Veget Hist Archaeobot (2005) 14:303–312
DOI 10.1007/s00334-005-0088-5

ORIGINAL ARTICLE

Alexandra Schmidl · Klaus Oeggl

Subsistence strategies of two Bronze Age hill-top settlements in the eastern Alps—Friaga/Bartholomäberg (Vorarlberg, Austria) and Ganglegg/Schluderns (South Tyrol, Italy)

Received: 21 October 2004 / Accepted: 25 April 2005 / Published online: 3 June 2005

Abstract Up to now, archaeobotanical investigations of prehistoric sites in the eastern Alpine region have been rare. Recent palaeoethnobotanical investigations of carbonised plant remains from two Bronze Age hill-top settlements, one located north and the other south of the main Alpine range, contribute essentially to the knowledge of subsistence strategies and husbandry regimes in the Alps in prehistoric periods. The principal cereals were *Hordeum vulgare* (hulled barley), *Triticum dicoccon* (emmer) and *Panicum miliaceum* (broomcorn millet). In general, hulled barley was the most important cereal crop in the eastern Alps. Legumes such as *Vicia faba* (horse bean) and *Pisum sativum* (pea) also occurred regularly in both hill-top settlements. In addition to these field crops, a large variety of wild plants was still gathered and contributed considerably to the daily diet. The arable weed flora suggests that crops were sown in spring and autumn and it indicates crop rotation in this period. The results of the plant macrofossils imply a complex pattern of plant resource utilisation in the Alpine area during the Bronze Age.

Keywords Palaeoethnobotany · Bronze age · Eastern alps · Subsistence strategy

Introduction

The aim of this study was to analyse and interpret recently collected archaeobotanical data from the two hill-top settlements of Friaga/Bartholomäberg (Vorarlberg, Austria) and Ganglegg/Schluderns (South Tyrol, Alto Adige, Italy) in order to improve our understanding of the role of arable farming in the eastern Alps during the Bronze Age (2200–800 B.C.). The archaeobotanical data base of the eastern Alps is still fragmentary. The archaeobotanical studies of four excavation sites (Crestaulta/Lumbrein-Surin, Karlihof/Chur, Tummihügel/Maladers and Padnal/Savognin in the eastern Swiss Alps are summarised in the recent publication of Jacomet et al. (1999). There, the most important excavation site, with a long stratigraphical sequence from the early to late Bronze Age, is the hill-top settlement of Padnal/Savognin at an altitude of 1210 m (Rageth 1986). The stored crops consisted principally of *Hordeum vulgare* (hulled barley) and *Pisum sativum* (pea). After some older work done by Werneck (1949, 1961), more recent palaeoethnobotanical investigations have been undertaken in western Austria and South Tyrol (Heiss 2001; Oeggl 1992; Stika 2000; Swidrak and Oeggl 1998). They provide new and basic data about agrarian history during the Bronze Age.

Hill-top sites dating to the Bronze Age are situated on the one hand at crossroads and river crossings, and on the other hand there are fortifications on hill-tops. The coexistence of both such settlement types proved to be a permanent feature in central Europe. However, hill-top settlements in the Alps are normally not situated on the highest peaks, but rather in a commanding position with regard to the valley floor. Also, most of the hill-top sites were occupied repeatedly in different periods, although not continuously (Primas 2002). The late Bronze Age hill-forts were connected with a system of land division and territorial control that could be maintained for several centuries. Hill-top sites were characterized as the places where metalworking and trade were organised. In the majority of excavation sites, open areas and terraces are located in the immediate vicinity of hill-top settlements. So, in the surrounding area there could be rural settlements where crop husbandry and livestock farming were practised (Krause et al. 2004). Therefore, woodland was diminished, and former areas of wilderness were incorporated into the cultural landscape. In the late Bronze Age a rise in the number of hill-forts coincided with an increase in the secondary and tertiary sectors of production. In new palaeoethnobotanical investigations the discussion of the role of hill-top settlements as either producer or consumer sites in prehistoric times should also be in-

A. Schmidl (✉) · K. Oeggl
Institute of Botany,
University of Innsbruck,
Sternwartestraße 15, A-6020 Innsbruck, Austria
e-mail: Alexandra.Schmidl@uibk.ac.at

Fig. 1 Location of the two excavation sites Friaga/Bartholomäberg and Ganglegg/Schluderns

cluded. In order to understand the function of the hill-top site in the local settlement network, the palaeoethnobotanical data from the two new excavation sites makes an important contribution in the eastern Alps.

The Bronze Age hill-top settlements

Friaga/Bartholomäberg

The prehistoric hill-top settlement of Friaga (Fig. 1) is situated on the south-facing slope of the village of Bartholomäberg in the Montafon valley, at an altitude of 940 m. This intermediate Alpine valley is characterised by an intermediate subcontinental to suboceanic climate with occasionally heavy rainfall. Annual precipitation measured at an altitude of 689 m in Schruns, below the study site, is about 1243 mm per year. Mean annual temperature is around 7.4°C (Walter and Lieth 1967). However, the climate of the northern intermediate Alps favours the growth of *Picea abies* (spruce) and here it thrives on acid bedrocks. So, coniferous woodland (Piceo-Abietetum) is widely distributed in the montane zones up to 1400 m (Ellenberg 1986). Above, there is a forest with *Larix decidua* (larch) and *Pinus cembra* (stone pine), and the tree line is at 1900–2000 m (Mayer 1974).

Ganglegg/Schluderns

The Bronze Age settlement of Ganglegg is located at Schluderns at an altitude of 1142 m (Fig. 1). The Vinschgau valley is surrounded by high mountain chains on the north, west, and east and is effectively shielded from the predominant moisture sources from the northwest and south. As a consequence, the Vinschgau is characterized by low precipitation (400 mm per year) and a long insolation period. The average number of hours of sunshine per year is 2400 and so this area is one of the sunniest of the Alps (excluding the French west Alps), with a mean annual temperature of 9–10°C (Walter and Lieth 1967). Therefore it belongs, together with the Valais in Switzerland and some valleys in the southwestern Alps such as the region of Briançon, to the group of so called “inner Alpine dry valleys” (Braun-Blanquet 1961). The potential natural vegetation is characterised by xerothermic or thermophilous mixed *Quercus pubescens* (oak) woods at lower altitudes and inner Alpine *Picea abies* forest up to 1400 m. *Pinus cembra* with *Larix decidua* form the sub-Alpine forest up to the tree line that lies between 2100 and 2300 m in the Vinschgau (Peer 1995). On the montane southern slopes of the Vinschgau valley are distributed typical semi-arid grasslands caused by low precipitation. The valley bottom (ca. 900 m) is used as agricultural crop land and meadows (Peer 1995).

Material and methods

Friaga/Bartholomäberg

The archaeological site recovered the foundations of six to eight houses which were built alongside the fortification wall. In all, 40 samples derive from different contexts within the settlement area. The occupation layer of the middle Bronze Age is dated from 1600 to 1500 B.C. (Krause et al. 2004). 21 samples were collected within two different houses. Six samples were taken in the vicinity of the hearths. In the same trench of the excavation site, 13 samples were taken from cultural layers outside the houses. The sparseness of carbonised botanical remains demanded a large sample volume (10 l per sample). As a macroremain recovery technique water screening was used (Pearsall 2000). The sandy soil sample was poured on the first sieve with a 2.0 mm mesh and washed with a water jet through following sieves with mesh sizes of 1.0, 0.5 and 0.25 mm at the excavation site. Following screening, the samples were dried in the open air and stored in plastic bags until sorting for charred botanical remains. The seeds and other plant fragments were picked out of the flots and were identified under the microscope by comparing the charred specimens with modern seed reference material at the Botanical Institute of Innsbruck University.

Ganglegg/Schluderns

Charred botanical remains in high densities (stores) were recovered from a late Bronze Age house excavated at the hill-top settlement Ganglegg/Schluderns (South Tyrol). The samples were taken from the Bronze Age storehouse that contained a unique structure: blocks

Table 1 The results of detrended correspondence analysis (DCA) including macrofossil concentration data of Ganglegg (SD = standard deviation units)

	Axis 1	Axis 2
Eigenvalues	0.878	0.636
Lengths of gradient	3.711	3.337
Cumulative percentage of variance of species data	19.7	34.0

of stone were set up along the house wall at an interval of 40 cm, supporting a wooden structure for storing cereals and pulses. A fire destroyed this building and the charred material spread all over the floor in the house (Gamper and Steiner 2000). Two different activity phases were recognized: 49 samples were taken from the two cultural layers which dated from 1400 to 1200 B.C. and additionally four samples derived from two occupation layers dated 1200 to 1000 B.C. A systematic sampling strategy was applied to check for any trace of the original spatial distribution of the crops within the storage building. So, if there was enough material available, a standard soil volume of 1 l material was used for water flotation technique in the laboratory (Pearsall 2000). The 53 samples were washed through three sieves with mesh sizes of 2.0, 0.5 and 0.25 mm. An efficient way was needed for analysing grain-rich samples of different layers and deposit types. Therefore, after stirring, the dried flotation samples were divided with the help of spoon sampling (van der Veen and Fieller 1982). The subsamples were weighed and the count for all taxa was then multiplied up to the total volume of each of the fractions. For comparison of the results, all counts were standardised to a sample size of one litre. So, in total a volume of 50.3 l of soil samples was investigated and identified as above.

Numerical analysis

The statistical analyses and the graphical plot were implemented by the computer program CANOCO 4.15 (ter Braak and Smilauer 2002). Detrended correspondence analysis (DCA) with downweighting of rare taxa was used to measure the length of the gradient in standard deviations (SD) units (Table 1). The species scores are themselves the eigenvectors of the ordination axes, and the dispersion of these scores is the eigenvalue (relative variance or scale) of each axis. The solution maximizes the eigenvalue on each subsequent axis, so that the first axis represents the longest dimension of the data, the second the next longest dimension, and so on (Legendre and Legendre 1998). This resulted in a gradient length of 3.711 standard deviations (SD) justifying the use of detrended correspondence analysis (DCA) as a unimodal response model (ter Braak and Prentice 1988). Untransformed plant macrofossil concentration values (macrofossil l^{-1}), detrending by segments and downweighting of rare taxa were used for the DCA ordination. Sample scores are weighted averages of the species scores, and so sample scores that lie close to the position of a species score are very likely to contain a high abundance of that particular species.

Results

Plant remains from Friaga/Bartholomäberg

The density of plant remains in the samples was in general low. Only 10 samples contained more than 50 items of grain, chaff or weeds. All the assemblages were dominated by cereals, chaff and fruits/nuts. A total of six cereal crops, *Hordeum vulgare* (hulled barley), *Triticum aestivum* (naked wheat), *T. dicoccon* (emmer), *T. monococcum* (einkorn), *T. spelta* (spelt) and *Panicum miliaceum* (broomcorn millet) were represented by grain and chaff at the hill-top settlement (Table 2). Among the cultivated plants, hulled barley occurred with a high frequency of 67.5% and represented the main crop in this period. In addition the glume wheats *T. dicoccon* and *T. spelta* were used for making bread in the settlement. Glumes and spikelet forks of *T. dicoccon* occurred in large amounts in a sample derived from a hearth feature in the settlement area. Grains and rachis internodes of *T. aestivum* were occasionally found in samples from Friaga.

Pulses such as *Vicia faba* (horse-bean) and *Pisum sativum* (pea) were poorly represented (frequency of about 15%; Table 2), but were an important source of protein during prehistoric times. The single find of *Lens culinaris* (lentil) makes its local cultivation questionable, and further investigations are needed to prove its cultivation in the Bronze Age in the Alpine area.

Beside crops, the samples from Friaga also contained a range of gathered plants. The charred remains of fruits and nuts were ubiquitous throughout the middle Bronze Age layer (Table 2). In more than 50% of the samples *Corylus avellana* (hazelnut), *Rubus idaeus* (raspberry) and *Sambucus racemosa* (red-berried elder) occurred. Additionally, *Rubus fruticosus* (blackberry), *Rosa* sp. (rose) and *Prunus spinosa* (sloe) were represented, although more scarcely (frequencies of 10–20%). These gathered plants are associated with forests, woodland edges and hedgerows, most probably in the near vicinity of the settlement.

Three groups of weeds are represented: Secalietea (winter annuals), as well as Chenopodietea (summer annuals) and ruderal plants growing on acid soil enriched in nitrogen by human activities and the proximity of settlements. Both winter and summer annuals were present among hulled wheat and barley. Therefore it is not possible to deduce the sowing seasons of the crops.

Plant remains from Ganglegg/Schluderns

The samples from the late Bronze Age store house contained grains of *Hordeum vulgare* (hulled barley), *H. vulgare* var. *nudum* (naked barley), *Triticum dicoccon*, *T. monococcum*, *T. spelta* and *Panicum miliaceum*. Here, *H. vulgare* (hulled barley) was the most abundant cultivated species (frequency of 86.8%). *P. miliaceum* is also represented in large quantities and occurs frequently in the stored grain (86.8% of all samples). Stored *H. vulgare* var. *nudum* (naked barley) was commonly mixed with *P. miliaceum*. Free-threshing wheat species were absent from the stored grain finds.

Beside cereals, there was also a large number of pulses such as *Vicia faba* and *Pisum sativum* in the stored material at Ganglegg. The abundance of grains and chaff was constantly low. Therefore, this kind of mixed charred assemblage suggests that the crop stores in the prehistoric

Table 2 Carbonised remains from Friaga/Bartholomäberg (middle Bronze Age) and Ganglegg/Schluderns (late Bronze Age). All plant names follow the nomenclature of Flora Europaea (Tutin et al. 1988–1990) and wild plants were coded according to the general habitat categories (based on groupings of phytosociological classes) presented by Ellenberg et al. (1992) *n* = number of charred remains, freq (%) = frequency of total samples in which a taxon is present, cf. = 'compares with' and denotes that a specimen most closely resembles those particular taxa more than any other

	Friaga		Ganglegg		
Number of samples	40		53		
Volume of samples (in 1)	400		50.3		
Taxon	*n*	freq (%)	*n*	freq (%)	sum
Cereal grains					
Hordeum vulgare	123	67.5	3837	86.8	3960
Hordeum vulgare var. *nudum*	0	0.0	26302	45.3	26302
Triticum aestivum	9	12.5	0	0.0	9
Triticum dicoccon	23	25.0	3820	41.5	3843
Triticum cf. *dicoccon*	3	7.5	0	0.0	3
Triticum monococcum	1	2.5	17	7.5	18
Triticum spelta	14	20.0	178	17.0	192
Triticum dicoccon/T. spelta	11	12.5	0	0.0	11
Hordeum vulgare var. *nudum/T. dicoccon*	0	0.0	6282	22.6	6282
Triticum sp	21	27.5	0	0.0	21
Panicum miliaceum	3	5.0	166277	86.8	166280
Cerealia indet	83	62.5	1560	39.6	1643
Cereal chaff					
Hordeum vulgare, rachis internodes	97	30.0	17	9.4	114
Hordeum vulgare, glumes	1	2.5	52	13.2	53
Triticum aestivum, rachis internodes	1	2.5	0	0.0	1
Triticum dicoccon, spikelet forks	508	67.5	515	20.8	1023
Triticum cf. *dicoccon* spikelet forks	7	7.5	0	0.0	7
Triticum dicoccon, glumes	805	65.0	1092	30.2	1897
Triticum dicoccon, rachis internodes	0	0.0	27	7.5	27
Triticum monococcum, spikelet forks	21	2.5	0	0.0	21
Triticum monococcum, glumes	2	5.0	0	0.0	2
Triticum monococcum., rachis internodes	1	2.5	0	0.0	1
Triticum spelta, glumes	30	25.0	402	13.2	432
Triticum spelta, spikelet forks	12	20.0	434	9.4	446
Triticum dicoccon/T. spelta, spikelet forks	3	7.5	0	0.0	3
Triticum dicoccon/T. spelta, glumes	8	15.0	0	0.0	8
Triticum monococcum/T. dicoccon, spikelet forks	24	5.0	0	0.0	24
Triticum monococcum/T. dicoccon, glumes	18	5.0	0	0.0	18
Triticum sp., spikelet forks	12	10.0	166	9.4	178
Triticum sp., glumes	273	25.0	312	28.3	585
Triticum sp., rachis internodes	5	5.0	5	3.8	10
Pulses					
Lens culinaris	1	2.5	1	1.9	2
Pisum sativum	12	15.0	11584	50.9	11594
Vicia faba	11	17.5	8762	62.3	8773
Fruits/nuts					
Corylus avellana	134	52.5	2	3.8	136
Malus sp/*Pyrus* sp	0	0.0	1	1.9	1
Prunus spinosa	33	15.0	1	1.9	34
Rosa sp	9	20.0	14	11.3	23
Rubus fruticosus	5	10.0	0	0.0	5
Rubus fruticosus/R. idaeus	1	2.5	0	0.0	1
Rubus idaeus	60	60.0	0	0.0	60
Rubus cf. *idaeus*	1	2.5	0	0.0	1
Rubus sp	33	52.5	0	0.0	33
Sambucus nigra	4	7.5	1	1.9	5
Sambucus racemosa	74	70.0	1	1.9	75
Sambucus nigra/S. racemosa	1	2.5	1	1.9	2
Sambucus cf. *racemosa*	2	5.0	0	0.0	2
Sambucus sp	73	85.0	0	0.0	73
Crop weeds—winter annuals					
Avena fatua, floret	4	7.5	0	0.0	4
Avena sp, grains	9	20.0	7	3.8	16
Avena sp., awn fragments	204	47.5	5	5.7	209
Bromus secalinus	1	2.5	0	0.0	1
Bromus cf. *secalinus*	1	2.5	0	0.0	1
Bromus sp	4	10.0	115	26.4	119
Fallopia convolvulus	22	30.0	31	17.0	53

Table 2 (continued)

	Friaga		Ganglegg		
Number of samples	40		53		
Volume of samples (in 1)	400		50.3		
Taxon	*n*	freq (%)	*n*	freq (%)	sum
Vicia hirsuta/*V. tetrasperma*	1	2.5	11	3.8	11
Crop weeds—summer annuals					
Chenopodium album	9	17.5	721	73.6	730
Chenopodium hybridum	0	0.0	1	1.9	1
Echinochloa crus-galli	0	0.0	3	3.8	3
Galium aparine	6	15.0	60	28.3	66
Polygonum persicaria	4	10.0	0	0.0	4
Solanum nigrum	1	2.5	73	13.2	74
Herbaceous vegetation of frequently disturbed sites					
Brassica oleracea	3	2.5	0	0.0	3
Daucus carota	0	0.0	3	1.9	3
Galeopsis tetrahit	0	0.0	3	3.8	3
Galeopsis speciosa/*G. tetrahit*	1	2.5	0	0.0	1
Malva neglecta	2	2.5	0	0.0	2
Picris hieracioides	0	0.0	1	1.9	1
Plantago major	3	2.5	0	0.0	3
Polygonum aviculare	1	2.5	37	11.3	38
Polygonum lapathifolium	4	7.5	10	9.4	14
Polygonum lapathifolium/*P. persicaria*	4	10.0	0	0.0	4
Portulaca oleracea	0	0.0	1	1.9	1
Rumex conglomeratus	0	0.0	6	7.5	6
Rumex conglomeratus/*R. sanguineus*	9	17.5	0	0.0	9
Rumex obtusifolius	14	12.5	2	1.9	16
Silene dioica	1	2.5	0	0.0	1
Stellaria graminea	1	2.5	0	0.0	1
Heaths and grasslands					
Plantago lanceolata	3	5.0	0	0.0	3
Rumex acetosella	5	10.0	72	13.2	77
Silene vulgaris	0	0.0	23	9.4	23
Trifolium arvense/*T. campestre*	1	2.5	40	1.9	41
Valerianella dentate	0	0.0	1	1.9	1
Coniferous and broadleaved woodland					
Abies alba, leaf fragments	1	2.5	0	0.0	1
Picea abies, leaf fragments	125	52.5	1	1.9	126
Picea abies, twig fragments	12	17.5	0	0.0	12
Veronica cf. *urticifolia*	2	5.0	0	0.0	2
Other wild taxa					
Apiaceae	0	0.0	1	1.9	1
Astragalus sp	0	0.0	1	1.9	1
Astragalus sp/*Trifolium* sp	2	2.5	0	0.0	2
Brassica sp	1	2.5	0	0.0	1
Carex sp	3	7.5	1	1.9	4
Caryophyllaceae	2	5.0	1	1.9	3
Chenopodium sp	0	0.0	11	5.7	11
Chenopodiaceae	0	0.0	1526	13.2	1526
Echinochloa sp	1	2.5	0	0.0	1
Echinochloa sp/*Setaria* sp	0	0.0	2553	20.8	2553
Fabaceae	0	0.0	2087	13.2	2087
Fragaria sp	3	2.5	0	0.0	3
Galium sp	3	7.5	6	5.7	9
Lamiaceae	0	0.0	11	5.7	11
Malvaceae	8	7.5	0	0.0	8
Medicago sp/*Melilotus* sp	2	5.0	0	0.0	2
cf. *Panicum* sp	1	2.5	0	0.0	1
Polygonum sp	1	2.5	1	1.9	2
Polygonaceae	5	2.5	28	13.2	33
Poa nemoralis/*P. pratensis*/*P. trivialis*	1	2.5	0	0.0	1
Poaceae	13	7.5	12	9.4	25
Potentilla sp./*Fragaria* sp	1	2.5	0	0.0	1
Rumex sp	4	2.5	1	1.9	5
Sambucus sp	0	0.0	1	1.9	1
Trifolium sp	1	2.5	0	0.0	1
Vicia sp	3	2.5	2	1.9	5
Total of carbonised plant remains	3086		239133		242207

house were carefully cleaned and were believed to have already been prepared for food.

In general, only small quantities of collected fruits and nuts were recovered in the stored remains from Ganglegg and are interpreted as a kind of unintentional impurity in the stored crops. A limited range of fruits and nuts has been recovered and among them *Rosa* sp. shows the highest frequency (Table 2). Additionally the samples contained several fruits/seeds of *Corylus avellana* (hazelnut), *Prunus spinosa* (sloe), *Malus* sp./*Pyrus* sp. (apple/pear) and *Sambucus nigra, S. racemosa* (edible elder species).

Most of the wild plants derived from crop fields in the vicinity of the settlement. The weed seeds accompanying crops in archaeobotanical samples give good information about crop cultivation. The occurrence of summer annuals (Chenopodietea) such as *Chenopodium album*, *Echinochloa crus-galli* and *Solanum nigrum* is associated with summer crops such as *Panicum miliaceum* and/or the pulses *Vicia faba* and *Pisum sativum*. *Hordeum vulgare* (hulled barley) has also been found together with *Avena* sp., *Bromus* sp. and *Fallopia convolvulus* and this context indicates winter crop cultivation.

Discussion

Type of seed assemblages

Detrended correspondence analysis (DCA) was used to explore the variation in the quantitative data set from Friaga and Ganglegg. First, the analysis of the presence/absence of taxa types from both excavation sites was done by detrended correspondence analysis (not shown). The DCA plot shows a clear distinction of the two separate groups. Significant differences between both hill-top settlements are caused on the one hand by the species composition of the samples: the stored remains from Ganglegg represent several palaeobiocoenoses (most probably original assemblages of cereals and legumes) in the palaeoecological sense and the crop yields were stored during the period in which the hill-top settlement was occupied. However, that deposit can also be a snapshot of what was found on one day in the late Bronze Age granary and reflect the situation of one harvest. In contrast to this, the open assemblages of Friaga contain only small amounts of cereals and associated plant remains. Such assemblages contain a mixture of plants which did not grow together and are called thanatocoenoses (Willerding 1991). Usually, the remains were deposited over a longer time period and therefore represent the activities at the site during its occupation. These two different types of deposits clearly separate the data set into taxa/type-rich samples from Friaga and taxa/type poor samples from Ganglegg.

Secondly, detrended correspondence analysis (DCA) was performed based on the data set of stored remains in the late Bronze Age house at Ganglegg, which provided new insights into the type of agriculture practised (Fig. 2 and Table 1). The DCA ordination of stores (Fig. 2) separates along the first axis samples (sample scores = squares) dominated by *Hordeum vulgare* var. *nudum* and *Panicum miliaceum* and samples (sample scores = up triangle and down triangle) dominated by the legumes *Vicia faba* and *Pisum sativum*. Along the second axis the samples from Ganglegg are separated into those which are dominated by weeds (sample scores = diamond) and those dominated by crops. An intermediate cluster group (sample scores = circle) is characterised by a mixture of crops or by samples with only few items per litre. One sample (sample score = star) is determined by *H. vulgare* and accurately reflects the status of the plant in the Bronze Age.

Crop processing: grain versus chaff

The number of seeds in the samples varies considerably from sample to sample. The results from smaller samples with few identified seeds are probably not reliable and so samples with fewer than 10 identifications were omitted from the analysis. Crop processing in Ganglegg must have been very effective, as chaff and weed seeds are exceedingly rare in the stored remains (Fig. 3). So, the carbonised plant remains found in the late Bronze Age house at Ganglegg are believed to originate from stores of grain ready for food production. The original volume of the stored grain cannot be given. In comparison to ethnographic models from Greece and Turkey, more than 75% samples of the late Bronze Age house look like a cleaned or semi-cleaned product (Hillman 1981; Jones 1984). The plots characterised by high percentages of weeds contained either a large number of the pulses *Vicia faba, Pisum sativum* or few items. One sample from Ganglegg was composed of 100% weeds (Fig. 3), dated to 1200–1000 B.C., and it is dominated by numerous seeds of *Chenopodium album* (fat hen) and their embryos. The high density (3500–4000 seeds/l), the absence of cereal chaff and the evidence of few cereal grains indicate deliberate gathering of this species. Ethnobotanical studies of Native American people show that leaves and stems are used as a substitute for spinach or other greens and the starch-containing seeds are ground into flour for baking into bread (Moerman 2000). The use of fat hen as food is already suggested for Neolithic dwelling sites of Switzerland (e.g. Jacomet et al. 1989); further evidence is for example yielded by the filling of a Roman Iron Age pottery vessel from Gørding in Denmark (Helbæk 1951) and the stomach contents of the Roman Iron Age bog body from Kayhausen in Germany (Behre 1999).

The former group of carefully cleaned storage assemblages in Ganglegg allow us to consider that this hill-top settlement could have been a consumer site, based on the ratio of cereal grain to cereal chaff and to cereal weeds (Fig. 3). Beside the storage construction, the late Bronze Age house also contained a hearth from a metalworking area. Additional archaeological evidence such as metalworking tools and imported ceramics supports the

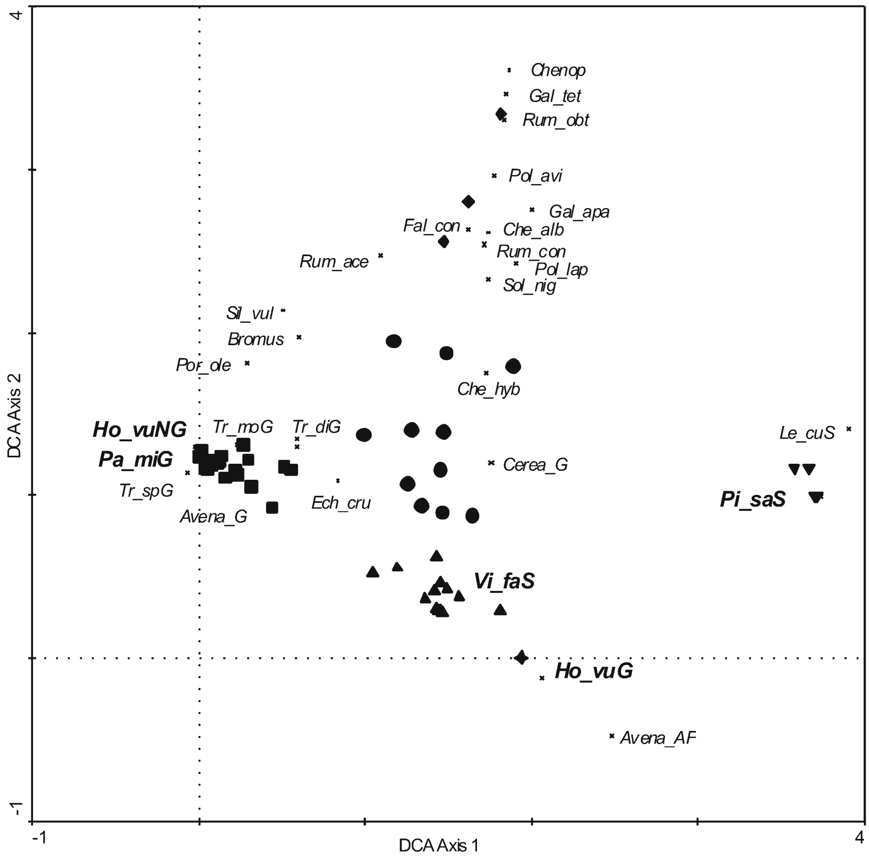

Fig. 2 DCA plot of 53 macrofossil samples and 67 taxa types (cross = species scores) from excavation site Ganglegg. To avoid crowding on the plot, the names of rare taxa are not shown (Avena_AF = *Avena* sp. awn fragments, Avena _G = *Avena* sp. grains, Bromus = *Bromus* sp., Cerea_G = Cereal indet. grains, Che_alb = *Chenopodium album*, Che_hyb = *Chenopodium hybridum*, Chenop = Chenopodiaceae, Ech_cru = *Echinochloa crus-galli*, Fal_con = *Fallopia convolvulus*, Gal_apa = *Galium aparine*, Gal_tet = *Galeopsis tetrahit*, Ho_vuG = *Hordeum vulgare* grains, Ho_vuNG = *Hordeum vulgare* var. *nudum* grains, Le_cuS = *Lens culinaris* seeds, Pa_miG = *Panicum miliaceum* grains, Pi_saS = *Pisum sativum* seeds, Pol_avi = *Polygonum aviculare*, Pol_lap =*Polygonum lapathifolium*, Por_ole = *Portulaca oleracea*, Rum_ace = *Rumex acetosella*, Rum_con = *Rumex conglomeratus*, Rum_obt = *Rumex obtusifolia*, Sil_vul = *Silene vulgaris*, Sol_nig = *Solanum nigrum*, Tr_diG = *Triticum dicoccon* grains, Tr_moG = *Triticum monococcum* grains, Tr_spG = *Triticum spelta* grain, Vi_faS = *Vicia faba* seeds)

view that the hill-top settlement was part of a wider network of communication and exchange (Gamper and Steiner 2000). So, this hill-top settlement was focused mainly on metalworking and trade and it could be possible that crops were grown at nearby rural settlements. Such an economic reconstruction should be seen as a theoretical model and should not be accepted without question. The identification of the economic function of sites as cereal producers or consumers based on archaeobotanical data is difficult; this is discussed in several papers (Hillman 1981; van der Veen and Fieller 1992; Jones 1985; Smith 2001).

In contrast, the triangular scatter plot of the data from Friaga (Fig. 4) represents no relationship between sample composition and features such as hearths and house areas. In Friaga, the plant remains obviously derived from different vegetation types which were growing in the surroundings of the settlement, and thus they reflect the occupied environment in the middle Bronze Age. Most of the plants were brought into the settlement area intentionally as food, together with weeds and also seeds/fruits of collected plants. On the other hand, some of the plants were brought into the hill-top settlement inadvertently by people and animals and were preserved charred as the result of accidental burning. So, these samples represent most probably rubbish or waste of the inhabitants of the hill-top settlement. The plant material from Friaga may thus provide insights into several kinds of food resources and the environment of the site during the middle Bronze Age.

Arable farming in the eastern Alps during the Bronze Age

The diet of the Bronze Age settlers in the Alpine area

In general the numbers of seeds in the Friaga/Bartholomäberg samples were very low compared to the stored remains from Ganglegg/Schluderns (Table 2). In the Bronze Age hill-top settlements 10 cultivated species could be attested with certainty (Table 2). In both excavation sites *Hordeum vulgare* (hulled barley) occurred

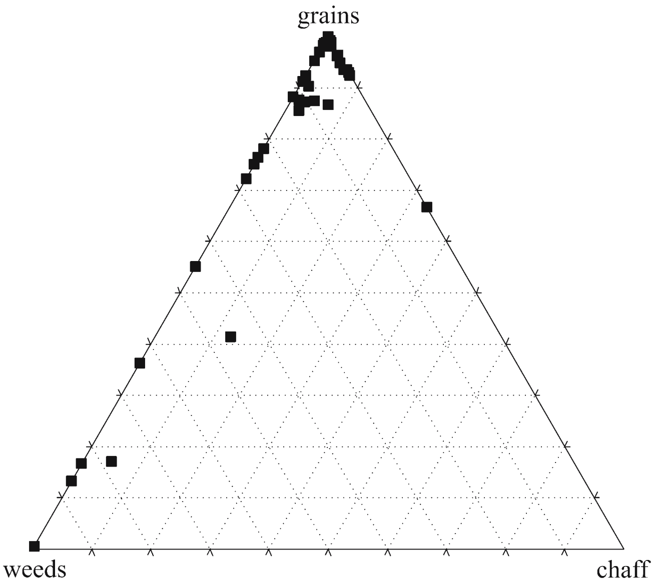

Fig. 3 Triangular scatter plot showing percentages of grain, chaff and weed seeds from Ganglegg

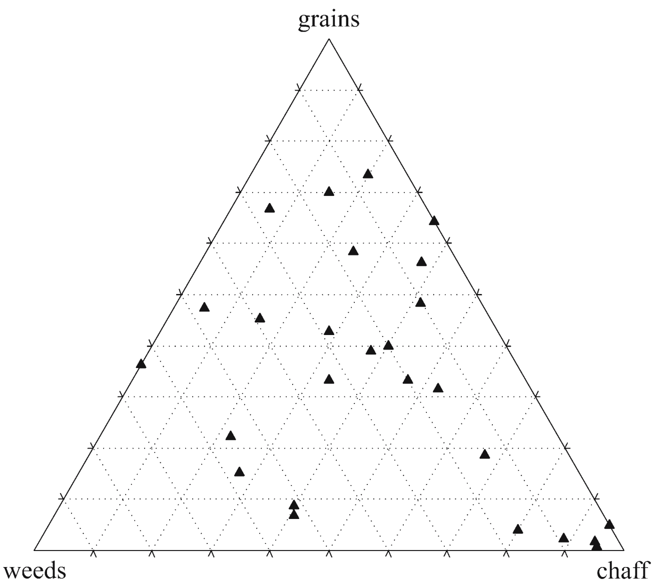

Fig. 4 Triangular scatter plot showing percentages of grain, chaff and weed seeds from Friaga

regularly in the samples. In other Bronze Age excavation sites in the Alpine area grains of *H. vulgare* were also frequently found (Heiss 2001; Jacomet et al. 1999; Oeggl 1992; Swidrak and Oeggl 1998). Besides this, *H. vulgare* var. *nudum* (naked barley) was present in Ganglegg/ Schluderns as a main crop. This cereal is represented rarely in other settlements of the region like Kulm/Trofaiach, Styria (Stika 2000), Mariahilfbergl/Brixlegg, North Tyrol (Oeggl unpubl.) and Sotciastel/Gadertal, South Tyrol (Swidrak and Oeggl 1998) but not in eastern Switzerland. Barley is one of the hardiest cereals, widely tolerant of soil condition and it also grows up to more than 1800 m (Hegi 1935). In Switzerland barley was cultivated in Lü/Münstertal (Grison) at an altitude of 1950 m. Also, in the climatically favoured south of Switzerland (Wallis) near Zermatt barley, peas and beans grow at an altitude of 2000 m (Jacomet et al. 1999). In the first part of 20th century spelt and einkorn were cultivated in Vorarlberg. The Montafon was well known for the cultivation of six-row summer barley. In Bartholomäberg and adjacent areas wheat, barley and oats were cultivated up to 1200 m (Mayr 1936).

Hulled wheats such as *Triticum dicoccon* and *T. spelta* are established in both excavation sites as important cereals and the cultivation of these undemanding crops was common in the eastern Alps (Jacomet et al. 1999). *T. aestivum* grains were occasionally found in samples from Friaga and seem to be rare in the eastern Alps in this period (Jacomet et al. 1999).

In addition to emmer, spelt and barley, broomcorn millet was found frequently in all chronological stages from the middle to late Bronze Age. In the stored remains from Ganglegg, *Panicum miliaceum* is found in large quantities and also occurs frequently. According to ethnoarchaeological investigations in Nepal and France (Lundström-Baudais et al. 2002), broomcorn millet grains are treated with a high temperature to extend the period of storage. Such a grain processing is also conceivable for the broomcorn millet grains from Ganglegg. Broomcorn millet grows well in intensive heat and severe drought up to 1000 m (Hegi 1935). So, these qualities seem to favour broomcorn millet locally in the dry region of Vinschgau and it was therefore one of the most important cereals.

Grains of *Avena* sp. were found regularly in both settlements. Awn fragments of oat were found more frequently in Friaga than in Ganglegg. The grains of different *Avena* species overlap in size and are impossible to differentiate, but in Friaga/Bartholomäberg the evidence of the scars on the spikelet bases are diagnostic for *A. fatua* (wild oat). Therefore, the carbonised oat grains in the Bronze Age layers are interpreted as a crop weed and no evidence of *A. sativa* (cultivated oat) is recorded up to now in the eastern Alps during the Bronze Age (see also Jacomet et al. 1999).

Three different pulses were found: *Lens culinaris*, *Pisum sativum* and *Vicia faba*. In Ganglegg, stores of horse-bean and pea also reflect the situation in Grisons (Graubünden, Switzerland, Jacomet et al. 1999). Seeds of legumes are rich in proteins and were therefore an important food resource for prehistoric people from the Neolithic onwards (Zohary and Hopf 2000). In both hilltop settlements, single seeds of lentil were recovered, but that is obviously an insufficient number to confirm the local cultivation of this plant. In the eastern Alps, lentil occurs as a few finds in Padnal/Savognin (Jacomet et al. 1999), Elvas Strada/Brixen (Oeggl unpubl.) and Sotciastel/Gadertal (Swidrak and Oeggl 1998). Further investigations should therefore prove the position of lentil as a cultivated plant in the Alpine area.

The food supply was supplemented with the collection of edible wild plants. The group of these gathered species (Table 2) includes *Corylus avellana*, *Malus*/*Pyrus* sp., *Prunus spinosa*, *Rubus fruticosus*, *R. idaeus*, *Rosa* sp., *Sambucus nigra* and *S. racemosa*.

The crop husbandry regime in Ganglegg

The cereal consumer model of Hillman (1981) was applied to the hill-top settlement and therefore we assume that crop husbandry was practised close to rural settlements such as Ganglegg. The most frequently occurring wild species in the samples are arable weeds (Table 2), which show something of crop cultivation. Detailed analyses of the crop husbandry were carried out on the data base of Ganglegg because the remains found in the late Bronze Age storage building are suitable for that kind of evaluation.

The data set from Ganglegg shows that there was a crop rotation system. In general, the dominant weed species in both sites are *Chenopodium album, Fallopia convolvulus*, *Galium aparine*, *Polygonum lapathifolium* and *Rumex acetosella* (Table 2). The seed assemblages from Ganglegg represent, in virtually all cases, harvested cereal crops and their associated impurities. *Vicia faba*, *Pisum sativum* and *Panicum miliaceum* were cultivated as summer crops indicated by associated summer annual crop species (Chenopodietea) such as *Chenopodium album*, *Galium aparine* and *Solanum nigrum* in the stored remains. Winter annual species (Secalietea) such as *Avena* sp., *Bromus secalinus* and *Fallopia convolvulus* occur frequently in barley-dominated storage finds, and suggest the cultivation of this cereal as a winter crop. Emmer and spelt occur as an admixture in stored barley of the late Bronze Age, so the time of sowing based on associated crop weeds is indeterminable.

Site catchment analysis is defined that in an area with a radius of 5 km (site territory) natural resources were used and within a 1 km circle crop fields were located (Higgs 1975). By using this model and the ecological indicator values (Ellenberg et al. 1992) of the crop species in the hill-top settlements, we must assume that the crop fields were located on well-drained slopes and hill-tops as well as in damper low-lying areas, within a 500 m radius around the settlement (Schmidl 2002).

Conclusion

The palaeoethnobotanical investigations of the two hilltop settlements provide new insights into the type of subsistence strategy in such Alpine settlement types during the Bronze Age. The crop samples from Ganglegg are most probably palaeobiocoenoses and represent a part of the original vegetation growing on the cultivated field with their related crop weeds. The opportunity to study crops from stored remains enables an insight to be obtained into their prehistoric cultivation. The evaluation of the field weed spectra suggests that both winter and summer crops were grown and confirm a crop rotation system in the eastern Alps during the Bronze Age. However, crop husbandry was one part of the subsistence strategy; mainly the second reference site, Friaga, gave additional information about other food resources. The open assemblages of Friaga are thanatocoenoses with plant material derived from rubbish which was preserved in the middle Bronze Age occupation layers. They reflect, besides crops, also other vegetation types in the surroundings of the hill-top settlement. The preservation of fruits and nuts in dry settlements is rare and consequently the occurrence of a wide range of gathered plants in Friaga provides basic data about the use of natural resources in the Alpine area during the Bronze Age. The hill-top settlement of Ganglegg as a cereal consumer site concentrated mainly on metalworking and trade in the local settlement network. In the vicinity of the settlement rural communities most probably carried out agricultural activities and provided the settlers with crops.

Acknowledgements Financial support was provided by Stiftung Südtiroler Sparkasse and the Austrian Science Foundation (P16457). We would like to thank R. Krause Free University of Berlin, H. Steiner and P. Gamper, Amt für Bodendenkmäler der Autonomen Provinz Bozen, for the fruitful cooperation in both excavation sites. We are grateful to our colleague W. Kofler, Botanical Institute of Innsbruck University, who provided assistance with the statistical program CANOCO. We thank S. Jacomet and two anonymous reviewers for constructive comments which improved the manuscript

References

Behre K-E, Jacomet S (1991) The ecological interpretation of archaeobotanical data. In: van Zeist W, Wasylikowa K, Behre K-E (eds) Progress in old world palaeoethnobotany. Balkema, Rotterdam, pp 81–108

Behre K-E (1999) Die letzte Mahlzeit des Jungen von Kayhausen: Eine Untersuchung der Speisereste aus dem Darmtrakt. Schriftenreihe des Staatlichen Museums für Naturkunde und Vorgeschichte, Oldenburg, 10:76–78

Braak CJFter, Prentice IC (1988) A theory of gradient analysis. Adv Ecol Res 18:271–317

Braak CJFter, Smilauer P (2002) CANOCO Reference Manual and CanoDRAW for Windows User's Guide. Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, New York

Braun-Blanquet J (1961) Die inneralpine Trockenvegetation. Von der Provence bis zur Steiermark. Fischer, Stuttgart

Ellenberg H (1986) Vegetation Europas mit den Alpen in ökologischer Sicht, 4th edn. Ulmer, Stuttgart

Ellenberg H, Weber HE, Düll R, Wirth V, Werner W, Paulisson D (1992) Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica, 18, Goltze, Göttingen

Gamper P, Steiner H (2000) Die Ausgrabungen 1998 und 1999 in der bronze- und eisenzeitlichen Siedlung am Ganglegg bei Schluderns. Stand der wissenschaftlichen Forschung. Der Schlern 74:599–684

Hegi G (1935) Illustrierte Flora von Mitteleuropa. Pteridophyta bis Graminea. Pteridophyta, Gymnospermae und Monocotyledones, vol 1, Lehmanns, München

Heiss A (2001) Anthrakologische und paläoethnobotanische Untersuchungen im bronzezeitlichen Bergbaugebiet Schwaz - Brixlegg (Tirol). Diplomarbeit Universität Innsbruck

Helbæk H (1951) Ukrudtsfrø som n#x01FD;ringsmiddel i førromersk Jernalder (Seeds of weeds as food in the pre-Roman Iron Age), Kuml 65–74

Higgs E (1975) Site catchment analysis: a concise field guide. In: Higgs E (ed) Palaeoeconomy. Cambridge University Press, Cambridge, pp 223–224

Hillman G (1981) Reconstructing crop husbandry practices from charred remains of crops. In: Mercer R (ed) Farming practice in British prehistory. Edinburgh University Press, Edinburgh, pp 123–162

Jacomet S, Brombacher C, Dick M (1989) Archäobotanik am Zürichsee. Ackerbau, Sammelwirtschaft und Umwelt von neolithischen und bronzezeitlichen Seeufersiedlungen im Raum Zürich. Zürcher Denkmalpflege. Monographien 7, Zürich

Jacomet S, unter Mitarbeit von Brombacher C, Schraner E) (1999) Ackerbau und Sammelwirtschaft während der Bronze- und Eisenzeit in den östlichen Schweizer Alpen - vorläufige Ergebnisse. In: Della Casa, P (ed) Prehistoric alpine environment, society, and economy. Universitätsforschungen zur prähistorischen Archäologie 55:pp 231–244

Jones GEM (1984) Interpretation of archaeological plant remains: ethnographic models from Greece. In: van Zeist W, Casparie WA (eds) Plants and ancient man. Studies in Palaeoethnobotany. Balkema, Rotterdam, pp 343–397

Jones MK (1985) Archaeobotany beyond subsistence reconstruction. In: Barker G, Gamble C (eds) Beyond domestication in prehistoric Europe. Academic Press, London, pp 107–128

Krause R, Oeggl K, Pernicka E (2004) Eine befestigte Burgsiedlung der Bronzezeit im Montafon, Vorarlberg—Interdisziplinäre Siedlungsforschungen und Montanarchäologie in Bartholomäberg und im Silbertal. Archäologie Österreichs, 15:4–21

Legendre P, Legendre L (1998) Numerical ecology, 2nd edn. Elsevier, Amsterdam

Lundström-Baudais K, Rachoud-Schneider A-M, Baudais D, Poissonnier B (2002) Le broyage dans la chaîne de transformation du millet (*Panicum miliaceum*): outils, gestes et écofacts. In: Procopiou H, Treuil R (eds) Moudre et Broyer. L'interprétation fonctionnelle de l'outillage de mouture et de broyage dans la Préhistoire et l'Antiquité. Methodes, 1, Paris, pp 181–209

Mayer H (1974) Wälder des Ostalpenraumes. Standort, Aufbau und waldbauliche Bedeutung der wichtigsten Waldgesellschaften in den Ostalpen samt Vorland. Fischer, Stuttgart

Mayr E (1936) Die Ausbreitung des Getreidebaues, die Anbau- und Erntezeiten und die Fruchtfolgen in Nordtirol und Vorarlberg. Veröffentlichungen des Museum Ferdinandeum Innsbruck, 5–27

Moerman D (2000) Native American ethnobotany. Timber Press, Portland

Oeggl K (1992) Zur Besiedlung des mittleren Alpenraumes während der Bronze- und Eisenzeit: Die Vegetationsverhältnisse. In: Kovar-Eder J (ed) Palaeovegetational development in Europe and regions relevant to its palaeofloristic evolution. Proceedings of the Pan-European Palaeobotanical Conference, pp 47–57

Pearsall DM (2000) Palaeoethnobotany: a handbook of procedures. Academic Press, London

Peer T (1995) Die natürliche Pflanzendecke Südtirols. Begleittext zur Karte der natürlichen Vegetation 1: 200.000, Bozen

Primas M (2002) Taking the high ground: Continental hill-forts in Bronze Age contexts. Proceedings of the Prehistoric Society, 68:41–59

Rageth J (1986) Die wichtigsten Resultate der Ausgrabungen in der bronzezeitlichen Siedlung auf dem Padnal bei Savognin (Oberhalbstein GR). Jahrbuch der Schweizerischen Gesellschaft für Ur- und Frühgeschichte 69:63–103

Schmidl A (2002) Ernährung und Wirtschaftsgeschichte in der Bronzezeit. Vorbericht zu den paläoethnobotanischen Untersuchungen aus der Höhensiedlung Ganglegg (Schluderns), Der Schlern 76:4–19

Smith W (2001) When method meets theory: The use and misuse of cereal producer/consumer models in archaeobotany. In: Albarella U (ed) Environmental archaeology: meaning and purpose. Kluwer, Dordrecht, pp 283–298

Stika H-P (2000) Pflanzenreste aus der Höhensiedlung der späten Urnenfelderzeit am Kulm bei Trofaiach. Fundberichte Österreich 38:163–168

Swidrak I, Oeggl K (1998) Palaeoethnobotanische Untersuchungen von Bodenproben aus der bronzezeitlichen Siedlung von Sotćiastel. In: Tecchiati U (ed) Sotćiastel - Un abitato fortificato dell'età del Bronzo in Val Badia (Bolzano), pp 334–346

Tutin TG, Heywood VH, Burges NA, Moore DM, Valentine DH, Walters SM, Webb DA (1988–1990) Flora Europaea (vols 2–5). Cambridge University, Cambridge

van der Veen M (1992) Crop husbandry regimes: an archaeobotanical study of farming in northern England 1000 B.C.–A.D. 500. Sheffield Archaeological Monographs vol 3, Collis Publications, Sheffield

van der Veen M, Fieller N (1982) Sampling seeds. J Archaeol Sci 9:287–298

Walter H, Lieth H (1967) Klimadiagramm-Weltatlas, 1. Lieferung, 11 Karten, Jena

Werneck HL (1949) Ur- und frühgeschichtliche Kulturpflanzenfunde in den Ostalpen und am Böhmerwaldes. Schriftenreihe der O.-Ö. Landesbaudirektion, Nr. 6, O.-Ö. Landesverlag, Betrieb Wels

Werneck HL (1961) Ur- und frühgeschichtliche Kultur- und Nutzpflanzen sowie mittelalterliche Kulturpflanzen und Hölzer aus den Ostalpen und den Ostalpen und dem südlichen Böhmerwald. Archeol Austriaca, 10:68–117

Willerding U (1991) Präsenz, Erhaltung und Repräsentanz von Pflanzenresten in archäologischem Fundgut. In: Zeist W van, Wasylikowa K, Behre K-E (eds) Progress in Old World Palaeoethnobotany. Balkema, Rotterdam, pp 25–51

Zohary D, Hopf M (2000) Domestication of plants in the Old World. Oxford University Press, Oxford