

Palynological data in support of the survival of walnut (*Juglans regia* L.) in the western Mediterranean area during last glacial times

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Abstract. This paper is based upon palynological data from Carihuela Cave (Granada, southeastern Spain), that support the presence of walnut (*Juglans regia* L.) in the western Mediterranean during the early and middle last-glacial stage. Pollen records of *Juglans* L. are closely associated with Mediterranean evergreen assemblages, particularly *Quercus* L., Oleaceae and other thermophilous taxa. Palaeoclimatic reconstruction, supported by sedimentological and palaeontological information, points to a further relationship between *Juglans* appearances and climatic improvements. Growth in refuges close to the site is proposed,

perhaps in intramontane river valleys of the Betic ranges. Finally, the possibility of early diversification in the western Mediterranean is evaluated taking into account both the classical viewpoint about its allegedly first arrival during Roman times, and other palynological data suggesting a native character for walnut within the area. Some problems are discussed concerning the poorly understood relationship between cultivated and wild relatives.

Key words. Spain, Upper Pleistocene, *Juglans*, pollen diagram.

INTRODUCTION

The geological history of the Juglandaceae has always been of particular interest to biogeographers. Certainly, an excellent fossil record is available from the late Cretaceous (Wolfe, 1973; Crepet, 1981; Muller, 1984) and, additionally, noteworthy extinctions and long-range movements have been pointed out (e.g. Nichols, 1973; Stone & Broome, 1975). With regard to the European *Juglans* L., the earliest pollen occurrences date from the Lower Eocene of France (*Multiporopollenites maculosus*: Gruas-Cavagnetto, 1978), becoming more frequent later in the Tertiary, when a widespread distribution of subtropical vegetation has been indicated (Suc, 1980; Bessedik, Guinet & Suc, 1984).

The common or Persian walnut, *Juglans regia* L., belonging to Section *Juglans* Rehder, is the only native species in Europe (Tutin, 1964), growing wild in mesic, mixed or deciduous forests of the Balkans, northern Turkey, the southern Caspian region, the Caucasus, and Central Asia (Zohary & Hopf, 1988). In contrast to North American *J. nigra* L., it rarely comprises closed forests, but enjoys sparse vegetational status, frequently in ravine woods. Important cover is only observed in the Balkans in association with *Platanus orientalis* L., *Corylus colurna* L. and *Castanea sativa* Miller (Huntley & Birks, 1983). Mainly because of its timber and edible nuts, several *J. regia* varieties are cultivated today in temperate areas of Europe, Asia and northern Africa, all of them displaying high edaphic versatility and adaptability to the Mediterranean bioclimate.

In recent decades, controversy has arisen over the origin of the European walnut. When areas where the tree appears as native nowadays are taken into account, authors usually postulate its more or less recent introduction by man from locations in western Asia. Nevertheless, especially for the western Mediterranean, no consensus yet exists about whether walnut disappeared completely during the Pleistocene, or survived the rigours of the cold, dry glacial intervals in limited areas where climatic conditions were milder. In this paper, pollen-stratigraphical data from archaeological deposits of Carihuela Cave lend support to the hypothesis of survival.

PALYNOLOGICAL INVESTIGATION

Detailed results of the palynological analysis carried out on Pleistocene deposits from Carihuela Cave have been reported elsewhere (Carrión, 1992). The site lies at an altitude of c. 1020 m above sea level in a high plateau within the Betic mountains of SE Spain, about 45 km northeast of Granada (Fig. 1). Sampling was undertaken near the centre of the Main Chamber, involving five stratigraphical sections the correlations of which had been previously established (Vega-Toscano *et al.*, 1988). Twelve lithostratigraphical units were defined, no pollen being recovered from either unit XII or the lowermost levels of XI.

Several facts lend support to the chronological attribution of the sequence as last glacial in age. First, there are thermoluminescence determinations from c. 82,500 to 13,400

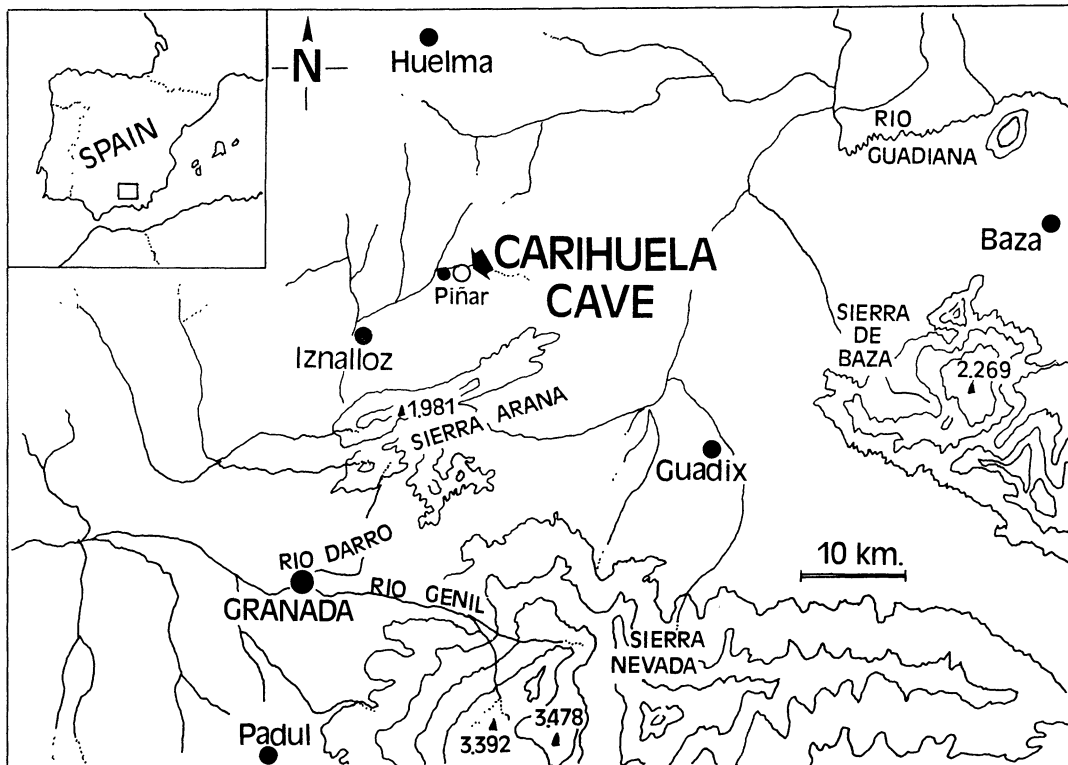


FIG. 1. Location of Carihuela Cave (Granada, Spain).

years BP from materials (mainly burnt flints) from the excavations carried out by a team from Washington State University (Göksu, thesis, unpublished) (Table 1). The exact stratigraphical correspondence of each is difficult to assess from the excavation records, but analysis of the lithic typology correlates the material dated with units XII–IV (Vega-Toscano, 1988). Secondly, the microfauna implies a typically Pleistocene environment, with cryophilous species such as *Allocrietus bursae* Schaub, *Microtus arvalis* Miller, *M. nivalis* Martins, and *Dicrostonyx andaluciensis* Ruiz-Bustos, which had migrated to higher latitudes by the later Upper Pleistocene and early Holocene (Ruiz-Bustos & García-Sánchez, 1977). Thirdly, units XII–V contained some human Neanderthal remains and the lithic material belongs to the typical Mousterian-Charentian forms which developed in southwestern Europe during the early and middle Upper Pleistocene. Fourthly, given the litho- and

biostratigraphical data, the sequence correlates well with widespread European palaeoclimatic findings for the last glacial cycle (Vega-Toscano et al., 1988; Carrión, 1992).

For the purpose of the present discussion, a comprehensive pollen diagram is presented, where distinct stratigraphical sections are separated by breaks in the vertical axis (Fig. 2). The palynological study did not include units I–III because of their interpretative problems as regards both stratigraphy and archaeology (Davidson, 1989; Vega-Toscano, 1990). The diagram was based on a total sum, including all types apart from those of entomogamous Asteraceae, which seem to be over-represented due to selective transport. This sum, always above 200, frequently surpassed 1000 palynomorphs. The sclerophyllous *Quercus*-type includes the evergreen *Q. rotundifolia* Lam. and *Q. coccifera* L. species, as well as the semideciduous *Q. faginea* Lam. species, the former being the predominant group. Oleaceae-type mainly

TABLE 1. Thermoluminescence dating series from Carihuela Mousterian deposits in accordance with H. Göksu (thesis, unpublished). All the dates were determined on burnt flints from the lithostratigraphical units XII to IV.

Sample no.	TL estimated age	Sample no.	TL estimated age
B48	13,400 ± 600	TB-5	33,000 ± 1,200
TB-7	13,600 ± 800	B44	37,350 ± 2,200
B52	19,300 ± 500	TB-1	39,400 ± 2,000
B6	20,200 ± 1,200	B54	42,400 ± 1,500
TB-6	20,200 ± 3,000	B49	49,200 ± 2,500
B47	20,950 ± 1,200	TB-3	57,700 ± 2,500
B43	21,100 ± 1,300	TB-9a	58,800 ± 2,000
TB-8b	27,000 ± 1,000	B53	68,000 ± 1,800
TB-12	27,400 ± 1,000	TB-8a	80,000
TB-2	28,000 ± 1,000	B46	82,500 ± 4,900

CARIHUUELA (S.E. Spain)

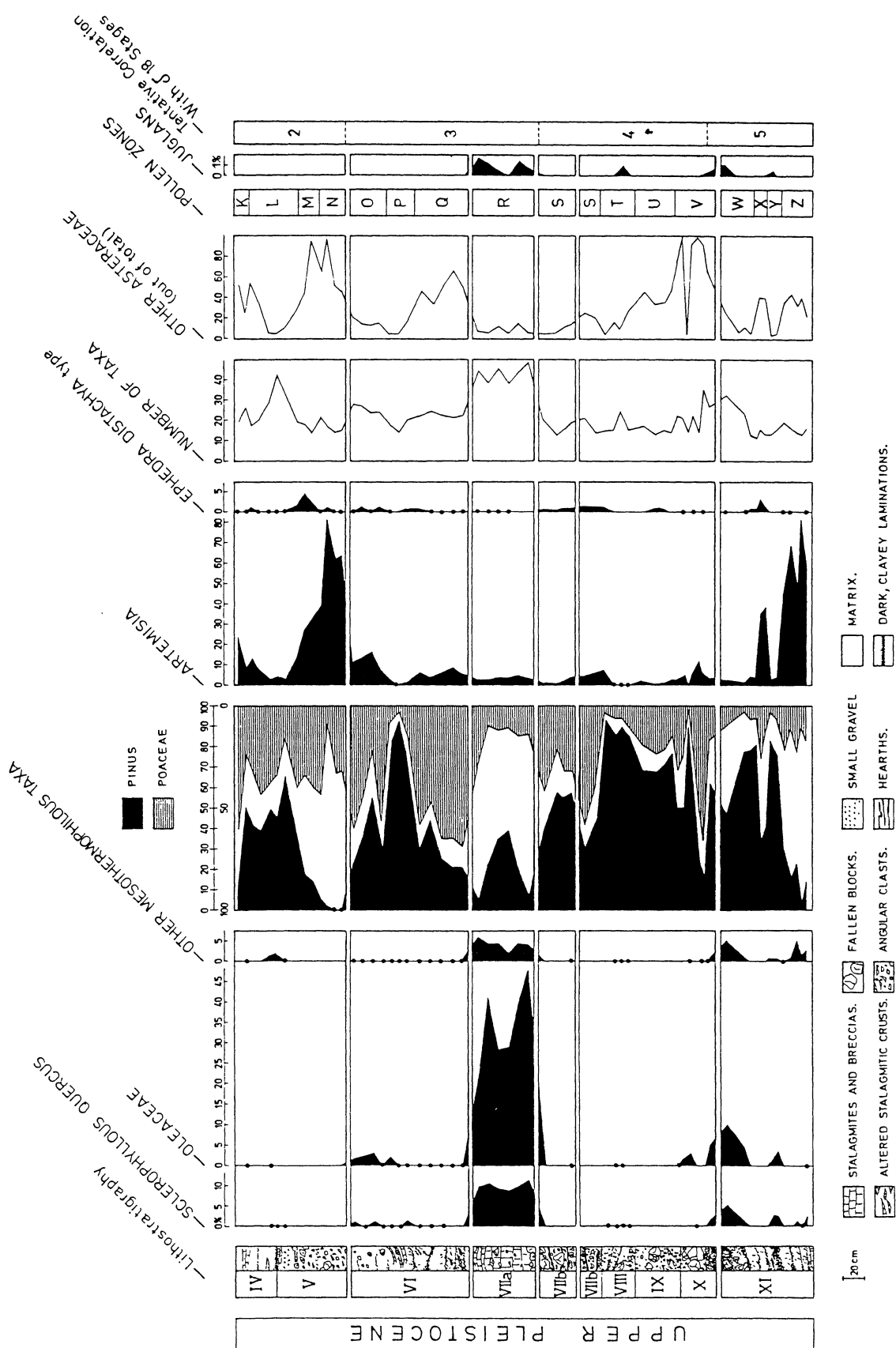


FIG. 2. Comprehensive pollen diagram of the Upper Pleistocene deposits from Carihuue Cave. Black dots indicate percentages below 2%. Distinct stratigraphical sections are separated by breaks in the vertical axis.

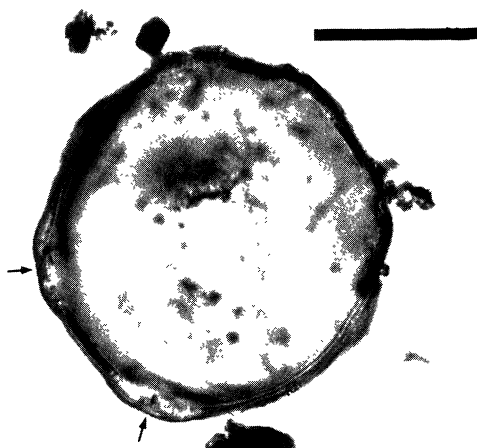


FIG. 3. Pollen grain of *Juglans regia* in optical section. Note dismembered endexine beneath the porii (arrows). Scale 10µm,



FIG. 4. Pollen grain of *Juglans regia* in surface view. Note slight microechinate pattern and typical exinic folds. Scale 10 µm.

refers to *Olea* L. pollen, although presence of *Phillyrea* L. and occasional appearance of *Fraxinus* L. were also noted. The pollen subsumed under 'Other mesothermophilous taxa' are of both trees (*Alnus* Miller, *Corylus* L., *Castanea* Miller, *Ulmus* L.) and shrub types (*Rhamnus* L., *Myrtus* L., *Lonicera* L., *Buxus* L., *Cistus* L.). Most *Pinus* L. pollen is believed to originate from *P. sylvestris* L. and/or *P. nigra* Arnold; however, rare identifications at zone R would permit *P. halepensis* Miller. Pollen findings for *Juglans* (Figs 3 and 4) comprised amounts below 2%. However, such percentages might indicate a local presence, because this pollen seems to be poorly dispersed despite its recognizable anemophily (Huntley & Birks, 1983). It is to be remarked on that the appearance of *Juglans* is always in relation to increases in Mediterranean types, especially for zones Y, W and R, in which peaks of *Quercus* L., Oleaceae, and other mesothermophilous taxa are well-defined. As a matter of fact, this represents the first occurrence for *Juglans* in southern Spain during the Upper Pleistocene. For the northern Iberian Peninsula it has been found by Sánchez-Goñi (1988), also in association with Mousterian industries.

DISCUSSION

As regards other archaeopalynological traces, taphonomic processes for the pollen assemblages in Carihuela Cave are poorly understood, although both predominance of anemophilous types and sedimentological features generally suggest mixed aeolian-fluvial transport. Bones, charcoal, and lithic material indicate human disturbance, perhaps critical, in such units as VI or VIIb, whereas selective transport by bats or rodents could be related to the abundance of Asteraceae pollen in zones V, Q, N, and M. Maxima of *Pinus* and herbs are open to different interpretations because many factors may intervene to characterize pollen assemblages where pine or grass are abundant.

With respect to *Juglans* pollen, they may have reached the beds that contain them by aeolian or water transport from the original entrance in zones Y, W, and T. The sedimentary context also suggests introduction by percolating water from cracks in the roof during deposition of subunit VIIa (zone R). In any case, no evidence has been found of recent influence or of palynomorph reworking. Contamination during sampling, or laboratory treatment, is unlikely because: (1) walnut is absent nowadays from the cave surroundings; (2) its cultivation begins only about 50–60 km away from the Murcia laboratory; (3) acetolysis was not included in the treatment; (4) neither differential susceptibility to stain, nor particular preservation, were noticed in the *Juglans* pollen with respect to the associated palynomorphs.

During early Holocene times the matter is more complicated because very little is known about the behaviour of pollen transporting into archaeological profiles. There are no grounds, in our opinion, for suspecting that *Juglans* pollen was introduced into Carihuela Cave much later than the time of deposition of the sediments in question. Dimbleby (1985) reported several studies where contamination seems clear. Considerable lateral variation of pollen types can be a good indicator of localized percolation. At Carihuela, several strata were analysed for pollen in different cuttings, showing a good correlation (Carrión, 1992). In fact, pollen of *Juglans* was recorded in zone W2 from two profiles 5 m apart. In breccias where pollen is partially intrusive, a distinction is often possible between well- and badly-preserved pollen, something that was not noted from the calcium-carbonate impregnated levels of unit VIIa. At several British palaeolithic sites, Turner (1985) was able to reject previous palynological interpretations based on spectra partially or wholly asynchronous with the containing beds. Some circumstances were repeatedly noticed at these unsuitable sites: namely, sharp contrasts in the palaeoclimatic implications of geological and palynological evidence, unreality of the ecological associations proposed, surprising uniformity of the assemblages over the profile, and absence of additional biostratigraphical evidence. Moreover, deposits involved were mostly coarse-grained, and riverine transport could be sometimes demonstrated to have occurred after deposition of palaeolithic beds.

Occurrence of *Juglans* pollen at Carihuela cannot be associated with any particular sediment type nor explained by displacement through coarser sediments with subsequent

stabilization in more favourable strata. Unit VIIa (zone R) comprises several breccia levels with an uppermost stalagmitic layer. The overlying stratum shows small clasts in an abundant clayey matrix. No remarkable calcareous concretion is present here such as might testify to infiltration of karstic water after calcification of unit VIIa. As regards unit VIII (zone T), it comprises a more sandy matrix, but supports more than 4 m of sediment, of which the uppermost 2 m are calcified. Unit XI (zones W, Y) is mainly peaty clay, containing abundant small calcium-carbonate nodules. Furthermore, it lies beneath a number of thick strata. Unit X appears a more suitable candidate for vertical downwash of pollen from the uppermost bed. In fact, an anomalous spectrum was stated (Carrión, 1992).

It is noticeable that Holocene sediments nowhere overlie the profiles under consideration. During the final Pleistocene, catastrophic recession of the overhang of the cave mouth sealed the palaeolithic beds, a phenomenon absent from those published sites where introduction of contaminant pollen has been established. Miller & Dort (1978) showed the importance of these such processes, which protect lower layers against weathering and bioturbation. In fact, the cave was first entered, not through its original entrance, but through adjacent openings (Spahni, 1955). When the Main Chamber was opened, the Mousterian deposits were extensively concealed by large fallen blocks and abundant cobbles.

From a sedimentological perspective, it must be borne in mind that some processes may go undetected, i.e. old bioturbation, insubstantial erosional surfaces, etc. It is impossible to rule out all chance of localized contamination because we can never know for certain all the precise contributions of the several processes involved in the evolution of a prehistoric site. All commentators on the misapplication of palynology to cave deposits (Bottema, 1975; Bryant & Holloway, 1983; Dimpleby, 1985; Turner, 1985; Davis, 1990) consider that, once careful, collaborative field work has been performed, with rejection of strata potentially contaminated, all that can be done to test the validity of the pollen findings is to evaluate those data within the total framework of supporting lines of evidence. In this respect, we think that there are circumstances of palaeoecological coherence which allow the consideration of *Juglans* pollen records in Carihuela as documenting walnut occurrence during at least those periods represented by zones Z, W, T, and R (Fig. 2).

Most of the pollen assemblages can be broadly compared with well established, present-day vegetational types, especially those of zone R, where elements typical of Andalusian sclerophyllous ecosystems are seen. Data were used, furthermore, to establish a scenario for vegetational and climatic evolution in the area. In the absence of pollen concentration measurements that might hint at statistical artefacts, we preferred to pay attention to the behaviour over the diagram of thermophilous taxa, in order to reconstruct the main climatic trends, backed up by sedimentological and palaeontological findings. Thus, disappearance of mesothermophilous elements in zones S and N–M is consistent with arid, cold conditions, also suggested by *Artemisia* L., *Ephedra distachya* L., thermoclastic scree, and a cryophyl-

lous microfauna. Correlation of these two critical episodes with stages 4 and 2 of the deep-sea isotope record was proposed elsewhere (Carrión, 1992), although it has not yet been possible to obtain secure limits for this comparison. On the other hand, the peaks in Mediterranean evergreen elements of zones Y, W, and R, proclaim vegetational changes in response, presumably, to warmer climate. Perhaps the phase covered by zones R–O represents isotopic stage 3, whereas zone Z might document, for our area, rupture of biostatic manifestations of the last interglacial (unit XII). The interpleniglacial peaks in Mediterranean elements have been discussed in another paper (Carrión, 1991).

Such a chronostratigraphical scheme links the appearance of *Juglans* to climatic improvements, regardless of the magnitude of the temperature increases involved. Such a relationship accords both with the known bioclimatic requirements for walnut and palynological information relating *Juglans* to deciduous forests and Mediterranean biotopes (Elhai, 1966; Lona & Bertoldi, 1973; Bertoldi, Rico & Thunell, 1989; García-Antón & Sainz-Ollero, 1991). In any case, the most plausible explanation for the changes of *Juglans* in the Carihuela sequence is that scattered populations may have survived in refuges that could have facilitated occasional development as environmental factors weakened. The site is in an area intermediate between several mountain ranges, which, indeed, may have protected appropriate refuges. Perhaps the available biotopes for walnut depended on availability of water. According to Suc (1981), a causative factor of the disappearance of subtropical species in the Mediterranean region during the Pleistocene was marked lowering of summer precipitation, rather than low temperature *per se*. Even today, in southern Spain and North Africa, those walnuts displaying greatest vitality are found in river valleys, gullies or watercourses. In the Betic Sierra Nevada, and Mágina, Cazorla and Segura mountains, there are also other trees, such as *Corylus avellana* L., *Betula celtiberica* Rothm. & Vasc., or *Ulmus glabra* Hudson, under particular mesoclimatic regimes involving subhumid or humid precipitation within a more xeric, regional environment. For walnut, climatic data must be considered critically, and in the context of parasites, in considering suitability or otherwise of areas for growing walnut. For instance, the nut diseases caused by *Cydia pomonella* L. and *Xanthomonas juglandis* (Pierce) Dowson show higher incidence in warm climates (Frutos, Verdud & Ruiz, 1983), consequently, the tree is more successfully cultivated above 700–1000 m, occurrence of late frosts notwithstanding: an extreme situation is that in Sierra Nevada, where walnut is found up to 1600 m.

Obviously, a major problem to be overcome here is to reconcile our proposal for an Upper Pleistocene presence of walnut in southeastern Spain with the argument of a Late Holocene spread from western Asia following commencement there of cultivation. The two need not be mutually exclusive, if occurrence was to have been present up to interpleniglacial times followed by local disappearance. Given its poorly-dispersed pollen (Huntley & Birks, 1983), *Juglans* could even have been a palynologically silent taxon during the Upper Pleniglacial at Carihuela. Such a defence of pollen findings in support of concomitant pres-

ence of walnut could also be used by other researchers in order to justify similarly very late occurrences. Indeed, Renault-Miskovsky, Bui-Thi-Mai & Girard (1984), after reviewing a large number of papers concerning chiefly pollen-analytical data, concluded that there was uninterrupted persistence of walnut in western Europe from the Plio-Pleistocene to Holocene, a noteworthy rarefaction being discernible during the conventional Würm III stage.

From our standpoint, this view is seductive, notwithstanding problems of biogeography of walnut presented by assuming its presence prior to the onset of agricultural activities in the western Mediterranean. Lower and Middle Pleistocene presences are perhaps the least questioned, several non-archaeologically associated *Juglans* findings being noticeable, even in Spain (Elhai, 1966; Florschütz, Menéndez-Amor & Wijmstra, 1971; Deckker, Geurts & Julia, 1979; Suc, 1980; Pérez-Obiol, 1987; Leroy, 1988). During the last interglacial, findings have been reported from southern Germany (Frenzel, 1976), the Balkans (Sercelj, 1966), and the northern Black Sea region (Bozilova & Djankova, 1976). However, apart from some chronologically dubious records (Beaulieu, 1974; Bertoldi, 1980), it is very rarely found in the European post-Eemian sequences from lakes or peat bogs, which seems to imply that the appearance of walnut followed planting in historical times, leading many authors to consider this tree as an anthropogenic indicator (Zoller, 1960; Beug, 1967, 1975; Brande, 1973; Schneider, 1978, 1985; Schneider & Tobolski, 1985).

Palynological data from the eastern Mediterranean suggest western Asian domestication and subsequent westward spread throughout Europe. During the last glacial, *Juglans* survived in the Black Sea and southern Caspian areas (Niklewski & Van Zeist, 1970; Van Zeist, Woldring & Stapert, 1975). It is reported from 6000 to 5000 BP in northern Turkey (Beug, 1962), although high amounts are not seen in pollen diagrams until about 3500 BP in Iran (Beug, 1962), Turkey (Van Zeist *et al.*, 1975; Bottema & Woldring, 1984), and around 3100–3300 BP in Greece (Bottema, 1974, 1980, 1982). Furthermore, for western and central Europe, the first consistent archaeobotanical records come from Roman sites (Van Zeist, 1991).

Most authors agree that humans played a determining role in the recent history and present range of the European walnut. Nevertheless, the hypothesis of western Asia as sole centre of distribution is not without its problems. For Huntley & Birks (1983), pollen data from Italy, the southern Alps, and the Balkans, dating from 5000 BP, suggest a native character of the species for these areas, on the grounds that it seems unlikely that Neolithic people had obtained it from the Near East by that time. Recent results from Lago di Martignano, in the Italian region of Latium (Kelly & Huntley, 1991), support this hypothesis as the first *Juglans* pollen here are from *c.* 11,640, becoming consistent at around 7000 BP. A similar argument could apply to Neolithic walnut shells found at central European lakeshores (Emberger, 1960), although modern contamination cannot be ruled out (Baas, 1974; Van Zeist, 1991). Van den Brink & Janssen (1985), discussing the pollen analysis from a pond in the Serra da Estrela (Portugal), noticed the occurrence of *Juglans* before about 4340 BP—before its

pollen became common in southern Turkish or Greek records (Bottema, 1980). Other thought-provoking findings come from the Atlantic period at La Moura peat-bog (Oldfield & Huckerby, 1979), and from the Lower and Middle Holocene in North Africa (Pons & Quézel, 1958; Balouche, 1986). A hypothesis can be entertained of another focus of walnut distribution, located somewhere in the western Mediterranean.

In the Iberian Peninsula, some facts suggest an early diversification. Frutos (1988) has differentiated four Spanish subspecies of walnut according to bark type and shape of the trees. Curiously, some geographical coincidence seems to exist between the range of these hypothetical subspecies and the territory of some pre-Roman human societies (i.e. Galai-cos, Vetones, Celtiberos, Iberos). Ancient geographical isolation of walnut subpopulations, each subject to separate cultural and environmental selective pressures, could have been responsible for much of this intra-specific variation. Indeed, the morphological characteristics inherent in each subpopulation maintain themselves when cultivation is effected outside its range; therefore it seems that responses are genetically established. Notwithstanding the attraction of this idea, it must be treated cautiously. Certainly, in order for differentiation to take place, populations must be isolated in some fashion, but this need not imply existence in the area of centres of origin or initial domestication. Walnut might also have developed secondary centres of variability, after spreading from the original place where cultivation began.

In either case, if early western cultivation be presumed, it is still necessary to put forward a hypothesis about the ancestral stock from which the cultivates were derived. Paradoxically, there are no contemporary wild populations growing extensively within the area. Because long-time cultivation usually leads to natural plants being improved, by freeing them from much competitive, defensive and opportunistic effort, many crop species are unable to survive extensively under natural conditions, making it difficult at present to throw light upon their botanical evolution from primordial morphotypes. For example, the progenitor and place of origin remain controversial for some cultivated Rosaceae such as *Prunus avium* L., *P. domestica* L., *P. domestica* subsp. *insititia* (L.) Schneider, *Sorbus domestica* L., *Malus sylvestris* Miller, etc (Hedrick, 1972). However, this seems not to be exactly the case for *Juglans regia*, because cultivated stands do not differ greatly from the subspontaneous or wild relatives. While it might be plausible to propose cultivation or gathering for *Pinus pinea* L., and domestication for many cereals, walnut should be considered at best as only partially domesticated, because there are no selected genotypes offering a whole range of characteristics desirable to man. Furthermore, the cultivated plant has lost neither its reproductive mechanisms and phenotypic plasticity nor its ability to regenerate subspontaneously. It is noteworthy that, whatever the genealogical processes responsible for its present status, early gathering or cultivation of walnut in the western Mediterranean need not be incompatible with additional, extensive planting during Roman and post-Roman times. As a matter of fact, noticeable increases in European pollen records are found from

2000 years BP, hinting at either increased cultivation or natural dispersal following the Subatlantic climatic change (Huntley & Birks, 1983).

In conclusion, the Carihuela pollen findings suggest some survival of walnut during the last glacial stage in southeastern Spain. On a more speculative level, it is suggested that there might have been some native species within the western Mediterranean area. Although evidence of introduction throughout Europe from western Asia is better documented, it is at best partial. There are insufficient supporting macrofossils, and even palynological information is scarce. The difficulty is to establish the state of domestication of walnut, a complex topic for which much more investigation is needed in order to understand the forces involved in its acculturation. Its important ethnobotanical heritage has to be taken into account when considering both its botanical history and behaviour within present-day ecosystems.

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