NUMERICAL ANALYSES OF WILD *JURINEA* SPP. (ASTERACEAE) IN TURKEY

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Abstract

Eighteen taxa of the genus *Jurinea* Cass. growing naturally in Turkey were classified by numerical taxonomic analysis. Morphological and palynological characters of each individual were measured and quantified on the basis of 51 traits. Ten plants were chosen randomly for the measurements of metric characters related to the external morphology of the taxa and the average values used for statistical analysis *via* NTSYS-pc package. Standardized data were used to generate the dendrogram that revealed the phenetic relationships of the taxa. Geographic distribution pattern of the *Jurinea* species appear to be closely related to the Anatolian Diagonal.

Introduction

Asteraceae is one of the largest Angiosperm families and according to recent classification it is divided into four subfamilies and 17 tribes (Hind and Beentje 1994). Within the family, a total of 1535 genera with 26,000 species have been recorded. *Asteraceae* is widely distributed within diverse regions ranging from Southwest of US, Mexico, Southern Brazil, South Africa, Middle and Southwest Asia as well as Australia. South America is accepted to be phylogenetically the geographic origin of the family (Bremer 1994).

Asteraceae is represented by 1209 species in the Flora of Turkey, out of which 447 are endemic, with an endemism of 37%. With a total number of 134 genera, this family constitutes the second largest family of Turkish Flora (Davis *et al*. 1988, Özhatay and Kültür 2006). The genus *Jurinea* is represented with 18 species within Mediterranean and Irano-Turanian phytogeographic regions of Anatolia. Five of these species are endemic to Turkey resulting in an endemism of 27.8% (Danin and Davis 1975, Dogan 2007, Dogan *et al.* 2007).

Jurinea Cass. is one of the most important genera within Asteraceae and it comprises about 200 species (Susanna *et al*. 2006). Native distribution of *Jurinea* specifically involves Central Asia, Iran, Turkey and the Mediterranean basin. It is located within the monophyletic tribe *Cardueae* which is constituted of five subtribes, namely, *Carduinae*, *Centaureinae*, *Carlininae*, *Cardopatiinae* and *Echinopinae*. *Jurinea* is a genus located within the subtribe *Carduinae* (Susanna *et al*. 2006).

Actual numerical-taxonomic studies of plant data were very scarce before the 1960s (Sokal and Sneath 1963). Numerical taxonomy has previously been applied in the classification of a number of plant taxa in Turkey (Togan *et al.* 1983, Kence *et al.* 1988, Dogan *et al.* 1992, Dogan 1997, Tutel *et al.* 2005). In this study, numeric taxonomic methods have been applied to classify 18 *Jurinea* taxa, on the basis of morphological and palynological characters.

Materials and Methods

Fifty one morphological and palynological characters were determined from the taxa of the genus *Jurinea* that are natural inhabitants of Turkey. List of species is given in Table 1. These characters were placed under eight headings and were included in the life form, shoot and leaf

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characteristics, flower structure, capitulum, involucrum, fillaries and achen characteristics (Table 2). Data obtained from 18 taxa and a total of 51 traits were organized into a matrix of 51 × 18 dimensions. The mean of ten individual sample measurements related to the external morphologies were considered for every metric character of the taxa. Analyses of standardized data were conducted using the NTSYS-pc package programme (Applied Biostatistic, Exeter Software, Setauket, New York, USA). Similarity coefficients were calculated and phenograms were constructed using the unweighted pair-group method with the arithmetic mean (UPGMA) method (Rohlf 1992). In order to determine the ability of numerical data to display the inter-relationships among the samples, principle co-ordinate analysis (PCoA) of pairwise genetic distances (Nei 1972) was also conducted using NTSYS-pc package.

Table 1. Origin of the materials and herbaria where the vouchers of *Jurinea* spp. are deposited.

Species	Origin, voucher
J. consanguinea	Turkey, Konya: Sultan Mountains, 1130 m, $37^0 14.913^'$N, 038^0 49.427$^'$E, 18.07.2006, B.Doğan 1501 (KNYA)
J. tortumensis	Turkey, Erzurum: From Erzurum to Tortum, 1880 m, 40º.15.08$^'$N, 041º.31.59$^'$E, 31.05.2003, A.Duran 6170 (KNYA), Endemic.
J. alpigena	Turkey, Karabük, Keltepe, 1630-1680 m, 41º03.796'N, 032º27.781'E, 21.07.2006, B.Doğan 1510 (KNYA), Endemic.
J. cadmea	Turkey, İzmir, Ödemiş, Bozdağ, 1650-1750 m, $38^° 20.671^'$ N, $028^° 06.403^'$ E, 19.07.2006, B.Doğan 1503 (KNYA), Endemic.
J. mollis	Turkey, Kırklareli, from Vize to Sergen, *Quercus* sp. forest, 310-320 m, 41º 37.312$^'$ N, 027º 40.950$^'$ E, 07.07.2005, B.Doğan 1504 (KNYA)
J. macrocalathia	Turkey, Tekirdağ, Malkara, Kumbağ, 5-25 m, 40º 51.852$^'$ N, 027º 27.604$^'$ E, B.Doğan 1507 (KNYA)
J. turcica	Turkey, Kırklareli, Kıyıköy, 5-10 m, 41º 38.283$^'$ N, 028º 05.661$^'$ E, 08.07.2005, B.Doğan 1008 (KNYA), Endemic.
J. pontica	Turkey, Kocaeli, Sapanca lake slopes, 40-50 m, $40^° 44.118^'$ N, $033^° 36.871^'$ N, 09.07.2005, B.Doğan 1011 (KNYA), Endemic.
J. pulchella	Turkey, Van, Campus of Yüzüncü Yıl University, 1650 m, 05.08.2005, B.Doğan 1025 (KNYA)
J. kilaea	Turkey, Kırklareli, Kasatura (Kastros), beach dunes, 1-5 m, $41^° 35.273^'$ N, $028^° 08.566^'$ E, 08.07.2005, B.Doğan 1010 (KNYA)
J. stoechadifolia	Turkey, Çankırı, from Çankırı to Ilgaz, 830 m, $39^° 54.362^'$ N, $040^° 41.903^'$ E, 23.09.2006, B.Doğan 1522, A.Duran & H.Duman (KNYA)
J. cypria	Turkey, Mersin, Mut, Mountain pasture of Kozlar, 1320 m, $37^° 14.913^'$ N, $038^° 49.427^'$ E, 28.07.2006, B.Doğan 1500 (KNYA)
J. macrocephala	Turkey, Konya, Aydos Mountain, Kayasaray village, 1700 m, $37^° 22.249^'$ N, $034^° 17.308^'$ E, 31.07.2005, B.Doğan 1017 (KNYA)
J. aucherana	Turkey, Erzincan, Spikor mountain, 760-2095 m, $39^° 53.429^'$ N, $039^° 45.778^'$ E, 22.08.2006, B.Doğan 1519 (KNYA)
J. ramulosa	Turkey, Kahramanmaraş, Ahir Mountain, 1390 m, $37^° 37.057^'$ N, $036^° 52.074^'$ E, B.Doğan 1513 (KNYA)
J. brevicaulis	Turkey, Erzincan, Spikor Mountain, 1420 m, $39^° 47.363^'$ N, $039^° 29.940^'$ E, 07.08.2005, B.Doğan 1028 (KNYA), Endemic.
J. cataonica	Turkey, Erzincan, Spikor Mountain, 10 km, 1750 m, $39^0 47.954^'$ N, $039^0 30.343^'$ E, 07.08.2005, B.Doğan 1029 (KNYA), Endemic.
J. ancyrensis	Turkey, Elazığ, from Keban to Ağlı, 800-850 m, $38^° 48.692^'$ N, $038^° 43.929^'$ E, 21.08.2006, B.Doğan 1516 (KNYA)

Table 2. List of characters used in numerical taxonomic analysis.

A-Life forms	F-Involucrate
1-Hemicryptophyte (0), Chamaephyte (1)	27- Hemispherical (0), globose (1) obconical (2), ovate-oblong (3)
B- Stems	28-Involucrum length (mm)
2-Stem length (cm)	29-Involucrum width (mm)
3-Stem thickness (mm)	**G-Phyllaries**
4-Stem hairiness; sparsely (0), densely (1)	30-5 seriate (0), 5-6 seriate (1), 6-7 seriate (2), 7-8 seriate (3)
5-Stem base hairiness; not woolly (0), woolly (1)	31-Phyllaries adpressed (0), adpressed to lax (1), lax (2)
6-Stem branched; absent (0), present (1)	32-Outer phyllaries length (mm)
7-Stem present; absent (0), present (1)	33-Outer phyllaries width (mm)
8-Stem decumbent (0), erect (1)	34-Inner phyllaries length (mm)
C-Leaves	35-Inner phyllaries width (mm)
9-Stem leaves; absent (0), decreasing in size upwards (1), present (2),	36-Phyllaries reflexed (0), not reflexed (1)
10-Stem leaf length (cm)	37-Phyllaries not keel (0), keel (1)
11-Stem leaf width (cm)	
12-Stem leaf shape; entire (0), pinnatisect (1)	**H-Achenes**
13-Basal leaf length (cm)	38-Achene smooth (0), tetragonal (1)
14-Basal leaf width (cm)	39-Achene length (mm)
15-Basal leaf shape; entire (0), pinnatisect (1)	40-Pappus scabrous (0), barbellate (1), plumose (2)
16-Basal leaf hairiness; absent (0), present (1)	41-Pappus length (mm)
17-Basal leaf narrow; absent (0), present (1)	**I-Pollens**
18-Basal leaf rosulate (0), not rosulate (1)	42-Polar axis length (μm)
D-Flowers	43-Equatorial axis length (μm)
19-Corolla lobe length (mm)	44-Exine thickness (μm)
20-Corolla tube length (mm)	45-Intine thickness (μm)
21-Anther length (mm)	46-Colpus length (μm)
22-Style length (mm)	47-Colpus width (μm)
E-Capitula	48-Pore length (μm)
23-Capitula length (cm)	49-Pore width (μm)
24-Capitula width (cm)	50-Clg/Clt ratio
25-Capitula solitary (0), two or more than (1)	51- Polar axis / Equatorial axis ratio
26-Capitula corymbose (0), not corymbose (1)	

Results and Discussion

In the present study, 18 taxa were evaluated on the basis of data matrix generated from 51 characters (18 × 51). Within the data set, 41 characters were related to the external morphology and the remaining ten characters were determined from palynologic data. Cluster analysis was conducted based on both discrete and continuous data that were first standardized. Numerical classification results on phylogenetic relationships of *Jurinea* taxa were determined according to the phenogram resulting from the UPGMA clustering (Fig. 1).

When the phenogram was studied, it was observed that all the *Jurinea* species were composed of two major groups. The species of the first group, namely *J. consanguinea, J. pontica, J. pulchella, J. kilaea, J. mollis, J. macrocalathia, J. turcica, J. alpigena* constituted the taxa with pinnatilobed to pinnatisect leaves. These taxa, with the exception of *J. consanguinea*, are distributed at the Western part of the Anatolian Diagonal. While *J. consanguinea* is widely grown at the West of the Diagonal, it is also present on the Diagonal as well as at the Eastern parts of it and appear to be very restricted. It is worth noting that this species is a transition taxon with mostly pinnatisect leaves but some of the samples were also observed with entire leaves. This species with various growing habitats, was observed not to be influenced by the geographical,

topographical and climatological factors determined by the Anatolian Diagonal. Another species, *J. pulchella* that is distributed at the Eastern parts of the Diagonal and possesses both pinnatisect and entire leaves, that is also expected to be present within both groups was observed within the Western group with pinnatisect leaves.
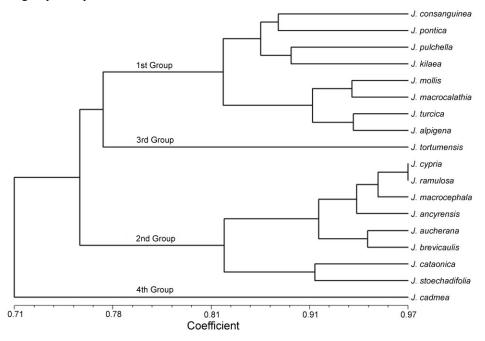

Fig. 1. Phenogram showing the relationships within the genus *Jurinea.*

    When the *Jurinea* taxa naturally grown in Turkey were examined, the ones with entire leaves that inhabit the Eastern parts of the Anatolian Diagonal were seen to be the taxa that are evolutionary more advanced. That is because entirety of the leaves is an advanced character (Stace 1992). *J. pulchella* is a species localized to Irano-Turanian phytogeographic region, but in previous geological times, due to different climatic conditions it was probably distributed in a more extensive region. Considering the remaining Western taxa, the second branch that was constituted of the species *J. mollis*, *J. macrocalathia*, *J. turcica* and *J. alpigena*, they varied from the first branch at a level of 85%. *J. kilea* is the only species collected from a coastal region of Black Sea, namely Kirklareli-Kiyikoy, and within the limits of the present study it was grouped with *J. pulchella*. This is in accordance with our previous work where the genetic relationships of 14 *Jurinea* species were determined *via* Inter Simple Sequence Repeats or simply ISSR (Dogan *et al.* 2007). Interestingly, in that study, *J. pulchella* appeared as a species loosely attached to the taxa that constituted the second major group with samples mainly collected from the Eastern parts of the Anatolian Diagonal.

    The taxa that constituted the second group include *J. cypria, J. ramulosa, J. macro-cephala, J. ancyrensis, J. aucherana, J. brevicaulis, J. cataonica* and *J. stoechadifolia*. Within this group, high level of morphological similarity was observed. Leaves of all taxa were entire, their stems were branched and the number of capitula per plant was more than one. With the exception of *J. stoechadifolia*, the taxa constituting this group are grown either on or at the East of Anatolian Diagonal, their distribution is closely related to the Diagonal.

Overall, the samples of the Western Anatolian Diagonal were equally distinct from *J. tortumensis* which appeared as the third discrete branch on the numerical dendogram. Its leaves are entire, undulate or lobed to a certain degree. With leaves from slightly pinnatilobed to lobular it presents an intermediate species. Additionally, with its hairless leaves and old-leaf remains abundant at the plant base it is very distinct from the other taxa.
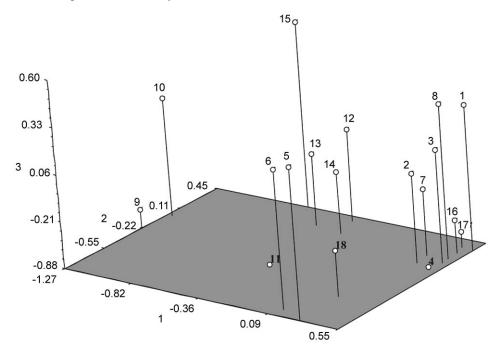

Fig. 2. Principal coordinate analysis of *Jurinea* species. 1. *Jurinea consanguinea*, 2. *J. tortumensis,* 3. *J. mollis,* 4. *J. cadmea,* 5. *J. macrocalathia,* 6. *J. turcica,* 7. *J. alpigena,* 8. *J. pontica,* 9. *J. cypria,* 10. *J. macrocephala,* 11. *J. aucherana,* 12. *J. ramulosa,* 13. *J. brevicaulis,* 14. *J. cataonica.* 15. *J. ancyrensis,* 16. *J. pulchella,* 17. *J. stoechadifolia,* 18. *J. kilaea.*

Although *J. stoechadifolia* is distributed in the West of the Diagonal and since its leaves are entire, it has a branched stem and the number of its capitula is more than one, this taxon was placed in the second group. This species is also distributed in Bulgaria and the former Soviet Union (Kozuharov 1964, Iljin 1962). Among the *Jurinea* species of Turkey *J. stoechadifolia* is the only taxon that is localized to gypsy soils. When the global distribution of this species is considered, it can be seen that its distribution in Turkey is not related to the Anatolian Diagonal.

In the study of Dogan *et al.* (2007), cluster analysis *via* molecular data was insufficient in clearly discriminating the species of the sub-branch of Western Diagonal group that was constituted of *J. brevicaulis*, *J. cataonica* and *J. ancyrensis*. In contrary, in the present study, it was impossible to distinguish the species *J. cypria* (a species not used in our previous work) from *J. ramulosa*. However, this distinction was possible with the use of Principle Coordinate Analysis (PCoA). The related species were clearly separated by the first and the second principle coordinates (PCo1 & PCo2). Both our previous molecular study and the current phenotypical analysis determined a close relationship between *J. ramulosa* and J. *macrocephala*. When the first two coordinates are considered, the last branch represented by *J. cadmea* in cluster analysis, was found to be grouped with the taxa of the first group of the dendogram. A comprehensive discrimination of the remaining taxa was also possible with the use of the first three coordinates

(Fig. 2). Not to mention, effective discrimination power of PCoA was also proven elsewhere (Dogan *et al.* 2007).

As of the stem character, of all the *Jurinea* taxa of Turkey, *J. cadmea*, has stems. The stemless species *J. cadmea* that is grown at the rocky places of Bozdag region at Western Anatolia is a local endemic species. By itself, this taxon was constituted of fourth separate branch on the numerical dendrogram. In other words, it served as an outlier sample.

Overall, the phenogram generated with the use of the morphological and the palynological data determined that the morphologically similar taxa gathered under the same branch. Similarly, numerical data presented highly similar clustering profile with that of the molecular data (Dogan *et al.* 2007). Additionally, the discrimination of the taxa with the use of both the numerical and the molecular phylogeny was also found to be closely related to the Anatolian Diagonal (Fig. 3). The existence of the *Jurinea* species is given in Fig. 3. Some taxa are rarely distributed outside the given areas.
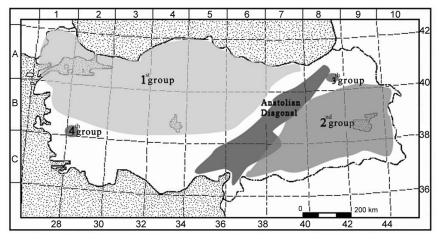

Fig. 3. Distribution of four *Jurinea* groups in Anatolia. The groups were obtained by the use of phenetic analysis of the Turkish taxa.

It appeared that, the phytogeographical distribution of the genus *Jurinea* was found to be closely related to the Anatolian Diagonal. The Diagonal is an interesting biodiversity area and it is rich in local endemic plants, than in any Mediterranean region (Duran *et al.* 2005). The concept of the Diagonal was first proposed by Davis who defined it as an oblique belt running from the north-east towards south-west to the Anti-Taurus: it was then divided into two, with one branch to the Amanus (Amanos Dağları), the other to the Cilician Taurus (Davis 1971). Thirty three per cent of the total species growing in Turkey are found along the Diagonal, while 5 per cent are more or less restricted to it. One explanation for the present richness of the species is neo-endemism and distribution patterns of the plants related to the Diagonal (Ekim and Güner 1986). Based on the physiographic disturbances that isolated the *Jurinea* species grown on the Anatolian Diagonal and its eastern parts from the species grown along the western regions of the Diagonal, two major taxonomical groups were constituted. Numerical data of this study provided strong and reliable support to clearly reveal biogeographic distribution of this genus and the taxonomic relationships.

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