this period, several other records confirm the presence of Cannabaceae in Italy: 1) in Latium, few Cannabaceae were present in Lago di Vico (Magri and Sadori 1999), and one *Cannabis* record was found at Lago di Martignano (Kelly and Huntley 1991); 2) in the central Adriatic the deepest *Cannabis* records in core RF93-30 were of this age (Lowe et al. 1996b); 3) in southern Italy, at Terragne (Taranto-Puglia) a few hop records were present in Mesolithic and Neolithic layers with low woodland cover, dated to around 7000 cal B.P. (Accorsi et al. 1998a); 4) in northern Italy, in Lago di Ledro (Trentino Alto Adige, Fig. 2) the deepest *Cannabis/Humulus* records dated to the same period (but the highest values were reached later at 800-600 B.C.; Beug 1964). In Lago di Annone and Lago di Alserio (Lombardy), while hop started at the beginning of the Holocene, hemp started at about 7000 cal B.P. in both lakes together with the first traces of early Neolithic human activity. The hemp curve was more or less continuous, and never higher than 1%

before the Middle Ages when its cultivation was evident. The continuous low values suggest that hemp was introduced with cereals during the Neolithic period in the area, and survived as a weed before it was cultivated (Wick pers. comm.). Finally, in pollen diagrams from the Po plain and the Emilia Romagna region, hop was quite frequent during the Sub-boreal phase (4700-2700 uncal B.P. according to de Beaulieau et al. 1994) when tree cover had decreased slightly to 54% compared with the Atlantic values of 58%, while only few uncertain records of hemp were recorded so far (Accorsi et al. 1997, 1999).

d) *from ca. 3000-2900 cal B.P. onwards*. In our cores, from ca. 3000-2900 cal B.P. onwards, in PAZIIId, human impact on the landscape is clearly indicated by the abrupt increase in cultivated trees such as *Castanea*, *Juglans* and *Olea*. The Cannabaceae curve reaches its first maximum, substantially due to *Cannabis* at ca. 1900-1760 cal B.P. or A.D. 50-190, which is the "*Cannabis* phase", which occurs immediately after peaks of cereals, weeds and cultivated trees. The latter, *Olea, Castanea* and *Juglans*, have already been recorded since the Late-glacial (PAZII) as elements of the pre-Holocene wild vegetation of Italy which survived the glacial periods in refuges (see also Paganelli and Miola 1991; Accorsi et al. 1999). Then, *Castanea,* more or less accompanied by *Juglans* and *Olea*, increased during the second half of the middle Holocene (see also the central Adriatic sea cores PAL94-8 and PAL94-9; Lowe et al. 1996b). In northern Italy, there was evidence that *Castanea* was spread together with *Juglans* by human activities in pre-Roman times, but the major increase was evident at around 2200 cal B.P. at the beginning of the Roman influence and colonisation in the area (Drescher-Schneider 1994; Speranza et al. 1996). Actually, in our cores, cultivated trees had began to increase about a thousand years before hemp (as mentioned above) and this is confirmed by other records from Latium. For example, the rise in *Castanea* pollen was also observed at Valle di Castiglione and Lago di Vico at around 3000-2600 uncal B.P. (Alessio et al. 1986; Magri and Sadori 1999). These records suggest that a developed agricultural economy was well established in central Italy at that time. So the earliest *Cannabis* peaks immediately following the rise of *Olea, Castanea* and *Juglans* suggest that hemp was part of this agricultural landscape (see below).

In northern Italy, isolated hemp pollen records from archaeological sites, dated from the Bronze Age to the Roman Age, were interpreted as crop markers based on the whole archaeobotanical-archaeological contexts (Fig. 2). In these sites, *Cannabis sativa* pollen was found in the early Bronze Age site of Canàr-Rovigo, Veneto, from 2129 to 1780 B.C. (Accorsi et al. 1998c). Later on, hemp pollen records were also found in some Roman age settlements on the Po plain, at Trino-Vercelli, Piemonte (Caramiello et al. 1996, 1999); near Bologna, Emilia Romagna (Marchesini 1997) and at Cognento-Modena, Emilia Romagna, at which site pollen and fruits were present in the same level archaeologically dated to the 6th-7th centuries A.D. (Accorsi et al. 1997). Also, a considerable quantity of *Cannabis* pollen was found in two middle Bronze Age layers from the Terramara di Santa Rosa-Reggio Emilia, Emilia Romagna (Ravazzi et al. in press, and pers. comm.).

Interestingly, hemp has also been found in archaeological sites in southern Italy, and pollen was recorded at two sites, Pomarico Vecchio, Basilicata and Locri Epizefirii, Calabria (Fig. 2), both dated to the 3rd century B.C. (Caramiello et al. 1992, 1997). In the central Adriatic sea core, PAL94-9, hemp was recorded from 2900 cal B.P. onwards (unpublished data).

Finally, in our cores, later, medieval, *Cannabis* peaks were observed between ca. 1070 and 730 cal B.P. in both lakes (A.D. 880 and 1220, see below). The highest hemp pollen values were recorded from this period in lake cores from northern Italy (Fig. 2), at Lago di Lod, northwestern Alps, after A.D. 1170±120 (Brugiapaglia 1996) and at Lago del Segrino, Insubrian southern Alps, from ca. A.D. 1000 to 1500 (Gobet et al. 2000), as well as at the lakes of Annone and Alserio which have already been mentioned (Wick pers. comm.). The fruit remains from Ferrara, Emilia Romagna, also proved the use of the plant in the 10-12th century A.D. (Mercuri et al. 1999).

The evidence of cultivation of Cannabis *for fibre in Latium.*

At ca. 1900-1760 cal B.P., *Cannabis* pollen reached about 20% in both lake sequences, the value in Nemi rising to 30% if *Cannabis/Humulus* is added to *Cannabis*. This was interpreted as proof that hemp had been cultivated in the surroundings, and possibly processed (retted) in the lakes to obtain the fibre. Several arguments support this hypothesis.

Arguments in favour of cultivation

First, the literature frequently reports hypotheses of cultivation of hemp based on similar or lower values than ours. In Italy, this occurred not only in cases of high values recorded from the medieval period onwards (more than 20% in the Lago di Lod, Valle d'Aosta, and 10-40% in the Lago del Segrino, Lombardy) but also of low values from archaeological sites from the Bronze Age onwards, as already mentioned. In other European countries, late Holocene pollen of *Cannabis/Humulus, Cannabis*-type and Cannabaceae have frequently been interpreted as reflecting hemp cultivation, as for example in Great Britain from the pre-Roman and Roman period (Bartley et al. 1976; Beales 1980), in Sweden from the Iron Age to the medieval period (Wallin 1996; Lagerås 1996), in The Netherlands from the late medieval period (Groenman-van Waateringe 1992). At Thorpe Bulmer, England, Bartley et al. (1976) ascribed the deposition of clay with hemp pollen (19%) in the lake to the ploughing of hemp fields surrounding the lake during the late Iron Age (ca. A.D. 220).

Secondly, our highest hemp values were observed in clear agricultural contexts (PAZIIId in both lakes) shown by cereals, cultivated trees and high weed values, altogether suggesting a well developed and diversified agricultural economy in the area at that time. With regard to weeds, we did not obtain clear evidence of *Cannabis* fields from any specific weeds, as it is not often possible to identify species from pollen. The anthropogenic indicators curve only provides a general indication of human impact. Note that most of these pollen types are already abundant in the Late-glacial deposits, suggesting links between those open dry natural landscapes and weeds growing in Holocene environments affected by human activities.

The third point is that our hemp peaks were probably even higher. In fact in the Nemi diagram, its highest peak coincides with that of *Cannabis/Humulus*, suggesting that the latter actually is also attributable to hemp, due to a possible larger pollen size range in cultivation. A similar large size range was observed in pollen diagrams from the island of Wolin in northwest Poland by Latałowa (1992) and from Llyn mire in central Wales (Great Britain) by French and Moore (1986), and in pollen recorded in recent hemp resins produced by cultivated plants (Gabrielli 1996, and unpublished data).

Arguments in favour of local retting and use for fibre

First, male hemp plants, producing abundant pollen, are used for fibre. Usually the male plants produce the best fibres currently used, although the use of female plants is also known, for example in Italy and Finland (Targioni Tozzetti 1802; Whittington and Edwards 1989). Male plants produce a great amount of pollen, 70,000 grains per anther, or 350,000 per flower (Subba Reddi and Reddi 1986), so cultivation in the past is traceable through pollen analysis. Our data indicated that male plants were abundant in the area and therefore suggest that the hemp was used for its fibre.

Secondly, abundant hemp pollen in fresh water environments suggests the practice of retting in water to extract the fibres. Hemp fibres were separated from the mature plants by the process of retting, in which the crop was submerged in a lake or suitable water body for about six weeks to bring about its degradation to residual fibres (French and Moore 1986; Pate 1994). Considering the high pollen production of hemp, the retting of male plants for fibre can leave a strong pollen record in the water.

Thirdly, authors usually suggest that a large quantity of hemp pollen in mire and lake sites, from 8-10% up to 80%, is the result of water retting, for example, in Scotland ca. 10% (Whittington and Edwards 1989), in England 15-52 % (Bradshaw et al. 1981), in Poland ca. 25% in (Latałowa 1992), and in Lake Praver, France 70-80% (Nakagawa et al. 2000). However, the 10% record of *Cannabis* in Llyn mire, central Wales, dated to more than 200 years ago, was considered by the authors to have been transported via the air from nearby hemp fields, because they considered that the environment was unsuitable for retting at that time (French and Moore 1986). In our case, in presence of a large amount of pollen (percentages of 20-30%, concentration of 20,000-40,000 grains/cm^3 at the time of pollen peaks) and a suitable environment for retting, it appears justified to conclude that hemp was cultivated in the area and that it was retted in both lakes.

Hemp cultivation by Romans in the Alban Hills

The earliest pollen peaks of hemp date to around A.D. 50-190 (the first peak in Nemi, and the second in both lakes). They can reliably be considered as unambiguous pollen evidence of this cultivation and practice by Romans in central Italy. Hemp retting seems to have been strictly local considering that no Cannabaceae peaks were observed in other pollen diagrams from Italian lakes spanning the same time range such as Lago di Martignano (Kelly and Huntley 1991).

Other uses of hemp by Romans

Beside fibre, no other uses for hemp may be inferred from pollen. Nevertheless the fruits were probably collected from female plants for re-sowing or for the other uses reported by classic authors (see above) and Pompeiian records (Borgongino pers. comm.; Pagano 1997).

Hemp cultivation in the Medieval period

The *Cannabis* peaks in our cores can be arranged in four phases: 1) ca. A.D. 50 at Nemi (21%; 31,800 p/cm^3); 2) ca. A.D. 160 at Nemi (5%, 2800 p/cm^3) and ca. A.D. 190 at Albano (20%, 18,400 p/cm^3); 3) ca. A.D. 880 at Albano (18.5%, 10,700 p/cm^3) and ca. A.D. 950 at Nemi (4%, 2900 p/cm^3); 4) ca. A.D. 1220 at Albano (18.5% and 6100 p/cm^3). Chronologically, the two oldest phases date to the Roman period, and the other two to the Medieval period.

After the two oldest peaks, dated to the Imperial period, the second of which was synchronous in both lakes, the cultivation of hemp persisted or was resumed in the early Medieval period, again synchronous in both areas, ending with further evidence, but only in Albano, in the late Medieval period. This indicates the cultivation of hemp during the Medieval period in central as well as northern Italy (see above).

The differences between peaks could be due to a different use of the lakes. Albano seemed to have been used longer as a basin for water retting than Nemi. In the latter lake, after the first episode (first peak), the retting in the lake may have been abandoned though cultivation (two subsequent low peaks) continued in the surrounding areas. Moreover Albano, larger and deeper than Nemi possibly offered more suitable water for retting. In fact, in stagnant water fibres are found to be less clear (Targioni Tozzetti 1802).

Conclusions

In central Italy, both hemp and hop have grown as wild plants since the Late-glacial period, and spread in the mid and late Holocene. Pollen diagrams from two lakes in the Alban Hills showed that hop was more continuous than hemp, but never abundant. Hemp, instead, reached high values, clearly due to human activity. In the area, human impact became more evident at about 3000 cal B.P. when the cultivated trees *Castanea, Juglans* and *Olea* spread simultaneously, suggesting that people who lived there before the Romans had an advanced agricultural economy. The '*Cannabis* phase', the first hemp pollen peak which closely followed the peaks in pollen records of the cultivated trees mentioned above, marked Roman times. *Can-*

nabis was cultivated and processed in the lakes, first in Lago di Nemi (ca. A.D. 50) and then in Lago Albano (ca. A.D. 190) too. Historical sources indicated that the Romans frequented the area at that time, and that they had knowledge of the cultivation of hemp. Our diagrams provide new information proving that during the 1st and 2nd centuries A.D. the Romans cultivated hemp near the lakes and extracted the fibre by retting. Hemp cultivation probably increased when the plant and its use became well known, considering its long lasting previous records. The tradition may have continued, with an evident resumption in the Medieval period, losing importance further on.

On the whole, this study shows that hemp grew wild in central Italy long before humans realised its use. The cultural history of hemp started later, possibly when the cultural tradition of its uses was imported from Asia, where its exploitation has had a long-standing tradition. The records from lakes Albano and Nemi are the first, and so far the most ancient, unambiguous evidence of hemp cultivation in central Italy, but the route followed by this culture, throughout the Near East and also southern Italy, or throughout east and central Europe and northern Italy as the available documents mostly suggest so far, is a still open question.

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