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Morphological characterisation of *Eruca vesicaria* (*Cruciferae*) germplasm

Abstract

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More than one hundred rocket (*Eruca vesicaria*) accessions collected from as many geographic localities have been characterised using vegetative, flower, fruit and seed characters. The species shows an ample reticulate variation which often makes it difficult to ascribe specimens to a particular subspecies. For flowering or early fruiting plants, the best discriminant character to distinguish subsps *vesicaria* and *sativa* is the persistence of the sepals (10-12 persistent calyces below the last open flower in subsp. *vesicaria* compared to 3-5 in subsp. *sativa*). In dry infructescences, pedicels of the basal fruits of each branch are longer in *vesicaria* (9-15 mm) than in *sativa* (3-6 mm). Subsp. *pinnatifida* also shows long pedicels but it can be easily distinguished by its small seed size (1-1.1 mm *versus*. >1.3 in all other subspecies). Fruit morphometry did not support a clear distinction for populations usually ascribed to subsp. *longirostris* in South Spain and Morocco. On the other hand, some naturalised subsp. *sativa* populations of cultivated origin can be differentiated by their large fruits and seeds.

Introduction

Four subspecies (i. e., subsp. *vesicaria*, subsp. *sativa* (Miller) Thell., subsp. *longirostris* (Uechtr.) Maire and subsp. *pinnatifida* (Desf.) Emberger & Maire) have been traditionally recognised within the species *Eruca vesicaria* (L.) Cav. All these four subspecies are present in the SW Mediterranean region (either in Spain, Morocco or Algeria) while only one of them (subsp. *sativa*) has spread – naturally or introduced by man - to other parts of the world. This suggests that the SW Mediterranean region is the center of diversification for this species. Collected or cultivated as a vegetable or for oil since ancient times, *Eruca vesicaria* subsp. *sativa* (syn. *Eruca sativa*) has recently received a renewed attention (Padulosi & Pignone 1997) from an economic point of view.

The species is very polimorphic and presents a marked reticulate variation throughout its area. The difficulty in determining dry herbarium specimens of *Eruca* has been already discussed (Gómez-Campo 1993). Shortly, some of the classical characters proposed to separate subsp. *sativa* and subsp. *vesicaria* specimens as f. i. leaf and anther shape or sepal cucullation (Tutin & al. 1993) may be difficult to observe in pressed material or present other types of difficulty (Table 1). On the other hand, the characters given by Maire (1965) to discriminate subsp. *pinnatifida* mostly refer to the vegetative stage. Naturalised forms

of cultivated subsp. *sativa* can also be found in many areas producing disturbances in possible patterns of geographic distribution.

A direct study on living plants of wild origin grown side by side under identical conditions was expected to shed some new light on our knowledge of the intra-specific variation of this species. During its execution, emphasis was placed on trying to find useful characters for subspecies differentiation.

Methods

More than one hundred and fifty seed samples of *Eruca* have been collected and preserved in the UPM (Universidad Politécnica de Madrid) seed bank in the past three decades. Most accessions are from Spain and Morocco but a number have also been collected in other parts of the world. Of these samples, 104 were grown to maturity under field conditions and were morphologically characterised using characters present in the leaves, stems, flowers, fruits and seeds.

Studied characters are partially mentioned in Table 1. All are discussed individually below:

1. Pubescence. Recorded at the base of the stems, young inflorescent branches, sepals and fruit valves. Leaf pubescence was ignored because of its inter-individual variation. A scale of 0 to 3 was applied in each case and the sum was used as an estimation of the overall pubescence.
2. Persistence of the calyx. It was easily evaluated by the number of young fruits keeping their calyx below the last open flower of the raceme. This is a simple and accurate procedure when the correct flowering stage is selected.
3. Pedicel length. Measured in the fruiting stage, using the 1-2 lowest fruits of the racemes. In mm.
4. Valve length. This was measured on the replum of shattered fruits.
5. Valve width. Same as in valve length. This means that the width is interpreted as a projected value.
6. Length of the fruit stylar portion. In mm.
7. Width of the fruit stylar portion at the base. In tenths of mm.
8. Seed size. In tenths of mm, taking the maximum dimension (length).

Data were also recorded on ten other characters: plant height, plant cycle, leaf and plant contour, branching system, petal color, flower size, calyx swelling, fruit position and seed color. However, only characters 1-8 were the object of numerical analyses because other characters were either semi-qualitative, influenced by the physical environment or showing other limitations. Data were taken during three consecutive seasons repeating some accessions to obtain an estimation on which characters were actually influenced by the environment. The relative value of the characters and the ascription to subspecies of dubious accessions was tentatively asessed in the first season and confirmed or completed in the following ones. With very few exceptions, data were recorded on at least six different plants.

UPGMA and WPGMA dendrograms based in characters 1-8 using Euclidian and correlation coefficients were constructed with only small differences in the results.

Dendrograms based in characters 1-3 or 1-2 with Euclidian coefficient were also constructed.

Table 1. Some possible distinguishing characters between subsp. *vesicaria* and subsp. *sativa* and their limitations.

subsp. *vesicaria*	**subsp. *sativa***	**Observations**
Plant height 60-100(120) cm	Plant height 80-140(150) cm	of variable expression under natural conditions
Plant contour hemisphaerical	Plant contour obconical	of difficult observation under natural conditions
Plant very hispid	Plant less hispid to glabrous	high inter-individual and inter-population variation
Lower leaves pinnatilobed	Lower leaves pinnatifid	pinnatifid leaves are often present in subsp. *vesicaria*
Racemes with 12-15(20) flowers	Racemes with 20-25(30) flowers	of difficult observation in poorly developed subsp. *sativa*
Calyx swollen	Calyx not swollen	not appliable in the SE part of the subsp. *vesicaria* area
Calyx persistent * **	Calyx caducous	of difficult evaluation in late fruiting stages or in dry years
Sepals all cucullate *	Sepals only two cucullate	only applicable to the first 2-3 flowers of each raceme
Corola cream, yellowish	Corola cream, whitish	only applicable within the Iberian Peninsula
Anthers subacute *	Anthers obtuse	difficult to asses
Lower fruit pedicels 9-12(15) mm **	Lower fruit pedicels < 6 mm	only applicable to basal siliques

* differential characters used in *Flora Europaea* (Tutin & al. 1993).
** proposed in this article as the most useful one.

Results and discussion

Differential characters are apparently abundant (see Table 1 and above). However, some are strongly dependent from environmental conditions (such as plant heigth), others are easily observed in cultivation but are often more difficult to observe in natural conditions (such as plant contour), others are amazingly homogeneous (such as the number of weeks to flowering) or almost completely erratic (such as the angle formed by the fruits in the branches) while others are only valid for limited geographical areas (such as petal color). Even resorting to detailed fruit morphometry (as in Fig. 1 dendrogram where 5 of 8 characters belong to this type) does not produce a good discrimination between subspecies. Combining four fruit dimensions in a scatter diagram (Fig. 3) also shows intense overlapping.

Unidimensional analysis (ordination by single characters within the data matrix) gave

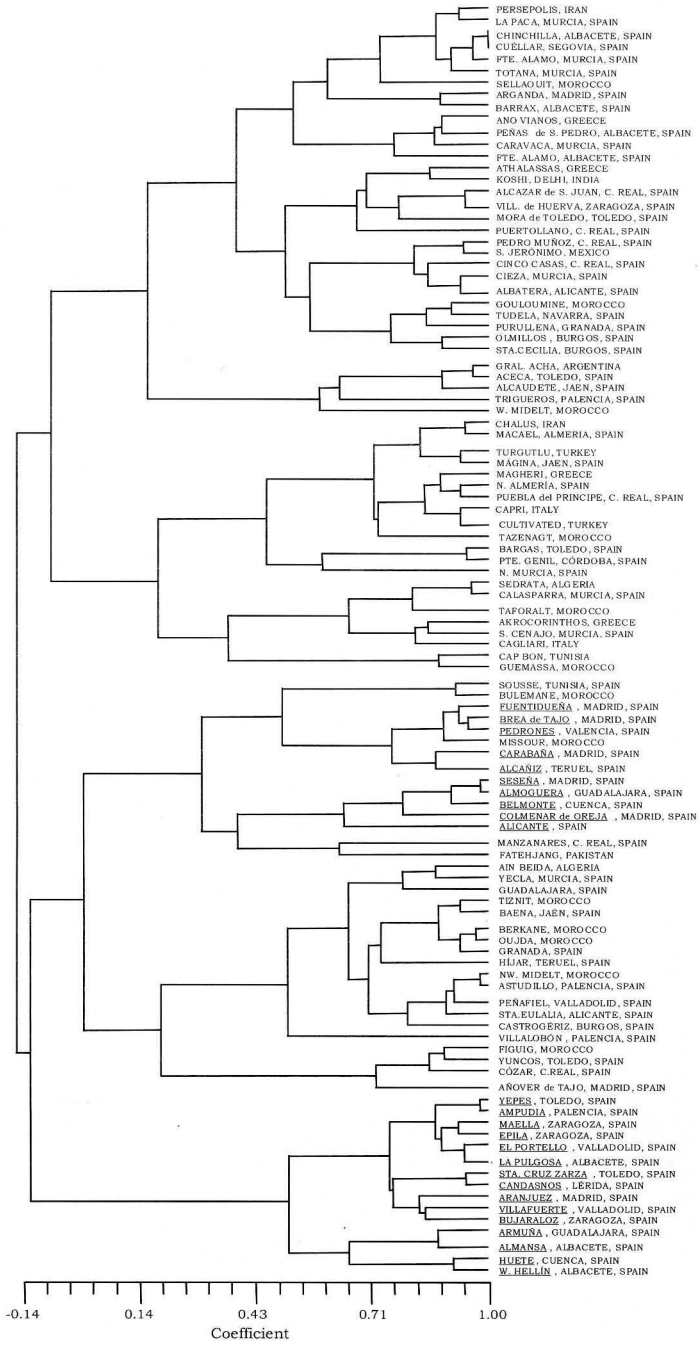

Fig. 1. WPGMA dendrogram with 104 accessions and 8 characters. Subsp. *vesicaria* accessions are underlined.

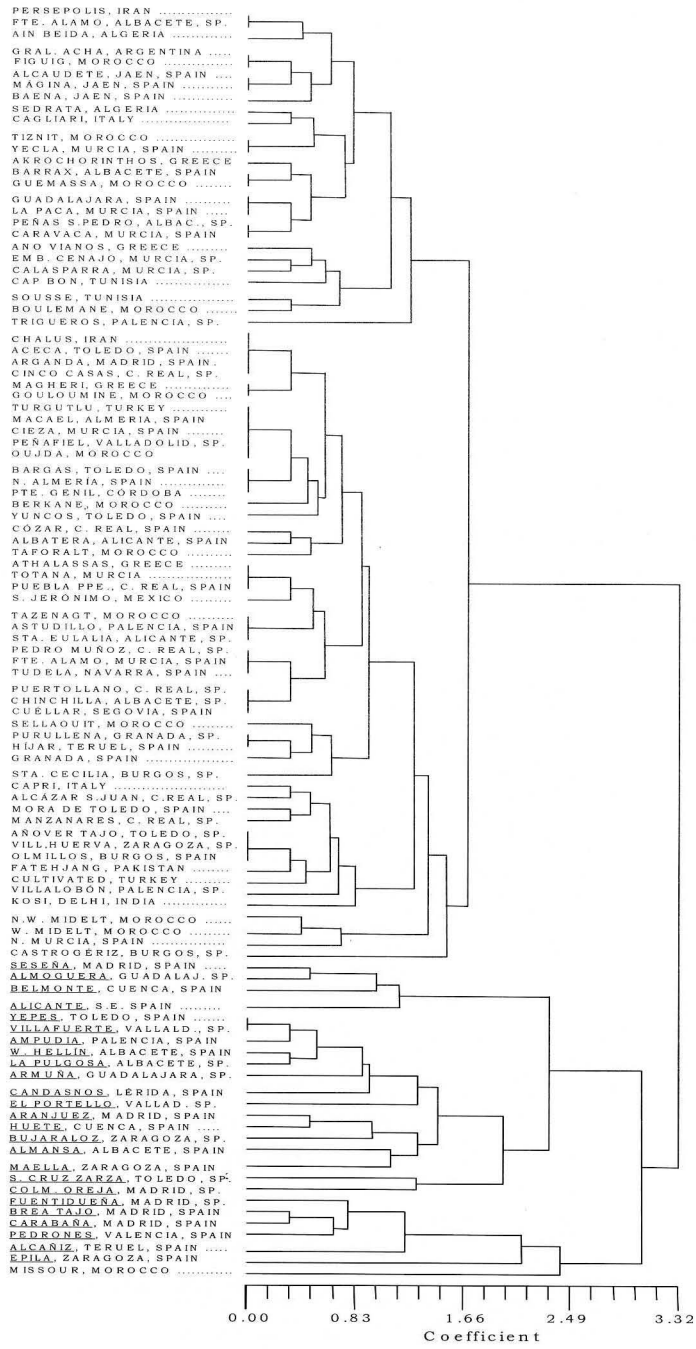

Fig. 2. WPGMA dendrogram with 104 accessions and only 3 characters (pubescence, calyx persistence and pedicel length). Subsp. *vesicaria* accessions are underlined.

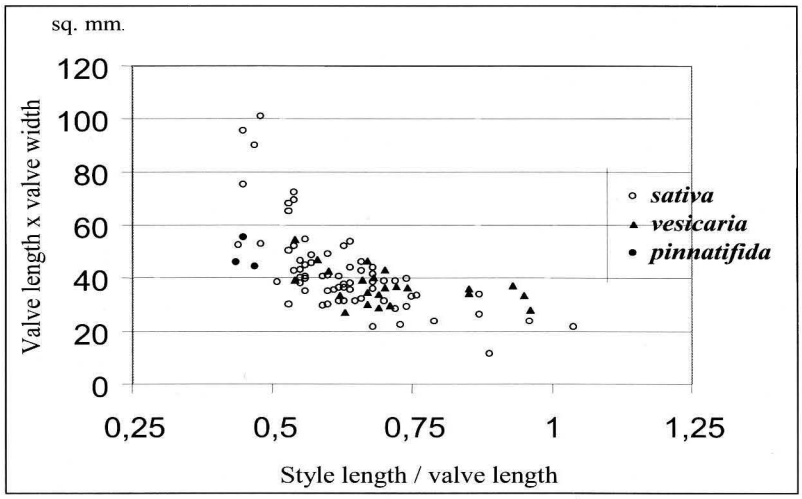

Fig. 3. Scatter diagram showing an estimation of the fruit size against the relative length of the style. All accesions with size over 60 are probably of cultivated origin. Those with relative style length over 0,80 only weakly correspond to taxa previously assigned to subsp. *longirostris*.

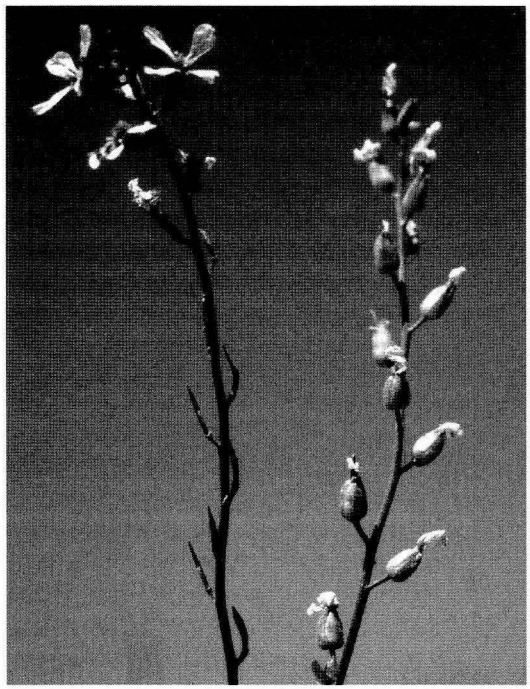

Fig. 4. Young inflorescences of subsp. *sativa* (left, with calyx caducous) and subsp. *vesicaria* (right, with calyx persistent).

good insigths on which characters should be taken as differential. For calyx persistence no practical overlapping occurred between subsp. *vesicaria* accessions and all other subspecies. For the length of the lower fruit pedicels there was only overlapping with accessions of subsp. *pinnatifida*. For pubescence there was little but noticeable overlapping. A dendrogram only based on these three characters (Fig. 2) separates all accessions of subsp. *vesicaria* together with one of subsp. *pinnatifida* (it is to be noted that studied *pinnatifida* accessions were markedly different in pubescence). When pubescence was excluded (2-characters dendrogram, not shown) subsp. *vesicaria* appeared in a single coherent group. Only two doubtful apparently intermediate populations of the Palencia province (Trigueros and Villalobón in NC Spain) consistently fall on the *sativa* side. In turn, the best diagnosis character for subsp. *pinnatifida* is the small size of its seeds (1-1,1 mm).

In side-by-side cultivation, subsp. *sativa* plants from C. Spain were generally taller and their abundant long branches from the basal buds produced an obconical contour. This contrasted with subsp. *vesicaria* plants, whose ramification occurred as well in the higher buds producing shorter racemes and an overall hemisphaerical contour. Swollen calyx, a character already noticed by Linnaeus (1773) for subsp. *vesicaria* is well expressed in the populations growing in gypsaceous soils S of Madrid but this expression is much poorer in northern or south-eastern populations or in the Oran area in Algeria (observation complemented on herbarium material from MA, P). Also petal color (creamy white for subsp. *sativa* vs. yellowish for subsp. *vesicaria*) is only applicable to Spanish material since subsp. *sativa* populations show yellowish petals in many other E. Mediterranean areas.

Fig. 5. Center: typical subsp. *sativa* infructescence. Left: id. from a culti vated form. Right: subsp. *vesicaria* mature infructescence. Though fruit position is often more regular in subsp. *vesicaria*, this cannot be considered a general rule.

Therefore, even if calyx persistence in subsp. *vesicaria* may be poorly expressed in advanced stages of fruit maturation, in very dry years or in dried specimens, it remains a good discriminating character to separate subsp. *vesicaria* (Fig. 4). The length of the lower pedicels of mature racemes is also a reliable character which become very useful in more advanced stages or when the conditions are not adequate to observe the calyces (Fig. 5). Although subsp. *pinnatifida* shares this character, seed size would again dissipate any doubt.

With respect to subsp. *sativa*, the variability of E. Mediterranean or Irano-Turanian populations is not significantly different from that of W. Mediterranean populatons, both always appearing intermixed in any dendrogram. Accessions from countries where no wild *Eruca* grows (Argentina, Mexico, India) must be interpreted as naturalised. They show especially vigorous plants and larger dimensions in the fruit and seed, strongly suggesting a cultivated origin. Therefore, large fruits (valves > 20 mm) or large seeds (length > 2 mm) may primarily be used to detect naturalised material in other countries. This is probably the correct interpretation for some of our accessions from Italy, Greece, Turkey, Pakistan, etc. where cultivation of *Eruca* is very popular.

Subsp. *longirostris* cannot be easily discriminated from other subspecies, even using its defining parameters as style length or stylar attenuation (Fig. 3). Difficult to recognise in advance, it is supposedly abundant in S. Spain (Valdés & al. 1987), Morocco and Algeria (Maire 1964) but fruit morphometric parameters of populations from these origins overlap with *sativa* or *vesicaria* populations from the same area or with *sativa* from as far as Turkey or Iran (Fig. 1). The longest stylar portions in our study were only about as long as the valves. Longer styles (twice the length of the valves) seem to be restricted to the area of Oran (NE Algeria) as observed in herbarium specimens under *Eruca vesicaria* var. *longistyla* (Pomel) O. E. Schulz but Maire (1964) explicitly states that its calyx is not persistent.

Figure 6 shows the geographic origin of the Spanish and Moroccan accessions studied. In general, *Eruca vesicaria* shows a preference for basic soils, either calcareous or gypseus, and this is the reason why the species is rare in the W part of the Iberian Peninsula where substrates are mostly acidic. Typical subsp. *vesicaria* in S Madrid area (SC Spain) is closely associated to gipseous soils.

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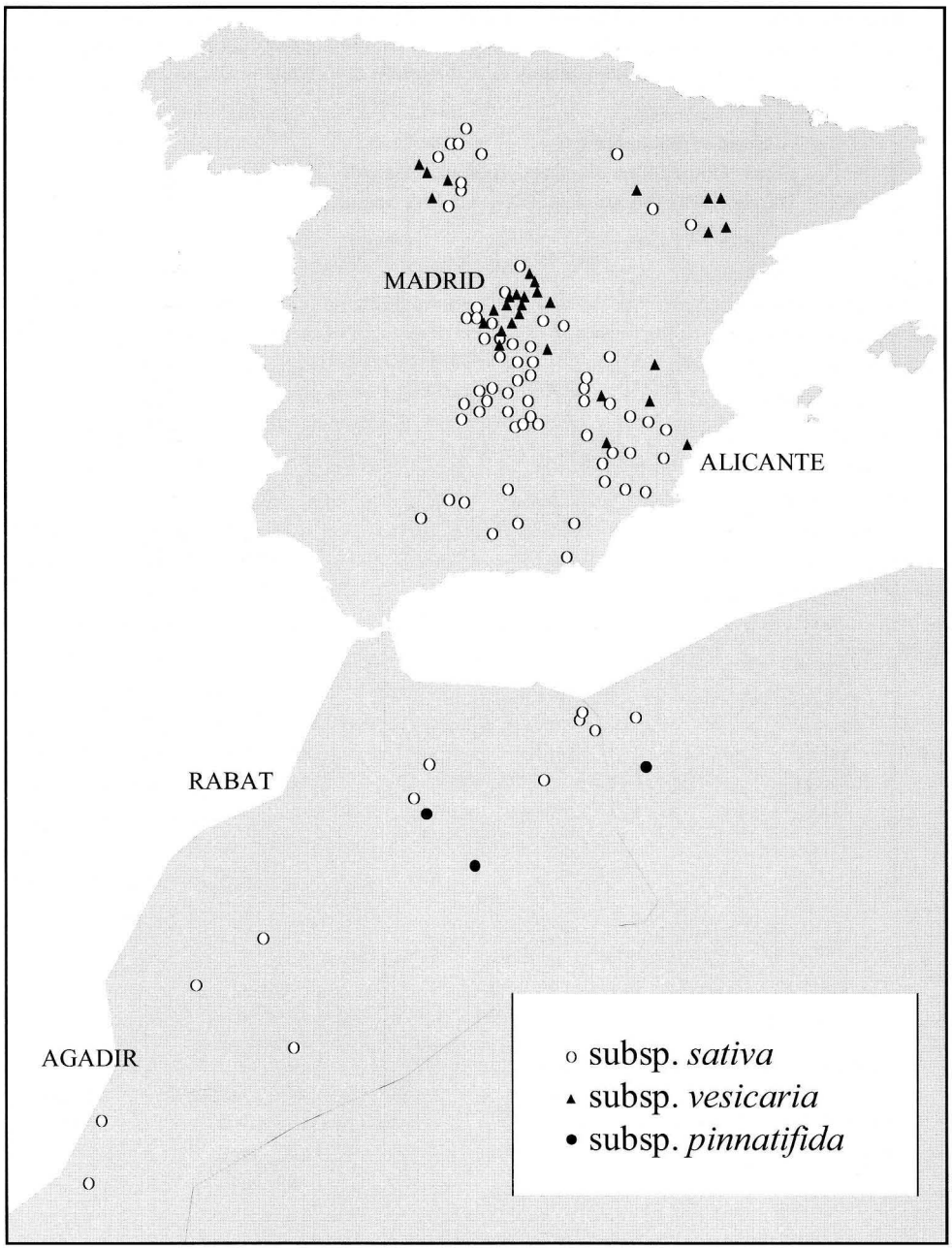

Fig. 6. Geographical origin of the studied Spanish and N. African accessions.

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