

New insights about *Quercus faginea* (s.l.) taxonomic status in northern Africa

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Abstract. The genus *Quercus* is known for its taxonomic complexity that is characterized by the abundant morphological diversity and phenomena of hybridization and introgression found in a number of its species. The number of taxa continues to change and evolve despite systematists' attempts to clarify and simplify it. The *Quercus faginea* s.l. complex represents one of the most conclusive and complex examples found in the North-Western Mediterranean and North Africa. Nevertheless, the systematics of this complex have undergone a remarkable evolution from the first Lamarckian taxa *Q. lusitanica* and *Q. faginea* to the present day, especially in the Iberian Peninsula, Tunisia, and Algeria, by virtue of the recognized taxa. To compare Moroccan taxa with those found in other regions, as well as update the taxonomic status of populations found in Morocco, data found in a corresponding bibliography was used for a critical and objective analysis. Although the taxonomic situation remains unresolved, the analysis found that there is a likely presence of the *faginea* variety in Morocco, while also anticipating the confirmation of a new morphological analysis that accounts for the stable criteria used for an infraspecific distinction. The rest of Morocco's stands seem to be represented by *Q. canariensis* and *Q. faginea* subsp. *broteroi*. Considering the uncertain existence of *maroccana*, further study of its distinct morphological and biogeographical peculiarity is required.

Keywords: morphological traits, infraspecific distinction, biogeographic peculiarity, *Q. faginea* subsp. *broteroi* f. *maroccana* (Braun-Blanquet & Maire) Villar.

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Introduction

The genus *Quercus* constitutes one of the most important and diverse components of the forest ecosystems of southwestern Europe and North Africa (Bussotti & Grossoni, 1998; Gil-Pelegrín *et al.*, 2017; Vila-Viçosa *et al.*, 2023). It has long been associated with great controversy, linked to the considerable genetic richness and intra- and interspecific hybridization, reflected in the high morphological variability disclosed by its taxa, as well as the numerous intermediate forms that result (Denk *et al.*, 2017 and references therein). The number of taxa is still debated among botanists, as the definition of the biological concept of a *Quercus* species is still unclear due to hybridization between different taxa and species, in particular (Burger, 1975; Vila-Viçosa *et al.*, 2022).

A key example is *Q. faginea* Lam. (s.l.), a complex of Ibero-Maghrebian species (Iberian Peninsula, Morocco, Algeria, and Tunisia) which includes different forms and species; *Q. faginea* Lam. (s.s.), *Q. canariensis* Willd., *Q. lusitanica* Lam., as well as *Q. infectoria* G.Olivier and *Q. valentina* Cav. (the shrubby form of

Q. faginea (Schwarz, 1964), before they were included in *Q. lusitanica* and *Q. pubescens* Willd., respectively.

The classification of this complex, otherwise known as *Q. lusitanica* (s.l.) (whose forms of the species *sensu lato* were included under *Q. lusitanica*) or *Q. faginea-mirbeckii* Villar, has continuously raised many problems since Lamarck (1783) described his *Q. faginea* Lam. as a different species from his *Q. lusitanica* Lam. (cf. Vázquez *et al.*, 2018; Aissi *et al.*, 2021). Despite this, there is a tendency towards simplification, especially in the Iberian Peninsula, since the separation of the two species *faginea* and *canariensis* (incl. *Q. lusitanica* var. *salzmanniana* Webb; *Q. salzmanniana* (Webb) Cout., Amaral Franco 1990, Vázquez *et al.*, 2018) by Schwarz (1964), and the subdivision of *Q. faginea* into two subspecies (*faginea* & *broteroi*) by Amaral Franco (1990).

The same status is in force in Algeria since the recent taxonomic study (Aissi *et al.*, 2021). On the latter, representative samples of the country's stands were selected and morphological analysis was carried out. Three taxa were identified: *Q. canariensis*, *Q. faginea* subsp. *faginea* and *Q. faginea* subsp. *broteroi* (Cout.)

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A. Camus. In Tunisia, it is accepted that *Q. canariensis* is the only species present in the country (Le Floch *et al.*, 2010). In Morocco, the taxonomy of the complex has not been updated recently, with the exception of Dobignard & Chatelain (2012) who retain four taxa, *Q. lusitanica*, *Q. canariensis*, *Q. f.* subsp. *broteroi* (incl. subsp. *tlemcenensis*, and var. *maroccana* (Braun-Blanq. & Maire) Villar), itself represents the majority of species stands, as well as a dubious presence for the subspecies *faginea*. Nevertheless, Zine el Abidine and Fennane (1995) based on a morphological study propose a division into three taxa belonging to *Q. faginea*, namely; subsp. *faginea*, subsp. *baetica* (Webb) Maire (= *Q. canariensis*) and subsp. *tlemcenensis* (A.DC.) Maire & Weiller ex Greuter & Burdet, without any intraspecific separation subsequently by Achhal (2002).

In their analysis of the nomenclature of the genus *Quercus*, Vázquez *et al.*, (2018) propose two other taxa for *Q. faginea* while maintaining the use of *Q. broteroi* (Cout.) Rivas-Mart. & Sáenz de Rivas, as a distinct species of *Q. faginea*; the first, subsp. *oscensis* (P.Monts) F.M.Vázquez (= *Q. lusitanica* subsp. *navarrana* O.Schwarz) is exclusive to the north of the Iberian Peninsula and probably results from hybridization of *Q. faginea* (sub-*Q. lusitanica*) and *Q. robur* L. (Schwarz 1936). The second, subsp. *maroccana* (Braun-Blanq. & Maire) F.M. Vázquez & Coombes (= *Q. faginea* subsp. *maroccana* (Braun-Blanq. & Maire) Villar, is only found in Morocco (Jahandiez & Maire, 1932).

It seems from this synthesis that the classification of *Q. faginea* (s.l.) remains imprecise, especially for the Moroccan taxa, which still contain some uncertainty. We will try to contribute to the clarification and re-evaluation of the taxonomic status of the Moroccan populations while analysing the morphological data of the study of Zine el Abidine & Fennane (1995) and all other available sources of information (e.g. Jahandiez & Maire, 1932; Del Villar, 1938). The practical objective is, therefore, to provide a critical and objective analysis of all the taxa identified in Morocco thus far, and to compare them with those already recognised in the Iberian Peninsula, Tunisia, and Algeria.

According to Trabut (1892), the comparative analysis of all forms of a species complex would, generally, reduce the number of types described as species and subspecies and would allow the enumeration of the different variations resulting from adaptation to environmental conditions. The great variability and morphological plasticity thus form intermediate series between the now stable races. The resulting concentration on individuals with specific characters can be misleading, so the sampling should not be limited to a simple analysis of herbarium samples but rather to representative sampling.

Taxonomic evaluation

To clarify and define the taxonomy of *Q. faginea* Lam. (s.l.) in Morocco, Zine el Abidine & Fennane (1995) described 17 morphological and micromorphological traits of leaves, buds and young twigs, and of lesser importance, catkins and young fruits. The study resulted in three taxa under the same binomial *Q. faginea*. The authors pointed out that, despite the distinctive power of the identified stable characters, the continuum effect is still very remarkable. The following taxa and groupings were identified (Table 1). We reevaluated the nomenclatural and taxonomic status of these taxa using retained designation and historical literature as our starting point.

Q. faginea subsp. *baetica* in Morocco

Although the authors refer to a single binomial and advocate the use of subspecies rank, they also acknowledge the easy distinction of the A group from the other two groups, which are partially overlapping. Group A (Table 1) is distinguished by glabrescent deciduous trichomes, and long leaves, and therefore corresponds to *Q. canariensis* Willd. (= *Q. faginea* subsp. *baetica* (Webb) Maire), whose name is retained to be the priority to the species rank. A comparison of the morphological features of this taxon reveals that it is the same as that found in the rest of its range, which includes the Iberian Peninsula, Algeria, and Tunisia.

Table 1. Taxonomic groups and taxon's main characteristic traits identified by Zine El Abidine & Fennane (1995).

Group A. Leaves (5)7–13(18) cm long), petioles and young twigs glabrescent below. Brownish trichomes (sometimes yellowish or whitish), deciduous flocculent (rarely persistent not applied). Hair length $\geq 300 \mu\text{m}$; <i>Q. faginea</i> subsp. <i>baetica</i> (Webb) Maire (<i>Q. canariensis</i> Willd.).
Group B. Leaves (3.5–8.5(13) cm long), petioles and young twigs tomentose. Whitish trichomes (rarely yellowish), persistent applied. Hair length $< 180 \mu\text{m}$; <i>Q. faginea</i> subsp. <i>faginea</i> .
Group C. Leaves (5.5)6–10.5(12) cm long), petioles and young shoots tomentose. Yellowish trichomes (white or brownish), persistent unapplied (rarely floccose deciduous). Hair length 180–300 μm ; <i>Q. faginea</i> subsp. <i>tlemcenensis</i> (A.DC.) Maire & Weiller ex Greuter & Burdet.

Uncertain presence of subspecies *faginea* in Morocco

The distinctive features of group B (Table 1), smaller leaves in comparison with the other groups, as well as a tomentum with short hairs $< 180 \mu\text{m}$, correspond relatively to those of subspecies *faginea*. According to

Amaral Franco (1990), this taxon is characterised by small leaves with a toothed margin and a persistent tomentum with short hairs of 122–155 μm . Due to their low contribution, the margin-related characteristics of the leaves were not maintained in the discriminant analysis by Zine el Abidine and Fennane (1995).

Without identifying the percentages for each group, forty-six per cent of the trees analysed have leaves with toothed and spinescent margins. The subspecies *faginea* is the synonym of the old binomial *Q. alpestris* Boiss. (= *Q. faginea* subsp. *alpestris* (Boiss.) Maire) and *Q. faginea* s.s. (= *Q. faginea* subsp. *eufaginea* Maire) which, according to Maire (1961), are absent in North Africa, whereas Del Villar (1938) relates the subspecies *alpestris* to the Moroccan forms, namely f. *glabrescens* Villar, f. *glabrata* Villar, and f. *spinosa* Maire & Trab. (= *Q. faginea* var. *spinosa* Maire & Trab.). For Maire (1961), the separation of these forms from subspecies *baetica* (= *Q. canariensis* Willd.), despite their tendencies towards subsp. *alpestris*, seemed unjustifiable. On the other hand, reporting the Algerian taxa *Q. faginea* subsp. *tlemcenensis* var. *microphylla* f. *lucida* Maire & Weiller to subsp. *eufaginea* ‘small leaves, 1.8–5 x 1–3 cm, exceptionally reaching 8 x 4 cm. Leaves sharp-toothed, subspinular, leathery, and shiny above, yearlings promptly glabrous. Small acorns’ seemed plausible. The stands of this variety are currently related to *Q. faginea* subsp. *faginea* (Aissi *et al.*, 2021) (Figure 1). From its description, ‘leaves with a flaky tomentum, very acute lobes, long spinules, 7–8 pairs of veins (Del Villar, 1938; Maire, 1961)’, *Q. faginea* subsp. *baetica* f. *spinosa* Maire & Trab. is closer to *Q. canariensis* than to subsp. *faginea*. In addition, Maire (1931) described it as follows: ‘*folia 7–8 jugis nervorum praedita, dentata denticibus longe spinosis, adulta subtus glabrata*’, the glabrescence of the tomentum of the adult leaves lead us to relate the *Q. faginea* f. *spinosa* to the concept of *Q. canariensis* (Figure 1). In the same vein, with *Q. alpestris* f. *glabrescens*, (*foliorum adultorum dorsum tantum residualiter vestitum*) and *Q. alpestris* f. *glabrata* (*foliorum dorsum modo omnino glabrum modo indumento ad pilos parcos simplices, bifurcatos vel fasciculatos, reduclo*) (Del Villar, 1938), their deciduous glabrescent tomentum, persisting only residually, make them perfectly corresponding to *Q. canariensis* (Figure 1). Regarding hair size, we consider this trait unreliable for intraspecific separation due to the observed disparity in tomentum hair lengths between the subspecies *faginea* and *broteroi* (Tschan & Denk, 2012; Aissi *et al.*, 2021).

All this being said, if attaching group B (Table 1) to *Q. faginea* subsp. *faginea* is a priori conceivable, one cannot help but think that it is particularly important

to avoid any assumption of recognising this group B attachment without confirming the toothed leaf margin, a character that distinguishes it from subsp. *broteroi*.

The subspecies *tlemcenensis*, subsp. *broteroi* or *Q. broteroi*?

The form *tlemcenensis* was initially described in Algeria, in the region of Tlemcen, between Terni and Sabdou, as *Q. lusitanica* subsp. *mirbeckii* f. *tlemcenensis* (A.DC.) Trab. (= *Q. faginea* subsp. *tlemcenensis* (A.DC.) Maire & Weiller ex Greuter & Burdet; *Q. lusitanica* var. *tlemcenensis* Warion; *Q. lusitanica* var. *broteroi* Cout.; *Q. lusitanica* subsp. *baetica* DC., *Q. lusitanica* subsp. *baetica* f. *mirbeckii* Webb (A.DC.)), according to Trabut (1890), it is characterised by fairly large trees with medium-sized, ribbed leaves that maintain their pubescence on the underside throughout the year. The author pointed out that the Iberian Peninsula’s Coutinho’s variety *Q. lusitanica* var. *broteroi* Cout. (= *Q. faginea* subsp. *broteroi*), is certainly confused with its *tlemcenensis* form. Morphological analysis carried out on the Terni stand confirms that it corresponds perfectly to the concept of *Q. faginea* subsp. *broteroi* (Aissi *et al.*, 2021) (Figure 1). Indeed, from the latter, and the study of trichome types, indumentum on leaves, and epicuticular wax on oaks of subgenus *Quercus* by Tschan & Denk (2012), it would seem that the differences in hair lengths adopted by Amaral Franco (1990) to separate subsp. *faginea* (122–155 µm) from subsp. *broteroi* (175–200 µm) are unstable for a reliable taxonomic diagnosis due to overlapping values between the two taxa. Despite the slight tendency towards longer branched fasciculate and stellate hairs in subsp. *broteroi*, these values still overlap with those of subsp. *faginea*, which is often the case for species of subgenus *Quercus* (Tschan & Denk, 2012). Furthermore, the hair length intervals on the lower leaf surface made by previous authors appears to vary depending on the specimens analysed (Table 2). Therefore, Tschan & Denk (2012) urge great caution in defining taxa and emphasise the importance of taking into account the natural variability of taxa in the form of large amounts of data that allow quantitative and qualitative assessment of hair variability, which may be lacking in previous work, such as that of Zine el Abidine (1995).

Table 2. Length intervals of the upper leaf hair of *Quercus faginea* (s.l.) taxa by previous authors.

Authority	subsp. <i>baetica</i> (= <i>Q. canariensis</i>)	subsp. <i>alpestris</i> (= subsp. <i>faginea</i>)	subsp. <i>eufaginea</i> (= subsp. <i>faginea</i>)	subsp. <i>broteroi</i> (= subsp. <i>tlemcenensis</i>)
Maire (1961)	350–700 µm	≤250 µm	100–150 µm	150–250 µm (subsp. <i>tlemcenensis</i>)
Amaral Franco (1990)	-	122–155 µm	-	175–200 µm
Zine el Abidine (1995)	≥ 300 µm	< 180 µm	-	180–300 µm
Llamas (1995)	-	250–370 µm	-	400–470 µm (<i>Q. broteroi</i>)
Tschan & Denk (2012)	66–619 µm	53–477 µm	-	69–477 µm (subsp. <i>broteroi</i>)
Aissi <i>et al.</i> (2021)	61–820 µm	54–440 µm	54–440 µm	52–521 µm

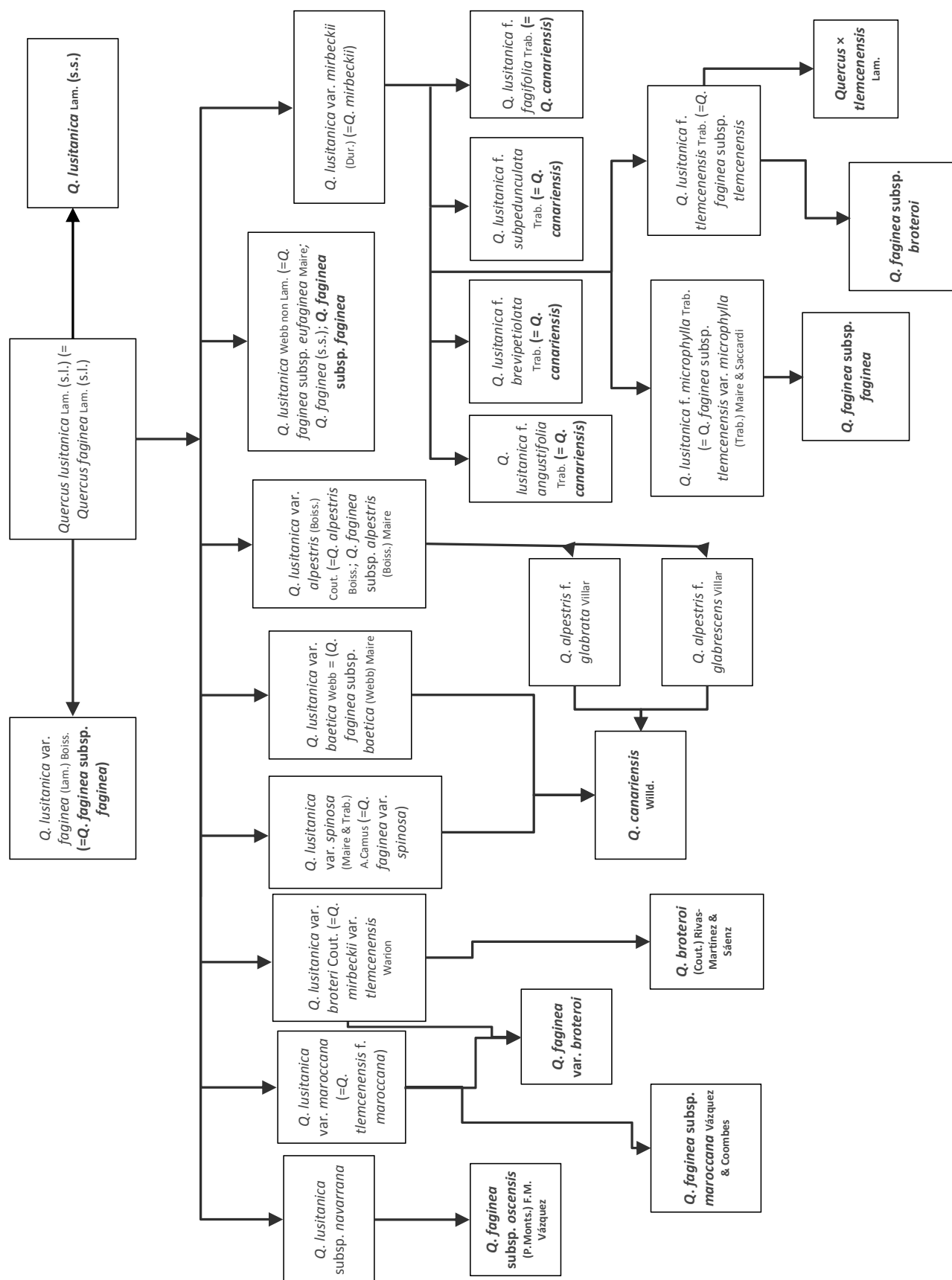


Figure 1. Summary of the nomenclature evolution of *Quercus faginea* Lam. (s.l.).

Rivas-Martínez & Sáenz de Rivas (1991) identifies *Q. broteroi* (Cout.) Rivas-Mart. & Sáenz de Rivas (= *Q. hybrida* Brot.) as a species distinct from *Q. faginea* by a long-haired tomentum of the multistellate type

(stellate variant) mixed with stellate and pedicellate hairs, of more than 200 μm (Vázquez *et al.*, 2018). In this context, Vázquez and Coombes (2016) noted a high morphological diversity within the stands of

Q. faginea subsp. *broteroi* (= *Q. broteroi*) in Extremadura (Spain) in terms of leaf, petiole, and hair length, with maximum values of the hair length ranging from 270 to 390 µm depending on the environmental characteristics of the sampling stands. We believe that this reinforces the hypothesis that *Q. broteroi* subsp. *broteroi* (Cout.) A.Camus and *Q. broteroi* subsp. *tlemcenensis* F.M. Vázquez & Coombes, which are supposed to be taxa of subspecies rank, are in fact separated by ecological barriers but also united by the morphological similarity of their leaves, and whose variability in pubescence below is probably related to environmental conditions (Gil-Pelegrin *et al.*, 2017), and which, according to Hardin (1979), increases at the intraspecific level in many species under the effect of drought. On the other hand, the subspecies *faginea* and *broteroi* seem to be separated by more stable morphological characters (i.e. longer and wider leaves with lobed margins). This is consistent with the results of Morales *et al.*, (2006) who concluded on the basis of genetic polymorphism analysis that the two taxa *Q. broteroi* and *Q. faginea* appear to be ecological forms of the same species. Lepais *et al.*, (2022) observed the same trend.

In reference to *Q. broteroi*, Llamas *et al.* (1995) considered the species rank to be adequate for it, citing the fact that it is characterised by a bulbous, solitary, multi-radiate hair tomentum (synonymous with the stellate type according to Tschan & Denk (2012), which is thin-walled and collapsed when dried. However, the findings of Tschan & Denk (2012) showed that the distinction between thin and thick hairs is hardly noticeable, and the collapsing type is present in every species of the genus *Quercus*.

It follows from the above that the distinction on the basis of hair values between *Q. faginea* and *Q. broteroi* or between subspecies *tlemcenensis* and *broteroi* is not justifiable, so we could assign group C to *Q. faginea* subsp. *broteroi* (Figure 1, Table 1).

Q. tlemcenensis* and *Q. x tlemcenensis

The description of the hybrid *Q. x tlemcenensis* (*Q. mirbeckii* x *Q. ilex*) (smaller leaves than *Q. mirbeckii* with year-round pubescence underneath, of which the latter was elevated to species status by Battandier and Trabut (1902) coincides with *Q. mirbeckii* f. *tlemcenensis* Trab. (= *Q. lusitanica* subsp. *mirbeckii* (Durieu) Ball), but also with *Q. mirbeckii* f. *microphylla* Trab. (= *Q. faginea* var. *microphylla* (Trab.) Maire & Saccardi) (Trabut, 1890, 1892). These persistently downy forms were not mentioned by Battandier and Trabut (1902) and therefore probably included under x *Q. tlemcenensis*, although *microphylla* (found in Aures region) does not appear in the localities of the taxon (Bouira, Tlemcen), thus creating confusion and uncertainty in nomenclature. Nevertheless, we believe that Battandier and Trabut considered these forms as products of hybridization (Del Villar, 1938). Furthermore, based on its morphological description, *Q. x tlemcenensis* Trab. seems to belong to the concept of *Q. faginea* s.s. Of particular interest is

the fact that this taxon differs slightly from the author's other hybrid *Q. mirbeckii-ilex* Trab. (= *Q. mirbeckii-ilex* Nob.) (Trabut, 1890), with a rarer status in isolation in Bouira. Having a somewhat cork-oak-like habit (*Q. suber* L.), its origin is probably a cross between *Q. suber*, *Q. canariensis* (sub. *Q. mirbeckii*) and *Q. ilex*.

The *maroccana* form as a subspecies?

The subspecies *maroccana*, which Braun-Blanquet and Maire (1921) first described from the Moroccan Middle Atlas as a variety of *Q. faginea* (under *Q. lusitanica*), differs from the Algerian variety *tlemcenensis* only in its rapidly glabrescent yearlings, but it also has partially separate natural habitats (Del Villar, 1938, 1943). Unfortunately, Zine el Abidine & Fennane (1995) have not analysed the pilosity of the twigs, therefore a possible distinction cannot be made. Del Villar (1942) noted that the name *maroccana* refers to two entities, *Q. tlemcenensis* f. *maroccana* (Braun-Blanq. & Maire) Villar (= *Q. lusitanica* var. *maroccana* Braun-Blanq. & Maire; *Q. lusitanica* var. *hipahea* Pau & Font Quer) of doubtful taxonomic value, and the hybrid *Q. maroccana* Braun-Blanq. & Maire (= *Q. x mirbeckii-tlemcenensis* Villar). The two entities also appear to be morphologically similar to each other (Vázquez *et al.*, 2018) and to the *broteroi* subspecies. Consequently, we do not believe that subspecies unity can be ascertained from the glabrescence of young twigs alone, and therefore this form should be assigned to *broteroi* subspecies (Figure 1). So, as long as the geographic individuality of its populations is confirmed, it should be given the status of a form (*Q. faginea* subsp. *broteroi* f. *maroccana* (Braun-Blanq. & Maire) Villar). Similarly for the taxa *Q. faginea oscensis* P.Monts. (= *Q. faginea* subsp. *oscensis* (P.Monts.) F.M. Vázquez; *Q. lusitanica* subsp. *navarrana* O.Schwarz), recently included as a subspecies by Vázquez *et al.*, (2018), a study of this Pyrenean oak populations and the persistence of its characteristic traits based on representative samples will contribute to the knowledge of its morphological variability (Montserrat, 1988).

***Q. lusitanica* Lam. in Morocco**

There was a long confusion between Lamarck's two binomials *Q. lusitanica* and *Q. faginea*, with *Q. faginea* often being subordinate to *Q. lusitanica*. It was Sampaio in 1913 who established the true *Q. lusitanica* Lam. (= *Q. humilis* Lam.) as a shrubby form not exceeding 1m in height, whereas *Q. faginea* Lam. corresponds to the tree species under *Q. lusitanica* Webb not Lam. (Del Villar, 1938) (Figure 1). Jahandiez and Maire (1932) considered it a subspecies *Q. faginea* subsp. *lusitanica* (Lam.) Maire (= *Q. humilis* Lam.), while Maire (1961) classified it as a separate species under the name *Q. fruticosa* Brot. (= *Q. humilis* Lam.). Del Villar (1935) mentions in this respect that the morphology of *Q. lusitanica*, along with its particular ecology and geography, support and justify

the choice of species rank. Schwarz (1964) considers the species to be close, but distinct from *Q. faginea*, while *Q. valentina* Cav. is considered therein to be a shrubby form of *Q. faginea*. On the other hand, Greuter *et al.*, (1986), Amaral Franco (1990), and Schwarz (1993) re-establish the priority use of *Q. lusitanica* over *Q. fruticosa*, and include both *Q. humilis* and *Q. valentina*. *Q. lusitanica* occurs in Morocco according to Maire (1931), Jahandiez and Maire (1932), Maire (1961) in the Bouhachem, Djebala and Zemzem mountains (between Ceuta and Tetuan), in Mount Khessana (South-West of Bab Taza), Afestel and Outka, where it crossbreeds with *Q. pyrenaica* Willd. (under *Q. toza* Bastard) (*Q. lusitanica* x *tozae* Cout.; *Q. x neomairei* A.Camus). Also in Tangier at Djbel Kebir, where it hybridizes with *Q. faginea* (under *Q. tlemcenensis*) (*Q. x tingitana* A.Camus).

Conclusion

The literature reviewed for this study has highlighted the substantial gaps in the available databases, from the earliest to that of Zine El Abidine and Fennane (1995), to clarify and update the taxonomic status of *Q. faginea* (s.l.) in Morocco. The study noted, however, that the groups A (= *Q. faginea* subsp. *baetica*) and C (= *Q. faginea* subsp. *tlemcenensis*) identified by the authors belong to the concepts of *Q. canariensis* and *Q. faginea* subsp. *broteroi*, respectively. In addition, the occurrence of the subspecies/form *maroccana* in the country seems doubtful but could be confirmed by a population analysis. At present, the stands of group C should be included under subsp. *broteroi* (Table 1). As for group B (= *Q. faginea* subsp. *faginea*), and despite its tendency towards subsp. *faginea* in terms of leaf size, it could not be assigned to that subspecies. A new analysis, taking into account the toothed margin of the leaves or other likely distinctive traits will make it possible to better grasp the multiple forms of morphological variability of the Moroccan stands and will help define the taxonomy of the *Q. faginea* complex.

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