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Some considerations about diversity, distribution and problems of *Quercus* L. in Sardinia.

Abstract

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The paper describes and critically analyses the distribution in Sardinia of the species of the genus *Quercus* L., their main morphological, biological and ecological traits. Particular emphasis is addressed toward the *Q. pubescens* Willd. s.l. complex and toward the evergreen *Q. coccifera* L. s.l., aiming to highlight the great variability of all traits, as well known from the literature concerning other oak populations of diverse geographical regions.

Introduction

The morphological variability in *Quercus* L. well known due to the fact that many Authors dealt with this genus in the Mediterranean region, remarking the difficulties involved in the taxonomic treatment (Camus 1936-39; Schwartz 1993; Maire 1961; Burger 1975; Hedge & Yaltrik 1982; Amaral Franco 1990; Greuter & al. 1986; Bussotti & Grossoni 1997). Very different view-points are found also in recent Italian literature (Moggi 1972; Moggi & Paoli 1972; Milletti & al. 1982; Filipello & Vittadini 1975, 1982; Pignatti 1982; Ronsisvalle & al. 1984; Camarda & Valsecchi 1983; Blue 1988; Gellini & al. 1992; Di Noto & al. 1995; Brullo & al. 1998; Bersacchi & al. 1997; Camarda 1987, 1998; Grossoni & al. 1998; Brullo & al. 1999) concerning consistency in the diagnostic value to be attributed to each single character and, consequently, to the rank of the relevant entities.

This paper aims to give a contribution to the knowledge of the genus *Quercus*, dealing with the island of Sardinia, *i.e.* a geographically limited area, taking into account a set of morphological characters of possible relevance in the species identification in the study area.

The speculative starting point is that a species should be a reproductive unit and should possess a clearly distinct set of morphological and ecological traits, according to the Cronquist definition (1988). Dealing with *Quercus*, these three key points are always put up for debate, due to the difficulties in tracing out definite borders at individual, species and population level (Burger 1975), despite the great variability of the genus.

Oak species of Sardinia

According to the main literature studies dealing with Sardinian evergreen oaks, the following taxonomic framework can be drawn:

Author	Entity
Different Authors	<i>Quercus ilex</i> L.
Different Authors	<i>Quercus suber</i> L.
Different Authors	<i>Quercus coccifera</i> L.
Mossa, Giannini & al.	<i>Quercus calliprinos</i> Webb

The taxonomic framework for deciduous oaks is far more complex:

Moris 1858-59	<i>Quercus robur</i> L. var. <i>sessiliflora</i> (Salisb.) <i>sensu</i> Moris <i>Q. robur</i> L. var. <i>pubescens</i> (Willd.) <i>sensu</i> Moris
Fiori 1923-27	<i>Q. robur</i> var. <i>lanuginosa</i> (Lam.) Fiori (= <i>Q. pubescens</i> Willd.)
Schwartz 1994	<i>Q. pubescens</i> Willd. <i>Q. virgiliana</i> (Ten.) Ten. <i>Q. congesta</i> C. Presl
Pignatti 1982	<i>Q. congesta</i> C. Presl <i>Q. pubescens</i> Willd. <i>Q. virgiliana</i> (Ten.) Ten.
Arrigoni 1983	<i>Q. pubescens</i> Willd. (?) <i>Q. congesta</i> C. Presl.
Camarda & Valsecchi 1983	<i>Q. pubescens</i> Willd. <i>Q. congesta</i> C. Presl
Mossa & al. 1998	<i>Quercus congesta</i> C. Presl <i>Quercus amplifolia</i> Guss. <i>Quercus dalechampii</i> Ten. <i>Quercus virgiliana</i> (Ten.) Ten.

The last Authors described also a new species, *Quercus ichnusae*, taking mainly into account acorn size and bark features, and denying the occurrence of *Q. pubescens* Willd in Sardinia.

Both a paper by Camarda (1998) concerning an oak population located at *Florinas* (North-West Sardinia) and similar researches on oak populations carried out in other Italian localities (e.g. Di Noto & al. 1995; Dupouey, Bandeau 1993) bring into clear evidence that within a single population, but also within a single individual, the variability is so high that single specimens might be determined as different oak species. This high variability has commonly been observed in all the Sardinian populations recorded.

Morphological variability concerns the general leaf shape, and all main traits such as blade size, petiole size, hairiness, stomata density, number of leaf veins, leaf lobes, size and shape of cupule; branching pattern and architecture, bark, number of female flowers, number of flower components, i.e. tepals, styles, stamens. In a single branch, the basal leaves are obovate and round lobed, while apical leaves are lanceolate and acute lobed.

At gene level a high diversity is found in the Sardinian oak populations, as highlighted

by Fineschi & al. (2002). Interesting results may be expected on the basis of the great morphological variability and wide ecological adaptability commonly observed in the field.

The matter is still being debated among the specialists, therefore the present paper aims at bringing a contribution to the discussion on the basis of data collected in Sardinia.

Discussion

Quercus ilex L.

It is the most common oak occurring in Sardinia. It is found from the sea level to 1,500 m a.s.l. on every parent material and soil, and this wide distribution is the result of its wide ecological adaptability. It forms both monospecific and mixed woods.

Holm oak leaves are very variable in shape and size, from mostly sessile to bearing a 20-25 mm petiole; leaf blade is always hairy, with starry hairs on the lower face, and ranging from round-shaped to elliptic, ovate, ovate-lanceolate. Leaf margin can be linear or moderately spiny, mainly as a consequence of grazing. There are also individuals with chestnut-like leaves, i.e. 10-12 cm long, bearing evident and awl-shaped secondary leaf veins.

Cupule are very variable in shape and size. Scales are always appressed, not upright, linear, lanceolate, triangular, usually greyish or, occasionally, reddish in their upper part. Cupule is frequently less than one third of acorn length, but sporadically it may be higher than one half of acorn length within the same population. At *Sette Funtani*, near Sassari, I collected samples from a plant bearing cupule enclosing from three-fourth to four-fifth of the acorn. Nevertheless, variability is high depending also on the seasonal climatic trend and acorns may show different size and shape from year to year.

Flowering occurs from December to the first decade of June, taking place following a scalar pattern, with differences related to altitude. A similar phenological pattern is also found in individuals of a single population monitored at *Sette Funtani*, where some plants start flowering in December, other in June, with many intermediate events. This scalar phenology at *Sette Funtani* takes place under consistent locality conditions concerning substrate, geomorphology and climate. Furthermore, in the same locality, one individual shows a continuous flowering pattern from the end of September to June, i.e. for a time interval of six months. In the same population I have observed two individuals bearing hermaphrodite flowers, the former with winter flowering and the latter with late-spring flowering. Hermaphrodite flowers are normally very rare, and this is the first record for the island of Sardinia.

The great variability of *Q. ilex* in the island is in good accordance with the great general variability of *Quercus*, even if it has not led to distinguishing new species or varieties, as occurred in other species of the genus.

Quercus suber L.

Cork oak is a thermo-mesophilous species. In Sardinia it finds its optimal environmental requirements on soils derived by siliceous rocks, between 400 and 850 m a.s.l. It dislikes limestone substrates, although it occasionally occurs on limited limestone areas in the Sardinian regions of *Sassarese* and *Sarcidano* as scattered plants or small patchy woods.

Q. suber is a more variable species than *Q. ilex*, but its biology seems to be more complex owing to the higher presence of individuals with biannual acorn production. Winter flowering may occasionally occur, as a consequence of the climatic trend.

The high economic interest of cork production led to a careful screening of species biodiversity. So far many different *formae* has been described in Sardinia that are based on differences in the scales of the cupule. There is not a geographical pattern in the distribution of these forms and therefore any hindrance to inter-crossing and gene flux.

The great variability of cork quality and features has not yet been correlated with the described forms or with the locality ecological conditions.

***Quercus coccifera* L.**

Plinio reported the presence of *Quercus coccifera* in Sardinia. So far, it is found only in the south-western part of the island. Taking into account its past use for the production of a red dye, it is possible to suppose, although difficult to demonstrate, that it might be introduced by the Phoenicians or the Romans. As a matter of fact, it mainly occurs in the coastal areas, on sandy dunes, near archaeological sites. Its presence in inner sites is very rare, and it is totally absent from limestone areas, which is the preferred habitat in other regions of its range.

Quercus coccifera, published by Linneo according to samples collected in *Gallia australis* (Provence, France), is a highly variable species. The variability occurs in all the traits, i.e. leaves, cupules, scales, acorns, flowering pattern, as found in other evergreen oaks.

Quercus coccifera L. s.l. has a circum-Mediterranean range. It has been divided into many entities, ranked as species, subspecies or varieties and forms. Among all the others, *Quercus calliprinos* Webb, according to Zohary (1966), occurs in the Eastern part of the Mediterranean. It must be remarked that *Quercus calliprinos* has been described by Webb in *Iter Hispanicum*, on the diagnostic trait of young branch hairiness, which lasts during the successive second year, while, on the contrary, star-shaped hairs are absent or scarce in *Q. coccifera*. As a matter of fact, within samples collected in Provence (FI!) it is possible to observe individuals with a different hairiness, therefore this character seems to be as variable as the others within a single population. Higher or lower branch hairiness cannot be regarded as a useful character to justify the ranking at species level described by Webb. Furthermore, *Q. calliprinos* has been indicated for the Eastern part of the Mediterranean, thus it is not correct to refer to this taxon also in the Western part of the Mediterranean, as frequently found in literature. Other traits, e.g. the presence of spiny leaves, are not always present in the single individuals of a population or within a single individual. Leaves and acorn size and shape are variable as well. Scales may be appressed, patent or curved, and cannot be regarded as diagnostic traits. This variability has been observed in samples collected in Sardinia and in other regions of the East and West Mediterranean (SS! FI!), and many Authors report the occurrence of both entities in the same geographical area. The ranking of *Q. calliprinos* Webb as a separated species from *Q. coccifera* L., has still to be undoubtedly demonstrated. A recent genetic research by Paffetti & al. (2001) highlights the similarity between Sardinian populations and Middle-East populations, yet does not bring any evidence of a possible separation from *Q. coccifera* L. Therefore, so far, I suggest to consider *Q. calliprinos* Webb as synonymous with *Q. coccifera* in accordance with most of the Authors of Mediterranean floras.

***Quercus pubescens* Willd. s.l.**

Deciduous oaks occur from the sea level to 1,600 m a.s.l., mainly on soils derived from siliceous parent materials, with the exception of a few localities in the Sardinian regions of *Sassarese*, *Sarcidano* and *Campidano*, where it grows on limestone substrates.

The variability of morphological traits has deeply been studied in a population located in the North Sardinian region of *Sassarese* (Camarda 1988). This study demonstrated that it is possible to determinate single individuals as different species, depending on the collected and observed specimens. Similar conclusions were drawn both by Cabiddu (2001) in a study on the oak populations of Central-East Sardinia and by Di Noto Grossoni & Bussotti (1995) comparing exsiccata collected in the *Madonie* region in Sicily.

I would like to remark that a great variability is present between the leaves on young branches and those on branches originating from apical buds in spring or in late summer, following rains or mitigation of the aridity trend.

The crown pattern and architecture is not a useful diagnostic trait in the exsiccata, yet in the field it is possible to distinguish round-shaped crowns and twisted branches commonly present in individuals occurring at lower altitudes. On the contrary, at higher altitudes the individuals show ovate to ob-ovate crowns, with upright branches.

Flowering is typically scalar, from December at the sea level (e.g. *Asinara* island, off north-western Sardinia), to late June in the *Gennargentu* mountain region. This six-months interval allows for a genetic flux between the different populations. In the mountain populations leaf shedding is very regular, while at lower altitudes during the winter period leaves may persist on some plants until the leaf renewal, as in evergreen oaks.

In their study on deciduous oaks of Sardinia, Mossa, Bacchetta & Brullo (1998) remarked the diagnostic importance of the bark, namely of its thickness, colour and creaking pattern. Nevertheless this trait is highly variable within a population and within a single plant, depending on the location of the examined parts, e.g. in the branch or stem.

These Authors report the following oak species for Sardinia: *Q. congesta* C. Presl, *Q. virgiliana* (Ten.), *Q. amplifolia* Guss., *Q. dalechampii* Ten., and a new species named *Q. ichnusae*. They also report the presence of many hybrids growing in close proximity with the parental species. Dot distribution maps equip their work. They almost totally refuse the presence of deciduous oaks in the warmest coastal regions of Sardinia, with the exception of *San Sperate* locality, and explain this distribution pattern by the presence of the vicariant species *Q. calliprinos* and *Q. suber*, regarded as more thermophilous and more xerophilous species.

As a matter of fact, following my researches and collections it is clear that deciduous oaks, that can be described as *Q. congesta*, commonly occur in coastal areas, e.g. on *Asinara* island, along the west coast reaching the *Sinis* region, in the *Campidano* plain, at *Sardara*, in the *Marmilla* region and along the east coast near *Santa Maria Navarrese*.

Quite huge *Q. pubescens* Willd. s.l. woods are found on Mesozoic limestone in the *Sarcidano* region and in central-east Sardinia (*Urzulei*). Deciduous oak woods are almost absent in the north coast of Sardinia, while are present near *Castelsardo* and in the regions of *Anglona* and *Coros*, where the climate is typically arid.

According to the above considerations, the presence of so many sympatric species seems to be not sufficiently justified and explained. Distributed independently from the

local ecological conditions and not genetically isolated, they cannot be distinguished by the exclusive use of morphological traits.

Hybrids

The hybrid *Quercus morisii* Borzì is quite rare to Sardinia and therefore its variability range is difficult to evaluate. It originates from *Q. ilex* and *Q. suber* and is generally male-sterile, with intermediate characters between parental species. The not-corky bark is creaking and reddish, leaves are more similar to *Q. suber* in shape and appearance (glaucous). A supposed hybrid between *Q. suber* L. and *Q. coccifera* L. has been indicated, but not described, by Martinoli on the basis of an exsiccata (*Planu de su Zippiri, Santa Lucia di Capoterra*, FI!). The following hybrids have been reported by Mossa & al. 1998 in their work on Sardinian deciduous oaks: *Q. virgiliana* × *Q. amplifolia*, *Q. virgiliana* × *Q. congesta*, *Q. virgiliana* × *Quercus ichnusae*, *Q. dalechampii* × *Q. congesta*, *Q. dalechampii* × *Q. ichnusae* e *Q. ichnusae* × *Q. congesta*.

Conclusions

The species of the genus *Quercus* are distributed as scattered plants or woods in most of the territory of the island of Sardinia. *Q. coccifera* L. is present only in a few nuclei in south-western Sardinia, *Q. suber* can be regarded, with a few exceptions, as a calcifugous, thermo-mesophilous species, growing at altitudes lower than 1,000 m a.s.l. *Q. ilex* is the most widespread species, owing to its great adaptability to the different conditions of the localities.

The distribution of deciduous oaks belonging to the *Q. pubescens* s.l. complex should be studied more in detail. The presence of many populations growing in close proximity and the anemophilous pollination, lead to a continuum in the gene flux. Therefore it is always risk full to rank as species the different morphotypes and hybrids that occur in the wild.

The variability of any trait in any population seems to be very high. This is a clear hindrance for the determination of single individuals. According to the analytical key used, they can be included in different species.

Both the presence of many hybrids and the lack of associated traits may support the hypothesis of the presence of a single species vs. a fragmentation of the populations into different species. According to recent genetic researches on chloroplast DNA, we can consider deciduous oaks of Sardinia as a single variable species. Within this species it could be possible to distinguish a set of subspecies, varieties and forms. This would be more feasible than considering a set of species, with mainly undefined traits, difficult to be recognized both in the field and in the laboratory.

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