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Distribution patterns of cultivated plants in the Eastern Alps (Central Europe) during Iron Age

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Abstract

Carbonized fruits and seeds from two recently investigated Iron Age hilltop settlements, one located north and the other south of the main Alpine range, were analyzed and reveal a detailed insight in the subsistence strategies of the Eastern Alps. The results were compared with archaeobotanical data sets from other Iron Age excavation sites in Austria, Eastern Switzerland and Northern Italy. On the basis of variable data from 17 sites it is not possible to detect a geographical pattern through statistical analyses. On the basis of the frequencies, however, it becomes clear that the principal cereals were *Hordeum vulgare* (hulled six-rowed barley), *Triticum dicoccon* and *T. spelta* (emmer and spelt) and *Panicum miliaceum* (broomcorn millet). In addition, foxtail millet (*Setaria italica*) as well as naked wheat played some role. Legumes such as *Vicia faba* (horse bean) and *Pisum sativum* (pea) also occurred regularly and supplemented the diet of the prehistoric settlers. More systematic research with standardized methods is however urgently needed to corroborate the existing data.

Keywords: Botanical macro remains; Eastern Alps; Iron Age; Numerical analysis; Prehistoric diet; Evaluation methods

1. Introduction

In the late Mesolithic (c. 6500 BC) the first signs of agricultural impact could be detected by the occurrence of cereal pollen in the eastern Alpine area [2,53]. Initial Neolithic settlements inside alpine valleys can be traced in the Eastern Alps in middle Neolithic times. North of the main Alpine range a settlement of the late Neolithic Münchshöfener culture, dating to around 4400 BC cal., is archaeologically documented in the Inn valley near Brixlegg (Tyrol, Austria) [24]. Most recently, a settlement of the middle Neolithic Hinkelstein culture, dating to around 4800 BC cal., was excavated in the Rhine valley near Chur (eastern Switzerland) [46]. First preliminary views of the sieved samples revealed the presence of carbonized cereals, which point clearly to an agricultural settlement (unpublished data, IPNA, Basel University). In the late Neolithic, during the 4th millennium BC people had definitively settled in the valleys and foothills near the Eastern Alps, cleared forests and practiced agriculture [3,33,41,44]. The discovery of the Tyrolean Iceman, dated to c. 3300 BC, confirms the occurrence of humans in high altitudes [5,10,47]. At the beginning of the Bronze Age (c. 2000 BC) the Alpine region experienced an economic boom related to copper deposits and forest clearing activities [44]. Settlements of this period are mostly located on exposed places in a commanding position with overview of the valley floor near important crossroads and river crossings in the Alpine area. Such hilltop sites at important trade routes proved to be a permanent feature, though shifts in occupation occurred frequently. It seems likely that copper mining continued in the Alpine region until at least the Iron Age, although a variety of other metals as well as salt were exploited in subsequent periods [36].

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Recently conducted palaeoethnobotanical analyses of carbonized plant remains from two hilltop settlements related to copper mining, Friaga located north and Ganglegg south of the main Alpine range, provide new and detailed information about agricultural activities and the use of natural resources in the Eastern Alps during metal ages [43,45]. The prehistoric occupation of both excavation sites Friaga (c. 18th BC) and Ganglegg (c. 15th BC) started in the early Bronze Age and lasted till the late Bronze Age (c. 10th BC). After a gap of some centuries, new activities followed during the late Iron Age [14,23]. Copper deposits are situated near the hilltop settlement Friaga and were exploited in prehistoric times [23]. In one of the late Bronze Age houses at Ganglegg a casting mold was found nearby a hearth, which suggests the production of metal tools [14]. Imported artifacts from north, south, and east of the Alps found at this excavation site indicate not only extensive trade relations but also the regional importance of the settlement.

In general, archaeobotanical investigations in the inner parts of the Eastern Alps are scarce. In the Canton of Grisons (Graubünden) of the eastern Swiss Alps only three sites were investigated up until now: The Areal Ackermann in Chur, Bot da Loz in Lantsch and Munt Baselgia in Scuol [18]; the two latter are hilltop sites. All were excavated many years ago. In Austria and Southern Tyrol (Italy), after some older studies conducted by Werneck [56,57], recent palaeoethnobotanical investigations have been undertaken by Oeggl [34,35], Küster [25], Rösch [42], Swidrak [49], and Swidrak and Schmidl [50] at four sites. Two more investigated sites, Monte Loffa and Castelrotto in Verona, are located southwards of the main Alpine range [31,32].

The main question of this study concerns a comparative analysis of archaeobotanical data from Friaga and Ganglegg with 15 other sites in the Eastern Alps (Figs. 1 and 2, Table 1) to detect possible reasons of the distribution patterns of cultivated plants based on similarities/dissimilarities within the data sets. The conclusion of the archaeobotanical data sets could be used simply to draw a dividing line between the north and south of the main Alpine range determined by climatic and topographic factors, e.g. temperature, precipitation and elevation [8,12,54]. Therefore, statistical analyses were applied on the available data set to prove a possible relationship between cultivated plants and their geographic distribution. Such distinctive geographical distribution patterns were demonstrated by archaeozoological studies from the Neolithic lake dwelling site Mondsee in Austria. Pucher and Engl [40] compared their data sets with those from other parts of middle Europe and evaluated similarities to other lake-dwelling communities in Europe. The animal husbandry differs significantly from the close by Danubian communities and thus Pucher and

Fig. 1. Location of the two hilltop settlements Friaga/Bartholomäberg and Ganglegg/Schluderns.

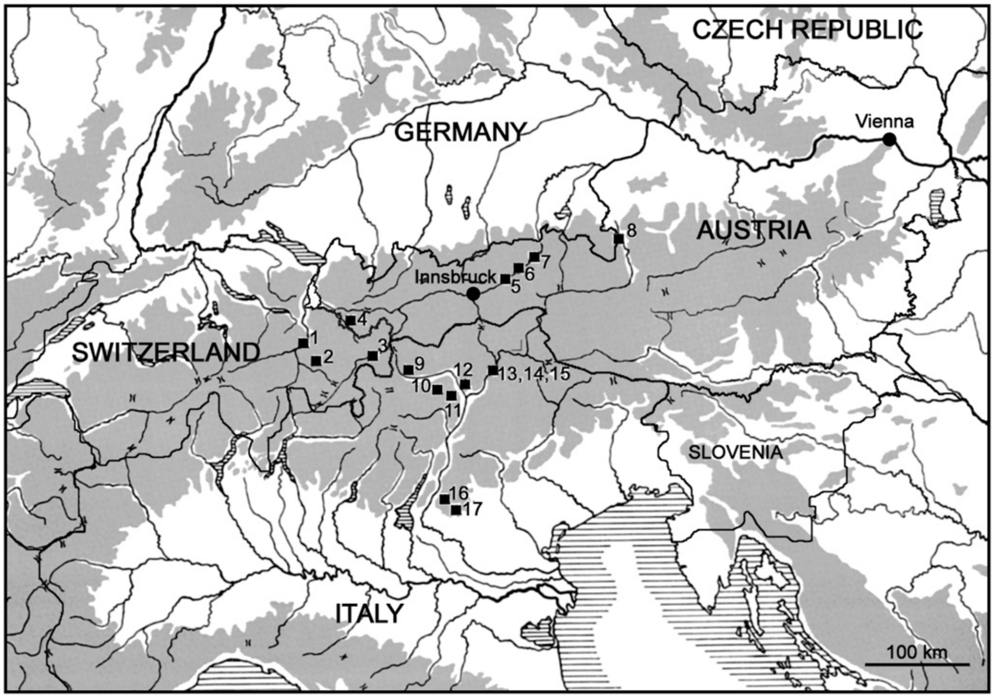

Fig. 2. Map showing the 17 Iron Age excavation sites in the Eastern Alps, the numbers of the sites correspond to Table 1.

Engl [40] established the hypothesis that the Mondsee-husbandry is related nearer to western or southern origins than to northern or eastern.

To address the hypothesis of the geographically related distribution pattern of crop plants, multivariate analysis was applied to gain an impression of the variability within the archaeobotanical data sets. Such statistical methods used here are already well known in studies related to palaeoecological topics or in general of community and landscape ecology [1,11,26,21].

2. Site description

2.1. Friaga/Bartholomäberg

The prehistoric hilltop settlement of Friaga is situated at an altitude of 940 m in the west of Austria (Fig. 1) on a south-facing slope of the village Bartholomäberg, north of the main alpine range. This region is characterized by an intermediate climate from subcontinental to suboceanic conditions with occasionally heavy rainfall. Annual precipitation measured

Table 1
Iron Age reference sites in the Eastern Alps

No.	Location	Altitude (m a.s.l.)	Epoch	Reference
1	Areal Ackermann/Chur, CH	595	Iron Age	[18]
2	Bot da Loz/Lantsch, CH	1320	Early Iron Age	[18]
3	Munt Baselgia/Scuol, CH	1250	Early Iron Age	[18]
4	Friaga/Bartholomäberg, A	940	Late Iron Age	This study
5	Himmelreich/Wattens, A	564	Late Iron Age	[35]
6	Stans/Schwaz, A	563	Late Iron Age	[57]
7	Kundl/Tirol, A	520	Late Iron Age	[25]
8	Dürrnberg/Hallein, A	740	Late Iron Age	[50]
9	Ganglegg /Schluderns, I	1142	Late Iron Age	This study
10	St. Walburg/Ulten, I	1190	Iron Age	[34,42]
11	Sanzeno/Bozen, I	645	Late Iron Age	[56]
12	Siebeneich/Bozen, I	264	Iron Age	[49]
13	Trattengasse/Brixen, I	566	Late Iron Age	[34]
14	Stufels/Brixen, I	566	Late Iron Age	[34]
15	Villa Dirce/Brixen, I	566	Iron Age	Oeggl, unpublished
16	Monte Loffa/Verona, I	1036	Iron Age	[32]
17	Castelrotto/Verona, I	172	Late Iron Age	[31]

CH, Switzerland; A, Austria; I, Italy.

below the study site, at an altitude of 689 m, reaches about 1250 mm per year, and the mean annual temperature is 7.4 °C [54]. However, the climate of the northern intermediate Alps as well as the acid bedrock favors the growth of *Picea abies* (spruce). Thus, the landscape is characterized by coniferous forests (Piceo-Abietetum) in the montane zones up to 1400 m [12] superseded by forests with *Larix decidua* (larch) and *Pinus cembra* (stone pine). The tree line is located at 1900–2000 m [29].

2.2. Ganglegg/Schluderns

The settlement of Ganglegg is located south of the main Alpine range in the Vinschgau near Schluderns at an altitude of 1142 m (Fig. 1) in South Tyrol (northern Italy). The Vinschgau Valley is surrounded by high mountains in the north, west and east, which retain the clouds and therefore, the Vinschgau valley belongs to the so-called inner-alpine dry valleys like the Aosta Valley (Italy), the Valais (Switzerland) or the region of Briançon (France) [8]. The climate is characterized by hot summers, cold winters, low humidity and above-average sunshine (average number of hours of sunshine per year is 2400. As a consequence, the mean annual temperature of 9–10 °C and the average precipitation is 400 mm/year with maximum in July [54]. The potential natural vegetation is characterized by xerothermic or thermophilous dawn oak forests (Querceto pubescentis) at lower altitudes and inner Alpine spruce forest (Piceetum montanum) up to 1400 m. *Pinus cembra* (stone pine) with *Larix decidua* (larch) form the subalpine forest up to the tree line that lies between 2100 and 2300 m [38]. The characteristic semiarid grasslands caused by the low precipitation are distributed on the montane southern slopes of the Vinschgau valley up to 1000 m. The valley bottom (ca. 900 m) is used as agricultural crop land and for meadows [38].

3. Material and methods

3.1. Material under study: Friaga/Bartholomäberg

The charred plant macro remains were taken by random a sampling strategy from the sandy loamy deposits of the Iron Age. Fifteen samples derive from the first excavation surface, which does not show distinctive differences of the cultural layer. Features like an ash pit, a door hinge stone and a post-hole surrounded by stones indicate settlement activities in that area. In the second excavated surface parallel to the fortification wall the recovered remains lie near an ash pit and also a small hearth. Here, 22 samples were collected for the archaeobotanical investigations.

The low density of carbonized botanical remains in the soil samples demanded a large sample volume (10 L per sample). Water screening was used to recover macro remains at the excavation site [37]. The sandy soil sample was poured on the first sieve with a 2.0 mm mesh and washed with water through downstream sieves with mesh sizes of 1.0 mm, 0.5 mm and 0.25 mm. The residues in the sieves were dried in the open air and stored in plastic bags until the analyses. Each fraction was sorted under a binocular microscope using a magnification from 10× to 63×. Fruits and seeds of all floats were retained for subsequent identification.

3.2. Material under study: Ganglegg/Schluderns

At Ganglegg, complex settlement structures such as foundations of several houses were recovered from the Iron Age. As a consequence of a fire these buildings were destroyed and high amounts of charred grains (stores) were preserved at the excavation site. Six different Iron Age houses were chosen for archaeobotanical sampling. Eight samples derive mainly from the inside of the different houses distributed at the settlement area; only one sample derives from the adjacent outdoor areas beyond a carbonized wooden beam.

Because the samples were very rich in remains, a standard soil volume of 1 L material was used for water flotation technique in the laboratory. The eight samples were screened through three sieves with mesh sizes of 2.0, 0.5 and 0.25 mm. An efficient method was needed for analyzing grain-rich samples of different layers and deposit types. Therefore, after stirring, the dried flotation samples were subsampled by the spoon method [52]. The subsamples were weighed and the count for all taxa was then multiplied up to the total volume of each of the fractions. In total a volume of 4.4 L of soil samples was investigated and identified as above.

In general, all plant names follow the nomenclature of Flora Europaea [51] and wild plants were coded according to the general habitat categories based on groupings of phytosociological classes presented by Ellenberg et al. [13].

3.3. Nature of the other archaeobotanical data from Eastern Alps

The data of Friaga and Ganglegg can be compared with 15 other Iron Age sites in the Eastern Alps (Table 1). In general, the sample size and number of samples differ significantly within the archaeobotanical data set (Table 2). Only one sample was investigated at the sites Trattengasse/Brixen, Stufels/Brixen, Villa Dirce/Brixen, Siebeneich/Bozen, and Monte Loffa/Verona. In older publications, concerning e.g. Stans/Schwaz and Sanzeno/Bozen conducted by Werneck [56,57] and Monte Loffa, analyzed by Nisbet [31], no quantitative information of the plant remains is given. Also at the three Swiss excavation sites (Areal Ackermann/Chur, Bot da Loz/Lantsch, Munt Baselgia/Scuol) which come from excavations done many years ago, no systematic sampling strategy was applied and in addition, it is impossible to reconstruct the pre-treatment of the samples a posteriori (see remarks in Jacomet et al. [18]). Only the Dürrnberg-site is analyzed in a rather systematic way similar to Friaga and Ganglegg. Therefore, as visible in Table 2, the data set is extremely heterogeneous. Only in Dürrnberg/Hallein was the preservation waterlogged; nevertheless, the cultivated plants (cereals and legumes) were found in carbonized state, only the wild plants being preserved uncarbonized.

In addition to the heterogeneous sampling methods applied, two types of assemblages can be differentiated in the data set of the Iron Age sites: closed assemblages and thanatocoenoses

Table 2
Quantitative results of nine Iron Age excavation sites including data of 13 cultivated plants

Site	Bot da Loz	Munt Baselgia	Friaga	Himmelreich	Kundl	Dürrnberg	Ganglegg	Siebeneich	Monte Loffa
Site number	2	3	4	5	7	8	9	12	17
Reference	[18]	[18]	This study	[35]	[25]	[50]	This study	[49]	[32]
Country	Switzerland	Switzerland	Austria	Austria	Austria	Austria	Italy	Italy	Italy
Seed assemblages	c	c	t	c	t	t	c	c	c
Epoch	EIA	EIA	LIA	LIA	LIA	LIA	LIA	IA	IA
Sample numbers	4	>2	31	2	2	66	8	1	1
Sample volume (L)	Unknown	Unknown	310.0	Unknown	335.0	27.9	4.4	0.4	1.2
Ho_vuG	>500	>20	97	66	80	130	31151	12	2
Ho_vuNG				20		11	272	47	
Se_ceG						3		1	
Tr_naG		50	1	38	13	15	28	8	11
Tr_diG	9	7	23	82	4		696	480	6237
Tr_moG					8	32	12		24
Tr_spG	4	>200	4	311	2		840	3	
Avena_G	3		2	1			236		
Pa_miG				6529	69	63	24036	4943	
Se_itG				3348	8	2	1077	10221	
Le_cuS			2	6		1		1	>100000
Pi_saS				17	39	6		4	
Vi_faS	>300	>3000	2	217		1	14		12

Avena _G, *Avena* sp. grains; 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; Tr_diG, *Triticum dicoccon* grains; Tr_moG, *Triticum monococcum* grains; Tr_naG, *Triticum aestivum* (incl. *compactum*)/*turgidum* grains; *Tr*_spG, *Triticum spelta* grains; Vi_faS, *Vicia faba* seeds. CH, Switzerland; A, Austria; I, Italy. c, closed assemblages (stores; partly may be palaeobiocoenoses); t, thanatocoenoses. EIA, early Iron Age; LIA, late Iron Age; IA, Iron Age. Site number corresponds to those given in Fig. 2.

(= open assemblages). A closed assemblage can represent a snapshot of what was found on one day when the settlement burnt down at the excavation site and may reflect the situation of one harvest. Closed assemblages may even reflect palaeobiocoenoses, which are original assemblages of cereals and legumes (= stores) in the palaeoecological sense [58]. As visible in Table 2, the quantitative data are dominated by material coming from such closed assemblages (Bot da Loz/Lantsch, Munt Baselgia/Scuol, Himmelreich/Wattens, Ganglegg/Schluderns, Siebeneich/Bozen, and Monte Loffa/Verona).

In contrast, thanatocoenoses (or open assemblages) contain a mixture of plants which did not grow together and come from different habitats [58]. Usually, the remains were deposited over a longer time period (for example as rubbish) and therefore represent the activities at the site during its occupation. Material of such thanatocoenoses was investigated at the excavation sites Friaga/Bartholomäberg, Kundl/Tirol and Dürrnberg/Hallein (Table 2). In addition to materials deriving from settlements, the data set also includes sacrifice sites as St. Walburg/Ulten and Kundl/Tirol. Here, one must consider that only deliberately selected plants may be represented.

Almost all sites are dated to the late Iron Age (5th to 1st century BC). Only the two sites in Switzerland (Bot da Loz/Lantsch and Munt Baselgia/Scuol) are dated to early Iron Age (begin 8th century BC) (Table 1).

3.4. Numerical analysis

We applied multivariate statistics to study the heterogeneous data set of all Iron Age excavation sites in the Eastern Alps. A similar approach was applied by Bouby and Marinval [4], who compared results from Roman cremations in Limagne (France) with published data from other French Roman cremation graves using numerical analysis. In archaeobotany no quantification method of general applicability exists; in addition, there are many taphonomical problems to consider (see above). Therefore, statistical analysis that involves material from several sites is based mainly on semi-quantitative (presence/absence) data [20]. However, this kind of data excludes a part of the information, mainly the quantities [20,39]. Also in the case of the Iron Age sites in the Eastern Alps, ubiquities could not be used because only one or very few samples are available from many sites. Nevertheless, we tried to detect some trends in the data set, mainly in relation to geography and the role of crops in the Eastern Alps involving a suite of multivariate analysis techniques. These included a classification through agglomerative, hierarchical clustering and ordination analysis using detrended correspondence analysis (DCA).

Cluster analysis was performed by the computer program Statistica for Windows (ver. 6.1, 1994; StatSoft, Inc., Tulsa, OK, USA) using Ward's hierarchical agglomerative method and Euclidean distance measure [55]. The advantages of this technique are: (i) any coherent group will not split among different categories; (ii) the boundaries between clusters fall, by definition, in regions of multivariate space where there are few points; if this subdivision derives from aspects of the geological process, the boundaries would be "natural"; (iii) the methodology readily allows consideration of all variables. Some disadvantages come from the instability introduced by the addition of observations to the analysis that is likely to add new clusters and will inevitably redefine old ones. The dendrogram is produced by clustering the semi-quantitative data of the 17 Iron Age excavation sites. In general, cluster analysis is a classification more than a statistical procedure and clusters are concentrations of points (the points being objects, observations or specimens) in space. In other words, a group of objects that is classifiable together on numerical grounds will form a cluster of points in multivariate space. By and large this method is regarded as very efficient; however, it tends to create clusters of small size [11].

The statistical analyses of quantitative data (Table 5) and the graphical plot were implemented by the computer program CANOCO 4.15 [7]. Ordination techniques have the common goal of projecting or aligning samples in a reduced space such that the proximity of two samples in ordination space reflects their similarity: similar samples should be close together in an ordination and dissimilar samples, far apart. Detrended correspondence analysis (DCA) is an eigenanalysis-based ordination technique derived from correspondence analysis [16]. DCA performs detrending to counteract the arch effect, a defect of correspondence analysis. For correcting this arch effect (detrending) the first axis is divided into a number of segments and within each segment, the second axis scores are recalculated so that they have an average of zero [11,15]. Detrended correspondence analysis (DCA) with downweighting of rare taxa was used to measure the length of the gradient in standard deviations (SD) units (Table 3). This resulted in a gradient length of 3.949 standard deviations (SD), justifying the use of detrended correspondence analysis (DCA) as a unimodal response model [6]. Untransformed plant macrofossil concentration values, detrending by segments and downweighting of rare taxa were used for the DCA ordination. Sample scores (= excavation sites) 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 cultivated species.

4. Results: The two hilltop settlements Friaga and Ganglegg

The discovery of the two hilltop settlements Friaga and Ganglegg allowed first detailed archaeobotanical investigations in order to improve our understanding of subsistence strategies in the Eastern Alps. The on-site data collected from both sites during the archaeological excavation period contains important information about the personal requirements of prehistoric settlers in the Alpine area and imply this comparative study to discuss a possible relationship between cultivated plants and their geographic patterns during the Iron Age.

Table 3
Results of detrended correspondence analysis (DCA) including macrofossil concentration data of Iron Age excavations sites in the Eastern Alps

	Axis 1	Axis 2
Eigenvalues	0.977	0.391
Lengths of gradient (SD = standard deviation)	3.949	1.914
Cumulative percentage of variance of species data	39.8	55.7

In general, the plant species found can be divided into four important groups: cereals, pulses, gathered fruits and crop weeds (Table 4). Table 4 shows that the numbers of remains in both settlements are highly different. The high amounts of botanical remains from Ganglegg represent stores of crops (maybe palaeobiocoenoses) and the open assemblages contain a mixture of plants, which did not grow together (thanatocoenoses). Even when ubiquities and ratios of cultivated plants are used to quantify the assemblages, the two sites differ significantly from each other. The data set from the Iron Age deposits can be clearly separated into taxa/type-rich samples from Friaga and taxa/type-poor samples from Ganglegg.

4.1. Plant remains of Friaga

Hordeum vulgare (hulled barley) was by far the most abundant grain (67.7% of all samples; Table 4). According to their frequency, *Triticum dicoccon* (emmer) and *Triticum spelta* (spelt) are, in decreasing order, cereals of secondary importance (from 26% to 13%; Table 4). A small number of spikelet forks and glume bases of *T. dicoccon* (emmer) and *T. spelta* (spelt) were found in the samples. *Panicum miliaceum* (broomcorn millet) and *Setaria italica* (foxtail millet) were found in negligible amounts. Only one grain of naked wheat has been recovered. Its differentiation between the hexaploid naked-wheat *Triticum aestivum* and the tetraploid *T. durum* or *T. turgidum* is impossible with grains only [17].

Most species in the group of gathered fruits (Table 4)—*Corylus avellana* (hazelnut), *Prunus spinosa* (sloe), *Rosa* sp. (dog rose), *Rubus idaeus* (raspberry) and elder (*Sambucus nigra*, *S. racemosa*)—occur in forest border scrubs (Prunetalia). Although the fruits and seeds of red *Sambucus racemosa* (red elderberry) are slightly toxic, they have been consumed. Ethnobotanical studies of Native Americans showed that red elderberry has been used commonly for food [30]. On the Northwest Coast of North America large concentrations of uncharred red elderberry seeds were recovered and confirmed the consumption of this fruit in prehistoric times [27]. In any event, the occurrence of several species of collected fruits in various samples suggests that at least some of the fruits were collected within a reasonably close distance from the settlement.

Insignificant numbers of crop weeds were recovered in the samples (Table 4). Some grains and awn fragments of *Avena* sp., nutlets of *Fallopia convolvulus*, and seeds of *Chenopodium album* are represented in the open assemblages of Friaga. Such small numbers and frequencies can be regarded as representative of the prevailing crop economy.

In more than 50% of the samples fragments of spruce (*Picea abies*) needles were recovered and reflect the use of spruce twigs for several purposes in the village (e.g. litter, fodder, fire wood etc.). Equally, they reflect the nearby lying inter-alpine montane spruce-fir forest (Piceo-Abietetum) on the acid bedrocks of the crystalline zone in prehistoric times.

Table 4
Carbonized remains from Friaga/Bartholomäberg and Ganglegg/Schluderns

	Friaga		Ganglegg		
Number of samples	31		8		
Volume of samples (L)	310		4.4		
Taxon	*n*	ubi (%)	*n*	ubi (%)	Sum
Cereal grains					
Hordeum vulgare	21	67.7	31151	100.0	31172
Hordeum vulgare var. *nudum*			272	25.0	272
Triticum aestivum (inl. *compactum*)/*turgidum*	1	3.2	28	37.5	29
Triticum dicoccon	8	25.8	696	87.5	704
Triticum monococcum			12	25.0	12
Triticum spelta	4	12.9	840	75.0	844
Triticum dicoccon/*T. spelta*	1	3.2			1
Triticum sp.	12	38.7			12
Panicum miliaceum			24036	100.0	24036
Setaria italica			1077	25.0	1077
Cerealia indet.	9	29.0	2473	100.0	2482
Cereal chaff					
Hordeum vulgare, rachis internodes			24	37.5	24
Hordeum vulgare, glumes			1	12.5	1
Triticum dicoccon, glumes	7	22.6	77	62.5	84
Triticum dicoccon, spikelet forks	4	12.9			4
Triticum cf. *dicoccon*, spikelet forks			46	50.0	46
Triticum spelta, glumes			21	37.5	21
Triticum spelta, spikelet forks	1	3.2	4	37.5	5
Triticum monococcum/ *T. dicoccon*, spikelet forks	1	3.2			1
Triticum sp., glumes			5	37.5	5
Triticum sp., spikelet forks	1	3.2	1	37.5	2
Pulses					
Lens culinaris	2	6.5			2
Vicia faba	1	3.2	14	25.0	15
Fruits/nuts					
Corylus avellana	13	41.9			13
Prunus spinosa	6	19.4			6
Rosa sp.	2	6.5			2
Rubus idaeus	6	19.4			6
Rubus sp.	1	3.2			1
Sambucus nigra	1	3.2			1
Sambucus racemosa	10	32.3			10
Sambucus sp.	9	29.0			9
Oil plants					
Papaver somniferum			2	12.5	2
Crop weeds—winter annuals					
Avena fatua, floret			1	12.5	1
Avena sp., grains	2	6.5	236	62.5	238
Avena sp., awn fragments	4	12.9	5	12.5	9
Bromus secalinus			326	25.0	326
Bromus sp.			25	25.0	25
Fallopia convolvulus	10	32.5	9	37.5	19
Scleranthus annuus	1	3.2			1
Crop weeds—summer annuals					
Bromus sterilis/*tectorum*			14	12.5	14
Chenopodium album	4	12.9	168	100.0	172
Chenopodium hybridum			1	12.5	1
Digitaria ischaemum			48	12.5	48
Echinochloa crus-galli			1273	62.5	1273
Galium aparine	2	6.5			2

Table 4 (*continued*)

	Friaga		Ganglegg		
Number of samples	31		8		
Volume of samples (L)	310		4.4		
Taxon	*n*	ubi (%)	*n*	ubi (%)	Sum
Herbaceous vegetation of frequently disturbed sites					
Plantago major	1	3.2			1
Rumex conglomeratus/ *R. sanguineus*	3	9.7			3
Needle-leaved and broadleaved woodland					
Picea abies, leaf fragments	17	54.8			17
Other wild taxa					
Carex sp.			1	12.5	1
Caryophyllaceae			4	12.5	4
Echinochloa sp./*Setaria* sp.			394	12.5	394
Fabaceae	1	3.2	1	12.5	2
Galeopsis sp.			1	12.5	1
Galium sp.	2	6.5			2
Malva sp.	1	3.2			1
Rumex sp.	1	3.2			1
Silene sp.			20	25.0	20
Total of carbonized plant remains	**170**		**63307**		**63477**

n, number of charred remains; ubi (%), 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.

4.2. Plant remains of Ganglegg

High amounts of carbonized grains (stores) of *Hordeum vulgare* (hulled barley) were recovered in all samples from the six Iron Age houses (Table 4). Among the cereals also *Panicum miliaceum* (broomcorn millet) occurred in every sample and in two samples from different houses this species is even the dominant crop (Table 4). Additionally, *Setaria italica* occurred in some samples and confirm its possible use as food plant at Ganglegg during the Iron Age. Grains of *Triticum dicoccon* (emmer) and *T. spelta* (spelt) are also represented in the samples with a high ubiquity (75–88%; Table 4). Glumes and spikelet forks from both wheat species occurred in low numbers and indicate carefully cleaned stores distributed in different houses of the hilltop settlement. Grains of free-threshing wheat species *Triticum aestivum* (incl. *compactum*)/*turgidum* were also recovered and may indicate the cultivation of this cereal by the settlers at Ganglegg during the Iron Age.

In contrast to the cereals the protein-rich seeds of pulses (*Vicia faba*) were represented sparsely in the samples (ubiquity of 25%) and were not stored therefore at time when the settlement burned down.

Besides crops, most probably also edible wild plants supplemented the diet of prehistoric settlers. However, these were obviously not stored at the moment of the fire, at least not at the excavated places.

Most of the wild plants found in the storages are associated with crop fields. Remains of crop weeds—winter and summer annuals—occurred regularly in the storage samples (Table 4).

Summer annuals (Chenopodietea) such as *Bromus sterilis/tectorum*, *Chenopodium album*, *C. hybridum*, *Digitaria ischaemum* and *Echinochloa crus-galli* are found with summer crops such as *Panicum miliaceum*. Winter annuals (Secalietea) such as *Avena fatua*, *Bromus secalinus* and *Fallopia convolvulus* are detected in connection with stores dominated by *Hordeum vulgare*, and suggest the cultivation of this cereal as a winter crop.

High amounts of *Bromus secalinus* grains in one sample with *Hordeum vulgare* (hulled barley), *Triticum spelta* (spelt) and *Panicum miliaceum* (broomcorn millet) suggest that it was intentionally harvested together with the cereal. At the late Bronze Age excavation site Kulm/Trofaiach (Austria), Stika [48] found *Bromus secalinus* (brome grass) as second important species beside *Triticum dicoccon* (emmer), and interpreted it as a possible food element. In Germany *B. secalinus* is presented regularly with *Triticum dicoccon* and *T. monococcum* and indicate the use as food in Neolithic times [22]. However, *Bromus* caryopses are large and therefore difficult to remove from harvested cereal grains.

4.3. Comparison of Friaga and Ganglegg to other sites

Fig. 3 shows the results of the cluster analysis performed on the semi-quantitative (presence/absence) data set of the 17 sites (Table 5). The classification shows—based on the similarity coefficient—that all excavation sites are separated in three clusters (A, B, C).

The group A encompasses sites from south (Ganglegg, Siebeneich) and north of the main Alpine range (Kundl, Dürrnberg, Himmelreich), and corresponds to the high taxonomic diversity and richness of crops. The sites Ganglegg and Kundl are additionally characterized by the lack of *Lens culinaris* (lentil) and therefore they produce a subcluster within group A.

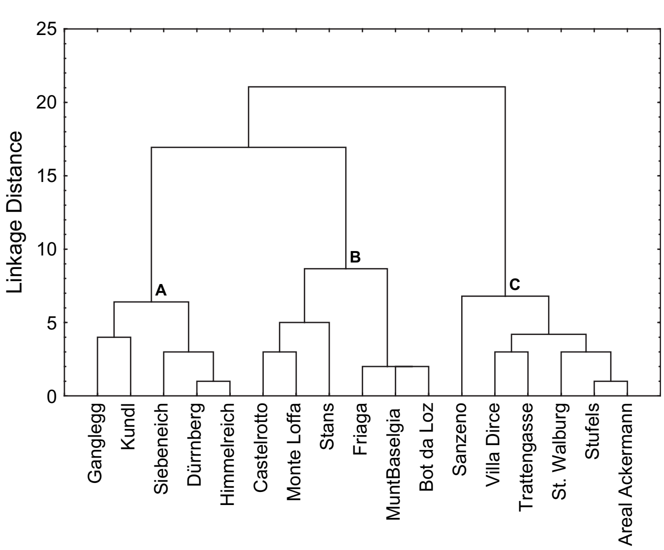

Fig. 3. Dendrogram produced by clustering 17 sites and 13 cultivated plants based on semi-quantitative data set of Table 5.

The group B includes sites from Austria (Stans and Friaga) and the adjacent countries Switzerland (Baselgia and Bot da Loz, Lantsch) and Italy (Castelrotto, Monte Loffa). The sites located in Italy lie south of the main alpine range are grouped together caused by the absence of *Triticum spelta* (spelt) and presence of *Triticum monococcum* (einkorn). The excavation site Stans, located north of the Alpine range in Austria, is separated by a high diversity of cultivated plants and is distinguished from group A by the absence of millets (*Panicum miliaceum, Setaria italica*). The recently investigated site Friaga, also north of the main Alpine range in Austria, forms a subcluster in group B together with the two sites Scuol/MuntBaselgia and Lantsch/Bot da Loz in the Swiss Alps. These are characterized by the similar composition of crops and furthermore by the absence of millets.

Group C includes excavation sites with low crop diversity, partly from the south (Sanzeno, Villa Dirce, Trattengasse, St. Walburg, and Stufels) and also the north (Chur, Areal Ackermann) of the main Alpine range. The classification of this group mainly results from analyzing a few samples of these excavation sites and probably the investigation of more samples would increase the crop diversity. The separate position of Sanzeno from Italy within the group C is affected by the absence of the cereal *Hordeum vulgare* (hulled barley).

To sum up, the data set of all sites in the Eastern Alps reflects a mixed distribution pattern of sites located to the north respectively the south of the main alpine range. There is no clearly visible patterning caused by the geographical location of the settlements.

A potential problem associated with the classification based on a presence/absence data set is the over-estimation of taxa that are present in low numbers. Therefore, detrended correspondence analysis (DCA) was used to explore the variation in the quantitative data set from the Iron Age excavation sites (Table 2, Fig. 4). Werneck [56,57] and Nisbet [31] gave no information about the quantification of the botanical macro remains in their investigations. Consequently, their data were excluded from the analysis. Additionally, the non-representative data of sites shown as group C (Villa Dirce, Trattengasse, St. Walburg, Stufels and Areal Ackermann) in the dendrogram (Fig. 3) are also omitted from this analysis because the very low sample numbers have obviously a strong negative effect on the taxonomic diversity. The results show that along the first axis Monte Loffa is displaced from the other sites by the occurrence of *Lens culinaris* (lentil) stores (Fig. 4). This settlement is located in the south of the main alpine range with submediterranean climate, which favors the cultivation of this warmth-demanding species. In general, records of lentil occur more frequently in the Iron Age as in the Bronze Age. The second axis separates the *Setaria italica* (foxtail millet) dominated site Siebeneich from the *Hordeum vulgare* (hulled barley) dominated sites Friaga, Ganglegg, Dürrnberg and Kundl (Fig. 4). Also, the type of deposits (thanatocoenoses) in Friaga, Dürrnberg and Kundl differ from the large, homogeneous samples of stored crops (closed assemblages, may be palaeobiocoenoses) of Ganglegg, Lantsch Bot da Loz, Scuol Munt Baselgia, Himmelreich, Siebeneich and Monte Loffa.

Table 5
Summary of 17 Iron Age archaeobotanical data (1, presence/0, absence) in the Eastern Alps

No	Site	Ho_vuG	Ho_vuNG	Se_ceG	Tr_naG	Tr_diG	Tr_moG	Tr_spG	Avena_G	Pa_miG	Se_itG	Le_cuS	Pi_saS	Vi_faS
1	Areal Ackermann/ Chur, CH	1	0	0	0	0	1	0	0	1	0	0	0	0
2	Bot da Loz/Lantsch, CH	1	0	0	0	1	0	1	1	0	0	0	0	1
3	Munt Baselgia/Scuol, CH	1	0	0	1	1	0	1	0	0	0	0	0	1
4	Friaga/Bartholomäberg, A	1	0	0	1	1	0	1	1	0	0	1	0	1
5	Himmelreich/Wattens, A	1	1	0	1	1	0	1	1	1	1	1	1	1
6	Stans/Schwaz, A	1	1	1	1	1	1	0	1	0	0	1	1	1
7	Kundl/Tirol, A	1	0	0	1	1	1	1	0	1	1	0	1	0
8	Dürrnberg/Hallein, A	1	1	0	1	1	0	1	0	1	1	1	1	1
9	Ganglegg/Schluderns, I	1	1	0	1	1	1	1	1	1	1	0	0	1
10	St. Walburg/Ulten, I	1	0	0	0	0	0	1	0	0	0	0	0	0
11	Sanzeno/Bozen, I	0	0	0	1	1	0	0	0	1	1	1	0	0
12	Siebeneich/Bozen, I	1	1	1	1	1	0	1	0	1	1	1	1	0
13	Trattengasse/Brixen, I	1	0	0	1	1	0	0	0	1	0	0	0	0
14	Stufels/Brixen, I	1	0	0	0	0	0	0	0	1	0	0	0	0
15	Villa Dirce/Brixen, I	1	0	0	1	0	0	0	0	0	0	0	1	0
16	Monte Loffa/Verona, I	1	0	0	1	1	1	0	0	0	0	1	0	1
17	Castelrotto/Verona, I	1	0	0	0	1	1	0	1	1	0	1	0	1
Constancy (%)		**94.1**	**29.4**	**11.8**	**64.7**	**76.5**	**35.3**	**52.9**	**35.3**	**58.8**	**35.3**	**47.1**	**35.3**	**52.9**

Avena _G, *Avena* sp. grains; 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; Tr_diG, *Triticum dicoccon* grains; Tr_moG, *Triticum monococcum* grains; Tr_naG, *Triticum aestivum* (incl. *compactum*)/*turgidum* grains; *Tr*_spG, *Triticum spelta* grains; Vi_faS, *Vicia faba* seeds. CH, Switzerland; A, Austria; I, Italy.

5. Discussion

Based on the results of the statistical analyses we can suggest that the pattern visible in the cluster dendrogram is caused primarily by methodological reasons such as sampling strategy (e.g. sample volumes and sample number), or the type of seed assemblages (e.g. closed or open assemblages). There are only a very few visible geographical patterns, and no patterns caused by geomorphology etc. arise. A reliable reconstruction of those depends on a data set collected using consistent/comparable methods. Up to now, in the Eastern Alps such a comparison has not really been possible, as our data set shows.

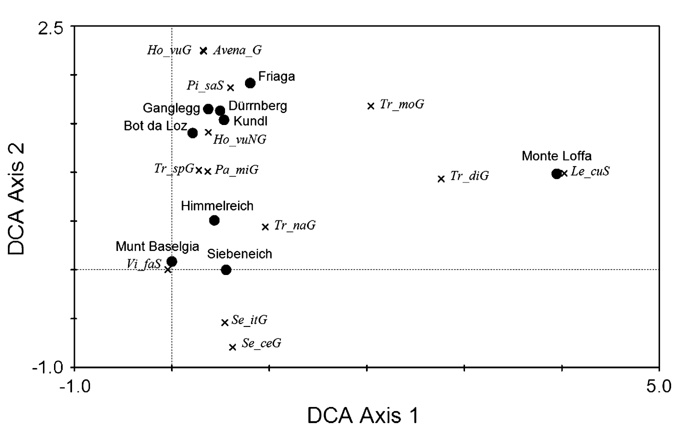

Fig. 4. DCA biplot showing quantitative archaeobotanical data (Table 2) nine excavation sites (circle, sample scores) and 13 taxa types (cross, species scores) from Eastern Alps. Avena _G, *Avena* sp. grains; Ho_vuG, *Hordeum vulgare* grains; Ho_vuNG, *Hordeum vulgare* var. *nudum* grains; Le_cuS, *Lens culinaris* seeds; Pa_miG, *Panicum miliaceum* grains; Pi_saS, *Pisum sativum* seeds; Tr_diG, *Triticum dicoccon* grains; Tr_moG, *Triticum monococcum* grains; Tr_naG, *Triticum aestivum* (incl. *compactum*)/*turgidum* grains; *Tr*_spG, *Triticum spelta* grains; Vi_faS, *Vicia faba* seeds.

However, based on simpler methods of comparison such as ubiquity and the presence of stores, a first survey of the state of the art concerning the Iron Age economy in the Eastern Alps is possible. The most common cereal is *Hordeum vulgare* (hulled barley) and in addition, the stores in Ganglegg (Italy) and Bot da Loz (Switzerland) indicate its importance as a main crop in the Eastern Alps during the Iron Age (Table 2). The reason perhaps is the wide ecological amplitude of this crop. Recent observations of Jacomet et al. [18] as well as ethnographic sources establish that the cultivation of barley reaches altitudes up to 2000 m in the south of Switzerland (Valais, near Zermatt). In contrast, there are no stores of hulled wheat such as *Triticum dicoccon* (emmer) and *T. spelta* (spelt) in the Iron Age data set of the Eastern Alps. Nevertheless, the consistent occurrence of these cereals, partly also in larger amounts, and the presence of chaff at the excavation sites Scuol Munt Baselgia (Switzerland) and Ganglegg (Italy) accentuates the cultivation of these species for bread production ([18]; this study). High amounts of free-threshing wheat (*Triticum aestivum* (incl. *compactum*)/*turgidum*) are also absent in the archaeobotanical data; however, the grains are found in almost all of the settlements (Table 2). The significance of naked wheat as crop is probably secondary, but cannot be judged definitively. *Secale cereale* (rye) is absent in Bronze Age excavation sites [18,45] and first appears in very minor quantities in some Iron Age sites; it has therefore most probably considered as a weed. To sum up, we have to wait for further archaeobotanical studies for being able to reveal more information about the role of the cereals, especially naked wheat and rye in the Eastern Alps during prehistoric times.

Evidence of millet stores at Himmelreich, Siebeneich and Ganglegg confirm the importance of millets as main crops in the Iron Age. *Panicum miliaceum* (broomcorn millet) and *Setaria italica* (foxtail millet) are represented in high amounts in the samples of Himmelreich and Siebeneich. The lack of millets in the samples of Canton Grisons (Graubünden) is most probably caused by methodological reasons [18]. In Brig/Gamsen (Canton Valais, Switzerland), representing an inner alpine dry-valley like the Vinschgau, high amounts of *Panicum miliaceum* (broomcorn millet) were found in Iron Age samples and prove also the growth of this crop in this region in the western Alps [28]. Altogether, these results suggest that *Panicum miliaceum* (broomcorn millet) was an important cultivated plant in the Alps during the Iron Age.

Stores of *Lens culinaris* (lentil) were found only in Monte Loffa (Italy) and point to the local cultivation of this plant only south of the main Alpine range in the area of the Eastern Alps (Fig. 4). In the western alpine valleys, *Lens* was found in larger amounts in Brig-Glis/Waldmatte (= Gamsen) in the Valais (Switzerland) [9], there accompanied by large amounts of *Vicia ervilia* (see the compilation of the data in Jacomet [19]). Outside of the Alps, lentil is commonly found in Iron Age settlements, both southwards and northwards of the Alps.

Besides lentil, high amounts of *Vicia faba* (bean) are represented in the samples of Scuol Munt Baselgia (Switzerland) and also in Lantsch Bot da Loz (Switzerland) where stores were excavated. In the other sites, broad bean is represented in smaller amounts. Overall, it shows a rather regular presence (Table 2). The role of broad bean in the Iron Age compared with the Bronze Age is far from being understood. In the Swiss sites in the Canton of Grisons, *Vicia faba* seems to be still very important during the Iron Age [18]. In contrast, the excavation site Ganglegg reveals the opposite trend can be traced: *Vicia faba* (bean) becomes less important in the Iron Age. However, this may be due to the fact that beans were not stored at the moment of the fire which destroyed the Ganglegg settlement in the late Iron Age.

Besides broad bean, *Pisum sativum* played a role as a pulse, occurring rather regularly in some of the settlements.

6. Conclusion

The new archaeobotanical data, in comparison with the existing results from Iron Ages sites in the Eastern Alps, allow a more representative picture of the subsistence strategies of this period. However, there are still a lot of gaps in the record. The objective of this study was to conduct a comparative analysis of the heterogeneous data sets to determine whether any pattern of crop distribution in the Eastern Alps were present. Such patterns might include the crop diversity of the sites that could be used to delineate growing preferences or differences in the use of cultivated plants between sites located southwards and northwards, respectively. This hypothesis is rejected from the perspective of the statistical analysis. The statistical evaluation of the data set rather reflects methodological patterns than geographical and ecological ones. The cluster groups are caused on the one hand by the fact that sampling and evaluation methods, and on the other hand some of the samples represent burnt stores whereas others represent thanatocoenoses sensu Willerding [58]. To sum up, low sample numbers have obviously a negative effect on the taxonomic diversity and reflect primarily the distribution pattern of crops in the Eastern Alps. Therefore, rough data are not comparable. In addition, the overestimation of taxa that are present in low numbers seems to be a problem in the classification. Thus, a combination of various statistical methods gives more information about the subsistence strategies of prehistoric settlers.

Apart from the methodical problems the present study shows that during the Iron Age a large variety of crops was cultivated in the Eastern Alps. Among the cereals, stores of *Hordeum vulgare* and *Panicum miliaceum* confirm their importance as staple food. Glume wheats like spelt and emmer were the most important “bread crops”. The regular occurrence of free-threshing wheat such as *Triticum aestivum* (incl. *compactum*/*turgidum*) and *Setaria italica* enlarge the agricultural system in the Iron Age. For the first time, rye appears, but in only a few settlements and in very low amounts; therefore it has to be considered as weed.

The diet of the prehistoric settlers was supplemented by protein-rich seeds of *Vicia faba*, *Pisum sativum* and *Lens culinaris*. Within the group of pulses a geographical distribution pattern becomes visible, but in general, for all cultivated plants it seems necessary to collect new archaeobotanical data from more Iron Age sites in the Eastern Alps, to gain a more representative picture of subsistence strategies and to enable the reconstruction of eventually existing geographical patterns.

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