Article

Species relationships in Festuca (Poaceae) of Iran

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Received July 27, 2010

Accepted August 27, 2010

Abstract

The genus Festuca is one of the largest genera whitin the Poaceae family, comprising OF 450-500 species distributed in the temperate areas and 11 species growing in Iran. The present study considers phenetic and cladistic analyses of 46 populations belonging to 11 Festuca species, trying to reveal their inter-population morphological variations and inter-specific relationships. Clustering PCO (GIVE FULL NAME) ordination based on qualitative characters produced two major clusters, grouping the species with filiform leaves including F. valesiaca, F. sulcata, F. chalcophaea, F. elwendiana and F. akhanii together and the species with flat form-leaves including F. drymeia, F. gigantea, F. pratensis and F. arundinacea together. Parsimony analysis supported these results, which IS PARTLY IN AGREEMENT WITH taxonomic treatment of the genus in Flora Iranica. Factor analysis identified the most variable morphological characters which along with those identified by ANOVA test, may be used in the taxonomy of the genus.

Key words: Festuca,.morphometry, parsimony.

Introduction

The genus Festuca L. belongs to the tribe Poeae R. Br. (= Festuceae Dumort.), family Poaceae . It is comprised of 450-500 species growing in Polar, temperate and alpine regions of both hemispheres and is considered as one of the main evolutionary lines in

the tribe Poeae (Tzvelev, 1976). So far, 10-12 Festuca species have been reported in Iran (Parsa, 1950; Bor, 1970). Although the available literature dealing with systematic and biosystematics of Festuca species indicate the importance (in what way) of these taxa (Tzvelev, 1989), there are few reports on biosystematic study of Festuca species from Iran (Sheidai and Bagheri-Shabestari, 2007a,b). Therefore, the present study considers phenetic and cladistic analyses of 46 plant population belonging to 11 Festuca species, trying to reveal their inter-population morphological variations and inter-specific relationships.

Materials and methods

Morphometric studies were performed on 46 plant population of 11 Festuca species belonging to 4 subgenera (Bor, 1970) namely: (1)- Subgen. Festuca including F. sulcata (Hack.) Beck., F. rubra L., F. heterophylla Lam., and F. valesiaca Gaud. s.l. according to Tzvelev (1984), F. chalcophaea V. Krecz & Bobrov., according to Smith (1985) and F. akhanii Tzvel., according to Tzvelev (1997), (2)- Subgen. Schedonarus (P.Beauv.) Ascher., including F. pratensis Huds., F. arundinacea Schreb., (3)- Sbgen. Drymanthele Krecz & Bobrov, including F. drymeia Mert. & Koch., (4)- Subgen. Drymonaetes (Ehrh.) V. Krecz & Bobrov, including F. gigantea (L.) Vill.,

Three to five plants from each population were randomly selected and used for morphometric studies. From the specimens collected, 5-10 readings were taken for each character. Details of the localities and the voucher numbers are provided in Table 1. Voucher specimens are deposited in TARI, IRAN and Herbarium of Shahid Beheshti University (SBUH). In total 77 quantitative and qualitative morphological characters were studied (Table 2). Characters were selected based on those reported by floras (Bor 1968, 1970), articles (Liu and Dengler, 1992) and our own field observations of Festuca species.

In order to detect significant difference in quantitative morphological characters among populations of each species and also among different species studied, analysis of variance (ANOVA) followed by the least significant difference (LSD) tests were performed (Sheidai et al., 2007). For multivariate analyses the mean of quantitative characters were used, while qualitative characters were coded as binary/multistate characters. Standardized variables (mean=0, variance=1) were used for multivariate statistical analyses (Podani, 2000). The average taxonomic distance and squared Euclidean distance were used as dissimilarity coefficient in cluster analysis of morphological data (Podani, 2000).

In order to group the population with morphological similarities cluster analysis using UPGMA (Unweighted Paired Group with Arithmetic Average) and WARD (Minimum Variance Spherical Cluster) was performed. In order to determine the most variable morphological characters among the species studied, factor analysis based on principal components analysis (PCA) was performed (Podani, 2000). Species relationships were also studied by cladistic analysis as well as ordination based on principal coordinate analysis (PCO) were performed

For ANOVA and LSD tests, SPSS ver.9 (1998) was used while clustering and

ordination plot analyses were performed by NTSYS ver. 2. (1998). Cladistic analysis based on parsimony was used which carried out with PAUP ver. 4. 10b (2000). Cophenetic correlation was determined to find out fit of dendrograms in clustering methods to the original data, while bootstrapping was performed for cladistic trees obtained (Podani, 2000).

Results and discussion

The cluster analysis (UPGMA and WARD methods) and PCO ordination of Festuca species studied based on qualitative characters produced similar results, therefore only clustering dendrogram is provided (Fig. 1). Cophenetic correlation obtained for different clustering method, showed the highest value for WARD dendrogram (r <0.90). The quantitative data would be useful to provide.

In general two major clusters were obtained. The species with filiform leaves of subgen. Festuca from the first major cluster. These species are F. valesiaca s.l , F. sulcata, F. chalcophaea, F. elwendiana and F. akhanii. The species F. heterophylla and F. rubra. show more similarity and are placed close to each other supporting Tzvelev (1984), Smith (1985) and Bulinska-Rondomska (1986) about affinity of these species.

The second major cluster is comprised of flat form-leaves fescues., including F. drymeia of the subgen. Drymanthele (margins of auricules are ciliate), F. gigantea of the subgen. Drymonaetes (presence of awned lemma, 10-20 mm length), F. pratensis (lemma without awn, margins of auricles are glaber), and F. arundinacea.(presence of ciliated auricles margins) both from the Subgen. Schedonarus. Bor (1970) in the Flora Iranica and Smith (1980) considered these two subgenera close to each other, which is supported by study.

The third sub-cluster has two sub-clusters , in the first of which F. pratensis populations have been placed together, based on characters like lemma without awn, margins of auricles are glaber, and also transverse oblong ligule margin. The second sub-cluster is comprised of the species of F. arundinacea, based on presence of ciliated auricles margins. These two species belong to subgen. Schedonarus and being considered close to each other by various researchers (Bor 1968, Smith 1980, Cope 1982 and Tzvelev 1984) which is supported by present study . Qualitative characters studied can separate the species of 3 subgenera of Drymanthele, Drymonaetes and Schedonorus very well.

Tzvelev (1997) reported the endemic species F. akhanii from Almeh in the Golestan Natural Park of Iran while; Smith (1985) reported F. chalcophaea from Kordestan province and F. elwendiana from Ganjnameh in Hamedan province of Iran. We studied specimens presumed to belong to these species (collected from their specific localities), which were placed in distinct, separate clusters. Therefore the present study confirms the presence of these 3 species in Iran. F. akhanii has non-membranous and ciliated glume margin and leaf blade 0.1-0.3 mm width, F. elwendiana has scabrous vagina margins, glaber glume margin and spikelets up to 15 mm length, while F. halcophaea shows open leaf vagina, glaber stem surface and golden margins of glumes and lemmas.

Parsimony tree obtained (Fig. 2), supports the result of clustering. The most parsimonious tree obtained has CI value of 0.22 and HI value of 0.77 indicating that morphological characters used in taxonomy of Festuca show high homoplasy. In general, the present study partly supports Bor (1970), taxonomic treatment of the genus Festuca, and it seems that more detailed studies including molecular investigations are required to illustrate the species relationships in the genus .

The ANOVA and LSD tests indicated that (data not shown), Festuca species differ significantly in most of the quantitative characters studied and such characters may be used for the species delimitation. These characters are: number of veins in basal leaf, ratio of panicle length to its width, length of inflorescence branches in the lowest node, spikelet width, ratio of lemma length to its width, palea length and width, upper glume width, and ratio of the upper glume length to its width.

In order to identify the most variable morphological characters among the species studied, PCA analysis revealed that the first 6 factors comprise about 65% of total variance. In the first factor with about 30% of total variance, characters like plant form, auricle form, auricle margin and awn position possessed the highest positive correlation (>0.80). This factor may be called auricle and awn factor.

In the second factor with about 9% of total variance, characters like similarity between basal leaf and culm-leaf and adaxial culm-leaf surface possessed the highest positive correlation (>0.60). This factor may be called culm-leaf factor.

In the third factor with about 7% of total variance, characters like panicle shape and ovary shape possessed the highest positive correlation (>0/50). This factor may have combined name of panicle-ovary factor.

Give separately concluding remarksTherefore these are the most variable morphological characters among the species studied, and along with characters identified by ANOVA test, may be used in the Festuca taxonomy.

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Table 1: Festuca species studied their localities and voucher numbers.

Species/ Population	Locality	Species code	Voucher Number
Festuca gigantea	Mazandaran:south-west of Tonkabon, Liresar, Lesakooti forest,1400 m	1	TARI ,71073
F. gigantea	Gilan: 10 km Asalem to Khalkhal, 600 m	2	TARI ,66027
F. gigantea	Golestan: Golestan Natural Park, Tange Gol, 1750 m	3	TARI ,14398
F. gigantea	Golestan: Golestan Natural Park, southwest of waterfall, m 800	4	TARI ,14282
F. drymeia	Mazandaran: Sari, Part Kala, Gare forest	1	* 759
F. drymeia	Golestan: Minoo Dasht, Loveh forest	2	SBUH-2060
F. drymeia	Gilan: Talesh to Asalem, 1200 m	3	IRAN-20460/1-6
F. pratensis	Prov. Armenia, Distr. Agri; Near agri, 4000ft	1	IRAN ,20485
F. pratensis	Azarbaijan: Moghan, Ghori chai	2	IRAN ,20484
F. pratensis	Azarbaijan: 20 km west of Marand, Northwest of Erelan Village, 2000 m	3	TARI ,65525
F. arundinaceae	Fars: Abadeh, Eghlid	1	IRAN-20451/1-5
F. arundinaceae	Hamedan: Alvand Mountains	2	IRAN-20459/1-3
F. arundinaceae	Tehran: Evin, Shahid Beheshti Univesity	3	SBUH-2061
F. arundinaceae	Tehran: Chalous Road, Koshk	4	SBUH,2062
F. arundinaceae	Mazandaran:Noshahr, Kojor Road, Hasan abad	5	SBUH ,2063
F. arundinaceae	Tehran: Evin	6	SBUH ,2064

F. arundinaceae	Mazandaran: Noshahr, Ecological & Botanical Garden	7	SBUH ,2065
F. heterophylla	Mazandaran: Lar Valley, 2420 m	1	TARI ,13348
F. heterophylla	Mazandaran: Kandovan, 2600 m	2	TARI ,438
F. heterophylla	Azarbaijan: Sarab to Sabalan	3	-204621/1-4 IRAN
F. rubra	Mazandaran: Kandovan, Azad bar	-	IRAN ,29198
F. sulcata	Eylam: Reno Mountain	1	IRAN ,20486
F. sulcata	Azarbaijan: Arasbaran Protected Area, Doghroon Mountain, 2500-2800 m	2	TARI ,23997
F.akhanii	North Khorasan: Golestan Natural Park, 2 km west of Almeh toward Sharlegh	-	SBUH ,2066
F. elwendiana	Hamedan: Ganjnameh, 2600 m	-	SBUH ,2067
F. chalcophaea	Kordestan: Sanandaj to Marivan	-	IRAN-20483/1-3
F.valesiaca	Tehran: Firozkouh, 1900 m	1	TARI ,24805
F.valesiaca	EastAzarbaijan:Maragheh,Hashtrood Road,16 km Khalife Kandi, 2070-2130 m	2	,299/274/288 TARI
F.valesiaca	Mazandaran: Sangdeh, Forest above Sarband 1600-m 2200	3	TARI ,73259
F.valesiaca	Khorasan: Koppe Dagh, between Ghochan & Alam Ali Mountain, 1600 m	4	TARI ,4768
F.valesiaca	Kordestan: Ali Abade Maran Village, 2250 m	5	TARI ,1049
F.valesiaca	Eylam: Quercus forest, 1350 m	6	TARI ,2091
F.valesiaca	Mazandaran: Karaj to Kandovan, 2500 m	7	TARI ,11182
F.valesiaca	Kermanshah:15 km East of Harsin, Tamerg Village, m 1900	8	TARI ,976
F.valesiaca	Semnan: Shahrood to Bastam, Khoshyeylagh, 2000-m 2200	9	TARI ,5448
F.valesiaca	Mazandaran: Noshahr Slavatabad	10	IRAN-20477/1-2
F.valesiaca	Hamedan:40 km Southwest of Hamedan	11	IRAN ,20465
F.valesiaca	Azarbaijan: Mianeh, 1170 m	12	IRAN ,20474
F.valesiaca	Khorasan: Talghor	14	IRAN ,20470
F.valesiaca	Khorasan:54 km Northeast of Shahrood	15	IRAN ,20473
F.valesiaca	Semnan: Shahrood, Khoshyeylagh	16	IRAN ,20475
F.valesiaca	Mazandaran: Noshahr, Kojor, Lashak, 1300 m	17	SBUH ,2068
F.valesiaca	Tehran: Damavand, Rineh	18	SBUH ,2069
F.valesiaca	North Khorasan: Golestan Natural Park, Yaghteh Kalan	19	SBUH ,2070
F.valesiaca	EastAzarbijan: Between Mianeh & Bostanabad, Ghara Chaman, Heydarbaba Mountain	20	SBUH ,2071
F.valesiaca	Golestan: Golestan Natural Park, Sharlegh	21	SBUH ,2072

Abbreviations: IRAN: Iranian Research Institute of Plant Protection Herbarium, TARI: Research Institute of Forests and Rangelands Herbarium, SBUH: Shahid Beheshti University Herbarium, *: Agriculture and Natural Resources Research Center of Mazandaran Herbarium.

Table 2: Morphlogical characters and their codings.

Characters	Data coding
Plant length	Cm
Basal leaf length	Cm
Basal leaf width	Mm
Number of veins in basal leaf	
Culm-leaf length	Cm
Culm-leaf width	Mm
Number of veins in culm-leaf	
Lodicule length	Mm
Panicle length	Cm
Panicle width	Cm
Ratio of length of panicle to width of panicle	
Length of inflorescence branches in the lowest node	Mm
Pedicel length	Mm
Total number of spikelets in panicle	
Number of inflorescence branches in the lowest node	
Spikelet length	Mm
Spikelet width	Mm
Ratio of length of spikelet to width of spikelet	
Number of florets in each spikelet	
Rachilla length	Mm
Lemma length	Mm
Lemma width	Mm
Ratio of length of lemma to width of lemma	
Palea length	Mm
Palea width	Mm
Ratio of length of palea to width of palea	
Upper glume length	Mm
Upper glume width	Mm
Ratio of length of upper glume to width of upper glume	
Number of veins on upper glume	
Lower glume length	Mm
Lower glume width	Mm
Ratio of length of lower glume to width of lower glume	
Number of veins on lower glume	
Anther length	Mm
Ratio of length of Pedicle to length of floret	
Plant form	1) Densely tufted, 2) Loosely tufted
Rhizome	1) Absent, 2) Present
Vegetative shoots position	1) Intravaginal, 2) Extravaginal
Stem surface	1) Scabrous, 2) Glaber, 3) Scabrous under panicle
Indumentum of node	1) Scabrous, 2) Glaber
Basal leaf and culm-leaf	1) Similar, 2) Not similar
Adaxial basal leaf surface	1) Scabrous, 2) Glaber
Abaxial basal leaf surface	1) Scabrous, 2) Glaber
Adaxial Culm-leaf surface	1) Scabrous, 2) Glaber
Abaxial Culm-leaf surface	1) Scabrous, 2) Glaber
Leaf vagina	1) Completely open, 2) Completely closed, 3) Up to half open 4) More than half open, 5) Less than half open
Vagina surface	1) Scabrous, 2) Glaber

Legend to Figures.

Fig.1: UPGMA clustering of Festuca species based on qualitative morphological characters

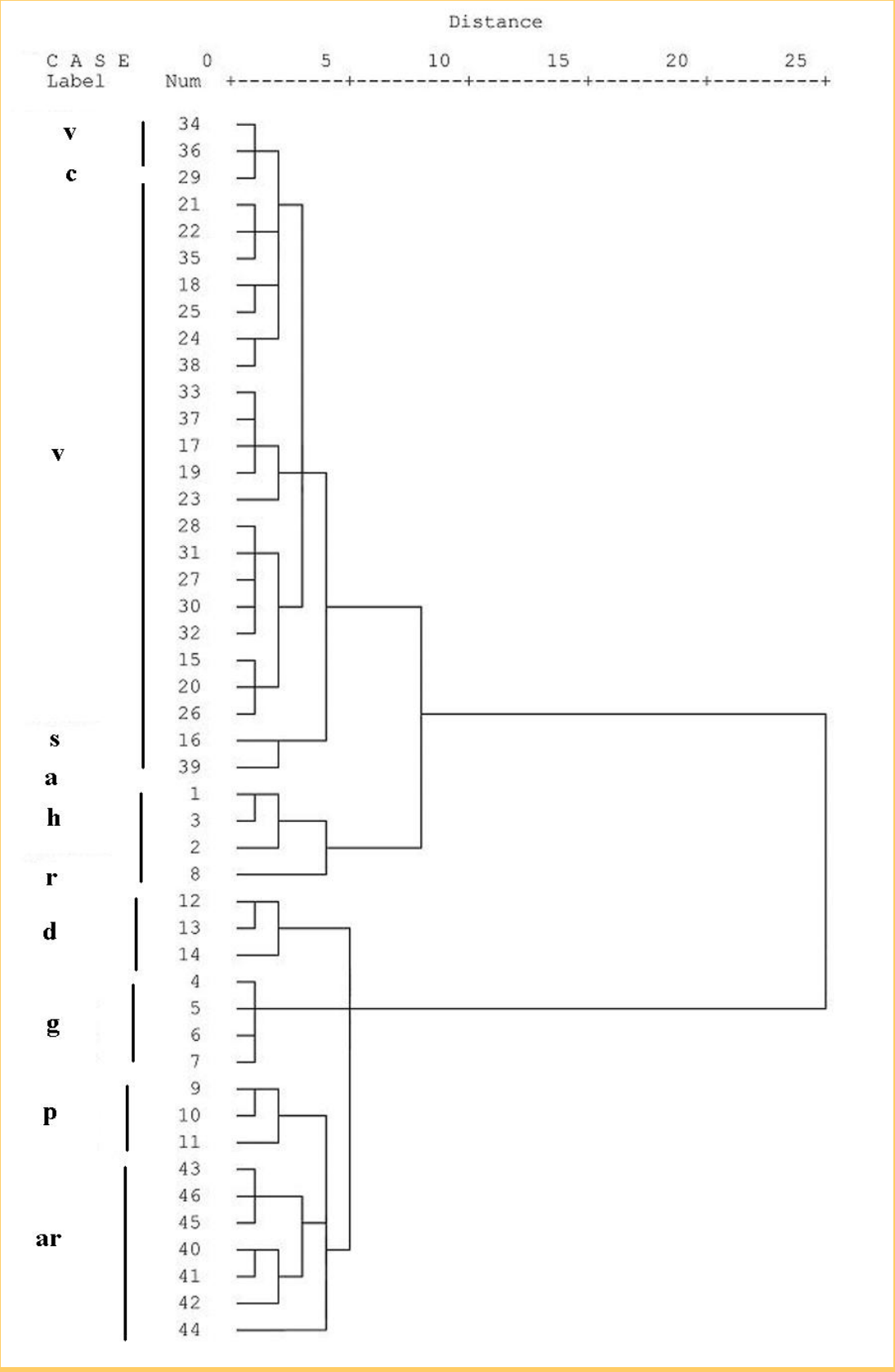
Species abbreviations:

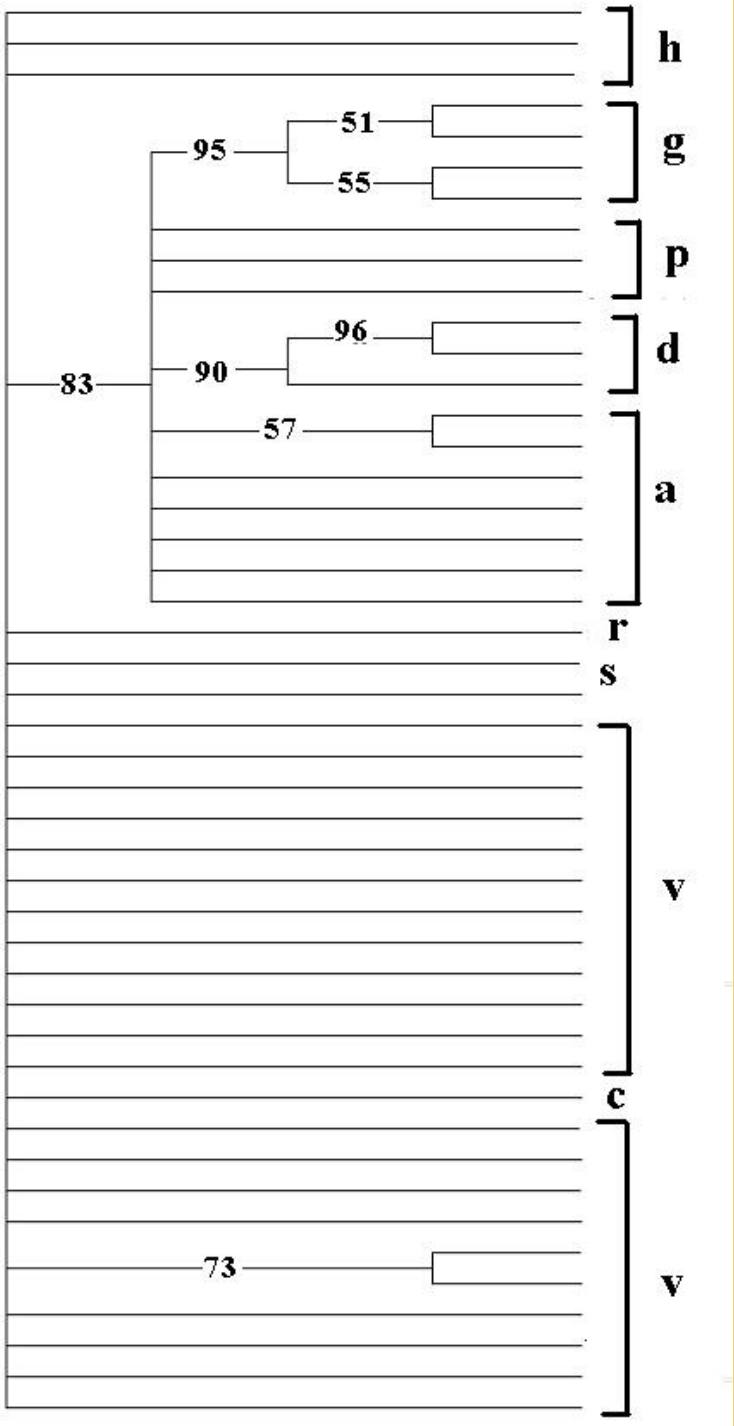
s = Festuca sulcata, r = F. rubra, h = F. heterophylla, p = F. pratensis, ar = F. arundinacea, d = F. drymeia, g = F. gigantea, v = F. valesiaca, F. chalcophaea, and F. akhanii.

Fig. 2: parsimony tree of Festuca species based on qualitative morphological characters.

(bootstrap values are given on branches).

s = Festuca sulcata, r = F. rubra, h = F. heterophylla, p = F. pratensis, ar = F. arundinacea, d = F. drymeia, g = F. gigantea, v = F. valesiaca, F. chalcophaea, and F. akhanii.

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