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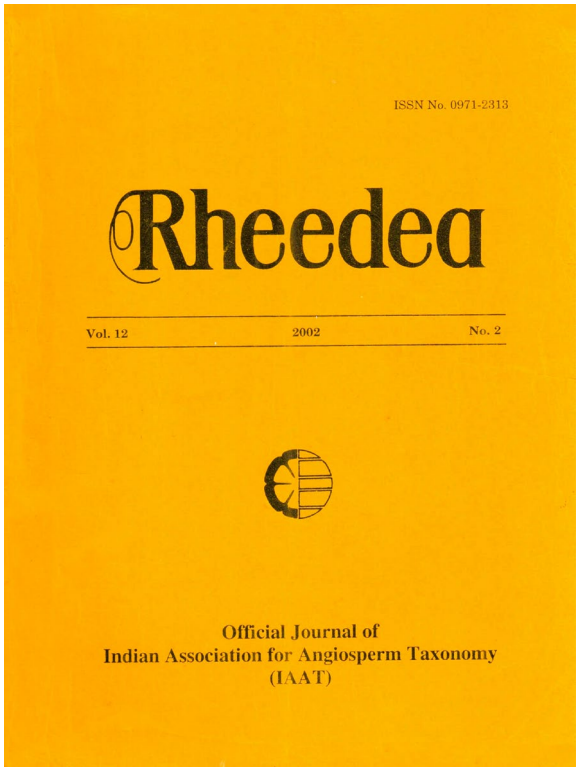

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Numerical taxonomic studies on some species of *Piper* L. (Piperaceae) of North East India

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Abstract

Eighteen taxa of *Piper* occurring in Arunachal Pradesh North-East India have been subjected to cluster analysis. Thirty-two characters were considered, of which 22 are qualitative and 10 are quantitative. The characters include 26 morphological and 6 anatomical. Cluster analysis was carried out using weighted pair group percent disagreement, and dendrogram was constructed. The dendrogram obtained through the analysis revealed that the species of the region fall under 6 distinct clusters under two broad sections each consisting of 3 clusters. Species of each cluster show close inter-specific relationship with more than 50% similarity among them. The study is helpful in establishing the relative affinity among the *Piper* species occurring in the region. The result also indicated that the species of Indian *Piper* could be grouped into two sub-generic sections.

INTRODUCTION

The genus *Piper* L. is distributed pantropically with more than 1000 species showing the greatest diversity in American tropics followed by Southern Asia (Jaramillo and Manos, 2001). According to Rahiman (1987) there are three distributional centres for the genus *Piper* L. in India. In India about 86 species are reported from two distributional centers of the genus - the North-East India comprising the Eastern Himalayas and the Western Ghats of South India with greater diversity in North-East where about 55 species have been reported (Gajurel, 2002). In the last two decades some important papers have been published dealing with the relationships of the South Indian taxa (Rahiman & Bhagawan, 1985; Ravindran, 1991; Ravindran & Nirmal Babu, 1996), but no such work has been carried out for the taxa occurring in North-East India. As most of the species of the North-East are endemic, the work carried out for South Indian taxa does not help in understanding the taxonomy and species relationship of the Northeastern taxa. In this context, a taxonomic survey of the species of North-East India, particularly of Arunachal Pradesh has been carried out since 1997, and some important findings have been made (Gajurel *et al.* 1999, 2000, 2001a & b). Collections of 27 wild species

have been made including 3 new species and 5 unidentified elements. Being a part of this taxonomic study, the present paper deals with the numerical analysis that contribute to the understanding of natural relationship among some of the *Piper* species of the region.

MATERIALS AND METHODS

Eighteen species of *Piper* were selected as Operational Taxonomic Units (OTUs), for numerical analysis following Sokal and Sneath (1963) (Table 1). All these taxa are grown in the experimental garden at the NERIST campus which were collected from different parts of the region. Detailed morphological and anatomical characterizations were carried out for each of the species. For the numerical evaluation, observations on 32 characters (22 qualitative and 10 quantitative) were recorded (Table 2). Only those characters, which showed significant variations among the OTUs, were considered. For the selection of characters the guidelines suggested by Sneath and Sokal (1973) was adopted. Morphological characters were selected from both the vegetative and fertile branches. Except for the leaf area, all the quantitative characters were measured in mm scale. The leaf area was measured in cm^2 using the standard *Leaf area meter.* At least 20 individual plants and 100 samples were observed for the purpose.

The selected OTUs and characters were subjected to cluster analysis following the methodology adopted by Ravindran *et al,* (1992) and Sahu, (1991). The qualitative characters were directly converted to numerical code using different codes for different character states (Table 3). The qualitative characters which exhibited 2 to 3 character states were coded with 0 and 1 or 0, 1 and 2. For each of the quantitative characters, the mean, variance, standard deviation and standard error of the mean were calculated. The Tukey Multiple Range Test (Zar, 1996) was performed to measure the difference among means and to find out whether the differences between means of the taxa are statistically significant. The result of Tukey test was tabulated, and each OTU was compared with all the others. For interpreting this, it is assumed that all the means which are over a given line are not significantly different. Only when two means are not over the same continuous line they differ significantly. Thus the OTUs, which are over the same line have similar characters and OTUs differ when they are on different lines. As a result of Tukey test, each of the quantitative characters were grouped in to 4 to 7 different character states which are coded as 0, 1, 2, 3, 4, 5, and 6 (Table 4). For comparison and calculation of the similarity matrix all the 32 characters were tabulated against the 18 OTUs using the character codes (Table 5). The following % similarity matrix was calculated using the following formula:

$$S = \frac{NS}{NS + ND} \times 100$$

Where S= similarity value expressed in percentage; NS= number of significantly similar means shared by any two OTUs and ND= number of significantly dissimilar means between any two OTUs. The similarity matrix is presented in Table 6.

Using the Similarity matrix the relationship among the OTUs was worked out which is represented in the form of a dendrogram or tree diagram. The statistical package STATISTICA loaded in a Personal Computer (Pentium III) was used to generate the dendrogram. Using the Weighted Pair Group Average (WPGA) different statistical tests viz. Percent disagreement, City-block (Manhattan) distances, Euclidean distances and 1-Pearson r were worked out. The Dendrogram generated using the test Percent disagreement was found suitable for the clustering of the OTUs where 6 distinct clusters of the 18 OTU's.

Table. 1. Species of *Piper* (OTUs) selected for the study

Code No.	Name of taxa (OTUs)
1.	*P. acutistigmum* C. DC.
2	*P. arunachalensis* Gajurel, Rethy *et* Kumar
3	*P. attenuatum* Buch.-Ham. ex Miq.
4	*P. betleoides* C. DC.
5	*P. boehmeriaefolium* (Miq.) C. DC.
6	*P. griffithii* C. DC.
7	*P. haridasanii* Gajurel, Rethy *et* Kumar
8	*P. lonchites* Roem. & Sch.
9	*P. longum* L.
10	*P. makruense* C. DC.
11	*P. mullesua* Buch.-Ham. ex D. Don
12	*P. nigrum* L.
13	**P. nirjulianum* Gajurel, Rethy *et* Kumar
14	*P. pedicellatum* C. DC.
15	*P. rhytidocarpum* Hook. f.
16	*P. sylvaticum* Roxb.
17	*P. sylvestre* Lam.
18	*P. wallichii* (Miq.) Hand.- Mazz.

*proposed new species

Table 2. Characters used in the cluster analysis

Qualitative Characters	
Code No.	Characters
1.	Growth habit: erect, creeping or climbing
2.	Colour of young vegetative shoot: pale green or purple reddish
3	Texture of vegetative shoot: glabrous, puberulent or pubescent
4.	Nature of stem: terete or ribbed
5.	Leaf nature: membranous or coriaceous
6.	Leaf texture: glabrous, puberulent or pubescent
7.	Leaf base in fertile branch: round, cuneate or oblique
8.	Leaf base in vegetative branch: round, cuneate or cordate
9.	Petiole texture: glabrous, puberulent or pubescent
10.	Spike orientation: erect or pendent
11.	Shape of female spike: globose to semi-globose, cylindric or flexuous
12.	Nature of bract: peltate or adnate
13.	Arrangement of fruit in spike: loose or dense
14.	Number of stamen: two, three or four
15.	Number of anther cells: two or four
16.	Number of stigma: two, three or five
17.	Colour of ripe fruit: black or red
18.	Fruit size: small or bold
19.	Mucilage canal in stem: present or absent
20.	Nature of stem collenchyma: continuous or discontinuous
21.	Mucilage canal in petiole: present or absent
22.	Medullary bundle in petiole: present or absent

Quantitative Characters			
Code No	Characters	Code No	Characters
23.	Length of internode in fertile branch	28.	Prophyll length
24.	Petiole length in fertile branch	29.	Length of male spike
25.	Petiole length in vegetative branch	30.	Length of female spike
26.	Leaf area in fertile branch	31.	Length of fertile branch
27.	Leaf length-breadth ratio	32.	Peduncle length

Table 3. Results of multiple range test of qualitative characters

Code No.	Characters	Grouping of taxa (represented by code numbers) according to their character states		
		0	1	2
1	2	3	4	5
1	Growth habit	Erect shrub 5, 8, 14	Creeping shrub 3, 9, 10,1 6,	Climbing shrub 1, 2, 4, 6, 7, 11, 12, 13, 15
2	Colour of young vegetative shoot	Pale green 1, 3, 5, 6, 7, 8 ,9, 10, 12, 14, 15, 16, 17	Purple reddish 2, 4, 11, 13, 18	
3	Texture of vegetative shoot	Glabrous 1, 5, 6, 8, 11, 12, 14, 15, 17	Puberulent 2, 3, 9, 13, 16	Pubescent 4, 7, 10, 18
4	Nature of stem	Terete 1, 2, 3, 4, 6, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18	Ribbed 5, 8, 14	
5	Leaf nature	Membranous 2, 3, 4, 5, 7, 8, 9, 10, 11, 14, 16, 18	Coriaceous 1,6,12,15	
6	Leaf texture	Glabrous 2, 5, 6, 8, 11, 12, 13, 14, 15, 17	Puberulent 1, 9, 16	Pubescent 3, 4, 7, 10, 18
7	Leaf base in vegetative branch	Round 3, 12, 15	Cuneate 2, 6, 7, 8, 10, 11, 13, 14, 16, 17, 18	Oblique 1, 4, 5, 9
8	Leaf base in fertile branch	Round 2, 3, 6, 11	Cuneate 8, 14,	Cordate 1, 4, 5, 7, 9, 10, 16
9	Petiole texture	Glabrous 5, 6, 8, 11, 12, 13, 14, 16, 17	Puberulent 1, 2, 9	Pubescent 3, 4, 7, 10, 18
10	Spike orientation	Erect 2, 8, 9, 10, 11, 13, 14, 16, 18	Pendent 1, 3, 4, 5, 6, 7, 12, 15, 17	

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1	2	3	4	5
11	Shape of female spike	Globose to semi-globose 2, 8, 11, 13	Cylindric 4, 9, 10, 14, 16	Flexuous 1, 3, 5, 6, 7, 12, 15, 17, 18
12	Nature of bract	Peltate 1, 2, 4, 5, 7, 8, 9, 10, 11, 13, 14, 16, 18	Adnate 3, 6, 12, 15, 17	
13	Arrangement of fruits on spike	Loose 1, 3, 6, 8, 12, 15, 17	Dense 2, 4, 5, 7, 9, 10, 11, 13, 14, 16, 18	
14	Number of stamen	Two 1,4, 5, 8, 9, 10, 11, 12, 13, 14, 18	Three 2, 3, 6, 15, 16, 17	Four 7
15	Number of anther cells	Two 3, 10, 11, 12, 13, 16, 17	Four 1, 2, 4, 5, 6, 7, 8, 9, 14	
16	Number of stigma	Three 1, 2, 3, 4, 5, 6, 7, 9, 10, 12, 14, 15, 16, 18	Four 11,13	Five 8, 17
17	Colour of ripe fruit	Dark green or black 2, 3, 4, 5, 6, 7, 9, 11, 13, 15, 16, 17	Yellow or red 1, 8, 10, 12, 14, 18	
18	Fruit size	Small 2, 5, 9, 10, 11, 13, 14, 16	Bold 1, 3, 4, 6, 7, 8, 12, 15, 17, 18	
19	Mucilage canal in the stem	Present 1, 2, 3, 4, 7, 9, 10, 11, 12, 13, 16, 17, 18	Absent 6, 8, 14,	
20	Nature of stem collenchyma	Continuous 1, 4, 6, 13, 15, 16	Discontinuous 2, 3, 5, 7, 8, 9, 10, 11, 12, 14, 17, 18	
21	Mucilage canal in petiole	Present 1, 2, 3, 4, 5, 6, 7, 11, 13, 17, 18	Absent 8, 9, 10, 12, 14, 15, 16	
22	Medullary bundle in petiole	Present 1, 2, 4, 6, 12, 13, 15, 18	Absent 3, 5, 7, 8, 9, 10, 11, 14, 16, 17	

Table 4. Results of multiple range test of quantitative characters

23. Length of internode in fertile branch

Species	11	16	10	7	8	6	2	14	12	13	3	9	4	18	5	1	16	15
Mean	24.33	26.70	27.27	27.83	30.13	30.40	36.07	39.37	39.67	39.80	40.27	49.07	49.30	49.60	52.83	54.60	67.77	71.30
S.E	0.42	0.83	0.70	0.69	0.70	0.65	0.73	0.61	0.83	0.72	0.92	0.67	0.79	0.66	0.84	1.14	0.83	1.37
			0						1					2			3	

24. Length of petiole in fertile branch

Species	9	8	14	11	5	10	2	7	6	13	4	17	15	18	1	16	12	3
Mean	0.60	4.73	5.53	5.80	6.90	7.23	7.57	8.33	9.07	10.13	11.07	12.10	13.57	14.87	15.00	17.97	18.00	23.70
S.E	0.10	0.23	0.23	0.24	0.29	0.30	0.27	0.30	0.25	0.45	0.37	0.97	0.40	0.38	0.34	0.65	0.65	0.61
	0						1					2				3		4

25. Length of petiole in vegetative branch

Species	8	5	14	11	5	10	2	7	6	13	4	17	15	18	1	16	12	3
Mean	8.77	8.97	9.07	10.33	31.93	39.87	40.17	41.00	41.90	47.47	47.47	48.70	55.17	58.03	64.57	74.57	85.07	92.50
S.E	0.34	0.24	0.35	0.38	1.07	0.70	0.97	0.80	1.09	0.76	0.81	0.94	1.24	1.43	1.42	1.95	1.53	1.62
		0				1					2					3		4

26. Leaf Area (in cm^2)

Species	8	13	2	9	7	11	6	14	16	17	18	4	3	10	15	5	12	1
Mean	72.10	75.91	76.32	86.00	87.50	87.58	87.89	89.97	90.80	91.28	92.44	92.46	95.03	109.28	145.92	150.97	180.06	182.12
S.E	0.96	0.82	0.91	1.03	1.34	0.38	1.07	0.91	1.40	0.78	1.44	1.18	1.16	1.33	1.55	1.21	1.33	1.77
		0						1						2		3		4

27. Leaf length-breadth ratio

Species	3	18	4	14	12	6	9	11	15	17	16	2	10	1	7	5	8	2
Mean	1.27	1.39	1.60	1.76	1.83	1.84	1.90	2.00	2.11	2.33	2.36	2.40	2.57	2.61	2.69	2.88	2.95	2.96
S.E	0.27	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02
		0	1		2			3			4			5			6	

28. Prophyll length

Species	10	9	13	18	11	4	17	2	7	16	3	12	14	18	1	6	15	5
Mean	5.53	5.67	5.77	7.23	7.80	9.50	10.07	11.57	12.33	12.77	13.07	13.80	13.80	15.27	17.73	20.07	23.13	36.30
S.E	0.16	0.15	0.15	0.36	0.21	0.25	0.25	0.33	0.27	0.26	0.31	0.24	0.29	0.20	0.36	0.34	0.28	0.25
		0										1					2	

29. Length of male spike

Species	8	2	13	9	4	11	16	10	3	13	1	7	5	18	17	6	14	15
Mean	28.47	31.00	35.87	57.53	58.67	64.40	64.93	68.03	84.57	95.03	101.67	101.73	104.20	107.50	110.70	111.53	154.07	39.67
S.E	0.78	0.72	0.69	1.05	0.70	1.45	1.56	1.04	1.49	1.28	2.17	0.92	1.37	1.75	1.33	1.23	1.82	2.68
		0		1					2			3					4	5

30. Length of female spike

Species	2	11	13	8	16	10	9	14	4	5	18	12	17	3	1	7	6	15
Mean	4.93	4.93	6.03	13.63	16.87	18.83	21.33	29.43	37.43	54.13	79.53	81.43	86.77	87.43	118.00	130.97	142.90	229.37
S.E	0.14	0.14	0.15	0.32	0.61	0.62	0.72	0.71	0.61	0.94	0.84	1.24	0.89	2.99	1.15	1.29	1.61	2.51
			0					1		2		3			4		5	6

31. Length of fruiting spike

Species	13	2	11	10	16	9	4	14	8	3	12	5	18	7	17	1	6	15
Mean	8.63	12.63	14.30	39.20	40.70	50.77	52.17	61.03	65.53	119.53	121.23	121.83	123.70	135.67	139.13	177.23	188.20	272.47
S.E	0.16	0.24	0.23	0.84	0.75	0.70	0.89	0.81	0.99	1.93	2.01	2.10	1.26	1.57	0.98	3.23	2.56	0.75
		0			1						2			3			4	5

32. Length of Peduncle

Species	2	11	13	10	7	16	3	17	18	9	12	7	6	14	1	15	4	5
Mean	2.80	4.70	5.27	5.53	5.67	8.20	8.33	12.07	16.13	17.33	17.47	17.87	19.63	19.77	20.90	23.53	36.30	44.30
S.E	0.19	0.18	0.25	0.25	0.19	0.41	0.36	0.46	0.57	0.38	0.33	0.24	0.49	0.46	0.68	0.57	0.47	0.76
			0								1					2	3	

Table 5. Character states of the OTUs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	2	2	1	2	0	2	2	0	1	1	0	2	2	0	2	1	2	2
2	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	1
3	0	1	1	2	0	0	2	0	1	2	0	0	1	0	0	1	0	2
4	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0
5	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0
6	1	0	2	2	0	0	2	0	1	2	0	0	0	0	0	1	0	2
7	2	1	0	2	2	1	1	1	2	1	1	0	1	1	0	1	1	1
8	2	0	0	2	2	0	2	1	2	2	0	0	0	1	0	2	0	0
9	1	1	2	2	0	0	2	0	1	2	0	0	0	0	0	0	0	2
10	1	0	1	1	1	1	1	0	0	0	0	1	0	0	1	0	1	0
11	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	0	1	0
12	2	0	2	1	2	2	2	0	1	1	0	2	0	1	2	1	2	2
13	0	1	0	1	1	0	1	0	1	1	1	0	1	1	0	1	0	1
14	0	1	1	0	0	1	2	0	0	0	0	0	0	0	1	1	1	0
15	1	1	0	1	1	1	1	1	1	0	0	0	0	1	1	0	0	1
16	0	0	0	0	0	0	0	2	0	0	1	0	1	0	0	0	2	0
17	1	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1
18	1	0	1	1	0	1	1	1	0	0	0	1	0	0	1	0	1	1
19	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0
20	0	1	1	0	1	0	1	1	1	1	1	1	0	1	0	0	1	1
21	0	0	0	0	0	0	0	1	1	1	0	1	0	1	1	1	0	0
22	0	0	1	0	1	0	1	1	1	1	1	0	0	1	0	1	1	0
23	2	1	1	2	2	0	0	0	2	0	0	1	1	3	3	3	0	2
24	2	1	4	1	1	1	1	1	0	1	1	3	1	1	2	3	2	2
25	2	1	2	1	0	2	1	0	2	4	0	1	1	0	3	4	3	2
26	4	0	1	1	1	1	1	0	1	2	1	4	0	1	3	1	1	1
27	5	4	0	1	6	2	5	6	2	6	3	2	6	2	3	4	4	0
28	1	0	3	0	2	1	3	0	0	0	0	3	0	3	1	3	0	3
29	3	0	2	1	3	3	3	0	1	1	1	3	0	4	5	1	3	3
30	4	0	3	1	2	5	4	0	0	0	0	3	0	1	6	0	3	3
31	4	0	2	1	2	4	3	1	1	1	0	2	0	1	5	1	3	2
32	1	0	0	3	3	1	1	0	1	0	0	1	0	1	2	0	0	1

Table 6. Similarity Matrix of the OTUs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	100	28.13	46.88	43.75	59.38	50.00	25.00	37.50	28.13	18.75	37.50	18.75	25.00	37.50	50.00	25.00	28.13	56.25
2		100	37.50	46.88	37.50	37.50	43.75	46.88	46.88	43.75	62.50	31.25	84.37	28.13	31.25	46.88	43.75	46.88
3			100	34.38	34.38	43.75	46.88	21.88	37.50	34.38	34.38	53.12	31.25	21.88	43.75	46.88	59.38	50.00
4				100	46.88	37.50	59.88	25.00	53.12	50.00	46.62	28.12	46.80	34.38	31.25	40.62	31.25	56.25
5					100	31.25	50.00	46.88	46.88	37.50	50.00	37.86	34.38	53.12	31.25	31.25	40.62	37.50
6						100	50.00	34.38	28.12	18.75	31.25	56.25	34.38	34.38	62.50	28.12	59.38	40.62
7							100	31.25	43.75	53.12	34.38	40.62	34.38	37.50	25.00	40.62	53.12	62.50
8								100	37.50	50.00	56.25	31.25	46.88	65.62	25.00	34.38	43.75	28.12
9									100	62.50	46.88	28.12	37.50	53.12	21.88	65.62	28.12	43.75
10										100	56.25	28.12	43.75	46.88	12.50	65.62	34.38	43.75
11											100	28.12	71.88	50.00	25.00	50.00	53.12	37.50
12												100	34.38	37.50	66.25	50.00	50.00	50.00
13													100	31.25	28.12	46.88	40.62	40.62
14														100	25.00	50.00	21.88	40.62
15															100	31.25	53.12	31.25
16																100	40.62	31.25
17																	100	43.75
18																		100

RESULTS

The dendrogram obtained through the analysis clearly revealed that the 18 taxa used in the numerical analysis fall under 6 distinct clusters in two broad sections each with 9 taxa (Fig. 1). The first section (Section A) consists of 9 taxa grouped in 3 distinct clusters (Cluster I, II and III) comprising 3 taxa in each cluster. The taxa in each cluster revealed close inter-specific relationship. *Piper pedicellatum* and *P. lonchites* exhibited 66% affinity and clustered with *P. boehmeriaefolium* that share only 45% similarity. The taxa of the first cluster were all erect shrubs with no demarcation of vegetative (orthotropic) and fertile (plagiotropic) branches as in the climbing and creeping species, and showed uniform leaf characters throughout the plant. Likewise *P. longum* and *P. sylvaticum* shared 66% affinity and clustered (II) with *P. makruense* that shared 65% relationship. All these 3 taxa are predominantly creeping shrubs or low climbers with erect cylindric spikes with compactly arranged fruits hardly distinguishable in their immature condition. Moreover, the shape and size of the leaf in the vegetative branches are similar. *Piper nirjulianum* and *P. arunachalensis* which exhibited the highest affinity (84%) and *P. mullesua* which shared 67% similarity formed the cluster III. All the three taxa of the third cluster possess short globose fruiting spikes having densely aggregated minute fruits, which become black on ripening. Although *P. mullesua,* a stout climbing shrub formed a cluster with the remaining two small climbing species, the former showing almost similar features with the latter in its leaves and flowering characters. The species of the three clusters of the first section are again related closely in a number of characters. All the species are smaller plants having densely aggregated flowers and fruits with peltate bracts in erect spikes. Moreover they can be easily distinguished with their erect short cylindric or globose fruiting spikes. The exceptions to these general observations include *P. boehmeriaefolium* with pendent spike and *P. lonchites* with loosely aggregated fruits. Except *P. boehmeriaefolium* the taxa in each cluster of the first section (Section A) shared more than 65% similarity.

The second section also consisted of 3 clusters (IV, V and VI) with 9 species. The fourth cluster consisted of 2 species, the fifth 3 while the sixth 4 species. *Piper sylvestre* and *P. attenuatum* shared 59% affinity in their characters and formed the fourth cluster (IV). They are related closely in their nature of leaf and flowering and fruiting spike. The flowers and fruits are distantly arranged in the spikes and the bracts are peltate and the fruits become black in both. The shape, size and the texture of leaves are also similar. *Piper wallichii* and *P. haridasanii* also shared 63% similarity and formed another cluster (V) with *P. betleoides* which shared 50% relationship. They show affinity among themselves in the nature of pubescence and flowering and fruiting characters. The young shoots are distinctly hairy, flowers and fruits are densely aggregated with peltate bract. *Piper rhytidocarpum* and *P. griffithii* are grouped together with 63% affinity and formed the cluster VI with *P. nigrum* and *P. acutistigmum* that shared 57% and 50% affinity respectively. The taxa of this cluster are closely related in their main characteristic features. All are huge climbers with long pendulous fruiting spikes with loosely arranged bold fruits. This group has the largest fruiting spikes and big coriaceous leaves. The species of the three clusters of the second section also shared a number of similar features. All the species have long pendulous fruiting and flowering spikes which lengthen upto more than 8 cm and are basically climbing shrubs except *P. attenuatum,* which shows

both creeping and climbing habits. The taxa of the each cluster in the second section (Section B) showed more than 50% similarity among them.

When the species of the two main groups are compared, it is found that the second section comprises more heterogeneous species combination. Although it contains the species with pendulous flowering and fruiting spike, also combines the species with both loosely and densely aggregated fruiting spike, adnate and peltate bracts. The small and huge climbers are also clubbed together in the second group. On the contrary the species composition of the first section was more homogeneous.

DISCUSSION

The present numerical analysis has yielded a good clustering pattern that reflects the natural relationship among the taxa. The result of the study by and large vindicates the existing specific level classification of the genus. The two distinct groups of the species in the present analysis represent two distinct sub-generic levels of the species of North-East India which is in complete agreement with the recent sub-generic classification of the South Indian taxa suggested by Ravindran (1991). Ravindran proposed two new sub-generic levels - *Pippali* and *Maricha*. The former group contains plants with erect spike like 'Pippali' (*P. longum*) and the latter group with pendent spike like 'Maricha' (*P. nigrum*) derived from the Sanskrit names of the two commonly cultivated species. The first group of the present investigation comprises species with erect spikes except one (*P. pedicellatum*) and the second group comprises all the species with pendent spikes. Thus the first group falls under the section *Pippali* and the second group in the section *Maricha* of Ravindran (1991). This grouping of the species also supports the classical grouping of Hooker (1886) to some extent. With the exception of *P. lonchites* all the members of the three clusters of the first group (section A) fall under the section *Chavica*. Again the fifth cluster comprises the species belonging to *Chavica* while the fourth cluster comprises the members of *Eupiper*. The sixth cluster is a heterogeneous combination of species where *P. nigrum* and *P. rhytidocarpum* are from the section *Eupiper,* while *P. griffithii* is from *Cubeba* and *P. acutistigmum* is from *Pseudochavica* (not included by Hooker but can be placed under the section *Pseudochavica*). Hooker has placed the species with densely aggregated fruiting spikes in his section *Chavica* and species with loosely aggregated fruit in the section *Pseudochavica*.

Although the results of the present study support the conventional taxonomic grouping, it also points out a few shortcomings of the conventional grouping of North-East Indian taxa. The grouping of *P. lonchites* with the other species of the section *Chavica* in the present analysis shows high degree of correlation of characters with the other species of the section. Hooker, has however, placed the species together with the species like *P. hamiltonii, P. suipigua* etc., under *Pseudochavica* because of the loosely aggregated nature of the fruit. But the other features of *P. lonchites* differ from the remaining species of the section *Pseudochavica*. The species of the fifth cluster in the present analysis, all of which fall under the section *Chavica*, are placed separately in another group with the species of the section *Eupiper* in the present analysis. These three species, although show relation with members of

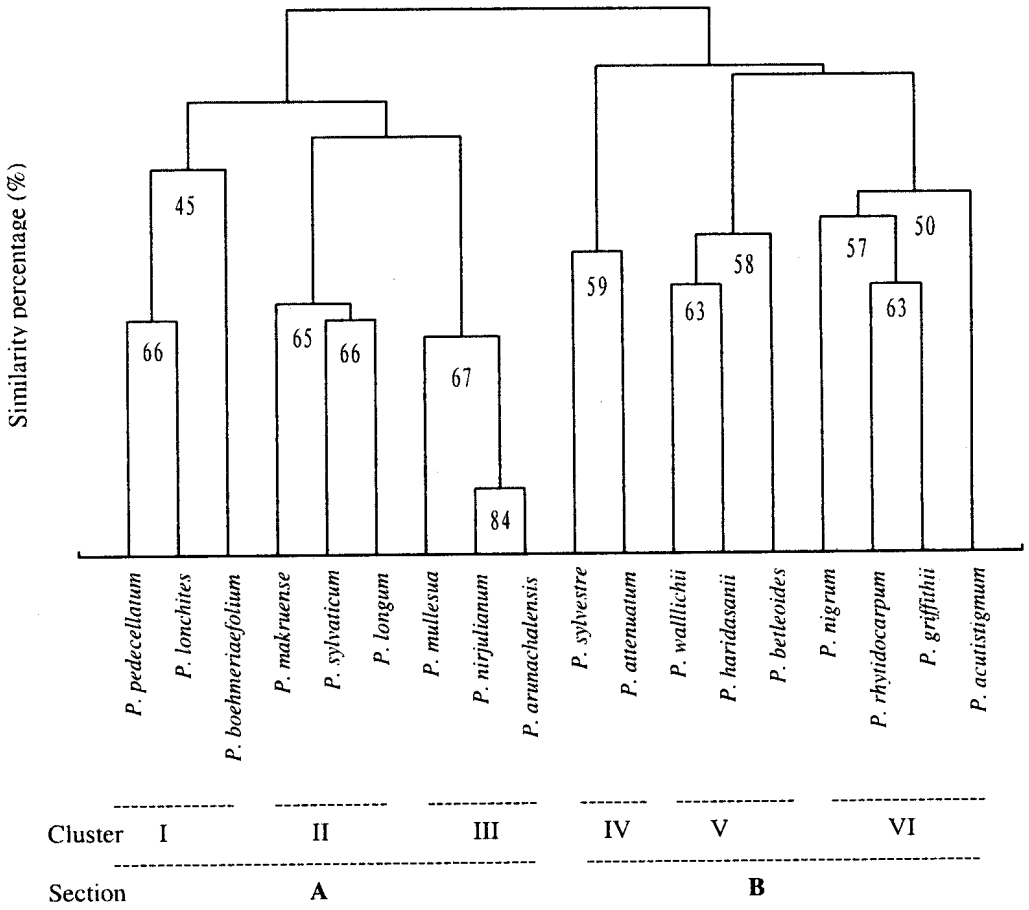

Fig. 1. Dendrogram showing clusters of species of *Piper*.

the section *Chavica* (densely aggregated fruits and peltate bracts), yet show differences with them leading to their separation. In the conventional method, *P. rhytidocarpum* and *P. nigrum* were separated from *P. griffithii* and *P. acutistigmum,* but in the present study they are grouped in a single cluster as many other characters were also being taken into consideration simultaneously for clustering. The study again supports the clustering of the South Indian taxa by Ravindran *et al.*, (1992). They grouped 17 OTUs under 10 species in 6 clusters using 30 characters where some of the species of the same section of the conventional methods are grouped in different clusters. They separated *P. longum* and *P. nullesua* of the same section Chavica of the conventional grouping into two different clusters. In this study also these two species are segregated into two different clusters but under the same broad section.

Thus the numerical analysis of the eighteen species of *Piper* occurring in Arunachal Pradesh of North East India helps to find out the natural relationship among the species and to group them on the basis of their similarity. The result clearly shows that the species can be segregated into two major sections representing two sub-generic levels with 3 clusters in each with closely related species in the following pattern: -

Section A: Species with erect short female spikes and densely aggregated flowers --- *Pippali*

Group I : Erect species with long cylindric fruiting spikes and uniform leafstructure (*P. pedicellatum, P. lonchites* and *P. boehmeriaefolium*)

Group II : Predominantly creeping species with short cylindric fruiting spikesand large leaf in vegetative branch (*P. makruense, P. sylvaticum*and *P. longum*)

Group III : Small climber or stout climbing shrub with short globose spikes and smaller leaves in vegetative runner shoot (*P. mullesua, P. nirjulianum,* and *P. arunachalensis)*

Section B: Species with pendent long flowering spikes with densely or loosely aggregated flowers – *Maricha*

Group IV: Small climber with long spikes with distantly arranged flowers and fruits and adnate bracts (*P. sylvestre* and *P. attenuatum*).

Group V: Small or big hairy climber with compactly arranged fruits and peltate bracts (*P. wallichii, P haridasanii* and *P. betleoides*).

Group VI: Huge glabrous climber with loosely aggregated fruits (*P. nigrum, P. rhytidocarpum, P. griffithii* and *P. acutistigmum*).

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