Intra and inter-specific morphological variations in *Bromus* L. sect. *Genea* (Poaceae) species in Iran

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Abstract

Phenetic studies were performed on 25 populations of 8 *Bromus* species and varieties of the section *Genea* concerning intra and inter-specific variations. Inter-specific relationships and the most variable morphological characters useful in the species delimitation were also determined. Descriptive statistical analysis showed that the range of quantitative characters is much different from what is given for description of *Bromus* species and varieties in different flora. The species studied differed significantly in most of the quantitative characters studied and using the mean of such characters may be of use in the species delimitation. The clustering showed distinctness of the *Bromus* species and principal components analysis identified the most variable morphological characters among the species studied. The present study suggests the use of some ratio characters along with other quantitative and qualitative characters in taxonomy of the *Bromus*.

Keywords: Bromus, Clustering, Principal components analysis.

تنوع ریختی درون گونه‌ای و میان گونه‌ای در گونه‌های جنس Bromus بخش Genea در ایران

مسعود شیدایی
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چکیده

تاکسونومی عددی ۲۵ جمعیت متعلق به گونه‌های جنس Bromus بخش Genea به منظور شناسایی تفاوت‌های میان حمعیتی و بین گونه‌ای و همچنین بررسی روابط فنتیکی گونه‌های این بخش انجام گرفت. بررسی‌های آماری اولیه نشان داد که دامنه تغییرات صفات کمی در گونه‌های مطالعه شده با آنچه در شرح گونه‌ها در فلورها ارائه شده متفاوت است و اینکه اختلاف معنی‌داری در میان جمعیت‌های مختلف یک گونه در این صفات وجود دارد. در نتیجه بایستی استفاده از این صفات در شناسایی گونه‌های مطالعه شده یا در نظر گیری تعداد جمعیت‌های بیشتری انجام پذیرد. آنالیز واریانس وجود اختلاف معنی‌داری را در میانگین صفات کمی در میان گونه‌های مختلف Bromus نشان داد، به‌علاوه تجزیه به مؤلفه‌های اصلی نیز نقش این صفات را در کنار صفات کیفی و نسبی مطالعه شده در تفکیک گونه‌های Bromus بخش Genea نشان داد. در نتیجه از مجموعه این صفات که برخی از آنها قبلا در تاکسونومی این گونه‌ها به کار برده نمی‌شدند می‌توان در تاکسونومی بخش Genea استفاده کرد. تجزیه خوشه‌ای و رسته بندی گونه‌ها قرابت گونه‌های مطالعه شده را نشان داد.

کلیدواژه‌ها: تاکسونومی عددی، Bromus، تجزیه خوشه‌ای.

Introduction

The genus *Bromus* L. (tribe Bromeae, Poaceae) comprises about 160 annual and perennial species (Acedo and Liamas, 1999), distributed all over the world. *Bromus* species are among important range grasses of Iran and are placed in 6 sections of which section *Genea* Dum. contains six perennial species found in Iran (Bor, 1970). The available literature dealing with biosystematics of *Bromus* (Devesa *et al.*, 1990; Lovkist and Hultgard, 1999) indicates the importance of such studies for understanding the evolution of the genus *Bromus*. There have been limited studies on cytogenetic and morphometric features of the genus *Bromus* section *Genea* in Iran (Aryavand, 2002; Sheidai and Fadaei, 2005).

As stated by Stebbins (Stebbins, 1987), The most important source of variation to be used for adaptation and evolution by plants in Poaceae is hybridization along with chromosome doubling. Hybridization has occurred either between adaptively different populations of the same species, or between different species, therefore high amount of variation exists in morphological characteristics of grasses which should be used in biosystematic study of them. Therefore the present study considers morphometric analyses of 28 populations belonging to 8 *Bromus* species and varieties with the aim to identify intra and inter specific morphological variations as well as illustrating the phenetic relationships among the species of the section *Genea*. Moreover importance of the morphological characters in species identification and delimitation is discussed.

Materials and Methods

Morphometric studies were performed on 25 populations of 8 *Bromus* species and varities of the section *Genea* Dum. (Bor, 1970) namely: 1- *B. tectorum* L. var. *tectorum*, 2- *B. tectorum* var. *hirsutus* Regel., 3- *B. sericeus* Drobov., 4- *B. madritensis* var. *madritensis* L., 5- *B. madritensis* var. *ciliatus* Guss., *B. rubens* L. var. *rubens*., 6- *B. rubens* L. var.

glabriglumis Maire., 7- *B. fasciculatus* Presl. Var. *alexandrianus* Thell. and 8- *B. sterilis* L. Voucher specimens are deposited in Herbarium of Shahid Beheshti University (HSBU) and TARI (Herbarium of Iran Botanical Garden).

Three to five plants from each population were selected randomly and 10 readings were done for each character from each plant making total observation of each character 3 x 10 = 30 or 5 x 10 = 50, used for morphometric studies. Details of the localities and the voucher numbers may be provided on request from the first author.

In total 43 morphological characters including 21 quantitative (denoted c1-c21) and 22 qualitative (denoted k1-k22) were studied (Table 1). Characters were selected based on those reported by Aryavand (2002), Sales (1994) and our own field observations. In order to detect any significant difference in morphological characters among different populations of each species as well as different species studied, t-test and analysis of variance (ANOVA) followed by the least significant difference (LSD) test were performed.

For phenetic analyses the mean of quantitative characters were used while qualitative characters were coded as binary/ multistate characters. Variables were standardized (mean=0, variance=1) for multivariate statistical analyses (Podani, 2000; Sheidai, *et al.*, 2002).

In order to determine the species interrelationships, cluster analysis using UPGMA (unweighted paired group with arithmetic mean) and WARD (minimum variance spherical clusters) as well as ordination based on principal component analysis (PCA) and PCO (principal coordinate analysis) were performed (9 & 10). The Euclidean, squared Euclidean and taxonomic distances were used as dissimilarity coefficient in cluster analysis of morphological data (Podani, 2000). SPSS ver. 9 (1998) and NTSYS Ver. 2.2 (1998) were used for multivariate statistical analyses.

Table 1- Morphological characters and their coding in *Bromus* species studied.

	Character	Short code	Coding
1	Length of plant	C1	cm
2	Culm position	K1	1- erect and without genicule 2- erect and geniculate at the base 3- erect and ascending
3	Indumentum of sheaths	K2	1- Glabrous 2- Glabrous to pubescent 3- Pubescent 4- Pubescent to softly pilose 5- Softly pilose 6- Softly pilose to pilose 7- Pilose 8- pubescent to tomentose to dense tomentose to sericeous 9- glabrous with villous marginal hairs 10- pubescent with villous marginal hairs 11- softly pilose to tomentose
4	Indumentum of leaf blade	K3	1- glabrous to hispid 2- pubescent 3- pubescent to softly pilose 4- softly pilose 5- softly pilose to pilose 6- pilose to tomentose 7- velutinose
5	Culm pubescence	K24	1- glabrous 2- hairy 3- softly pubescent to pubescent 4- pubescent to pilose 5- softly pubescent to pilose 6- dense pubescent to tomentose
6	Panicle branches pubescence	K22	1- glabrous 2- hairy 3- pubescent 4- softly pilose to pilose 5- tomentose 6- pubescent to velutinose 7- dense tomentose to villous
7	Panicle position	K4	1- erect 2- erect sometimes nodding 3- drooping 4- nodulose
8	Panicle density	K5	1- loose 2- little dense 3- dense 4- dense sometimes little loose 5- very dense
9	Number of panicle branches per node	K7	1- with little branches up to 3 to 5 2- branches numerous frequently more than 5
10	Panicle branches size	K6	1- short, up to 1.5 cm 2- long, up to 3.5 cm 3- very long often more than 3.5 cm and until 6 cm
11	Number of spikelets on the panicle branch	K9	1- 1 to 3 rarely more 2-1 until more than 3
12	Pedicle length comparing to spikelet without awn	K8	1- often very longer than spikelet 2- shorter than spikelet, sometimes equal with 3- shorter than spikelet, sometimes sessile
13	Spikelet length	C17	Cm
14	Number of florets in spikelets	K10	1- up to 8 2- more than 8
15	Number of sterile florets in spikelets	K11	1- up to 3 2- more than 3
16	Lower glume length	C2	Cm
17	Lower glume width	C3	Cm
18	Lower glume length / Lower glume width	C4	-
19	Lower glume shape	K12	1- lanceolate 2- lanceolate to anguste lanceolate 3- anguste lanceolate 4- anguste lanceolate to subulate 5- linear lanceolate 6- deltoid lanceolate

	Character	Short code	Coding
20	Vein number on lower glume	K15	1- only one 2- one and sometimes with one or two additional sub distinct vein 3- three 4- three sometimes with one additional vein
21	Upper glume length	C5	Cm
22	Upper glume width	C6	Cm
23	Upper glume length / Upper glume width	C7	-
24	Upper glume shape	K13	1- lanceolate 2- long lanceolate 3- anguste lanceolate 4- linear lanceolate 5- linear lanceolate to lanceolate 6- anguste lanceolate to linear lanceolate
25	Vein number on upper glume	K16	1- only 3 2- 3 sometimes with one or two sub distinct vein 3- 5, 4- often 5 sometimes more or less
26	Glumes texture	K14	1- with less development membranous margin 2- with development membranous margin 3- 1 and 2 cases
27	Glumes pubescence	K23	1- glabrous 2- softly pubescent to pubescent 3- softly pilose to pilose 4- tomentose 5- sericeous 6- velutinose and more dense
28	Lemma length	C8	Cm
29	Lemma width	C9	Cm
30	Lemma length / Lemma width	C10	-
31	Lemma shape	K17	1- lanceolate 2- long lanceolate 3- anguste lanceolate 4- anguste lanceolate to linear lanceolate 5- linear lanceolate
32	Lemma texture	K18	1- herbaceous and viridis 2- with developmental membranous margin
33	Lemma pubescence	K19	1- glabrous 2- glabrous to softly pubescent 3- hairy 4- softly pubescent to pubescent 5- pilose 6- tomentose 7- more dense than tomentose
34	Lemma length / Lower glume length	C15	-
35	Lemma length / Upper glume length	C14	-
36	Length of lemma hyaline teeth	C11	Cm
37	Awn length	C12	Cm
38	Awn length / Lemma length	C13	-
39	Spikelet length / Awn length	C19	-
40	Palea length	C18	Cm
41	Awn length / Palea length	C21	-
42	Number of stamens	K20	1- only two 2- two and sometimes three 3- three, sometimes two 4- only three
43	Anther length	C16	Cm

Results and Discussion

Descriptive statistics of the morphological characters studied are presented in Table 2. The analyses showed that the size of quantitative characters is much different from what is given in different flora for the species studied. It is further supported by the fact that different populations of each species differed significantly in these quantitative characters further showing the level of variation in them.

For example in *B. tectorum* L. var. *tectorum*, the populations studied differed significantly in 11 quantitative morphological characters (Table 3), including number of panicle branches per node, lower and upper glume width, which are used in this species description. The range of these quantitative characters differs from what is given in description of *B. tectorum* L. var. *tectorum* (sales, 1993), there fore a more number of populations should be considered for describing such quantitative characters and we believe that data presented in table 2 can help in this regard. A similar situation is present in the other *Bromus* species studied.

Most of the quantitative characters studied also differed significantly among *Bromus* species studied (Table 4). Some of these quantitative characters are not used in taxonomy of *Bromus* therefore it seems that the mean of such quantitative characters may be of use in *Bromus* species delimitation. This is further supported by the result of PCO analysis of only quantitative characters (Figure 1), as the species are well separated from each other.

Clustering (Figure 2) of the species studied based on both quantitative and qualitative morphological characters further supported distinctness of each species as the populations of each species are placed close to each other and separate from the other species. Different clustering methods including UPGMA and WARD produced similar results, which were also supported by ordination of the species and varieties based on PCA axes (Figurs. 3 & 4).

In all analyses, 4 major clusters or groups are formed. The first major cluster is comprised of populations belonging to *B. sterilis* standing separate from the other species. Bor (1970) considered *B. sterilis* as the ancestor of *B. madritensis* var. *madritensis*, *B. fasciculatus* and *B. rubens*. The last 3 species show similarity and are place close to each other in cluster analysis and ordination, supporting their relationship as suggested by Bor (1970). Close relationship of *B. madritensis* var. *madritensis* and *B. fasciculatus* is also suggested by Sales (1993).

The populations of *B. tectorum* L. var. *tectorum* and *B. tectorum* var. *hirsutus* are placed close to each other in one cluster, more over Populations of *B. sericeus* are placed close to *B. tectorum* supporting their close relationship suggested by Bor (1970) in Flora Iranica.

PCA analysis of morphological characters revealed that the first 6 components comprise about 70 % of total variance. In the first component with about 20 % of total variance characters like length of plant (c1), length of lower glume (c2), ratio of length of lower glume to width of lower glume (c4), upper glume length (c5), ratio of upper glume length to upper glume width (c7), awn length (c12) and size of panicle branches (k6) possessed the highest positive correlation (>0.60).

In the second component with about 15 % of total variance, characters like length and width of lemma (c8 & c9), length of lemma hyaline teeth (c11), ratio of lemma length to length of upper glume (c14), length of spikelet (c17) and vein number on lower glume (k15) showed highest positive correlation (>0.6).

In the third PCA component with about 14 % of total variance, characters like width of lemma (c9), anther length (c16), vein number on upper glume (k16) and the number of stamens (k20) showed the highest positive correlation (>0.50) while, characters like ratio of lemma length to lemma width (c10), ratio of lemma length to lower glume length (c15), panicle density (k5) and shape of lemma (k17) possessed the highest negative correlation (>0.50) with this component. Therefore these are the most variable morphological characters among the *Bromus* species

Table 2- Mean and standard error (±)of quantitative characters in *Bromus* species. (characters code as in Tab 1).

	SP	Species code		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	Fasciculatus Booshehr	fas1	Mean	18.62	0.87	0.10	8.11	1.18	0.20	5.70	1.40	0.22	6.25
			±	1.20	0.06	0.01	0.30	0.05	0.01	0.10	0.04	0.01	0.20
2	Fasciculatus Fars	fas2	Mean	20.25	0.92	0.09	9.72	1.25	0.21	5.81	1.87	0.29	6.35
			±	75.00	0.07	0.01	0.27	0.05	0.01	0.09	0.02	0.01	0.02
			Mean	19.16	0.89	0.10	8.65	1.20	0.21	5.74	1.50	0.24	6.28
	Mean total												
			±	21.37	22.77	0.05	0.03	0.09	28.24	0.36	5.10	0.13	0.77
3	madritensis var. ciliatus Fars	mc	Mean	33.66	0.74	0.09	7.79	1.08	0.25	4.26	1.25	0.29	4.23
			±	5.89	0.03	2.88	0.26	0.02	0.01	0.09	0.02	0.01	0.12
4	madritensis var. madritensis Hormozgan	mm	Mean	33.33	0.89	0.11	7.64	1.29	0.22	5.78	1.79	0.29	6.17
			±	10.89	2.08	3.33	0.37	0.02	0.01	0.22	0.02	0.01	0.08
5	rubens var. glabriglumis Hormozgan1	rg1	Mean	35.25	0.62	0.10	6.26	1.00	0.21	4.73	1.28	0.26	4.96
			±	6.18	0.04	0.01	0.43	0.06	0.01	0.27	0.01	0.01	0.01
6	rubens var. glabriglumis Hormozgan2	rg2	Mean	10.00	0.68	0.10	6.40	0.65	0.18	3.51	1.26	0.23	5.44
			±	2.08	0.01	0.01	0.01	0.27	0.01	1.49	0.01	0.01	0.23
7	rubens var. glabriglumis Hormozgan3	rg3	Mean	15.66	0.61	0.08	7.00	0.89	0.17	5.18	1.20	0.21	5.56
			±	2.33	0.01	0.01	0.25	0.02	0.01	0.21	0.01	0.01	0.15
			Mean	21.80	0.64	0.09	6.53	0.86	0.19	4.47	1.25	0.23	5.28
	Mean total												
			±	4.43	0.01	0.01	0.20	0.08	0.01	0.45	0.01	0.01	0.11
8	rubens var. rubens Hormozgan	rr1	Mean	19.16	0.89	0.10	8.65	1.20	0.21	5.74	1.55	0.24	6.28
			±	0.88	0.04	0.01	0.42	0.03	0.03	0.12	0.10	0.01	0.18
9	rubens var. rubens Booshehr	rr2	Mean	33.66	0.74	0.09	7.79	1.08	0.25	4.26	1.25	0.23	5.28
			±	5.89	0.03	0.01	0.26	0.02	0.01	0.09	0.01	0.01	0.11
10	rubens var. rubens Kerman1	rr3	Mean	21.80	0.64	0.39	4.03	0.89	0.20	4.37	1.20	0.22	5.36
			±	4.43	0.02	0.28	1.71	0.02	0.01	0.07	0.02	0.01	0.09
11	rubens var. rubens Kerman2	rr4	Mean	11.66	0.63	0.39	4.03	0.89	0.20	4.37	1.20	0.22	5.36
			±	2.45	0.02	0.28	1.71	0.02	0.01	0.07	0.02	0.01	0.09
12	rubens var. rubens Kerman3	rr5	Mean	15.63	0.90	0.17	5.31	1.19	0.29	4.09	1.60	0.35	4.49
			±	1.44	0.04	0.01	0.19	0.05	0.01	0.14	0.05	0.01	0.10
			Mean	19.37	0.78	0.15	6.39	1.06	0.23	4.55	1.42	0.28	5.11
	Mean total												
			±	1.76	0.02	0.02	0.30	0.04	0.01	0.17	0.04	0.01	0.13
13	sericeus Khorasan	se1	Mean	17.66	0.81	0.17	4.63	1.21	0.29	4.10	1.63	0.38	4.30
			±	1.20	0.01	0.01	0.0	0.18	0.04	0.01	0.19	0.30	0.01	0.07
14	sericeus Kerman	se2	Mean	19.25	1.05	0.19	5.40	1.33	0.31	4.36	1.69	0.38	4.36
			±	1.79	0.02	0.01	0.18	0.01	0.01	0.31	0.01	0.01	0.08
15	sericeus Zahedan	se3	Mean	10.50	0.81	0.14	5.73	1.05	0.27	3.80	1.50	0.31	4.76
			±	1.04	0.06	0.01	0.33	0.10	0.01	0.18	0.15	0.01	0.22
			Mean	15.63	0.90	0.17	5.31	1.19	0.29	4.09	1.60	0.35	4.49
	Mean total												
			±	1.44	0.04	0.01	0.19	0.05	0.01	0.14	0.05	0.01	0.10
16	sterilis Golestan	st1	Mean	50.60	0.62	0.08	7.48	1.05	0.14	7.50	1.22	0.20	6.05
			±	1.43	0.03	0.01	0.45	0.06	0.01	0.29	0.09	0.00	0.48
17	sterilis Kerman	st2	Mean	43.25	0.92	0.10	9.04	1.41	0.24	5.89	1.62	0.29	5.60
			±	2.86	0.02	0.01	0.37	0.02	0.01	0.19	0.01	0.01	0.05
18	sterilis Fars	st3	Mean	33.00	0.71	0.11	5.96	1.46	0.25	5.78	1.85	0.30	6.14
			±	8.08	0.31	0.01	2.57	0.01	0.01	0.01	0.05	0.02	0.28
			Mean	43.13	0.75	0.100	7.63	1.29	0.20	6.45	1.54	0.26	5.91
	Mean total												
			±	3.08	0.08	0.01	0.74	0.06	0.01	0.27	0.08	0.01	0.18
19	tectorum var. hirsutus Zahedan	th1	Mean	17.25	0.77	0.15	5.08	1.09	0.22	4.91	1.30	0.29	4.44
			±	1.18	0.04	0.01	0.21	0.01	0.01	0.11	0.02	0.01	0.01
20	tectorum var. hirsutus Kerman1	th2	Mean	16.50	0.61	0.14	4.39	0.85	0.22	3.80	1.03	0.27	3.73
			±	1.80	0.03	0.01	0.33	0.03	0.01	0.30	0.03	0.01	0.19
21	tectorum var. hirsutus Fars	th3	Mean	18.75	0.55	0.07	7.32	0.77	0.18	4.18	1.12	0.22	5.11
			±	1.25	0.05	0.01	0.17	0.02	0.01	0.02	0.02	0.01	0.11
22	Tectorum var. hirsutus Kerman2	th4	Mean	16.75	0.73	0.13	5.46	1.01	0.21	4.77	1.47	0.32	4.63
			±	0.62	0.06	0.01	0.19	0.06	0.02	0.27	0.09	0.03	0.28
			Mean	17.15	0.69	0.13	5.38	0.96	0.21	4.50	1.26	0.28	4.44
	Mean total												
			±	0.57	0.03	0.01	0.28	0.04	0.01	0.16	0.05	0.01	0.15
23	tectorum var. tectorum Kerman	tt1	Mean	12.50	0.59	0.11	5.07	0.89	0.18	4.73	1.15	0.21	5.30
			±	0.28	0.05	0.01	0.07	0.05	0.01	0.14	0.02	0.01	0.07
24	tectorum var. tectorum Fars	tt2	Mean	21.00	0.66	0.13	4.92	0.98	0.21	4.63	1.06	0.29	3.67
			±	1.52	0.03	0.01	0.46	0.01	0.01	0.18	0.03	0.01	0.06
25	tectorum var. tectorum Zahedan	tt3	Mean	15.00	0.74	0.14	5.10	1.02	0.25	4.10	1.30	0.28	4.57
			±	1.00	0.01	0.01	0.10	0.02	0.01	0.10	0.01	0.01	0.24
			Mean	16.31	0.65	0.13	5.02	0.96	0.21	4.53	1.15	0.26	4.51
	Mean total												
			±	1.52	0.02	0.01	0.15	0.02	0.01	0.12	0.03	0.01	0.27

Continue Table 2

				C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
1	Fasciculatus Booshehr	fl	Mean										
			±										
2	Fasciculatus Fars	f2	Mean										
			±										
			Mean	19.16	0.89	0.10	8.65	1.20	0.21	5.74	1.50	0.24	6.28
	Mean total												
			±	21.37	22.77	0.05	0.03	0.09	28.24	0.36	5.10	0.13	0.77
3	madritensis var. ciliatus	mc	Mean	0.23	1.44	1.15	1.15	1.69	0.07	1.86	1.12	1.50	0.95
			±	0.01	0.04	0.04	0.03	0.09	0.01	0.14	0.01	0.15	0.00.
4	madritensis var. madritensis	mm	Mean	0.28	1.53	0.85	1.38	2.01	0.09	4.76	1.26	2.66	1.25
			±	0.01	0.08	0.05	0.03	0.05	0.01	0.31	0.03	0.20	0.02
5	rubens var. glabriglumis	rg1	Mean	0.19	1.13	0.88	1.30	2.09	0.05	2.10	1.06	1.64	---
			±	0.10	0.11	0.01	0.11	0.17	0.01	0.29	0.02	0.26	---
6	rubens var. glabriglumis	rg2	Mean	0.28	1.31	1.03	5.23	1.85	0.08	1.70	1.18	1.34	---
			±	0.01	0.10	0.05	3.88	0.01	0.01	0.17	0.06	0.13	---
7	rubens var. glabriglumis	rg3	Mean	0.22	1.00	0.83	1.34	1.95	0.09	1.83	0.94	1.52	---
			±	0.01	0.05	0.04	0.03	0.05	0.01	0.17	0.02	0.14	---
			Mean	0.23	1.15	0.91	2.49	1.98	0.07	1.90	1.06	1.51	-.--
	Mean total												
			±	0.01	0.06	0.04	1.16	0.07	0.01	0.13	0.03	0.11	-.--
8	rubens var. rubens	rr1	Mean	0.26	1.47	0.94	1.28	1.75	0.08	2.55	1.22	1.61	---
			±	0.01	0.11	0.02	0.07	0.11	0.01	0.33	0.04	0.12	---
9	rubens var. rubens	rr2	Mean	0.23	1.44	1.15	1.15	1.69	0.07	1.86	1.12	1.50	---
			±	0.01	0.04	0.04	0.03	0.09	0.01	0.14	0.01	0.15	---
10	rubens var. rubens	rr3	Mean	0.23	1.15	0.91	2.49	1.98	0.07	1.90	1.06	1.51	---
			±	0.01	0.06	0.04	1.16	0.07	0.01	0.13	0.03	0.11	---
11	rubens var. rubens	rr4	Mean	0.22	1.23	1.02	1.35	1.88	0.10	2.13	1.08	1.76	---
			±	0.01	0.04	0.02	0.07	0.11	0.01	0.15	0.04	0.10	---
12	rubens var. rubens	rr5	Mean	0.38	1.64	1.02	1.34	1.80	0.14	2.38	1.15	1.50	---
			±	0.02	0.10	0.04	0.01	0.05	0.01	0.22	0.02	0.15	---
			Mean	0.28	1.40	0.98	1.66	1.84	0.09	2.19	1.13	1.55	---
	Mean total												
			±	0.01	0.05	0.02	0.35	0.04	0.01	0.11	0.01	0.06	---
13	sericeus	se1	Mean	0.45	1.73	1.06	1.34	2.00	0.16	3.43	1.23	2.10	---
			±	0.02	0.14	0.09	0.07	0.07	0.01	0.06	0.01	0.08	---
14	sericeus	se2	Mean	0.39	1.93	1.14	1.26	1.61	0.15	2.00	1.11	1.18	---
			±	0.01	0.09	0.05	0.01	0.01	0.01	0.19	0.05	0.11	---
15	sericeus	se3	Mean	0.33	1.28	0.86	1.42	1.83	0.10	1.97	1.13	1.38	---
			Std. Error	0.04	0.08	0.04	0.03	0.06	0.01	0.21	0.05	0.26	---
			Mean	0.38	1.64	1.02	1.34	1.34	0.14	2.38	1.15	1.50	---
	Mean total												
			±	0.02	0.10	0.04	0.01	0.03	0.01	0.22	0.02	0.15	---
16	sterilis	st1	Mean	0.11	2.35	1.94	1.18	1.99	0.10	1.70	0.93	1.39	---
			±	0.01	0.11	0.15	0.11	0.24	0.01	0.12	0.02	0.03	---
17	sterilis	st2	Mean	0.23	2.38	1.46	1.15	1.75	0.19	2.47	1.10	1.52	---
			±	0.01	0.12	0.06	0.01	0.01	0.01	0.20	0.01	0.12	---
18	sterilis	St3	Mean	0.28	2.45	1.32	1.26	7.88	0.15	2.80	1.26	1.50	---
			±	0.01	0.12	0.01	0.01	0.01	0.01	0.36	0.01	0.17	---
			Mean	0.20	2.39	1.60	1.19	3.51	0.15	2.28	1.08	1.47	---
	Mean total												
			±	0.02	0.06	0.10	0.04	1.65	0.01	0.18	0.04	0.06	---
19	tectrum var. hirsutus	th1	Mean	0.22	1.50	1.15	1.19	1.69	0.07	1.40	0.48	1.07	---
			±	0.01	0.05	0.03	0.02	0.08	0.01	0.10	0.02	0.08	---
20	tectrum var. hirsutus	th2	Mean	0.18	1.10	1.07	1.20	1.70	0.10	1.46	0.78	1.43	---
			±	0.01	0.03	0.05	0.06	0.15	0.01	0.20	0.06	0.23	---
21	tectrum var. hirsutus	th3	Mean	0.30	1.17	1.04	1.45	2.06	0.05	1.55	0.08	1.38	---
			±	0.01	0.02	0.04	0.01	0.23	0.01	0.25	0.01	0.25	---
22	tectrum var. hirsutus	th4	Mean	0.40	1.43	0.97	1.46	2.04	0.10	1.57	0.95	1.08	---
			±	0.04	0.14	0.05	0.11	0.20	0.01	0.04	0.01	0.09	---
			Mean	0.28	1.34	1.06	1.32	1.86	0.08	1.49	0.63	1.21	---
	Mean total												
			±	0.02	0.06	0.02	0.02	0.09	0.01	0.06	0.08	0.07	---
23	tectrum var. tectorum	tt1	Mean	0.30	1.28	1.11	1.29	1.96	0.08	1.23	0.66	1.07	---
			±	0.01	0.07	0.08	0.07	0.16	0.01	0.03	0.03	0.05	---
24	tectrum var. tectorum	tt2	Mean	0.17	1.20	1.12	1.08	1.60	0.08	1.60	0.98	1.50	---
			±	0.01	0.02	0.04	0.04	0.03	0.01	0.05	0.01	0.10	---
25	tectrum var. tectorum	tt3	Mean	0.21	1.35	1.03	1.26	1.75	0.09	1.30	0.70	1.00	---
			±	0.01	0.10	0.07	0.03	0.02	0.01	0.01	0.01	0.07	---
			Mean	0.23	1.26	1.10	1.20	1.77	0.08	1.38	0.79	1.21	---
	Mean total												
			±	0.02	0.03	0.03	0.03	0.08	0.01	0.06	0.05	0.09	---

Table 3- ANOVA of quantitative morphological characters among the *Bromus tectorum* var. *tectorum* populations. (characters code as in Table 1).

Character		Sum of Squares	df	Mean Square	F	Sig.
C1	Between Groups	112.969	2	56.484	17.116	0.006
	Within Groups	16.500	5	3.300		
	Total	129.469	7			
C2	Between Groups	0.026	2	0.013	2.833	0.150
	Within Groups	0.023	5	0.004		
	Total	0.049	7			
C3	Between Groups	0.001	2	0.005	2.807	0.152
	Within Groups	0.009	5	0.196		
	Total	0.002	7			
C4	Between Groups	0.049	2	0.024	0.091	0.915
	Within Groups	1.359	5	0.272		
	Total	1.408	7			
C5	Between Groups	0.023	2	0.011	3.216	0.127
	Within Groups	0.018	5	0.003		
	Total	0.042	7			
C6	Between Groups	0.004	2	0.002	23.605	0.003
	Within Groups	0.004	5	0.004		
	Total	0.005	7			
C7	Between Groups	0.531	2	0.265	3.652	0.105
	Within Groups	0.360	5	0.072		
	Total	0.894	7			
C8	Between Groups	0.065	2	0.032	14.040	0.009
	Within Groups	0.011	5	0.002		
	Total	0.077	7			
C9	Between Groups	0.009	2	0.004	33.387	0.001
	Within Groups	0.007	5	0.001		
	Total	0.001	7			
C10	Between Groups	3.993	2	1.997	57.536	0.001
	Within Groups	0.174	5	0.034		
	Total	4.167	7			
C11	Between Groups	0.002	2	0.012	35.053	0.001
	Within Groups	0.001	5	0.003		
	Total	0.002	7			
C12	Between Groups	0.028	2	0.014	1.236	0.366
	Within Groups	0.025	5	0.011		
	Total	0.084	7			
C13	Between Groups	0.010	2	0.005	0.429	0.673
	Within Groups	0.063	5	0.012		
	Total	0.074	7			
C14	Between Groups	0.077	2	0.038	4.453	0.078
	Within Groups	0.043	5	0.008		
	Total	0.121	7			
C15	Between Groups	0.199	2	0.099	2.808	0.152
	Within Groups	0.177	5	0.035		
	Total		7			
C16	Between Groups	0.003	2	1.687	1.875	0.247
	Within Groups	0.004	5	0.009		
	Total		7			
C17	Between Groups	0.222	2	0.111	11.897	0.013
	Within Groups	0.046	5	0.009		
	Total		7			
C18	Between Groups	0.174	2	0.086	52.156	0.001
	Within Groups	0.008	5	0.001		
	Total		7			
C19	Between Groups	0.405	2	0.203	11.205	0.014
	Within Groups	0.090	5	0.018		
	Total		7			
C21	Between Groups	0.940	2	0.470	21.969	0.003
	Within Groups	0.107	5	0.021		
	Total		7			

Table 4- ANOVA of quantitative morphological characters among the *Bromus* species and varieties studied. (characters code as in Table 1).

| Character		Sum of Squares	df	Mean Square	F	Sig.
C1	Between Groups	1908.097	7	272.585	7.616	.001
	Within Groups	608.437	17	35.790		
	Total	2516.535	24			
C2	Between Groups	.279	7	3.982E-02	3.163	.025
	Within Groups	.214	17	1.259E-02		
	Total	.493	24			
C3	Between Groups	1.093E-02	7	1.561E-03	2.676	.046
	Within Groups	9.917E-03	17	5.833E-04		
	Total	2.084E-02	24			
C4	Between Groups	36.459	7	5.208	3.983	.009
	Within Groups	22.229	17	1.308		
	Total	58.688	24			
C5	Between Groups	.547	7	7.810E-02	4.735	.004
	Within Groups	.280	17	1.649E-02		
	Total	.827	24			
C6	Between Groups	.145	7	2.077E-02	2.175	.090
	Within Groups	.162	17	9.548E-03		
	Total	.308	24			
C7	Between Groups	12.577	7	1.797	4.999	.003
	Within Groups	6.110	17	.359		
	Total	18.686	24			
C8	Between Groups	.816	7	.117	2.006	.114
	Within Groups	.988	17	5.811E-02		
	Total	1.804	24			
C9	Between Groups	3.660E-02	7	5.229E-03	2.067	.105
	Within Groups	4.301E-02	17	2.530E-03		
	Total	7.961E-02	24			
C10	Between Groups	7.833	7	1.119	1.731	.168
	Within Groups	10.990	17	.646		
	Total	18.823	24			
C11	Between Groups	.108	7	1.547E-02	2.286	.078
	Within Groups	.115	17	6.769E-03		
	Total	.223	24			
C12	Between Groups	3.357	7	.480	14.506	.000
	Within Groups	.562	17	3.306E-02		
	Total	3.919	24			
C13	Between Groups	1.011	7	.144	4.274	.007
	Within Groups	.574	17	3.378E-02		
	Total	1.585	24			
C14	Between Groups	8.864E-02	7	1.266E-02	.720	.657
	Within Groups	.299	17	1.760E-02		
	Total	.388	24			
C15	Between Groups	8.044E-02	7	1.149E-02	.247	.966
	Within Groups	.790	17	4.644E-02		
	Total	.870	24			
C16	Between Groups	1.682E-02	7	2.402E-03	2.364	.070
	Within Groups	1.728E-02	17	1.016E-03		
	Total	3.409E-02	24			
C17	Between Groups	8.289	7	1.184	2.419	.065
	Within Groups	8.320	17	.489		
	Total	16.609	24			
C18	Between Groups	1.331	7	.190	5.358	.002
	Within Groups	.603	17	3.549E-02		
	Total	1.934	24			
C19	Between Groups	1.761	7	.252	2.294	.077
	Within Groups	1.865	17	.110		
	Total	3.626	24			
C21	Between Groups	35.168	7	5.024	.968	.485
	Within Groups	88.277	17	5.193		
	Total	123.445	24			
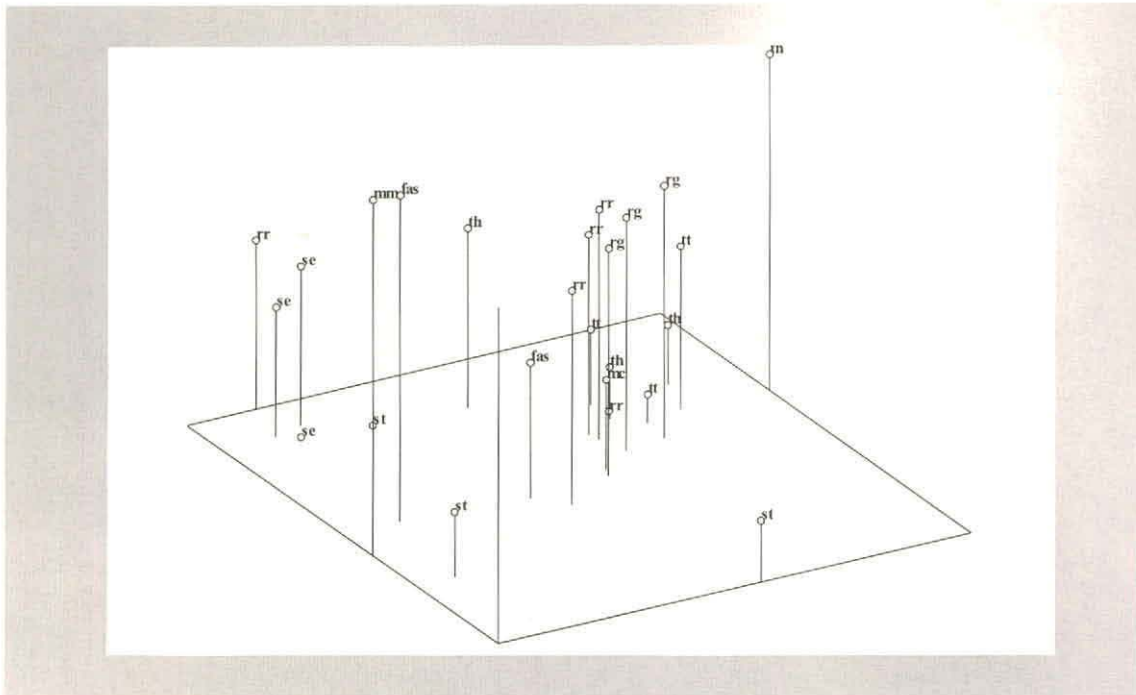
Figure 1- PCO ordination of *Bromus* species based on quantitative morphological characters. (Species code as in Table 2).
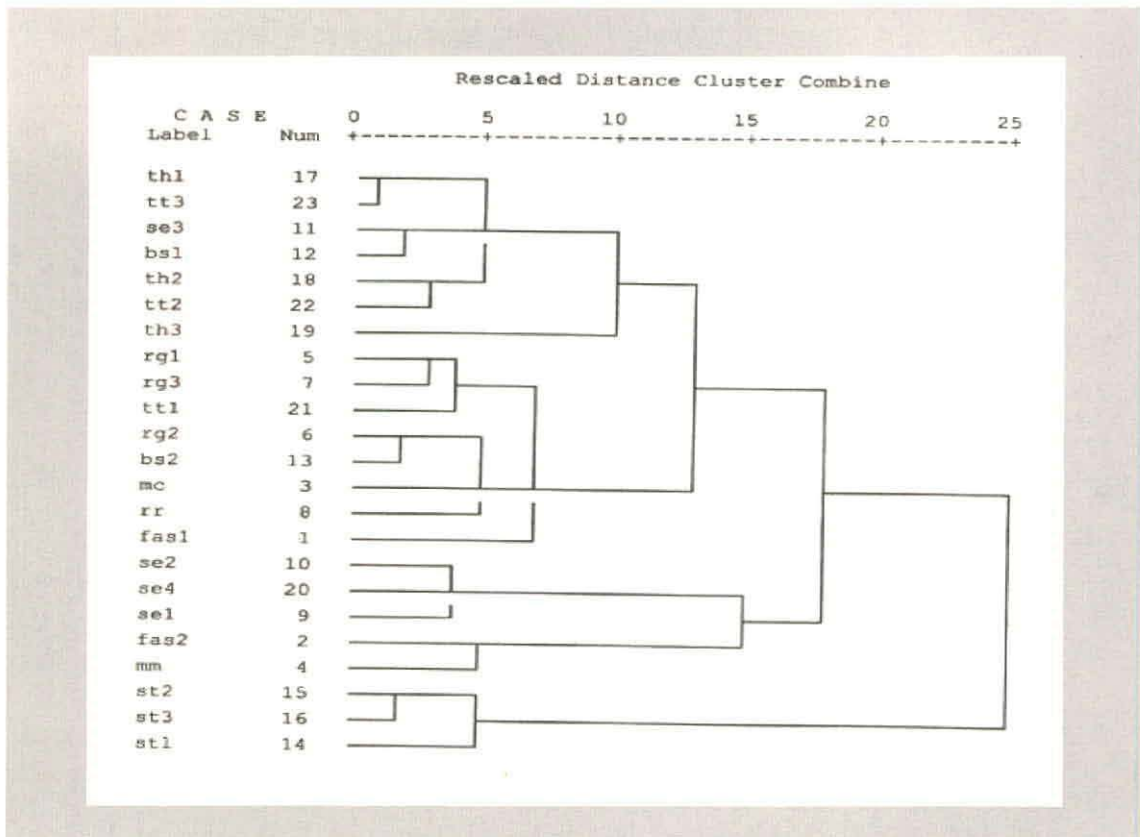

Figure 2- UPGMA cluster analysis of *Bromus* species based on morphological characters. (Species code as in Table 2).
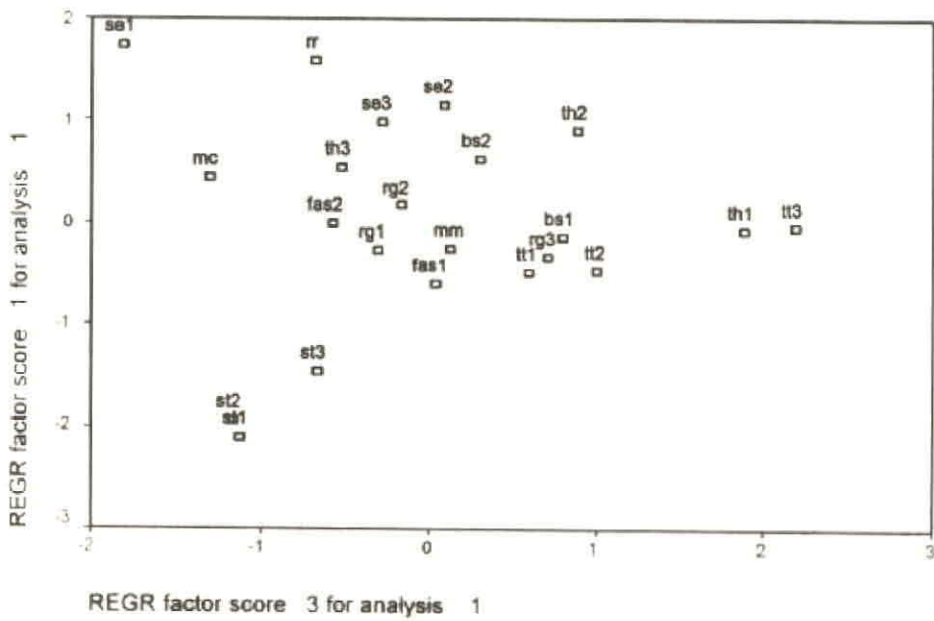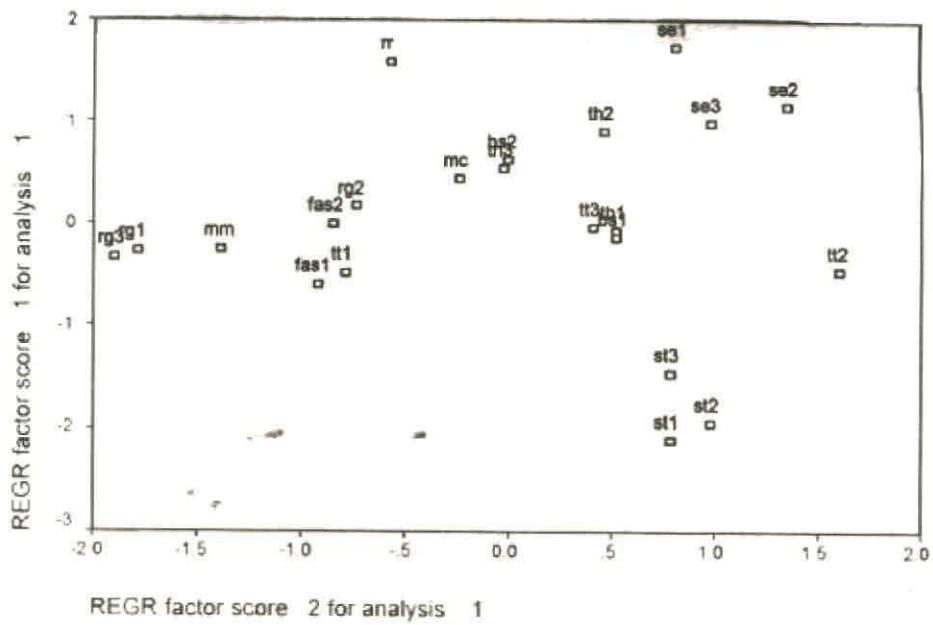
Figure 3 & 4- PCA ordination of *Bromus* species. (Species code as in Table 2).

and varieties studied separating them as indicated in ordination plots.

The PCA result clearly indicates the importance of quantitative characters (particularly ratio of these characters) along with qualitative characters in taxonomy of *Bromus* species and varieties studied as also suggested by ANOVA test discussed earlier. Some of these characters have not been used in description of *Bromus* species; therefore the present study suggests that such morphological characters should be considered for a better description of *Bromus* species.

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