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Numerical Taxonomy of *Stipa* (Poaceae) Species in Iran

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Abstract: Numerical taxonomic studies were performed on 57 populations of 15 *Stipa* species belonging to 5 different sections, concerning intra-population and inter-populations variations as well as inter-specific relationships. The most variable morphological characters useful in the species delimitation were also determined. The species studied also differed significantly in most of the quantitative characters studied and the mean of such characters may be of use in the species delimitation. The clustering showed distinctness of the species studied as the populations of each species are placed close to each other and separate from the other species.

Key words: Cluster analysis, ordination, *Stipa*

INTRODUCTION

The genus *Stipa* L. (Poaceae) is comprised of 300-400 species throughout the world, with about 90-100 species distributed in the old world (Freitag, 1985; Barkworth and Everett, 1987). Discrepancy about the umber of *Stipa* species is due to taxonomic problems existing in this genus (Vázquez and Devesa, 1997).

The *Stipa* species distributed in various regions of the country are among important forage plants of Iran. The number of *Stipa* species growing in Iran varies from 6 to 18 according to different authors (Parsa, 1950; Bor, 1970; Freitag, 1985). Although the available literature dealing with systematic and biosystematics of *Stipa* species indicate the importance of these taxa (Freitag, 1985; Tzvelev, 1989), no report is available on the biosystematics of *Stipa* species and populations from Iran and only recently some basic information about cytogenetics of some of the species has been provided (Sheidai and Attaei, 2005). Therefore the present study considers the numerical taxonomic study of 57 populations belonging to 15 *Stipa* species growing in Iran, trying to reveal the inter-population morphological variations and inter-specific interrelationships.

MATERIALS AND METHODS

Morphometric studies were performed on 57 populations of 15 *Stipa* species belonging to 5 sections (Freitag, 1985) namely: (1)- Sect. *Lasiagrostis* (Link) Hackel, including *St. caragana* and *St. haussknechtii*, (2)- Sect. *Aristella* (Trin.) Hackel including *St. bromoides* (L. Doerf., (3)- Sect. *Stipella* Tzvelev, including *St. parviflora* and *St. capensis*, (4)- *Stipa* L., species group 1 (*Eriostipa*), including *St. lessingiana* Trin. and Rupr. and *St. pennata* L., species group 2 (*Brevigeniculatae/unigenicuatae*), including *St. caucasica* Schmalh. subsp. *caucasica*, species group 3 (*Leiostipa*), including *St. capillata* and (5) Sect. *Barbatae* Junge, including *St. arabica* Trin. and Rupr. (3 populations), *St. hohenackerana* Trin. and Rupr., *St. ehrenbergiana* Trin. and Rupr., *St. gaubae* Bor, *St. iranica* Freitag and *St. holosericea* Trin. (Table 1).

Three to five plants from each population were used for morphometric studies, from which 5-10 readings were done for characters studied. Details of the localities and the voucher numbers may be provided on request from the first author. Voucher specimens are deposited in TARI, IRAN and Herbarium of Shahid Beheshti University (HSB). In total 53 quantitative and qualitative morphological characters were studied (Table 1). Characters were selected based on those reported by Scagel and Maze (1984) and our own field observations.

In order to detect any 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.

In order to determine the species interrelationships, cluster analysis and principal component analysis (PCA) were performed (Ingrouille, 1986; Sheidai *et al*., 2002). 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. The average taxonomic distance and

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squared Euclidean distance were used as dissimilarity coefficient in cluster analysis of morphological data (Podani, 2000). 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). SPSS ver. 9 (1998) and STATISTICA ver. 5 (1995) were used for statistical analyses.

RESULTS AND DISCUSSION

The analyses showed that the range of size in quantitative characters studied is much different from what is given in different flora in the species descriptions Table 1. Therefore it is important to describe such characters after studying several populations of each species as performed in the present work. It is further supported by the results of ANOVA test as different populations of each species differed significantly in these quantitative characters.

The species studied also differed significantly in most of the quantitative characters as revealed by ANOVA and LSD tests. The mean of such quantitative characters may be useful for the species delimitation. This is partly supported by the clustering (Fig. 1) of the species studied based on merely quantitative morphological characters, as populations of some of the species are separated in distinct clusters including *St. haussknechtii*, *St. iranica*, *St. hohenackerana*, *St. lessingiana* and *St. capensis* (dented ha, I, ho, l and c respectively in Fig.1). However some populations of the species were mixed with the other species including *St. arabica*, *St. parviflora* and *St. caragana* in all of which only one population was separated and mixed with the other species.

The cluster analysis and PCA ordination of *Stipa* species studied based on both qualitative and quantitative characters produced similar results (Fig. 1-3). In the analyses based on all morphological characters, two major clusters or groups are formed. The first major cluster is comprised of two sub-clusters, in the first of which populations belonging to *St. bromoides* and *St. caragana* are placed close to each other. Bor (1970) in the Flora Iranica also considered these two species

Table 1: Morphological characters and their coding

Characters	Character code	Data coding
Indumentum of nod	NOD	1) Hairy, 2) Glabrose
Indumentum of sub-nod	SUBNOD	1) Hairy, 2) Glabrose
Surface of culm	SUR.CUL	1) Hairy, 2) Glabrose
Length of flag leaf	L.LE.FLA	Mm
Length of sheath in flag leaf	L.SH.FLA	Mm
Rate of sheath\ length in flag leaf	R.SH.LEF	Mm
Length of ligule in vegetative leaf	L.LI.VEG	Mm
Shape of ligule in vegetative leaf	LI.VEG	1) Acuminate, 2) Ttruncate, 3) Rounded
Length of ligule in culm leaf	L.LI.CUL	Mm
Shape of ligule in culm leaf	LI.CULM	1) Acuminate, 2) Truncate,3) Rounded
Length of culm leaf	L.LE.CUL	Mm
Width of culm leaf	W.LE.CUL	Mm
Length of leaf in vegetative shoot	L.LE.VEG	Mm
Width of leaf in vegetative shoot	W.LE.VEG	Mm
Indumentum of upper surface in vegetative shoot	UP.VEG	1) Pilose, 2) Smooth, 3) Scabrous
Indumentum of lower surface in vegetative shoot	LOW.VEG	1) Pilose, 2) Smooth, 3) Scabrous
Indumentum of upper surface of culm leaves	UP.CUL	1) Pilose, 2) Smooth, 3) Scabrous
Indumentum of lower surface of culm leaves	L.CUL	1) Pilose, 2) Smooth, 3) Scabrous
Length of upper glume	L.GLU.UP	Mm
Length of lower glume	L.GLU.LO	Mm
Ratio of lower glume to upper glume	R.GLO.UP	Mm
Margin of glume	MAR.GL.	1) Hyaline, 2) Green, 3) Purple
Length of anthecium	L.ANTHEC.	Mm
Length of callus	L.CAL	Mm
Ratio of length of anthecium to length of callus	R.ANT.CA	Mm
Indumentum of callus	CO.CAL	1) Densely barbed, 2) Barbed, 3) Un-barbed
Shape of scar	SCAR	1) Round, 2) Elliptic
Length of glabrous part of lemma	L.GB.LEM	Mm
Ratio of length of lemma to length of glabrous part of lemma	R.LEM.GB	Mm
Pilose rows of lemma	V.ROW	1) Scatter, 2) Along the nerves
Coronula of lemma	CORON	1) Present, 2) Absent
Length of lemma Coronula	L.CORON	Mm
Length of awn	L.AWN	Mm
Length of seta	L.SETA	Mm
Length of first segmentation in awn	L.SEG.FI	Mm
Ratio of length of seta to length of first segmentation	R.SET.FI	Mm
Length of second segmentation in awn	LEG.SEG.SE	Mm
Rate of length of seta to length of second segmentation of awn	R.SET.SE	Mm
Rate of length of second segmentation in awn to length of first segmentation	R.FIR.SE	Mm
Rate of awn to seta	R.AW.SET	Mm
Length of hair in seta	L.HA.SET	Mm
Shape of seta	SET.S	1) Straight, 2) Wavy, 3) Curved
Twisting in column of seta	COL.T	1) High twisted, 2) Twisted, 3) Erect
Indumentum of seta	CO.SET	1) Pilose, 2) Smooth, 3) Scabrous
Indumentum of column	CO.COL	1) Pilose, 2) Smooth, 3) Scabrous
Length of palea	L.PALEA	Mm
Length of glabrose part of palea	L.GB.PAL.	Mm
Ratio of palea to glabrose part	R.PAL.GB	Mm
Rate of palea to lemma		Mm
Apex of anther	ANT.B	1) Barbed, 2) Un-barbed
Apex of rachila	RACH	1) Hairy, 2) Smooth
Indumentum of palea	PAL.HA	1) Hairy, 2) Smooth
No. of geniculation in awn	N.BAND	1) 1, 2) 2

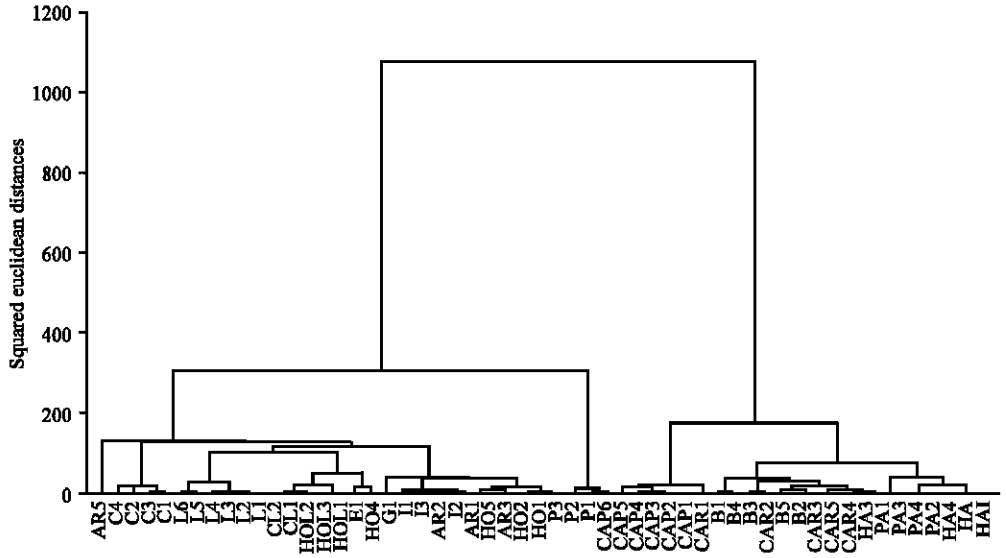

Fig. 1: WARD clustering of *Stipa* species based on quantitative morphological characters. (Species code: CAR = *St. caragana*, HA = *St. haussknechtii*, B = *St. bromoides*, PA = *St. parviflora*, CAP = *St. capensis*, L = *St. lessingiana*, P = *St. pennata*; C = *St. caucasica*, CL = *St. capillata*, AR = *St. arabica*, HO = *St. hohenackerana*, G = *St. gaubae*, E = *St. ehrenbergiana*, I = *St. iranica* and HOL = *St. holosericea*)

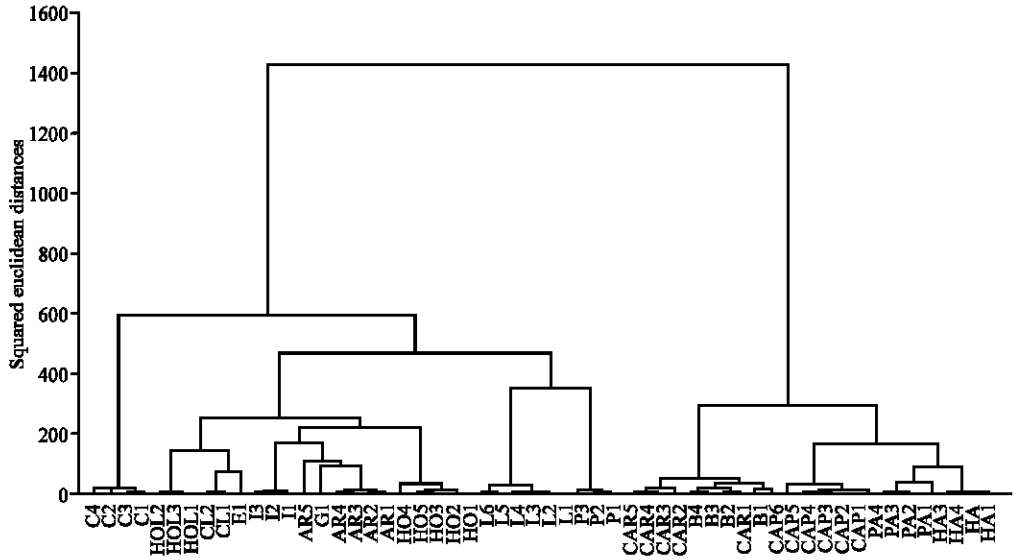

Fig. 2: WARD clustering of *Stipa* species based on all morphological characters (species code as in Fig. 3)

closely (morphologically) related to each other. Based on characters like presence of a rounded callus, straight awn measuring up to 35 mm and lemma with apical lobes, placed them in the sect. *Lasiagrostis*. However Freitag (1985) placed them in different sections.

The second sub-cluster is comprised of three species, *St. capensis*, *St. parviflora* and *St. haussknechtii* in which, the last two species show more similarity and are placed close to each other. Bor (1970) in the Flora Iranica also considered the two species of *St. haussknechtii* and *St. parviflora* closely related to each other, while *St. capensis* is considered to be close to *St. capillata*.

Freitag (1985) based on the characters like palea being significantly (usually 2-4 x) shorter than lemma and the latter usually more or less constricted bellow the apex and by the extremely short upper lodicule, has placed *St. capensis* and *St. parviflora* in the sect. *Stipella*, which is supported by present analysis. But he considered

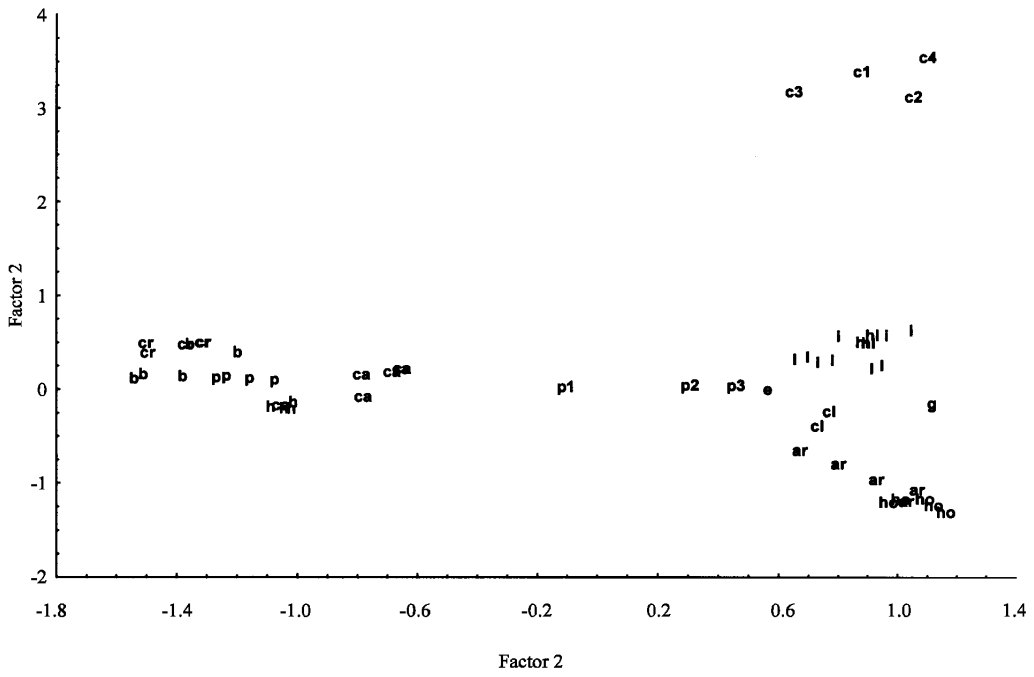

Fig. 3: PCA ordination of the *Stipa* species based on all morphological characters (species code as in Fig. 1)

St. haussknechtii close to *St. caragana* and placed them in the sect. *Lasiagrostis*, which is not supported by our analyses.

The second major cluster is comprised of three sub-clusters. Populations of *St. caucasica* form the first sub-cluster/group much separated from the other species. Bor (1970) in the Flora Iranica considered this species close to *St. gaubae*, while Freitag (1985), considered this species close to *St. capillata* and *St. lessingiana* as the members of the section *Stipa*. However the present study dos not support these considerations.

The second sub-cluster is comprised of the species of *St. holoserica*, St. *ehrenbergiana*, *St. iranica*, *St. arabica*, *St. gaubae* and *St. hohenackerana*, supporting Freitag (1985) taxonomic treatment of the genus. Based on the presence of an ovary always with 3, more rarely 4, equal or unequal styles and stigmas he placed all these species in the sect. *Barbatae*.

The third sub-cluster is comprised of populations of *St. lessingiana*, *St. pennata* which, are along with *St. capillata*, are also grouped together in PCA plot, supporting Freitag (1985) taxonomic treatment of the genus. Based on the presence of a bigeniculate and hairy to plumose awn, he considered them close to each other in the species group 1 (*Eriostipa*) of the sec. *Stipa*.

However since Freitag (1985) stated that he is not sure about the position of *St. gaubae*, whether it is a member of sect. *Stipa* or sect. *Barbata*, cluster analysis was carried out only for the species present in these two sections only (Fig. 4). *St. gaubae* shows more similarity to *St. arabica* and *St. hohenackerana* of the sect. *Barbata*. Therefore the present numerical taxonomic study suggests inclusion of St. *gaubae* in the sect. *Barbata*.

In general, it seems that the present study partly supports Freitag's (1985) taxonomic treatment of the genus *Stipa*. Therefore, it seems that more detailed studies are required to illustrate the species inter-relationships in the genus. In order to identify the most variable morphological characters among the species studied, PCA analysis was performed. The analysis revealed that the first 4 factors comprise about 67% of total variance. In the first factor with about 31% of total variance, characters like Apex of anther, length of upper glume, length of anthecium, length of awn, length of seta, ratio of seta to the first segment of awn, length of palea and ratio of palea to lemma possessed the highest positive correlation (>0.70). In the second factor with about 14% of total variance, characters like rachila, Length of ligule in culm leaf, indumentum of sub-nod and Indumentum of callus possessed the highest positive correlation (>0.50). Therefore these are the most variable morphological characters among the species studied. Qualitative and ratio characters identified in PCA along with those quantitative characters showing significant difference among the species studied (stated earlier) may be used in the *Stipa* taxonomy.

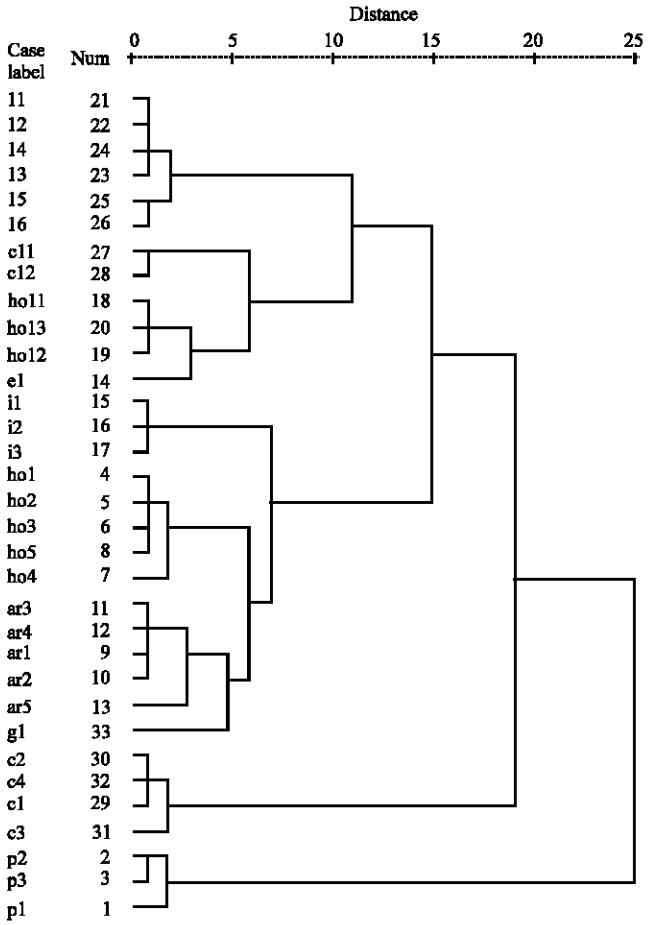

Fig. 4: WARD clustering of sections *Stipa* and *Barbata* species based on all morphological characters (species code as in Fig. 1)

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