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Taxonomical relationships between *Anthoxanthum aristatum* and *A. ovatum* (*Poaceae: Pooideae*) assessed by Numerical Taxonomy Methods

Abstract

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Two annual species belonging to genus *Anthoxanthum* L. s. l. (*Poaceae: Pooideae*) (*Anthoxanthum aristatum* Boiss. and *A. ovatum* Lag.) occur in the Iberian Peninsula where several infra-specific taxa have been described. Nevertheless, the taxonomical treatment of these taxa has been widely discussed throughout the 20th century. The purpose of this study was to provide information to help clarify the morphological relationships between these taxa. To achieve this aim, six wild populations from Doñana National Park (Andalusia, Spain) were analysed. In these populations several taxa grew in simpatry. A total of 24 traits (quantitative and qualitative) were considered in 389 specimens. The number of individuals collected per population was variable depending on the morphological variation observed. Statistical analysis of the data was performed using the program SPSS 11.0. A principal component analysis was carried out to select the most interesting traits to characterise each taxon. These traits were then used to establish relationships among populations applying the Phi coefficient for qualitative data and the Manhattan distance for quantitative data. These relationships were summarised in two phenograms using UPGMA clustering methods.

Introduction

The genus *Anthoxanthum* L. s. l. (*Poaceae*: *Pooideae*) (including *Hierochloë* R. Br.) comprises roughly 45 species that are distributed world-wide (Schouten & Veldkamp 1985). In the Iberian Peninsula five species are present: three are perennial [*Anthoxanthum odoratum* L., *A. amarum* Brot. and *A. nitens* (Weber) Y. Schouten & Veldk. (= *Hierochloë odorata* (L.) P. Beauv.)] and two are annual (*A. aristatum* Boiss. and *A. ovatum* Lag.).

Although this genus has been studied in the Iberian Peninsula by different authors (Willkomm & Lange 1870; Paunero 1953; Valdés 1973), the annual species have not been well characterised morphologically and sometimes both taxa have been included as subspecies or varieties in *A. odoratum* (Battandier & Trabut 1895; Jahandiez & Maire 1931; Maire 1953). Moreover, different widely-discussed infra-specific taxa (Fig. 1) have been described (López-González 1994) for these annual species.

High diversity of annual *Anthoxanthum* taxa can be found in southern Iberian Peninsula. *A. aristatum* usually grows in dry open habitats of southern Europe, and is locally naturalized further north, while *A. ovatum* Lag. inhabits open habitats of coastal areas in Southwest Europe. Doñana National Park (Andalusia, Spain) offers many advantages for the study of this genus, since it is a well-known preserved area where different taxa can be found growing in simpatry (Valdés 1973; Rivas-Martínez & al. 1980).

The purpose of this study was to establish the morphological relationships among samples belonging to several annual *Anthoxanthum* taxa, collected from Doñana National Park. Moreover different numerical taxonomy methods (Sneath & Sokal 1973) were used to help clarify their taxonomy.

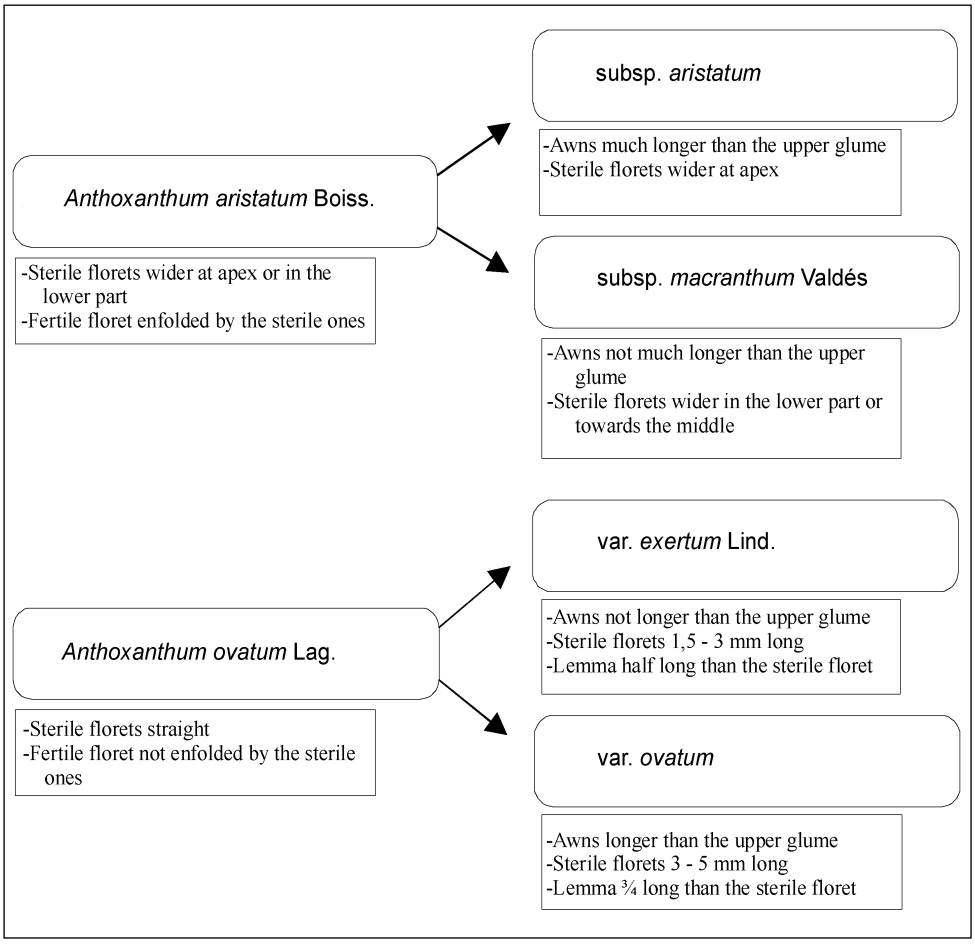

Fig. 1. Infra-specific taxa described in *Anthoxanthum aristatum* and *A. ovatum*.

Materials and methods

A total of 389 specimens from 6 populations at Doñana National Park were analysed (Fig. 2). The selection of the sampling areas was based on a bibliographical review and on the study of herbarium specimens from Sevilla University Herbarium (SEV). In all populations different taxa grew in simpatry, and therefore, a high morphological diversity was observed.

The number of specimens gathered in each locality was variable, depending on the morphological diversity observed, and different subgroups were made using several traits such as spikelet hairiness, awn length and plant size. Each of the specimens collected was also identified following Valdés (1973), although many of them presented intermediate charac-

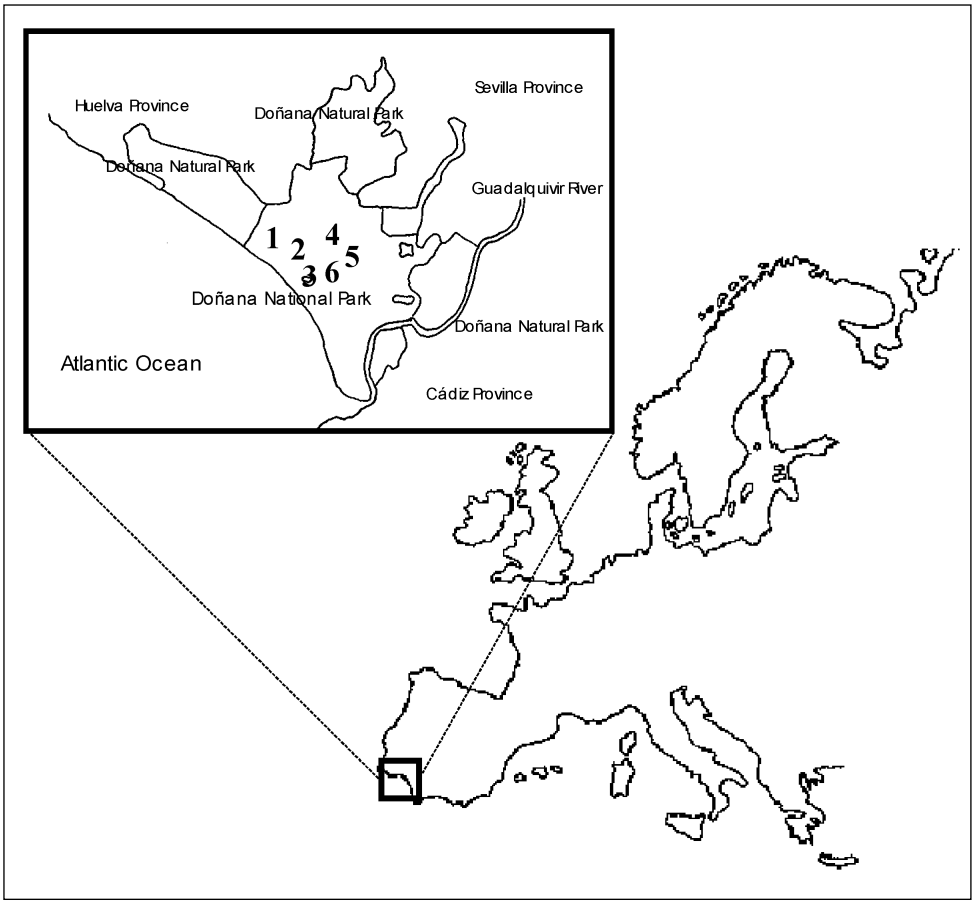

Fig. 2. Sampled localities in Doñana National Park. **1.** El Acebuche; **2.** Navazo del Toro; **3.** Laguna de Santa Olalla; **4.** El Martinazo; **5.** Caño del Tío Antoñito; **6.** Pinar de San Agustín.

Table 1. Sampled localities, taxa found per population and number of specimens collected.

POPULATION	Different taxa identified per population	No. of specimens collected per population
Laguna de Sta Olalla	*Anthoxanthum ovatum* var. *exertum*	60
	A. aristatum subsp. *macranthum*	
Navazo del Toro	*A. aristatum* subsp. *aristatum*	55
	A. ovatum var. *ovatum*	
El Acebuche	*A. ovatum* var. *ovatum*	57
El Martinazo	*A. aristatum* subsp. *macranthum*	37
	A. ovatum var. *ovatum*	
	A. aristatum subsp. *aristatum*	
Caño del Tío Antoñito	*A. aristatum* subsp. *macranthum*	120
	A. aristatum subsp. *aristatum*	
	A. ovatum var. *ovatum*	
	A. ovatum var. *exertum*	
Pinar de S. Agustín	*A. ovatum* var. *ovatum*	60
	A. aristatum subsp. *aristatum*	
Total Number		**389**

teristics among different taxa. The sampled localities, the number of individuals collected and the different taxa identified per population are listed in Table 1.

Twenty-four morphological macroscopic traits (13 quantitative and 11 qualitative) were considered in the statistical analyses performed (Table 2). The exploratory analyses consisted in calculating the coefficient of variation and in performing a principal components

Table 2. Studied traits.

QUANTITATIVE TRAITS	QUALITATIVE TRAITS
Plant size	Presence of convolute leaves
Leaf length	Ligule shape
Leaf width	Hairiness of the sheath
Inflorescence length	Hairiness of the upper glume
First branch of the inflorescence length	Upper glume mucronate
First internode of the inflorescence length	Hairiness of the lower glume
Spikelet length	Outline of the upper sterile lemma
Upper glume width	Hairiness of the sterile lemmas
Lower glume length	
Upper sterile lemma length	Superposition of the sterile lemmas over the fertile one
Upper sterile lemma width	Area of the upper sterile lemma covered by hairs
Awn length	
Fertile lemma length	Hairiness of the fertile lemma

Table 3. Influence of each of the analysed traits on the components and relative weight of each component.

Characteristics	P.C.A. Components		
	1	2	3
Plant size	**0.8150**	0.2417	0.2329
Leaf length	**0.8659**	0.2041	-0.0428
Leaf width	**0.7667**	0.1641	-0.1244
Inflorescence length	**0.8269**	0.3778	0.2056
Spikelet length	-0.3056	**0.4487**	0.3824
Lower glume length	0.0013	**0.2677**	-0.2307
Awn length	-0.5986	**0.6319**	0.2485
Upper sterile floret length	**-0.6073**	**0.5886**	-0.2787
Upper sterile floret width	-0.3335	**0.4620**	0.0044
Lemma length	-0.4001	0.1396	**0.8091**
Upper glume width	0.2130	**0.3482**	0.0811
First branch of the inflorescence length	0.1317	**0.5939**	-0.0694
First internode of the inflorescence length	**0.7922**	0.3445	0.0570
Weight of each component	32.58%	16.95%	11.69%
Total	61.22%		

analysis (PCA) for quantitative characteristics. Contingency table analysis was applied for the qualitative data. Subsequently, the similarity among samples was established using the Phi-coefficient for the qualitative data and the Manhattan distance for the quantitative values (Rohlf 1993). The relationships among samples and subgroups were summarised in phenograms obtained using UPGMA clustering methods. Statistical analyses were carried out with the software SPSS 11.0.

Results and discussion

The statistical exploratory analyses showed that the vegetative characteristics were more variable than the floral ones in all populations and subpopulations. For example, in the "Laguna de Santa Olalla" locality the mean coefficient of variation for the floral traits was 0.17, yet for the vegetative characteristics it was 0.38. The variability observed in the data was similar, considering each population as a whole or subpopulation by subpopulation. This behaviour was common in all localities and seems to indicate that there are no significant differences among the subpopulations, regarding the variability of the quantitative data. Also, several characteristics, usually considered of taxonomical interest, presented high coefficient of variation values (upper sterile lemma length, fertile lemma length).

As a result of the PCA, three components were obtained to explain 61% of the variance observed. The influence of each trait in the first, second and third components and their weight explaining the total variation observed can be seen in Table 3. It is worth noting that certain characteristics that are usually considered to be taxonomically interesting, such as

the upper sterile lemma length or fertile lemma length were found in the second or third component showing weight.

The diagram displayed as a result of this analysis, shows high continuity and mixture among populations (Fig. 3). Only three subpopulations (characterised by awn length and upper sterile lemma length), identified as *A. aristatum* subsp. *macranthum* Valdés and *A. ovatum* var. *exertum* Lind. from "El Martinazo" and "Caño del Tío Antoñito", seem to be slightly apart from the others. However, the subpopulations belonging to these taxa are not clearly grouped.

A cluster analysis was performed using the traits pointed out as being more interesting in the PCA. In the dendrogram obtained the subpopulations are all mixed. If all characteristics are used to construct the dendrogram, this mixture is even greater (Fig. 4).

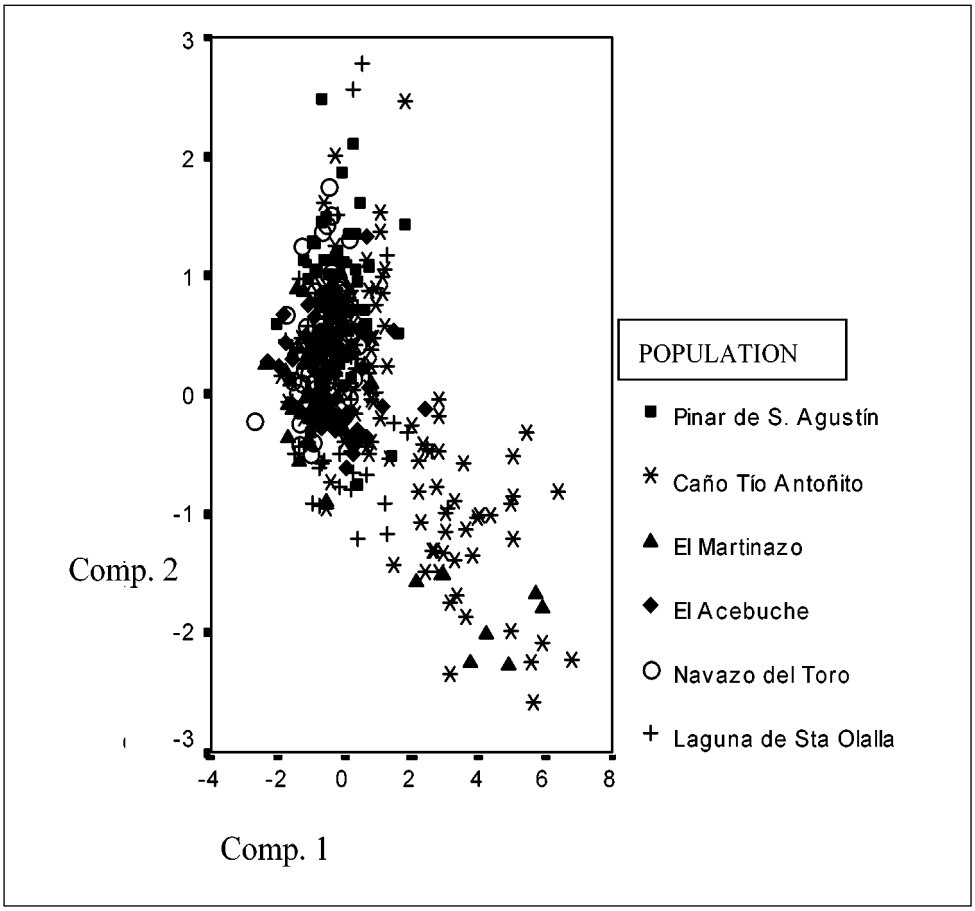

Fig. 3. Scatterplot from the principal component analysis.

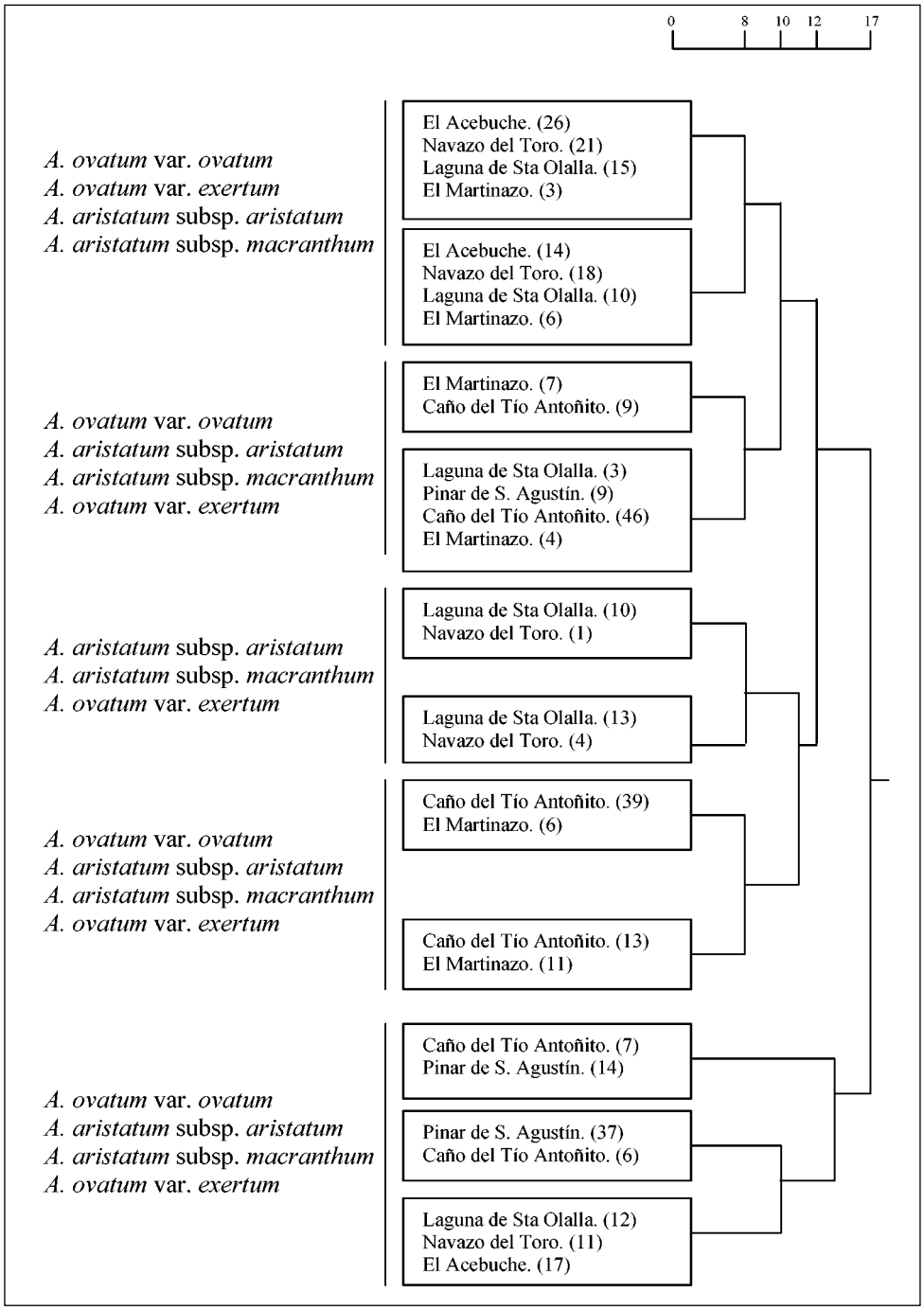

Fig. 4. Dendrogram obtained using the quantitative data (Number of individuals are indicated between parentheses).

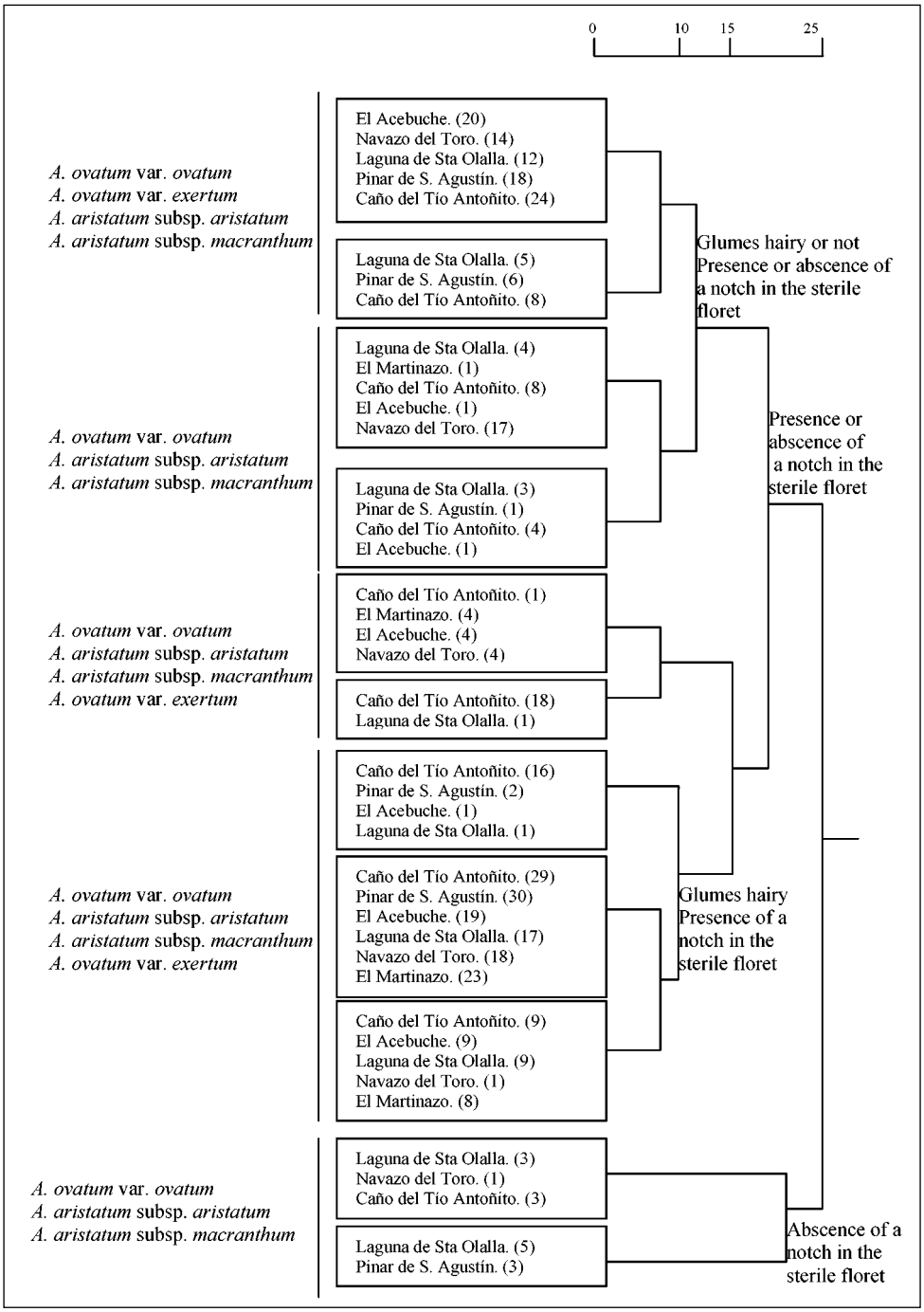

Fig. 5. Dendrogram obtained using the qualitative data (Number of individuals are indicated between parentheses).

Regarding the qualitative characteristics, the contingency table analysis showed the existence of significant differences among the populations and subpopulations for almost all traits studied, however, numerous exceptions within each characteristic were observed. Some of these characteristics, such as the outline of the upper sterile lemma or the superposition of the sterile lemmas over the fertile one, have been pointed out as being taxonomically significant despite their high variability. The cluster analysis performed with the qualitative data was summarised in a dendrogram (Fig. 5) where the different subpopulations appear, once again, totally mixed.

Our results suggest that no differentiation can be done at the specific level between *A. aristatum* and *A. ovatum* and that no infra-specific taxa should be defined. This idea has been supported by several authors throughout the 20th century. (Battandier & Trabut 1895; Briquet 1910; Jahandiez & Maire 1931; Maire 1953; Quezel & Santa 1962; Lopez-González 1994).

Conclusions

The morphometric analyses performed do not support the taxonomical differentiation of the populations or subpopulations studied. The differences among taxa that have been highlighted by other authors because of their taxonomical interest seem to be just due to intra- or inter-population variation.

Our results do not support the differentiation between *Anthoxanthum aristatum* and *A. ovatum* nor the separation of any infra-specific taxa in these species.

Complementary studies (molecular, karyological, anatomical, etc.) should be performed to support our results. Furthermore, it would be interesting to include new populations to analyse the relationship between the environment and the morphological traits considered.

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