BIOMETRICS OF SOME SIWALIK CHAROPHYTA*

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ABSTRACT

The charophyte taxa of the Siwalik Group have been so far distinguished mainly on their morphological characters. However, statistical analysis of physical parameters of some of the charophyte taxa already described from these rocks shows that there exists considerable variation with respect to size, shape and number of convolutions within each taxon which would otherwise be overlooked. The present contribution deals with the biometric analysis of eight charophyte taxa namely, *Sphaerochara tewarii* Bhatia & Mathur, *S. pecki* Bhatia & Mathur, *Hornichara maslovi* Bhatia & Mathur, *Tectochara sahnii* Bhatia & Mathur, *Chara contraria* Braun *ex* Kuetzing, *C. soulie-maerschei* n. sp., *C. rantzieni* Tewari & Sharma and *C. rantzieni sivalensis* Bhatia & Mathur from the Siwalik Group. The procedure adopted for statistical analysis of these charophytes is also dealt with in this contribution.

INTRODUCTION

In recent years, charophytes of the Siwalik Group have received attention from various workers namely, Bhatia and Mathur (1970, 1978), Tewari and Sharma (1972) and Lakhanpal *et al.* (1976). However, none of these works deal with the biometric analysis of physical parameters of charophyte populations. It has been observed that the populations of charophyte taxa from the Middle and the Upper Siwalik contain sufficiently large samples to allow statistical analysis of their physical parameters like length of the polar axis (LPA or L), largest equatorial diameter (LED or l), anisopolarity index (ANI) and number of convolutions (NC). A study of charophytes shows that within each species there is considerable variation in size and shape which necessitates fixing of physical parameters to define the limits of variation. This can be achieved by using univariate as well as multivariate statistical methods. The procedures adopted for univariate and bivariate statistical methods in the present contribution is mainly derived from the works of Reeve (1939), Rao (1952), Imbrie (1956), Koch and Link (1970 a, b), and Bonnet and Soulie-Märsche (1971).

PROCEDURES FOR BIOMETRIC ANALYSIS

The procedure adopted in this work deals first with the univariate statistical methods followed by the bivariate methods and the discrimination of systematic units.

Univariate Statistical Methods

(*a*) *Choice of quantitative characters* : The shapes of the charophyte gyrogonites play an important role in differentiating various species. This shape is expressed in terms of ISI (Isopolarity index) and ANI (Anisopolarity index) and are given by the expression

$$\text{ISI} = \frac{\text{L}}{\text{l}} \times 100 \text{ and } \text{ANI} = \frac{\text{AND}}{\text{l}} \times 100$$

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where L is the length of the polar axis (LPA), l is the largest equatorial diameter (LED) and AND is the anisopolarity distance as implied by HORN af RANTZIEN (1956).

(*b*) *Statistics and corresponding parameters* : The following table (Table 1) gives the statistics and their corresponding parameters required for univariate analysis.

Table 1—Statistic and Corresponding Parameter

Statistic	How calculated	Corresponding Parameter
Univariate Mean	$\bar{X} = \frac{\Sigma (X)}{N}$	μ
Standard Deviation	$S = \sqrt{\frac{(X-\bar{X})^2}{N}}$	σ

(*c*) Standard error of the Mean ($\bar{X}$) and its (mean) Confidence Interval : For judging the reliability of an estimate of parameter, a quantity 'standard error' is computed for the mean by the formula

$$\sigma \bar{X} = \frac{s}{\sqrt{N}}$$

where $\sigma \bar{X}$ is the standard error of the mean.
The confidence interval for mean at P_c probability level (here $P_{0\cdot05}$) is given by the expression

$$\bar{X} \pm t . \sigma \bar{X}$$

where $_{0\cdot05}$ is taken from t-tables for probability level $P_{0\cdot05}$. Thus, in the present case 95 per cent of the time the mean value of the population lies between

$$\bar{X} - t_{0\cdot05} \cdot \bar{X} \text{ and } \bar{X} + t_{0\cdot05} \cdot \bar{X}$$

This is called confidence interval with confidence coefficient 0.95.

(*d*) *Coefficient of variation* : The coefficient of variation is the measure of relative variation calculated in percentage of s and $\bar{X}$

$$V = \frac{100.s}{\bar{X}}$$

(*e*) *Criteria for homogenity* : (i) Test of goodness of 'fit' : To see whether there is any significant difference between the observed frequencies (f_i) and theoretical frequencies (F_i) for the same set of classes ,we use the χ^2—statistic computed as

$$\chi^2 = \Sigma \frac{{}^2(f_i - F_i)}{F_i}$$

This is known as chi-square (χ^2) test. For given degrees of freedom (v) the value of χ^2 is taken from the Tables (chi-square Tables) for a given level of significance (say $P_{0\cdot05}$). If the calculated value of χ^2 is less than the tabulated value then χ^2 is nonsignificant. In such cases the population is said to be normal and the observed and expected frequencies do not differ significantly.

(ii) Coefficient of Pearson (Moments) : For a variable to follow normal distribution

$$B_1 = \frac{\mu_3^2}{\mu_2^3} = 0 \text{ and}$$

$$B_2 = \frac{\mu_4}{\mu_2^2} = 3$$

where μ is the central moment of the order q. The coefficient β_1 and β_2 are calculated by estimating the moments M_q (qth moment) about the sample mean $\overline{X}$ given by the expression

$$M_q = \frac{1}{n} \overset{n}{\underset{1}{E}} (x_i - \overline{X})^q$$

The hypothesis of 'univariate normal distribution' is rejected if the value of B_1 and B_2 estimated for β_1 and β_2 are significantly different from 0 and 3 respectively.

The estimates of coefficients of Pearson reflect skewness and kurtosis of a curve, A curve is symmetrical if $B_1 = 0$.

Method for Bivariate Statistical Analysis

The relative growth in length, height or width of a species is important in living forms as well as fossil forms. While in the living forms the relative growth can be actually determined, the fossil forms provide growth pattern. The growth pattern of any two characters (in the present case L and l) may be shown by following method :

Graphic Method : By plotting the two variables L on ordinate and l on abscissa, the distribution pattern may be obtained.

For this, the regression coefficients (B) of L on l and of l on L are calculated. Also, the intercepts (A) are calculated.

The regression for L on l is

$$L = A + B.l$$

and regression for l on L is

$$l = A_1 + B_1.L$$

Statistical Discrimination of Taxa

Student's 't' distribution : The application of 't' distribution is sought to discriminate between the means (M_1 and M_2) of two populations A and B. The formula used for 't' ratios is

$$t = \frac{M_1 - M_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

where s_1 and s_2 are the standard deviations and N_1 and N_2 the number of individuals in the two populations. If the observed 't' is statistically significant (i.e., greater than tabulated 't' at the desired probability level), then the taxa may be concluded as different. If the observed 't' is nonsignificant, then the taxa belong to the same population.

The above mentioned statistical methods have been applied in characterisation of eight charophyte taxa listed below and which, with the exception of the new taxon, were described by the author in collaboration with BHATIA (BHATIA & MATHUR, 1978) :

Sphaerochara tewarii Bhatia & Mathur
S. pecki Bhatia & Mathur
Tectochara sahnii Bhatia & Mathur
Hornichara maslovi Bhatia & Mathur
Chara contraria Braun ex Kuetzing
C. soulie-maerschei Mathur n. sp.
C. rantzieni Tewari & Sharma
C. rantzieni sivalensis Bhatia & Mathur

Details regarding the material and geographic and geological distribution of these taxa may be seen in BHATIA AND MATHUR (1978).

The estimates of parameters of various characters of these charophyte taxa follow brief pertinent remarks on individual taxon classified according to GRAMBAST (1962).

Order CHARALES
Family CHARACEAE
Subfamily CHAROIDEAE
Tribe GYROGONAE
Genus **Sphaerochara** Maedler, 1952 emend. Horn af Rantzien & Grambast, 1962

Sphaerochara tewarii Bhatia & Mathur
Pl. 1, Figs. 1a, b

Sphaerochara tewarii Bhatia & Mathur, 1978, p. 85; pl. 1, figs. 1a-c.

Table 2—Showing frequency (f_i) distribution of six characters of *Sphaerochara tewarii*.

LPA (L)	f_i	LED (l)	f_i	AND	f_i	ISI	f_i	ANI	f_i	NC	f_i
350-357	5	335-345	1	175-182	1	85-88	4	20-42	1	7-8	12
357-364	0	345-355	0	182-189	1	88-91	1	42-44	0	8-9	36
364-371	0	355-365	1	189-196	1	91-94	22	44-46	1	9-10	42
371-378	8	365-375	9	196-203	12	94-97	13	46-48	0	10-11	2
378-385	8	375-385	10	203-210	5	97-100	24	48-50	0	11-12	0
385-392	0	385-395	0	210-217	1	100-103	7	50-52	10		
392-399	0	395-405	31	217-224	3	103-106	15	52-54	3		
399-406	49	405-415	3	224-231	42	106-109	2	54-56	16		
406-413	3	415-425	28	231-238	6	109-112	2	56-58	25		
413-420	5	425-435	5	238-245	1	112-115	1	58-60	22		
420-427	13	435-445	0	245-252	18	115-118	1	60-62	10		
427-434	2	445-455	3	252-259	0	118-121	0	62-64	4		
434-441	0	455-465	1	259-266	0						
441-448	0			266-273	0						
448-455	4			273-280	1						

Table 3—Estimates of parameters of various characters of *Sphaerochara tewarii*.
No. of individuals : 92

Characters / Estimates of Parameters	LPA (L)	LED (l)	AND	ISI	ANI	Number of convolutions (NC)
Mean ($\bar{x}$)	402.880	406.521	225.869	98.913	55.358	9.358
Standard error of mean ($\sigma\bar{x}$)	2.209	2.303	1.864	0.619	0.687	0.080
Confidence interval for mean at $P_{0\cdot05}$ (t. $\sigma\bar{x}$)	±4.312	±4.533	±3.653	±1.213	±1.343	±0.516
Standard deviation (s)	20.995	22.023	17.783	5.907	6.559	0.764
Standard error of standard deviation	1.551	1.628	1.314	0.436	0.484	0.056
Coefficient of variation in percentage (V)	5.211	5.417	7.873	5.971	11.848	8.167
$\chi^2 = \Sigma \frac{(f_i - F_i)^2}{F_i}$	3.141	67.836	64.445	21.043	74.880	11.130
Degrees of freedom (v= n—1)	14	12	14	11	11	4
Tabulated χ^2 for v at $P_{0\cdot05}$	23.69	21.03	23.69	19.68	19.68	9.49
χ^2— significant/nonsignificant	Nonsignif.	Signif.	Signif.	Signif.	Signif.	Nonsignif.
Coefficients of B_1	0.1470	0.0647	0.0352	0.1755	Error	0.2716
Pearson (Moment) B_2	3.9379	3.1104	3.2054	3.4396	Error	2.9254

Remarks—This small-sized *Sphaerochara* with distinct apical nodules has been described by Bhatia and Mathur (1978) from the Middle Siwalik (Dhok Pathan Formation) near Daulatpur, Himachal Pradesh.

Tables 2, 3 give frequency distribution and estimates of various parameters of characters of *S. tewarii*. Fig. 1 gives lines of regression between L and l for *S. tewarii*.

Schaerochara pecki Bhatia & Mathur

Pl. 1, Figs. 2 a, b

Shpaerochara pecki Bhatia & Mathur, 1978, p. 85, pl. 1, figs. 2a-c

Remarks—This *Sphaerochara* was also described from the Middle Siwalik by Bhatia and Mathur (1978) and is distinguished from *S. tewarii* in having concave lime spirals and absence of apical nodules. The statistical parameters also show that these are two separate entities. Both these taxa are restricted to Middle Siwalik.

Tables 4, 5 give the frequency distribution and estimates of parameters of various characters of *S. pecki*. Fig. 2 gives lines of regression between L and l for *S. pecki*.

Genus **Tectochara** Grambast & Grambast, 1954

Tectochara sahnii Bhatia & Mathur

Pl. 1, Figs. 3 a, b

Tectochara sahnii Bhatia & Mathur, 1978, p. 89, pl. 1, figs. 5a-c

Remarks—*Tectochara sahnii* distinguished by its small size, narrowly oblate sphaeroidal to prolate shape, and prolonged basal pore has been described by Bhatia and Mathur

Table 4—Showing frequency (f_i) distribution of six characters of *Sphaerochara pecki*.

LPA (L)	f_i	LED (l)	F_i	AND	f_i	ISI	f_i	ANI	f_i	NC	f_i
335—345	1	310—317	1	155—160	6	94—96	3	42—43	6	7—8	8
345—355	4	317—324	0	160—165	3	96—98	0	43—44	3	8—9	36
355—365	1	324—331	5	165—170	3	98—100	12	44—45	6	9—10	28
365—375	19	331—338	1	170—175	13	100—102	9	45—46	13	10—11	7
375—385	11	338—345	4	175—180	3	102—104	5	46—47	15	11—12	3
385—395	6	345—352	11	180—185	15	104—106	13	47—48	4	12—13	1
395—405	27	352—359	11	185—190	11	106—108	11	48—49	14		
405—415	2	359—366	4	190—195	0	108—110	9	49—50	10		
415—425	11	366—373	1	195—200	20	110—112	5	50—51	6		
425—435	0	373—380	26	200—205	3	112—114	5	51—52	2		
435—445	0	380—387	8	205—210	4	114—116	6	52—53	4		
445—455	1	387—394	2	210—215	0	116—118	2				
		394—401	8	215—220	2	118—120	1				
		401—408	1			120—122	2				

Table 5—Estimates of parameters of various characters of *Sphaerochara pecki*.
No. of individuals : 83

Characters / Estimates of Parameters	LPA (L)	LED (l)	AND	ISI	ANI	Number of convolutions (NC)
Mean ($\bar{x}$)	391.927	366.807	187.168	106.855	47.698	9.554
Standard error of mean ($\sigma \bar{x}$)	2.307	2.327	1.627	0.663	0.297	0.112
Confidence interval for mean at $P_{0.05}$ ($t. \sigma \bar{x}$)	±4.521	±4.560	±3.188	±1.299	±0.582	±0.219
Standard deviation(s)	20.892	21.073	14.737	6.004	2.694	1.015
Standard error of standard deviation	1.616	1.640	1.147	0.467	0.209	0.079
Coefficient of variation in percentage (V)	5.330	5.745	7.873	5.619	5.649	10.625
$\chi^2 = \Sigma \frac{(f_i - F_i)^2}{F_i}$	28.927	8.783	23.325	2.036	81.012	50.903
Degrees of freedom ($v = n - 1$)	11	13	12	13	10	5
Tabulated χ^2 for v at $P_{0.05}$	19.68	22.36	21.03	22.36	18.31	11.07
χ^2—significant/nonsignificant	Signif.	Nonsingnif.	Signif.	Nonsignif.	Signif.	Signif.
Coefficient of B_1	0.0901	0.1163	0.0113	0.0831	0.0084	0.5022
Pearson (Moment) B_2	3.2141	2.6374	2.4413	2.6676	2.5880	4.2750

(1978). Tables 6, 7 give the frequency distribution and estimates of parameters of various characters of *T. sahnii*, while Fig. 3 gives the lines of regression between L and l.

Table 6—Showing frequency distribution (f_i) of six characters of *Tectochara sahnii.*

LPA (L)	f_i	LED (l)	f_i	AND	f_i	ISI	f_i	ANI	f_i	NC	f_i
315—325	1	275—287	1	175—181	1	87—89	3	50—52	7	7—8	52
325—335	1	287—299	0	181—187	0	98—91	3	52—54	4	8—9	26
335—345	2	299—311	2	187—193	1	91—93	6	54—56	7	9—10	1
345—355	2	311—323	1	193—199	0	93—95	9	56—58	11		
355—365	4	323—335	3	199—205	8	95—97	13	58—60	19		
365—375	29	335—347	1	205—211	1	97—99	6	60—62	17		
375—385	11	347—359	9	211—217	1	99—101	17	62—64	3		
385—395	3	359—371	5	217—223	5	101—103	3	64—66	11		
395—405	18	371—383	17	223—229	28	103—105	2				
405—415	3	383—395	9	229—235	10	105—107	5				
415—425	5	395—407	12	235—241	1	107—109	3				
		407—419	3	241—247	1	109—111	3				
		419—431	13	247—253	21	111—113	2				
		431—443	1	253—259	1	113—115	3				
		443—455	2	259—265	0	115—117	1				

Table 7—Estimates of parameters of various characters of *Tectochara sahnii.*
No. of individuals : 79

Characters Estimates of Parameters	LPA (A)	LND (l)	AND	ISI	ANI	Number of convolutions (NC)
Mean ($\bar{x}$)	383.164	383.924	229.430	99.721	59.405	8.265
Standard error of mean ($\sigma\bar{x}$)	2.343	3.886	1.940	0.756	0.466	0.0718
Confidence interval for mean at $P_{0.05}$ (t. $\sigma\bar{x}$)	±4.592	±7.616	±3.802	±1.481	±0.913	±0.139
Standard deviation (s)	20.695	34.321	17.134	6.677	4.118	0.634
Standard error of standard deviation	1.651	2.739	1.367	0.532	0.328	0.050
Coefficient of variation in percentage (V)	5.401	8.939	7.468	6.696	6.932	7.678
$\chi^2=\Sigma\frac{(f_i-F_i)^2}{F_i}$	58.531	51.848	51.848	14.632	6.696	210.645
Degrees of freedom (V=n—1)	10	14	14	14	7	6
Tabulated χ^2 for v at $P_{0.05}$	18.31	23.69	23.69	23.69	14.07	5.99
χ^2—significant/nonsignificant	Signif.	Signif.	Signif.	Nonsignif.	Nonsignif.	Signif.
Coeffcient of B_1	0.0097	0.3499	0.3381	0.3387	0.1379	0.0025
Pearson (Moment) B_2	3.9026	3.4929	3.2095	2.7737	2.5987	2.7856

Genus **Hornichara** Maslov, 1963

Hornichara maslovi Bhatia & Mathur

Pl. 1, Figs. 4a, b

Hornichara maslovi Bhatia & Mathur, 1978, p. 90, pl. 1, figs. 6a-c; pl. 7, fig. 8

Remarks—*Hornichara maslovi* distinguished by its sharp intercellular ridges, wider convolutions and relatively less elongate pentagonal basal pore has been described by Bhatia and Mathur (1978).

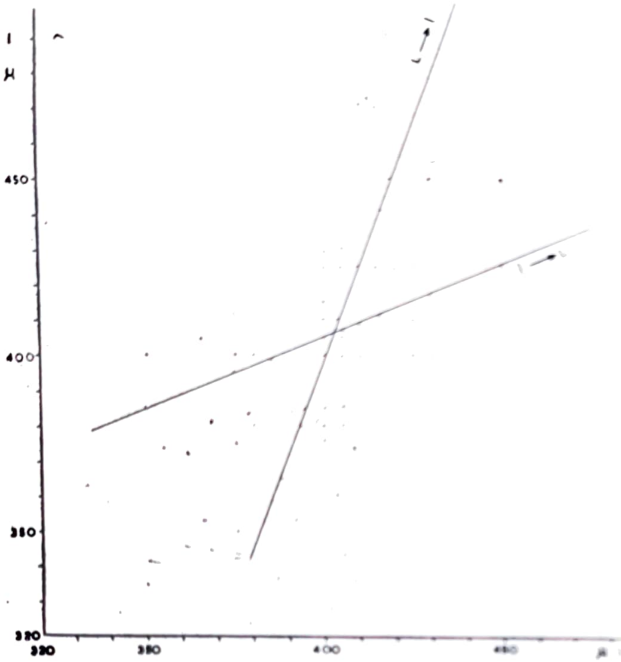

Fig. 1. Showing Lines of Regression between L & I for *Sphaerochara tewarii*.

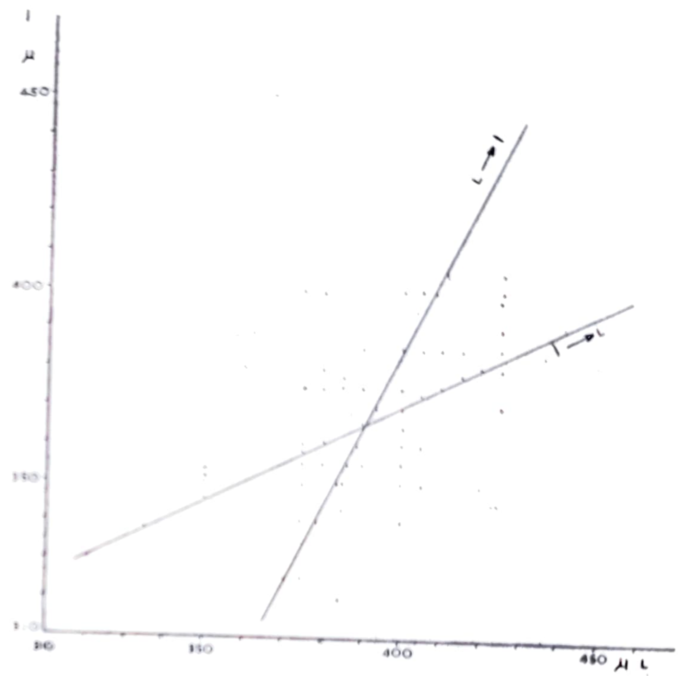

Fig. 2. Showing Lines of Regression between L & I for *Sphaerochara pecki*.

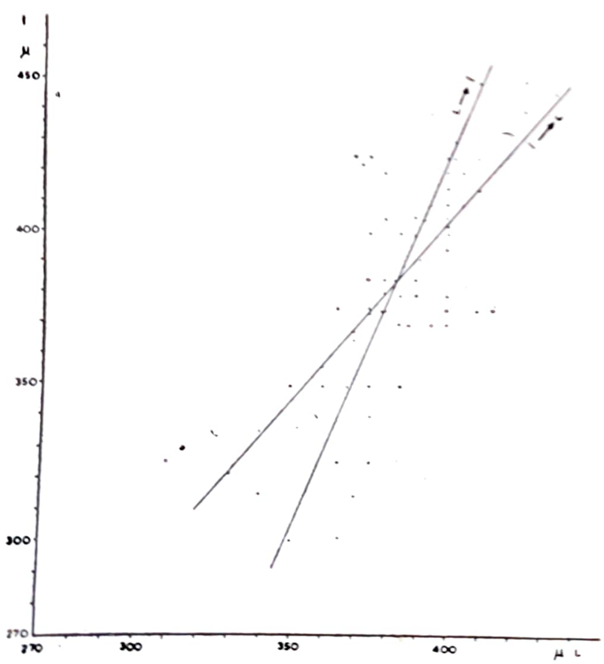

Fig. 3. Showing Lines of Regression between L & I for *Tectochara sahnii*.

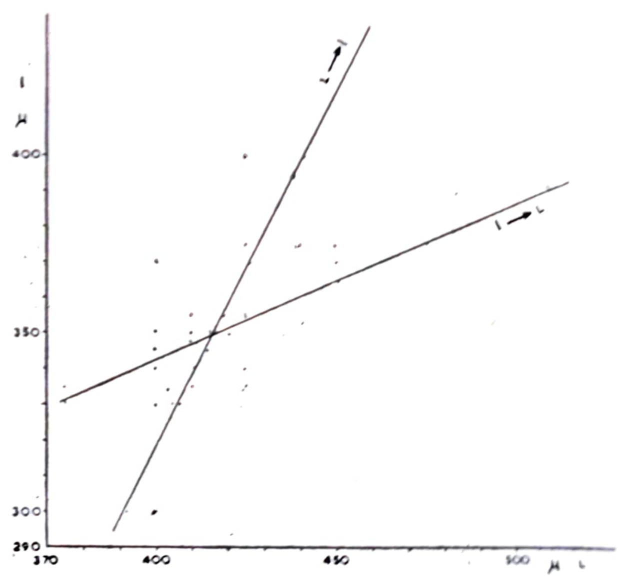

Fig. 4. Showing Lines of Regression between L & I for *Hornichara maslovi*.

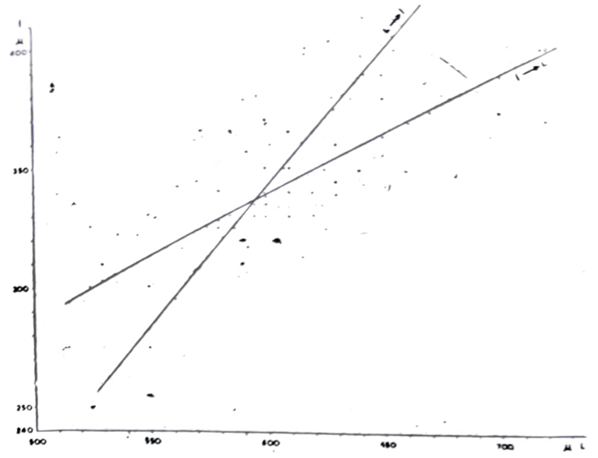

Fig. 5. Showing Lines of Regression between L & I for *Chara contraria* Braun ex Kuetzing.

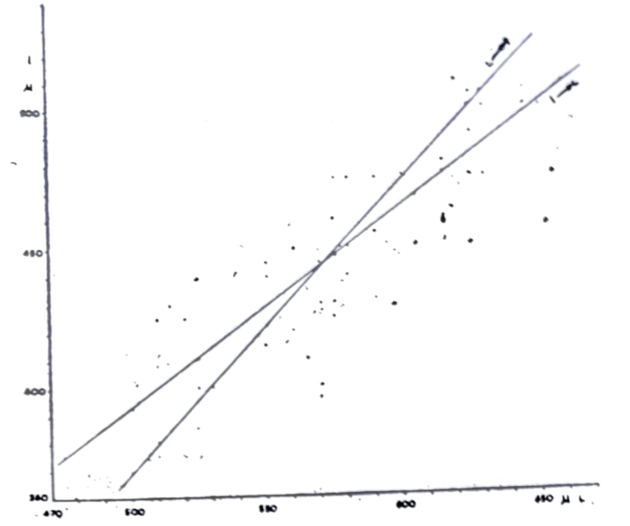

Fig. 6. Showing Lines of Regression between L & I for *Chara soulie-maerschei*.

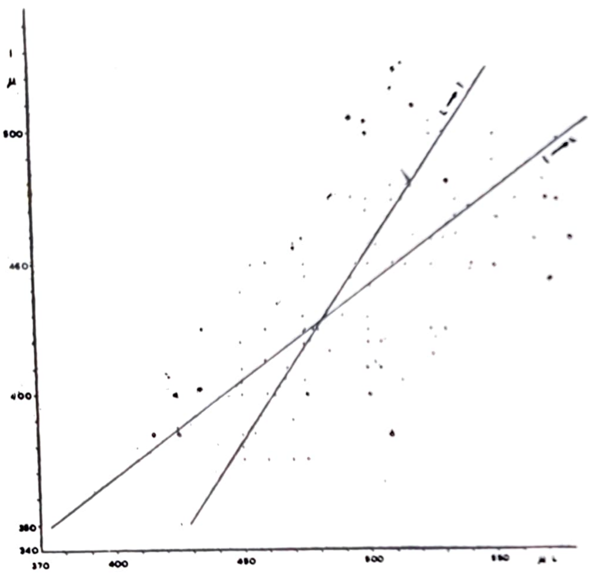

Fig. 7. Showing Lines of Regression between L & I for *Chara rantzieni*.

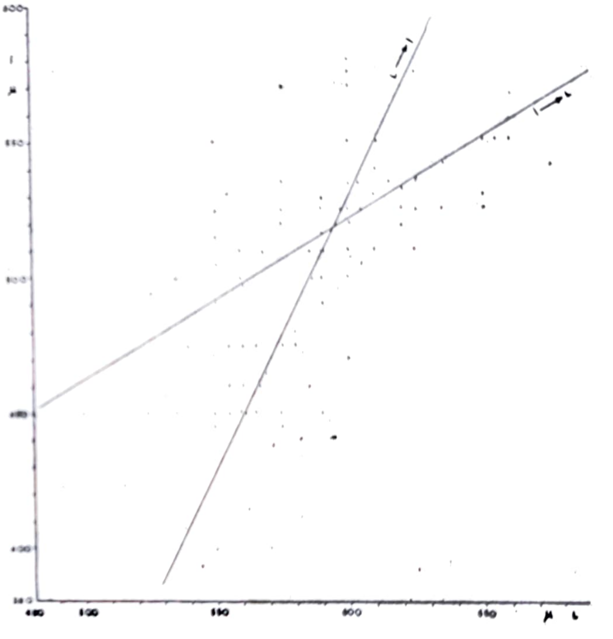

Fig. 8. Showing Lines of Regression between L & I for *Chara rantzieni sivalensis*.

The population of *H. maslovi* in the present collection is somewhat lower than the other charophyte populations yet, the results show that these individuals belong to one and the same species.

Tables 8, 9 show frequency distribution and estimates of parameters of various characters for *H. maslovi* and Fig. 4 gives lines of regression between L and l.

Tribe CHAREAE
Genus **Chara** Linnaeus, 1753, emend. Bhatia & Mathur, 1978

Chara contraria Braun ex Kuetzing

Pl. 1, Figs. 5a, b

Chara contraria Braun *ex* Kuetzing, 1845, p. 258 (*non-vidi*), Horn af Rantzien, 1959, pp. 260-263, pl. 12, figs. 1-11, Daily, 1961, pp. 53, 54, pl. 1, figs. 11-13, 19-21; pl. 2, figs. 6-8; Pal *et al.* 1962, p. 103, figs. 243-247 *et syn.*; Bhatia & Mathur, 1978, pp. 91-92, pl. 3, figs. 4a-c

Table 8—Showing frequency distribution (f_i) of six characters of *Hornichara maslovi*.

LPA (L)	f_i	LED (l)	f_i	AND	f_i	ISI	f_i	ANI	f_i	NC	f_i
375—382	1	300—307	1	185—190	4	102—105	1	46—47	4	9—10	20
382—389	0	307—314	0	190—195	0	105—108	2	47—48	1	10—11	2
389—396	0	314—321	0	195—200	6	108—111	1	48—49	1	11—12	1
396—403	7	321—328	0	200—205	1	111—114	3	49—50	8		
403—410	3	328—335	5	205—210	2	114—117	3	50—51	2		
410—417	2	335—342	2	210—215	4	117—120	4	51—52	5		
417—424	1	342—349	1	215—220	1	120—123	4	52—53	1		
424—431	5	349—356	8	220—225	2	123—126	2	53—54	0		
431—438	0	356—363	0	225—230	0	126—129	1	54—55	1		
438—445	1	363—370	2	230—235	2	129—132	0				
445—452	2	370—377	3	235—240	0	132—135	2				
452—459	0	377—384	0	240—245	0	135—138	0				
459—466	0	384—391	0	245—250	1						
466—473	0	391—398	0								
473—480	1	398—405	1								

Table 9—Estimates of parameters of various characters of *Hornichara maslovi*.
No. of individuals : 23

Characters Estimates of Parameters	LPA (L)	LED (l)	AND	ISI	ANI	Number of Convolutions (NC)
Mean ($\bar{x}$)	417.173	350.652	209.565	118.391	50.086	9.782
Standard error of mean ($\sigma\bar{x}$)	4.622	4.410	3.635	1.689	0.493	0.169
Confidence interval for mean at $P_{0.05}$ ($t.\sigma\bar{x}$)	±9.059	±8.643	±7.124	±1.350	±0.966	±0.331
Standard deviation (s)	21.680	20.687	17.050	7.924	2.314	0.795
Standard error of standard deviation	3.231	3.083	2.541	1.181	0.344	0.118
Coefficient of variation in percentage (V)	5.197	5.899	8.136	6.693	4.620	8.129
$\chi^2 = \Sigma \frac{(f_i - F_i)^2}{F_i}$	2.782	2.782	36.565	5.260	7.347	141.260
Degrees of freedom (v=n-1)	14	14	12	11	8	2
Tabulated χ^2 for v at $P_{0.05}$	23.69	23.69	21.03	19.68	15.51	5.99
χ^2—significant/nonsignificant	Nonsignif.	Nonsignif.	Signif.	Nonsignif.	Nonsignif.	Signif.
Coefficients of B_1	0.5796	0.0075	0.2281	0.0071	0.0545	0.9270
Pearson (Moment) B_2	3.7802	3.7410	2.7719	2.9565	2.7656	3.8112

Remarks—This is a widely distributed species in the Recent of Indian subcontinent (Pal *et al.*, 1962) and is also well known from the Quaternary of Europe and North America (Daily, 1961). Bhatia and Mathur (1978) recorded *C. contraria* from the Pinjor Formation. Tables 10, 11 show its frequency distribution and estimates of parameters of

Table 10—Showing frequency (f_i) distribution of six characters of *Chara contraria*.

LPA (L)	f_i	LED (*l*)	f_i	AND	f_i	ISI	f_i	ANI	f_i	NC	f_i
515—530	5	250—262	2	235—243	1	140—146	1	42—43	2	9—10	2
530—545	1	262—274	1	243—251	1	146—152	0	43—44	4	10—11	8
545—560	7	274—286	5	251—259	2	152—158	1	44—45	4	11—12	24
560—575	8	286—298	0	259—267	9	158—164	7	45—46	1	12—13	15
575—590	5	298—310	4	267—275	4	164—170	7	46—47	5	13—14	0
590—605	4	310—322	1	275—283	3	170—176	11	47—48	8		
605—620	1	322—334	10	283—291	7	176—182	6	48—49	6		
620—635	8	334—346	5	291—299	0	182—188	6	49—50	13		
635—650	3	346—358	7	299—307	9	188—194	3	50—51	3		
650—665	2	358—370	5	307—315	4	194—200	1	51—52	2		
665—680	2	370—382	5	315—323	0	200—206	2	52—53	1		
680—695	0	382—394	1	323—331	5	206—212	3	53—54	0		
695—710	2	394—406	3	331—339	2	212—218	1				
710—725	1	406—418	1	339—347	0	218—224	0				
				347—355	2						

Table 11—Estimates of parameters of various characters of *Chara contraria*.
No. of individuals : 49

Characters Estimates of Parameters	LPA (L)	LED (l)	AND	ISI	ANI	Number of convolutions (NC)
Mean ($\bar{x}$)	597.244	337.346	290.877	177.897	48.163	12.061
Standard error of mean ($\sigma\,\bar{x}$)	7.224	5.617	3.972	2.297	0.367	0.115
Confidence interval of mean at $P_{0.05}$ ($t.\sigma\,\bar{x}$)	±14.159	±11.009	±7.785	±4.502	±0.719	±0.225
Standard deviation (s)	50.052	38.919	27.523	15.916	2.544	0.801
Standard error of standard deviation	5.082	3.951	2.794	1.616	0.258	0.081
Coefficient of variation in percentage (V)	8.380	11.536	9.462	8.947	5.282	6.643
$\chi^2 = \Sigma \frac{(f_i - F_i)^2}{F_i}$	8.999	8.999	23.591	24.999	12.755	31.040
Degrees of freedom ($v=n-1$)	13	13	14	13	11	4
Tabulated χ^2 for v at $P_{0.05}$	22.36	22.36	23.69	22.36	19.68	9.49
χ^2—significant/nonsignificant	Nonsignif.	Nonsignif.	Nonsignif.	Signif.	Nonsignif.	Signif.
Coefficients of B_1	0.2379	0.0926	0.0950	0.2491	0.2928	0.3548
Pearson (Moment) B_2	2.5967	2.6351	2.3429	3.0246	2.5924	2.9837

various characters and Fig. 5. gives lines of regression between L and l for *C. contraria*.

Chara soulie-maerschei n. sp.

Pl. 1, Figs. 6a, b ; 7a, b ; 8a-c

Chara sp. indet. Bhatia & Mathur, 1978, pp. 92-93, pl. 2, figs. 3a-c

Name—This species is named in honour of Dr. I. Soulie-Märsche, Laboratoire de Paleobotanique et Evolution des Vegetaux, Universite des Sciences et Techniques, Montpellier, France.

Material—78 gyrogonites from Tatrot and Pinjor Formations (Upper Siwalik) near Chandigarh.

Type level—Tatrot Formation (Upper Siwalik).

Type Locality—In a stream near village Dhamala, 6 kilometres WNW of Pinjaur.

Diagnosis—Gyrogonites small to medium-sized ; subprolate to prolate, rarely prolate sphaeroidal, and ellipsoidal, rarely subobovoidal ; apically slightly protruding to broadly rounded, basally broadly rounded ; nine to eleven (rarely seven to twelve) moderately thick concave convolutions ; width of the convolutions reduced in the apical periphery to about 3/4 or 2/3 of their equatorial width, without distinct groove in the apical periphery ; apical cells very wide, joined at a point or along short straight line ; basal pore pentagonal wide-conical ; basal plug thinner than wide.

Remarks—This species was described as an "indeterminate *Chara*" by Bhatia and Mathur (1978) and measurements of two hypotypes CASGMF 526, 527 were given. The former hypotype (Casgmf, 526) is here designated as holotype while the latter (Casgmf, 527) as a paratype and for the sake of brevity these measurements are omitted here.

Table 12—Showing frequency (f_i) distribution of six characters of *Chara soulie-maerschei*.

LPA (L)	f_i	LED (*l*)	f_i	AND	f_i	ISI	f_i	ANI	f_i	NC	f_i
475—490	2	365—375	7	235—243	3	109—112	2	40—42	0	6—7	1
490—405	1	375—385	1	243—251	4	112—115	0	42—44	1	7—8	0
505—520	6	385—395	0	251—259	3	115—118	0	44—46	1	8—9	8
520—535	5	395—405	2	259—267	5	118—121	11	46—48	7	9—10	32
535—550	2	405—415	1	267—275	7	121—124	5	48—50	15	10—11	9
550—565	4	415—425	6	275—283	3	124—127	10	50—52	15		
565—580	13	425—435	4	283—291	11	127—130	6	52—54	12		
580—595	3	435—445	1	291—290	0	130—133	6	54—56	2		
595—610	5	445—455	8	299—307	5	133—136	7	56—58	0		
610—625	7	455—465	2	307—315	6	136—139	5				
625—640	2	465—475	11	315—323	1	139—142	2				
640—655	3	475—485	2	323—331	3						
655—670	0	485—495	1	331—339	0						
670—685	1	495—505	8	339—347	2						
				347—355	1						

The present statistical analysis of the population of *C. soulie-maerschei* shows that this is obviously a new species of the genus *Chara*.

Tables 12, 13 show frequency distribution and estimates of parameters of various characters and Fig. 6 shows lines of regression between L and l of this species.

Chara rantzieni (Tewari & Sharma) Bhatia & Mathur

Pl. 1, Fig. 9a, b

Grambastichara rantzieni Tewari & Sharma, 1972, pp. 7-9, pl. 1, figs. 3a-c.

Chara rantzieni (Tewari & Sharma) Bhatia & Mathur, 1978, pp. 93-94, pl. 3, figs. 1a-c, 2a-c (*et syn.*).

Remarks—This species was originally described from Tatrot Formation near village Naipli, northeast of Chandigarh as *Grambastichara rantzieni* by TEWARI AND SHARMA (1972). BHATIA AND MATHUR (1978) have already commented upon its placement in the genus *Chara*.

Table 13—Estimates of parameters of various characters of *Chara soulie-maerschei*.
No. of individuals : 54

Characters / Estimates of Parameters	LPA (L)	LED (*l*)	AND	ISI	ANI	Number of convolutions (NC)
Mean ($\bar{x}$)	574.537	446.944	285.592	127.611	57.092	11.759
Standard error of mean ($\sigma\bar{x}$)	6.412	5.594	3.833	0.988	0.787	0.170
Confidence interval for mean at $P_{0 \cdot 05}$ ($t . \sigma\bar{x}$)	±12.567	±10.964	±7.512	±1.936	±1.542	±0.333
Standard deviation (s)	46.685	40.729	27.909	7.199	5.733	1.240
Standard error of standard deviation	4.513	3.937	2.698	0.695	0.554	0.119
Coefficient of variation in percentage (V)	8.125	9.112	9.772	5.641	10.041	10.546
$\chi^2 = \Sigma \frac{(f_i - F_i)^2}{F_i}$	4.740	12.518	8.166	83.129	1.499 (error)	208.074 (error)
Degrees of freedom (v=n—1)	13	13	14	10	8	4
Tabulated χ^2 for v at $P_{0 \cdot 05}$	22.36	22.36	23.69	18.31	15.51	9.49
χ^2—significant/nonsignificant	Nonsignif.	Nonsignif.	Nonsignif.	Signif.	Signif.	Signif.
Coefficients of B_1	0.0153	0.2291	0.0757	0.0803	error	error
Pearson (Moment) B_2	2.4145	2.1948	2.4497	2.6871	error	error

Tables 14, 15 show the frequency distribution and estimates of parameters of various characters and Fig. 7 shows the lines of regression between L and l for *C. rantzieni*.

Chara rantzieni sivalensis Bhatia & Mathur

Pl. 1, Figs. 10a, b

Chara rantzieni sivalensis Bhatia & Mathur, 1978, pp. 94, pl. 3, figs. 3a-c, 6

Remarks—This subspecies of *Chara rantzieni* (Tewari & Sharma) described by BHATIA AND MATHUR (1978) has so far been found to be restricted to the Dhok Pathan Formation (Middle Siwalik).

Table 14—Showing frequency (f_i) distribution of six characters of *Chara rantzieni*.

LPA (L)	f_i	LED (l)	f_i	AND	f_i	ISI	f_i	ANI	f_i	NC	f_i
375—390	1	350—362	3	210—220	2	100—102	12	47—49	2	8— 9	22
390—405	0	362—374	0	220—230	2	102—104	3	49—51	6	9—10	54
405—420	2	374—386	17	230—240	5	104—106	14	51—53	10	10—11	28
420—435	10	386—398	1	240—250	9	106—108	10	53—55	16	11—12	3
435—450	14	398—410	17	250—260	11	108—110	9	55—57	18		
450—465	11	410—422	7	260—270	4	110—112	16	57—59	12		
465—480	20	422—434	16	270—280	25	112—114	6	59—61	19		
480—495	3	434—446	2	280—290	9	114—116	6	61—63	13		
495—510	23	446—458	16	290—300	24	116—118	7	63—65	4		
510—525	12	458—470	7	300—310	3	118—120	6	65—67	6		
525—540	5	470—482	11	310—320	1	120—122	7	67—69	1		
540—555	3	482—494	1	320—330	11	122—124	4	69—71	0		
555—570	1	494—506	8	330—340	1	124—126	7				
570—585	2	506—518	1			126—128	0				

Table 15—Estimates of parameters of various characters of *Chara rantzieni*.
No. of individuals : 107

Characters Estimates of Parameters	LPA (L)	LED (l)	AND	ISI	ANI	Numder of convolutions (NC)
Mean ($\bar{x}$)	483.084	430.084	280.887	112.018	58.087	10.102
Standrard error of mean ($\sigma\bar{x}$)	3.711	3.866	2.631	0.711	0.444	0.075
Confidence interval for mean at $P_{0\cdot05}$ ($t.\ \sigma\bar{x}$)	±7.273	±7.577	±5.156	±1.393	±0.870	±0.147
Standard deviation (s)	38.212	39.805	27.090	7.326	4.978	0.776
Standard error of standard deviation	2.618	2.727	1.856	0.502	0.313	0.053
Coefficient of variation in percentage (V)	7.910	9.255	9.644	6.540	7.888	7.683
$\chi^2 = \Sigma \frac{(f_i - f_i)^2}{F_i}$	106.9994	106.999	61.317	39.485	11.448	248.308
Degrees of freedom ($v = n - 1$)	13	13	12	13	11	4
Tabulated χ^2 for v at $P_{0\cdot05}$	22.36	22.36	21.03	22.36	19.68	9.49
χ^2 – significant/nonsignificant	Signif.	Signif.	Signif.	Signif.	Nonsignif.	Signif.
Coefficients of B_1	0.0129	0.0091	0.0385	0.0739	0.0024	0.0056
Pearson (Moment) B^2	2.8898	2.2179	2.6393	2.0820	2.5299	2.8240

Tables 16, 17 give frequency distribution and estimates of parameters of various characters of *C. rantzieni sivalensis*. Fig. 8 shows lines of regression between L and l for this species.

Table 16—Showing frequency (f_i) distribution of six characters of *Chara rantzieni sivalensis*.

LPA (l)	f_i	LED (l)	f_i	AND	f_i	ISI	f_i	ANI	f_i	NG	f_i
480—495	1	387—402	3	275—283	2	100—103	5	47—49	4	8—9	5
495—510	2	402—417	0	283—291	3	103—106	7	49—51	13	9—10	26
510—525	4	417—432	1	291—299	0	106—109	12	51—53	17	10—11	46
525—540	4	432—447	2	299—307	22	109—112	11	53—55	14	11—12	26
540—555	10	447—462	9	307—315	11	112—115	13	55—57	23	12—13	6
555—570	4	462—477	13	315—323	2	115—118	9	57—59	14	13—14	0
570—585	27	477—492	9	323—331	27	118—121	24	59—61	8		
585—600	3	492—507	17	331—339	4	121—124	10	61—63	6		
600—615	3	507—522	8	339—347	1	124—127	6	63—65	8		
615—630	13	522—537	28	347—355	13	127—130	6	65—67	0		
630—645	5	537—552	9	355—363	3	130—133	3	67—69	1		
645—660	7	552—567	0	363—371	1	133—136	0				
660—675	1	567—582	8	371—379	16	136—139	1				
		582—597	1	379—387	3	139—142	1				

Table 17—Estimates of parameters of various characters of *Chara rantzieni sivalensis*.
No. of individuals : 108

Characters Estimates of Parameters	LPA (L)	LED (l)	AND	ISI	ANI	Number of convolutions (NC)
Mean ($\bar{x}$)	588.675	505.268	330.601	115.731	56.111	11.018
Standard error of mean ($\sigma\bar{x}$)	3.543	3.892	2.726	0.801	0.430	0.091
Confidence interval for mean at $P_{0.05}$ ($t\,\sigma\bar{x}$)	±6.944	±7.628	±5.342	±1.569	±0.842	±0.178
Standard deviations (s)	35.649	40.261	28.207	8.293	4.449	0.947
Standard error of standard deviation	2.499	2.745	1.923	0.565	0.303	0.064
Coefficients of variation in percentage (V)	6.225	7.968	8.532	7.104	7.930	8.594
$\chi^2 = \Sigma \frac{(f_i - F_i)^2}{F_i}$	62.259	107.999 (error)	40.333	0.925	11.342	21.333
Degrees of freedom ($v = n - 1$)	12	13	13	13	11	5
Tabulated χ^2 for v at $P_{0.05}$	21.03	22.36	22.36	22.36	19.68	9.49
χ^2—significant/nonsignificant	Signifi.	Signifi.	Signifi.	Nonsignifi.	Nonsignifi.	Signifi.
Coefficients of B_1	0.0701	0.1229	error	0.0369	1.1146	0.0032
Pearson (Moment) B_2	3.1518	3.2203	error	2.9658	2.5064	2.6704

Chi-square Test—The application of Chi-square test has been sought on the six variables individually in each of the eight charophyte taxa under consideration for testing normality of distribution. The tables for each taxon showing the estimates of different 'statistical' also give value of chi-square calculated for the variable and its tabulated value at v (v=n—1) degrees of freedom (Tables 3, 5, 7, 9, 11, 13, 15 and 17). Thus in case calculated value of χ^2 is less than its tabulated value, χ^2 is nonsignificant which implies that the variable tends to be normally distributed. In the non-normal variables, the calculated value of χ^2 are significant. This accounts for significant variations between the observed and the expected frequencies. The frequency (fi) distributions of six characters of the eight charophyte taxa are given in Tables 2, 4, 6, 8, 10, 12, 14 and 16.

The χ^2 estimates has been observed to be nonsignificant in the characters LPA and numbers of convolutions of *Sphaerochara tewarii*, LED and ISI of *S. pecki*, ISI and ANI of *Tectochara sahnii*, LPA, LED, ISI and ANI of *Hornichara maslovi*, LPA, LED, AND, ISI and number of convolutions of *Chara contraria*, LPA, LED, and AND of *C. soulie-maerschei*, ANI of *C. rantzieni* and ISI and ANI of *C. rantzieni sivalensis*.

Pearson's Coefficients (Moments)—The estimates of coefficients of Pearson B_1 and B_2 have been shown for each of the six variables in the tables showing estimates of other characters for each of the eight charophyte taxa (Tables 3, 5, 7, 9, 11, 13, 15 and 17). The estimates of β_1 is nearly zero in LED and AND of *Sphaerochara tewarii*, LPA, AND, ISI and ANI of *S. pecki*, LPA and number of convolutions of *Tectochara sahnii*, LED, AND, ISI and ANI of *Hornichara maslovi*, LED and AND of *Chara contraria*, LPA, AND and ISI of *C. soulie-maerschei* all the variables of *C. rantzieni* and LPA, AND and ISI of *C. rantzieni sivalensis*. It is thus obvious that the above mentioned characters of different taxa closely approximate normalcy when considered from the point of view of skewness (β_1). The estimates of β_2 for each of the six variables of the eight charophyte taxa are positive and vary between 2.082 and 4.2750. The results indicate that the distribution for variables LPA, LED, AND and ISI of *Sphaerochara tewarii*, LPA and number of convolutions of *S. pecki*, LPA, LED, and AND of *Tectochara sahnii*, LPA, LED and number of convolution of *Hornichara maslovi*, ISI of *Chara contraria* and LPA and LED of *C. rantzieni sivalensis* are leptokurtic whereas for variables number of convolutions of *Sphaerochara tewarii*, LED, AND, ISI and ANI of *S. pecki*, ISI, ANI and number of convolutions of *Tectochara sahnii*, AND, ISI and ANI of *Hornichara maslovi*, LPA, LED, AND, ANI and number of convolutions of *Chara contraria*, LPA, LED, AND, and ISI of *C. soulie-maerschei*, all the variables of *C. rantzieni* and ISI, ANI and number of convolutions of *C. rantzieni sivalensis*, kurtosis resembles platykurtic curves. These two types of statistical analyses advanced in the present study for testing normality of distributions for the six variables of eight charophyte taxa reveal different results. These differences however, do not reflect inconsistency as to the implications of results. χ^2—test essentially provides information regarding the disparities between observed and expected frequencies, whereas β_1 refers to skewness and β_2 to kurtosis. In numerous situations, as in the present study, the distribution may not be normal on the basis of χ^2—test but these may be normal from the point of view of skewness and kurtosis.

Coefficient of Correlation—From Table 18 showing coefficient of correlation between LPA (L) and LED (l), it is obvious that all the taxa are significantly correlative with respect to these two characters.

Lines of Regression—The lines of regression between the characters LPA (L) and LED (l) for each of the eight charophyte taxa have been shown in Figs. 1 to 8. The slopes (B and B_1) and the intercepts (A and A_1) are given in Table 18. The divergence in the two lines of regression increases with the decrease in the estimates of slopes of L and l and the coefficient of correlation for each taxon. This implies that the variables L and l tend to be less dependent on each other with the greater divergence of lines.

Table 18—Correlation and regression constants for LPA (L) and LED (l) of charophyte taxa.

Constants → / Taxa ↓	Degrees of freedom	Coefficient of Correlation between L & l		Regression of L on l		Regression of l on L	
	$V=n-2$	For v degrees of freedom at $P_{0.05}$	Calculated	Slope (B)	Intercept (A)	Slope (B_1)	Intercept (A_1)
Sphaerochara tewarii	90	0.205	0.389	0.408	241.831	0.371	251.858
S. pecki	81	0.216	0.486	0.490	174.4757	0.482	214.997
Tectochara sahnii	77	0.224	0.706	1.170	60.729	0.426	219.710
Hornichara maslovi	21	0.413	0.470	0.448	163.376	0.493	244.276
Chara contraria	47	0.286	0.668	0.519	27.101	0.859	307.403
C. soulie-maerschei	52	0.272	0.711	0.740	72.196	0.682	189.449
C. rantzieni	105	0.191	0.538	0.591	156.832	0.490	340.860
C. rantzieni sivalensis	106	0.190	0.826	0.720	32.761	0.947	151.216

Student's 't' Distribution—The 't'-test has been used to discriminate between the means of the populations of various taxa taking one character at a time for one pair of species. In a majority of cases under present investigation, the estimates of 't'-test are significant (Table 19). This implies that the means of these populations differ significantly on account of actual differences and not due to sampling error.

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Table 19—'t' ratios for six characters with respect to eight charophyte taxa.

Sr. No.	Taxonomic A	Combination B	Degrees of freedom ($v=N_1+N_2-2$)	Tabulated value of 't' at P0.05 for	Characters					
					LPA	LED (l)	AND	ISI	ANI	Number of convolutions
1	*Sphaerochara tewarii*	*S. pecki*	173	1.97	3.454	12.157	15.577	−8.812	9.909	−1.447*
2	—	*Tectochara sahnii*	169	1.97	6.162	5.192	−1.327*	−0.840*	−4.738	10.071
3	—	*Hornichara maslovi*	113	1.98	−2.901	11.008	3.963	−13.157	3.785	−2.360
4	—	*Chara contraria*	139	1.98	−32.355	13.490	−16.856	−42.518	7.378	−19.659
5	—	*C. soulie-maerschei*	114	1.98	−30.458	−7.786	−16.637	−13.740	−3.375	−6.790
6	—	*C. rantzieni*	197	1.97	−17.932	−5.050	−30.775	−17.218	−0.960*	−13.480
7	—	*C. rantzieni sivalensis*	198	1.97	−42.978	−20.995	−15.793	−26.104	−0.287*	−1.855*
8	*S. pecki*	*Tectochara sahnii*	160	1.98	2.680	−3.845	−16.856	7.157	−21.507	9.629
9	—	*Hornichara maslovi*	104	1.98	−5.086	−3.265	−6.230	−7.580	−3.869	−0.966*
10	—	*Chara contraria*	130	1.98	−32.894	5.644	−28.200	−36.568	−0.976*	−14.774
11	—	*C. soulie-maerschei*	135	1.98	−31.198	−15.103	−28.413	−5.205	−18.258	−4.221
12	—	*C. rantzieni*	188	1.97	−19.574	13.121	−42.102	−9.158	−15.207	−10.265
13	—	*C. rantzieni sivalensis*	189	1.97	−43.735	−28.465	−26.907	−18.265	−1.493*	−1.614*
14	*Tectochara sahnii*	*Hornichara maslovi*	100	1.98	−6.862	4.412	4.898	−113.03	10.360	−9.503

15	—	*Chara contraria*	126	1.98	—33.711	7.087	—15.581	—38.589	17.168	—29.698
16	—	*C. soulie-maerschei*	131	1.98	—32.145	—9.633	—14.829	—11.744	2.100	—17.208
17	—	*C. rantzieni*	184	1.97	—21.062	—8.280	—28.278	—15.011	5.158	—22.407
18	—	*C. rantzieni sivalensis*	185	1.97	—44.862	—31.642	—14.369	—22.914	0.357*	—2.503
19	*Hornichara maslovi*	*Chara contraria*	70	1.99	—6.493	1.536*	—13.016	—16.926	—3.076	—11.277
20	—	*C. soulie-maerschei*	75	1.99	—15.428	—10.734	—12.100	3.730	—8.090	—1.787*
21	—	*C. rantzieni*	128	1.98	—7.984	—9.284	—19.786	0.878*	—6.300	—5.831
22	—	*C. rantzieni sivalensis*	129	1.98	—21.610	—17.882	—12.109	—4.990	—0.583*	—0.760
23	*Chara contraria*	*C. soulie-maerschei*	101	1.98	—2.382	13.929	—2.127	—35.474	14.115	—14.479
24	—	*C. rantzieni*	154	1.98	—15.660	13.600	8.237	—31.644	11.655	—6.693
25	—	*C. rantzieni sivalensis*	155	1.98	—1.205*	—24.464	—0.966	—20.979	1.088*	—0.170*
26	*C. soulie-maerschei*	*C. rantzieni*	159	1.98	13.287	2.517	—9.607	8.213	0.177*	0.619*
27	—	*C. rantzieni sivalensis*	160	1.98	—2.107	—8.658	—1.029	—12.823	0.169*	—1.380*
28	*C. rantzieni*	*C. rantzieni sivalensis*	213	1.96	—20.679	—13.929	13.178	4.414	—3.128	7.749

*Nonsignificant

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EXPLANATION OF PLATE 1

(Unless stated otherwise, all figures ×43, a, lateral view ; b, apical view ; c, basal view)

1a-1b. *Sphaerochara tewarii* Bhatia & Mathur

2a-2b. *Sphaerochara pecki* Bhatia & Mathur

3a-3b. *Tectochara sahnii* Bhatia & Mathur

4a-4b. *Hornichara maslovi* Bhatia & Mathur

5a-5b. *Chara contraria* Braun ex Kuetzing

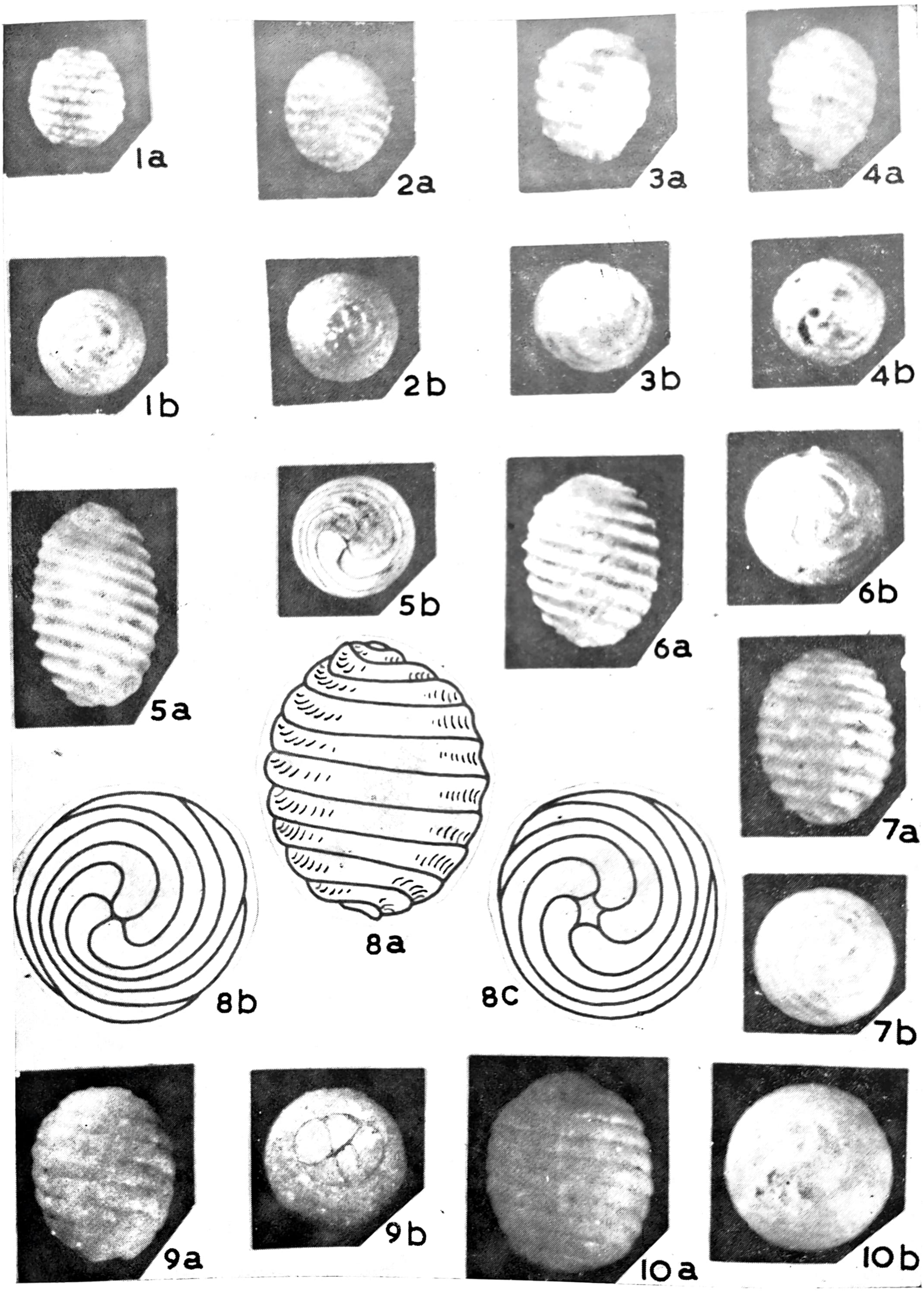
6a-6b. *Chara soulie-maerschei* n. sp. (Holotype)

7a-7b. *Chara soulie-maerschei* n. sp. (Paratype)

8a-8b. *Chara soulie-maerschei* n. sp. (Holotype) ×62

9a-9b. *Chara rantzieni* (Tewari & Sharma)

10a-10b. *Chara rantzieni sivalensis* Bhatia & Mathur


1a
2a
3a
4a
1b
2b
3b
4b
5b
6b
6a
5a
7a
8a
8b
8c
7b
9a
9b
10a
10b