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The barley (*Hordeum vulgare* L.) of Sardinia, Italy

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Abstract

Since ancient times, barley has been an important food resource for the people of Sardinia. The oldest traces of its cultivation are from the mid-Neolithic (fourth millennium B.C.). Archaeological, historical and anthropological aspects of barley cultivated in Sardinia are discussed in this paper. We describe the traditional process for making barley bread (*orgiathu*) in Sardinia, where a special starter called *ghimisone* was prepared. Today, barley is cultivated only as animal feed, with two uses, grain yield and grazing. Many farmers prefer to grow local populations belonging to landrace locally known as "*S' orgiu sardu*". Local Sardinian populations of barley evolved in diverse environments, being cultivated from sea-level up to 1000 m elevation, on various soil types at different intensities of abiotic stresses, and with climates and environments associated with various agricultural practices, depending both on production strategies and climatic conditions. These barley materials are thought to be valuable genetic and cultural inheritance which must be preserved and used for both productive and research purposes.

Introduction

There is an increasing interest in both *in situ* and *ex situ* conservation of crop biodiversity (Brush, 1995). Traditionally *ex situ* conservation has received more attention than *in situ* conservation, particularly in the case of landraces. *In situ* conservation has the advantage of preserving evolutionary processes and generating continuously new gene combinations under both natural and human selection. The identification of areas where little genetic erosion has occurred and limited introduction of modern varieties has taken place is essential to plan and implement *in situ* conservation.

The objective of this paper is to document the history of barley in Sardinia, Italy, where barley evolved in a multitude of microenvironments and remained relatively isolated, and to describe the agronomic and the climatic factors which have affected the evolution of the crop in this area.

Historical background

Since ancient times, barley (*Hordeum vulgare* L.) has been an important food resource for Sardinian people (Acerbo, 1934).

The earliest traces of barley cultivation in Sardinia are from the middle Neolithic period (fourth millennium B.C.) (Loria & Trump, 1978; Sadori et al., 1989). The crop was probably introduced to the island more than once since that time, due to the frequent trading in the Mediterranean. The cultivation of barley in Sardinia, where the wild progenitor of cultivated barley – *Hordeum vulgare* L. ssp. *spontaneum* (C. Koch) Thell. – is absent, most probably originated from introduced cultivated forms.

Other archaeological findings (such as those at Villanovaforru, south Sardinia) belong to between the Nuragic period and the first Iron Age (Badas, 1987). Recently large amounts of cereal (barley and wheat),

dating from the same period, came to light during excavations by Fadda & Madau (Fadda, 1991) at the Nurdole nuraghe (Orani, Central Sardinia). The cereals were stored in typical earthenware tanks called *Dolia* or in simple tanks made of wood and cork. The temple represented the center of the religious, political and economical power where, as in the Middle East, cereals and various manufactured goods were stored. The work of Fadda (1991) indicates the occurrence of frequent exchanges between Sardinian and both Aegean and Middle Eastern peoples (Fadda, 1991).

These findings support the hypothesis of Rowland (1989), whereby the nuragic civilization was based mostly on communities of *contadini guerrieri* (warriors-farmers) with barley being the most important crop at the time.

Barley continued to be an important crop in later centuries. It was the cereal used for internal consumption, while wheat was generally exported. In 1839, de La Marmora wrote: "In Sardinia barley is not less important than wheat, since it provides food to the people living in the mountain".

The English historian Day (1984) demonstrated that under Pisan and Genoese domination (14th century), the people of Sardinia had to be reduced to eating barley alone, while wheat – the classic colonial commodity – was shipped to cities and international markets. According to Day, five-sixths of the barley production and only a sixth of the wheat production were for local consumption. The rest was exported, forcing the Sards to use poor cereals like barley as food.

In the 17th century, the increased demand for wheat caused the Spanish government to adopt a new agricultural policy. More wheat was left for internal consumption (Anatra, 1984), leading to progressive marginalization of barley as human food among the people of the lowlands. However, until the end of that century, barley was certainly used in various ways in the diet of Sards. Barley was eaten as a soup, and especially as bread produced with "pure barley flour, or mixed with one-third, one-half or two-thirds of wheat flour" (Cossu, 1780). The barley-bread preparation in the seventeenth and eighteenth centuries is well documented (Marrosu, 1991) and continued until quite recently (Murru Corriga, 1991, 1992).

In the last two centuries the consumption of barley bread gradually decreased in the cereal-growing areas on the plains. It continued intermittently in the hilly areas, where, in periods of food scarcity of family indigence, farmers made bread from barley and even from maize. Barley bread had been widely eaten and was still systematically prepared in the villages of the mountainous areas of the interior. In Barbagia, bread-making with barley was common up to the 1950s, together with the preparation of barley polents and barley soups.

In the economic regime of alimentary self-sufficiency typical of pastoral mountain communities, barley alone, which in these areas yields more than wheat, could satisfy the local cereal requirements. The idea was to protect their independence from the island's grain market and from price fluctuations caused by external speculation.

Barley breads

Up to the first half of the 20th century, several kinds of barley bread had been made in Sardinia: *orgiathu*, a flat, large biscuit made from bran or flour, or from a mixture of the two; *pistoccu*, another type of flat bread, but smaller and thicker; *kivargiu*, made with wholemeal; and *tippe*, also of wholemeal. *Orgiathu* being of the *carasau* (biscuit) type, was the barley bread of transhumant shepherds since it could be kept for several months. It was baked in thin, flat sheets in different shapes. The baking of *carasau*, whether of wheat or barley, was directly linked to the transhumance of shepherds of the Barbagia region, to such an extent that certain differences in the making of *orgiathu* found in Barbagia were dependent on the length of the transhumance cycle (Murru Corriga, 1991).

The anthropologist of the University of Cagliari, Murru Corriga (1992), documented and reconstructed the entire *orgiathu* making process with help from old ladies of Fonni (Central Sardinia). The preparation of *ghimisone*, a special starter probably containing yeast and other dough-raising microorganisms, attracted particular interest. The *ghimisone* was prepared by kneading the barley flour, baking it in a warm oven which was pre-heated and then extinguished for a 24-hour period. The *ghimisone* was kept in a asphodel chest (*corbula*) covered by wool tissues, and, after four to five days, cooled slowly by taking out one by one the tissues. At the end of this process, the *ghimisone* was similar to a *panettone* (the Italian Christmas cake), with a crusted surface and a brownish, sweetly, creamy, chocolate core. The *ghimisone* was melted with warm water with which all the amount of barley flour was kneaded. The dough was gently worked, left to leaven and then baked twice.

The *ghimisone* preparation shows many similarities with the first steps of beer preparation known in ancient Egypt, and still practised by Ethiopian and Eritrean people who call it *Tellà* or *Suwa* (Ricotti, 1991). The first step of *Suwa* processing is also the preparation of a soft cooked bread – with the difference that pre-germinated kernels are used. In Eritrea there is a type of bread called *Ambascià*, prepared with the malt used for *Suwa* processing. The preparation of *ghimisone* could also parallel other cold beer processes, some of which might have been known in ancient Sardinia. This hypothesis is supported by the evidence of repeated contacts of Sards with other Mediterranean peoples who made much use of beer.

If the hypothesis is correct, it is not clear why the kernel pre-germination has been lost in the preparation of *ghimisone*. One possibility is that the old ladies of Fonni had only a vague memory of it. Alternatively, this practice could have been lost recently. A third possibility is that for the *ghimisone* preparation the pre-germination is not so important. In any case, the sweet taste of *ghimisone* suggests the presence of a hydrolysis process, with the production of simple sugars favoring the fermentation.

Barley bread, once a part of the diet of most of the inhabitants ceased to be produced in the 1950s, together with the fading out of nomadism and transhumance. Mechanized transhumance and increased prosperity finally brought to an end the need for alimentary self-sufficiency of Barbagia's sheep-raising communities.

Barley today

From the end of the Second World War the cultivation of barley in Sardinia declined sharply, due to the decrease in its consumption as food. However, barley is still the second most widely-cultivated cereal in Sardinia, after wheat, producing green fodder, grain and straw, all used in animal feed. In the last decade (1983–1992) the average area cultivated with barley has been about 29,500 ha with an average grain yield of 1.7 t ha^{-1}.

In contrast with many European countries, barley is cultivated in Sardinia not only for grain and straw but, in many cases, for a second purpose: the production of green fodder in winter for direct sheep grazing. In some cases, depending on the climate, the availability of green fodder for sheep in winter is far more important than the production of grain in summer. In poor rainfall years, or when planting is delayed, the crop is not harvested, but left standing for direct grazing.

This double use is a deliberate strategy which gives the farmer a wide range of choices, depending on rainfall and temperature. This is a flexible strategy well suited to Mediterranean environments where wide fluctuations in yield are not due to a single abiotic stress, but, rather, to a widely varied and unpredictable combinations of climatic factors (Connor & Loomis, 1989; Ceccarelli et al., 1991). This probably explains why many Sardinian farmers prefer to grow local populations that only a few decades ago represented the only source of cultivated barley (Favilli, 1955). Many farmers still produce the seeds to be used on the following cropping season. Cultivation of modern varieties in Sardinia is limited.

The climate and vegetation of Sardinia

The climate of Sardinia is typically Mediterranean, characterized by two different seasons: a hot and dry season, and a cold and humid winter season. The intensity and duration of the hot and dry season increase with the decrease of altitude and latitude. Sardinian environments are characterized by diverse climatic conditions, as shown by the classification of Arrigoni (1968) listed below and shown in Figure 1.

Climax of prostrate bush of mountain and Mediterranean mountain slopes

Climate: Typically mountain, cold, with winter (days with average temperature $\leq 10°C$) longer than 6–7 months. Minimum average temperatures of the coldest months are below $-3°C$. Snowfall is frequent, but periods of snow cover are short, except in the highest tops of Gennargentu. Drought periods can last up to two months, but are mitigated by fog and hidden rainfall. Strong winds prevail all year, particularly on the tops of the western-northern slopes.

Climax of Quercus ilex *L. forest*

Cold and humid horizon of mountain forest of Q. ilex *and* Q. pubescens

Climate: Semicontinental, with humid winter and high water-surplus. Cold period is longer than 4 months, with minimum temperature in the coldest month below $-3°C$; the average minimum temperature of the year is about 4°C–5°C. The length of the dry period in summer

● Climax of prostrate bush of mountain and Mediterranean mountain steep
● Climax of *Quercus ilex* L. forest – horizon a
● Climax of *Quercus ilex* L. forest – horizon b
● Climax termoxerophile of sclerophyllous mixed forest and coastal wood lands – horizon a
○ Climax termoxerophile of sclerophyllous mixed forest and coastal wood lands – horizon b

Fig. 1. Phytoclimatic map of Sardinia (from Arrigoni, 1968)

is less than three months with moderate water-deficit; average summer temperatures are below 24°C.

Mesophile horizon of Q. ilex *forest*
Climate: Typically characterized by two seasons with moderate cold in winter, subhumid with an excess of water, and with a hot and dry summer. The cold period is about 2–4 months long, with average minimum temperatures higher than 4°C. The dry period is longer than three months, with average temperature of the hottest month generally higher than 23–24°C and with a maximum temperature in the same month around or higher than 30°C.

Climax termoxerophile of mixed forest of sclerophyllous and coastal woodlands

Mixed forest of sclerophyllous evergreen horizon
Climate: Semiarid, with moderate winter water-surplus and high water-deficit during the summer. The arid period is 3.5–4.5 months long, with high maximum temperatures (average of the annual maximum temperature) of about 36–40°C. The cold period is seldom longer than two months with average minimum temperatures of the coldest month of about 3–4°C, and the average of the annual minimum temperatures generally higher than −2°C.

Coastal woodland horizon
Climate: Semiarid, with hot summer and high water-deficit but with maximum temperatures mitigated by the buffer effect of the sea. The cold period is almost absent, with consequent reduced presence of species with winter dormancy.

Barley is grown in almost every environment of Sardinia – from the semicontinental (such as Fonni and San Nicollò Gerrei) to the semiarid ones. In Sardinia the prevailing winds are from the west (except in summer), so that on the west coast the wind is rich with sea-water causing air-borne salt stress (Papa et al., 1994). The salty spray and the sea-water infiltration are two of the most important phenomena connected to the genesis of salty soils. These soils are found along the coastline, particularly in the south and west (Szabolcs, 1989). Moreover, there is a wide variation of soil types. From the geological point of view, Sardinia represents a very peculiar case because rocks of all eras (except the archeozoic) are represented (Pietracaprina, 1980).

The Sardinian barley collection

The widespread presence of locally-adapted germplasm in a very diverse set of environments led the Istituto di Agronomia of Sassari University to make a collec-

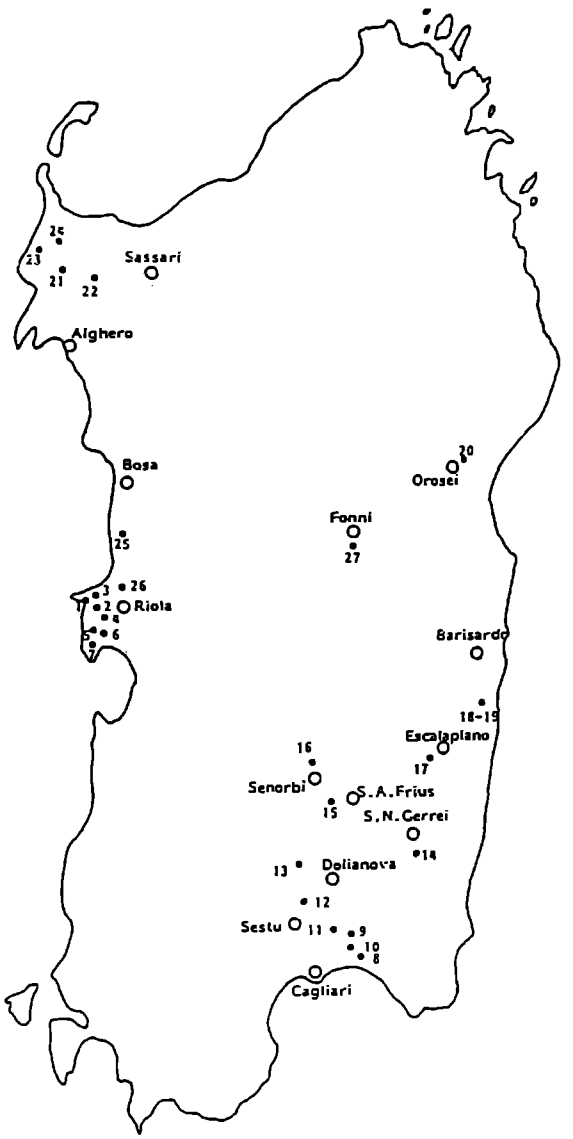

Fig. 2. Map of the collection sites ● and the meterological stations ○

tion of barley local populations. During the summer of 1990, 27 barley populations were collected in Sardinia (Figure 2). The collection sites are listed in Tables 1 and 2, together with altitude, latitude, type of soils, cropping system, and the name of the nearest meteorlogical station. The altitude, latitudes, and average rainfall of 30-year of the meterological stations are given in Table 3.

The annual rainfall of the meterological stations varies from 431 mm (Cagliari) to 871 mm (Fonni). They are only indicative values, since comparison of Tables 1 and 3 and Figure 1 shows that the meterological stations often differ from the collection sites in altitude and distance from the sea. These can dramatically affect the environmental characterstics. A better description can be had by comparing the map of the collection sites (Figure 2) with the phytoclimatic characterization (Figure 1). The data relative to altitude, latitude and soil are also useful. The altitude changes from the sea-level of the Sinis sites to 600 and 1000 m.a.s.l. at the sites of S.N.Gerrei and Fonni respectively. The latitude varies from 47°47′70″ (Nurra 4) and 39°15′00″ (Quartu 1). Nine different soil types were represented in the collection sites.

The samples were collected from farms which had produced their own seed for at least 20 years. In each field, 100 heads were randomly taken at maturity. The seeds from each spike were sown as individual rows during the 1990/91 season in the experiment farm of the Istituto di Agronomia of Sassari University, at Ottava (Sassari). Whenever possible, bulk samples of the previous harvest were also collected. In this case several sub-samples were initially collected (from different heaps, from different sacks and from different parts of them). All sub-samples were bulked, mixed, and other smaller sub-samples were taken to be part of the final sample. The bulk sampling was only possible for seven populations: Nurra 2, Senorbì, Sestu, Fonni, San Niccolò Gerrei, S. Andrea Frius and Cuglieri, and was the only type of sampling which could be done at Fonni. Also, in this case, the materials were sown as bulk populations in 1991/92.

Much information was recorded about the farming system.

Twelve populations, all of them collected from the Sinis and Quartu areas, where salinity and drought are the most important limiting factors, were utilized only for grain production. In these cases the nitrogen fertilization varies from 30 to 40 kg/ha of N, which is usually distributed at sowing. With a few exceptions, phosphatic fertlization is practiced, although the amount is highly variable. Chemical control of weeds is practiced in several farms. Sowing date varies with annual rainfall and occurs between the end of November and the end of January.

The agronomic practices in those farms where the winter grazing is important are more varied and diversified. Fertilization at sowing is no different from the other farms, although in many cases nitrogen also is applied after the grazing period. Chemical weed control is not practiced.

Table 1. Sites of collection and their description

Location	Collection site	Cropping System[a]	Latitude	Elevation	Soil type[b]	Nearest meterological station
Sinis	1 Sinis north 1	G	40° 01′ 20″	4	3	Riola
	2 Sinis north 2	G	40° 01′ 00″	4	8	
	3 Sinis north 3	G	40° 02′ 50″	4	8	
	4 Sinis north 4	G	39° 59′ 00″	10	3	
	5 Sinis south 1	G	39° 53′ 00″	40	3	
	6 Sinis south 2	G	39° 57′ 20″	40	4	
	7 Sinis south 3	G	39° 58′ 00″	20	3	
Quartu	8 Quartu 1	G	39° 15′ 00″	35	6	Cagliari
	9 Quartu 2	G	39° 17′ 00″	80	6	
	10 Quartu 3	G	39° 16′ 00″	55	6	
	11 Quartu 4	G	39° 22′ 00″	95	6	
Sestu	12 Sestu	G	39° 22′ 00″	105	6	Sestu
Ussana	13 Ussana	F/G	39° 25′ 00″	150	7	Dolianova
S.N.Gerrei	14 S.N. Gerrei	F/G	39° 28′ 00″	600	1	S.N. Gerrei
S.N.Frius	15 S.N. Fruis	F/G	39° 28′ 50″	300	5	S.A. Fruis
Senorbi	16 Senorbi	F/G	39° 32′ 50″	200	6	Senorbi
Escalaplano	17 Esclaplano	F/G	39° 38′ 00″	300	1	Escalaplano
Cardedu	18 Cardedu 1	F/G	39° 17′ 00″	10	7	Barisardo
	19 Cardedu 2	F/G	39° 46′ 50″	10	7	
Orosei	20 Orosei	F/G	40° 15′ 50″	240	2	Orosei
	21 Nurra 1	F/G	40° 43′ 80″	150	1	Sassari
Nurra	22 Nurra 2	F/G	40° 43′ 50″	85	7	
	23 Nurra 3	F/G	40° 47′ 40″	170	1	
	24 Nurra 4	F/G	40° 47′ 70″	100	7	
Cuglieri	25 Cuglieri 1	F/G	40° 12′ 00″	110	3	Cuglieri
	26 Cuglieri 2	F/G	40° 04′ 00″	80	2	
Fonni	27 Fonni	F/G	40° 07′ 00″	1000	9	Fonni

[a]G = only grain, F/G = green forage and grain production
[b]Description of soil types is given in Table 2

Table 2. Soil types of the collection sites according to the USDA soil taxonomy (USDA, 1988; Aru et al., 1989)

Soil type	Description
1	typic dystric and lythic xerorthens, typic Dystric and lithic Xerothens
2	rock autcrop, lythic xerothens
3	rock autcrop, lythic and typic xerorthens, lythic and typic rhodoxeralfs
4	typic and lythic xerorthens, typic and lithic xerochrepts, typic rhodoxeralfs
5	lythic xerorthens, rock autcrop
6	typic and veric xerochrepts, calcixerollic xeorchrepts, typic xerorthens
7	typic, acquic and ultic palexeralfs
8	lithic calcixerolls
9	typic dystric and lithic xerochrepts typic dysric and lythic xerothens

Table 3. Altitude, latitude and average rainfall over 30 years: meteorlogical stations nearest to the collection sites in Table 1

Meteorological station	Latitude	Elevation (m a.s.l.)	Annual rainfall (mm)	Minimum and maximum annual rainfall over thirty years (mm)
Cagliari	39° 12′	7	431	231–695
Sestu	39° 18′	42	526	327–725
Dolianova	39° 22′	191	562	349–785
S.A. Fruis	39° 28′	279	606	373–894
S.N. Gerrei	39° 29′	365	810	489–1126
Senorbi	39° 31′	186	560	348–762
Bari Sardo	39° 51′	50	675	314–1226
Riola	39° 59′	9	685	336–1071
Fonni	40° 07′	992	871	619–1435
Cuglieri	40° 11′	479	809	596–1099
Orosei	40° 21′	19	519	190–1095
Sassari	40° 43′	224	596	394–961
Escalaplano	39° 38′	338	672	289–998

Some farmers referred to an old practice in the Nuoro area (in the interior of Sardinia) where the fields were fenced and sheep kept in them for one year, then the field was ploughed and planted for seed production. Because of the availability of mineral fertilizers this practice was abandoned. However, seed production is often done in specialized fields where grazing is either not practiced or stopped at an early date. Generally these fields are planted late because of seasonal events. In any case, no fixed schemes are used by farmers, and the specific practices depend on the need for green forage in winter and on the season. In this area the sowing date is usually between October and March. When grazing pressure is strong oversowing is practiced.

Grain production is subordinated to green forage production to the point that, as already indicated, farmers may not harvest the field but let the animals graze it directly.

Some farmers who grow barley do not produce seed on-farm, but buy the seed of local barley sold as forage on the market (at seed stores or from other farmers). This unofficial seed market is supported by the production of the Sinis area (central western Sardinia), which farmers acknowledge as the center of Sardinian barley. In the Cagliari area one farmer, from whom we have collected the seed, usually sells his production as seed, and regularly selects and treats the seed.

All the farmers are able to recognize the Sardinian barley by the general traits of the spike, the size of the kernel, the height of the plant and especially by the presence of strong awns, the proximal portion of which is solidly connected to the lemma even after threshing.

The farmers are not able to make other morphological distinctions and to make more precise classification within Sardinian barley, although they are aware that some areas are more important than others for barley production.

The evaluation of pure lines extracted from Sardinian local populations has shown, as expected, large variation for many characters such as days to heading, plant height, kernel weight, grain yield, biological yield and harvest index (Papa, 1993). At least thirty different patterns were found in the electrophoretic analysis of hordeins, all different from those of the modern barley varieties most commonly grown in Italy (Papa, 1993). In addition different responses to salinity were found between lines derived from a population collected in a salt-stressed area of the Sinis peninsula (Papa et al., 1991).

The cultivation of local populations is very important in Sardinia. It is linked to the two-fold utilization (grain yield and grazing) and to the presence of stress conditions. Following the definition of Harlan (1975a, 1975b), which credits farmers with the ability to discriminate between landraces, we can recognize

in Sardinia only one landrace, called by farmers *S' orgiu sardu*. All the local populations collected therefore belong to this landrace.

Conclusion

Sardinian barley local populations have evolved in variable and diversified environments. They have been cultivated from sea-level up to an altitude of one thousand meters, and on widely different soil types, with climates and environments associated with varied and diversified agricultural practices according to both production and strategies and climatic conditions. Some areas are also subject to special phenomena, such as in the coastal areas where the salty wind transports sea water in suspension, thus inducing an air-borne salt stress.

Local barley populations in Sardinia have therefore evolved within a range of widely varying agroecosystems. Each one is different, but at the same time reproductively isolated from the others and connected by exchanges and contacts within a relatively small (about 24,000 km^2) and geographically isolated region.

Since 1987, a research project has been under way with the objective of collecting and studying Sardinian barley germplasm. The most interesting of the findings emerging from the project is the wide genetic variability present within these populations. This has been confirmed by a series of studies on their morphological, agronomic and physiological features (Attene & Veronesi, 1991; Papa, 1993, 1994; Papa et al., 1991).

The material collected, and the entire germplasm in general, represents a valuable genetic inheritance that must not only be protected from extinction by encouraging its conservation, but must also be used both for direct productive purposes and for research. Also, this germplasm represents a cultural inheritance consisting of traditional ways of transforming and using it, of the impact that the evolution of distribution of cultivated species have had on the environment and, more generally, of the history of the human populations that have cultivated them.

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