ON THE VARIATION OF LEAF CHARACTERS OF AN ANTARCTIC MOSS, *BRYUM INCONNEXUM*

Satoshi NAKANISHI

Faculty of Education, University of Kobe, 3-11, Tsurukabuto, Nada-ku, Kobe 657

Abstract: The taxonomical status of *Bryum inconnexum* CARD., one of the most common mosses found on ice-free areas in and around Ongul Islands, is still inconclusive. One of the reasons bringing about such condition is a good deal of variability in their morphological characters.

This study is made to understand precisely the actual state of the variation of the leaf size and the leaf shape. An individual plant of this moss grows taking the innovation system of monopodial sympodium. The leaves of an innovation shoot show a remarkable variability in the size and the shape as well as in the length and stoutness of the midrib according to their position in an innovation.

The correlation between the variation of leaf characters and the water condition in their habitat was analyzed using the specimens from the sandy bank of a brook where the water condition changed gradually from the center of stream to the upper part of bank. Generally, the leaf size is smaller and more diversified in the dry habitats than in the moist habitats. On the other hand, the leaf shape seems to be invariable independently of the water condition in their habitat.

1. Introduction

Bryum inconnexum CARD. is the most abundant species among the mosses which occur on the Ongul Islands and the neighboring ice-free areas in the continental Antarctica. However, the taxonomical status of this species is still inconclusive because there are several species which are closely related to the present species. Recently, OCHI (1976) reported preliminarily that *Bryum inconnexum* may be the so-called "bimum" type of *Bryum pseudotriquetrum* (HEDW.) GAERTN. which is a cosmopolitan moss.

The taxonomical indistinctness of this moss is caused by the facts that it is very variable in its morphological characters as pointed out by HORIKAWA and ANDO (1961, 1967). Moreover, the sporophyte has not been discovered yet.

In order to make clear the taxonomical status, it is an indispensable subject to understand precisely the actual state of the variation of the morphological characters in addition to a close taxonomical revision based on the holotype specimens of *Bryum inconnexum* and the allied species. In this paper, the author reports the results of the investigation into the actual state of the variation, especially that of the leaf shape and the leaf size. The study on the cell characters such as the cell pattern, cell size and cell structure remains as a future subject.

2. Materials and Method

The present study was carried out as a part of the project of the 16th Japanese Antarctic Research Expedition. The moss specimens for this study were obtained from the investigation stand in the downstream of Yukidori Valley, Langhovde. The stand is located at 69°14′S and 39°44′E.

On the channel bank, the moss community is developed in various degrees of luxuriance corresponding to the microtopography where the water content decreases gradually toward the upper part of bank. As reported already (NAKANISHI, 1977), *Bryum inconnexum* grows abundantly forming a large cushion with a hummocky appearance in the wet habitat moistened by running or see page water. The moss becomes gradually poor in abundance toward the upper part of sandy bank where it is liable to dry, and *Ceratodon purpureus* is relatively abundant. Fig. 1 shows the transection profile of the investigation stand.

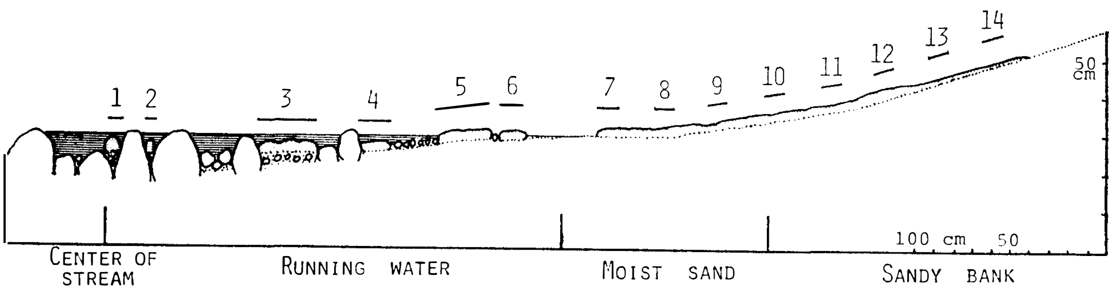

Fig. 1. Transect profile of the investigation stand. The numerals in the figure show the plot number. Site: Downstream of Yukidori Valley, Langhovde, Sôya Coast, Antarctica. Altitude: 8 m.

The materials for this study were collected at nine plots, *i.e.*, plot Nos. 2, 3, 4, 5, 6, 7, 8, 10 and 11. At plots Nos. 2, 3, 4 and 5 the moss plants were submerged by the running water during the summer season. At plots Nos. 6, 7 and 8 the plants grew on moist sand humidified by the water permeated from stream. The plants at plots Nos. 10 and 11 occurred on rather dry sand bank.

The sample plants were selected randomly from the cluster collected at each plot. The leaves of sample plant were measured with respect to the leaf length, leaf width and midrib length using the microscope micrometer. Moreover, the leaf shape was redrawn with ABBE's apparatus. The leaf shape was represented in terms of leaf shape index that is the ratio of the maximum length to the maximum width. The actual number of samples in each measurement is not the same owing to the poorness and richness of the sample plants.

3. Results and Considerations

3.1. Variation of the leaf characters in an individual plant

In the oasis of the ice-free areas in the Antarctic Continent, mosses grow making a thick, compact cushion where water supply is adequate (see Fig. 2). The cushion becomes thin and frail where water supply is not sufficient. In general, only the uppermost part of the plant is alive having greenish leaves but the rest of the plant is dead retaining withered, brown-red or brown leaves.

Observing in detail an individual plant in the cushion it is known that a plant grows taking the innovation system of monopodial sympodium as shown in Fig. 3. The shoot does not grow uniformly but the flagelliform part covered thinly with somewhat little leaves and the part thickly covered with the normal leaves grow one after another. Many rhizoids go out from near the boundary of the two parts. Such innovation system of an individual plant makes an annual ring like pattern in the cross section of the cushion as described by MATSUDA (1964, 1968).

MEUSEL (1935), who studied the shooting periodicity of the European species of the genus *Bryum*, reported that one innovation is generally formed once a year. Following his observation, the author considered an innovation shoot as the growth of one growing period in a year, although he had not ascertained how this kind of shooting pattern corresponded with the seasonal change in the Antarctic.

Fig. 2. Transection of a thick cushion composed of Bryum inconnexum.

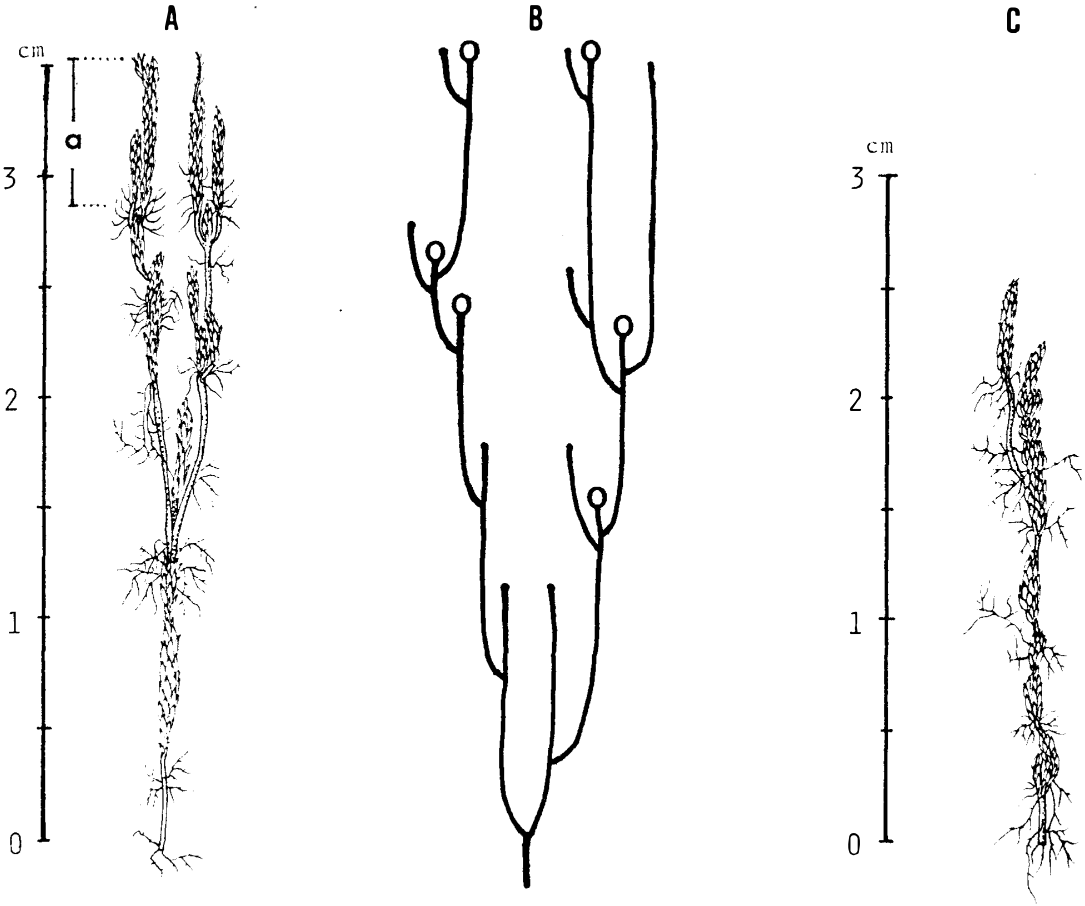

Fig. 3. Innovation system of Bryum inconnexum.
A: *A sample from moist habitat.* *a*: *Indicates an innovation shoot.*
B: *Schematic representation of a sample from moist habitat. The circle shows the presence of sex organs.*
C: *A sample from the habitat where the water supply is insufficient.*

The observation of the leaf shape and leaf size was made from the lowermost to the uppermost of an innovation shoot. Fig. 4 shows the typical case among the results obtained. The lowest leaf (1 in Fig. 4) of an innovation that is formed at first is small scale-like with obtuse apex. It has no midrib. The leaves of the lower part (2–6) are ovate and elliptic with acute or acuminate apex becoming larger toward the upper position. The midrib is distinct but does not reach the apex. The leaves of the middle part (7–10) are large and oblong lanceolate with acuminate apex and the costa protrudes at the apex. The leaves in a somewhat upper position of the middle part (11 and 12) are rather small and their costae are ending just below the apex. Moreover, the leaves of the upper part (13 and 14) are ovate with acute apex, similar to those of the lower part. The midrib also does

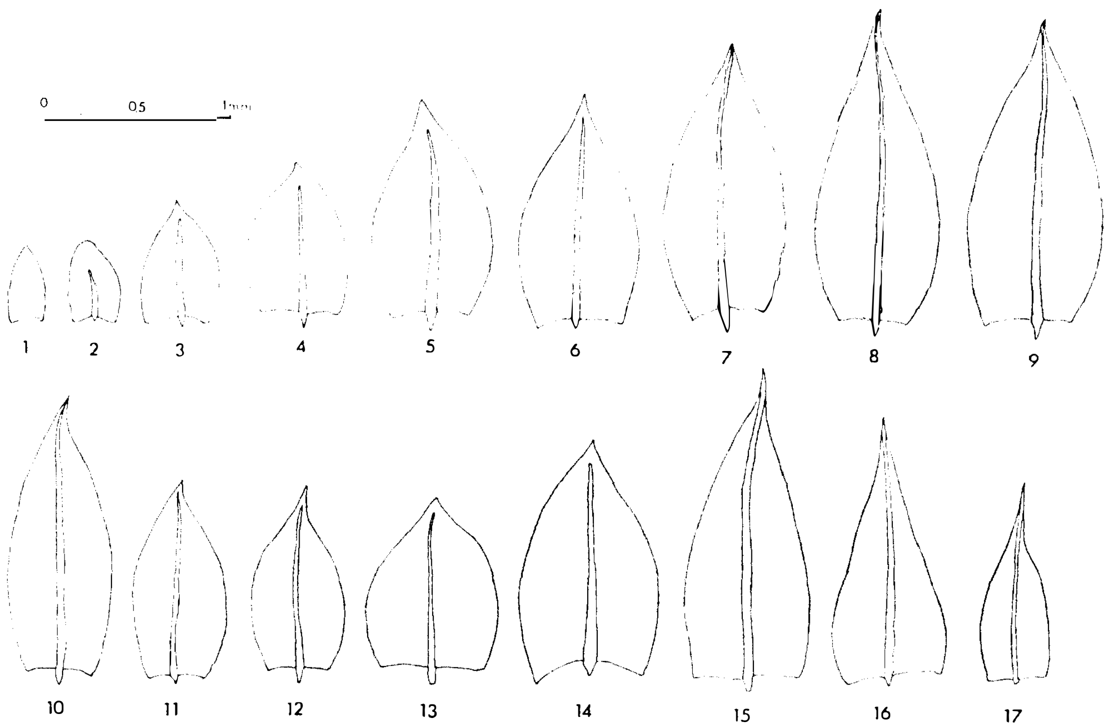

Fig. 4. Variation of leaves in the terminal innovation shoot (a in Fig. 3-A) of Bryum inconnexum. *They are arranged in order of position from the lowest one.*

not reach the apex. The leaves from 15 to 17 should not be treated in the same way because they are perichaetial leaves surrounding sexual organs.

In his observation about the foliating aspect in one innovation shoot, MEUSEL (1935) pointed out that the mosses of *Bryum* are more or less heterogenous in the leaf size and the foliation density. According to him, in the species with a distinct heterogeneity the leaves of the lower part of innovation show cataphyllous characters, and those of the upper part exhibit hypsophyllous characters. Considering such facts as mentioned above, it seems that the variation of leaf characters of *Bryum inconnexum*, for example, leaf shape, leaf size and stoutness of midrib, is correlated to the inherent ontogenetic sequence.

As one of the tests to ascertaining this assumption, the author examined the correlation of the leaf length (Y) and the leaf width (X) that represents the leaf shape. The examination was made regarding to the leaves of the lower part or the upper part of an innovation shoot and those of the middle part. The moss plants at plot Nos. 3, 5, 7, 10 and 11 were used for this examination.

The results obtained from the leaves of the lower or the upper parts of one innovation shoot are shown in Table 1 and Fig. 5. Those from the leaves of the middle part of one innovation are presented in Table 2 and Fig. 6. In both cases, the correlation of the leaf length and leaf width is very similar to each other

Table 1. Variation of the morphological characters of leaves from the lower or the upper parts of an innovation shoot.

Plot No.	Number of sample	Mean of leaf length (0.1 mm) (*Y*)	Mean of leaf width (0.1 mm) (*X*)	Mean of leaf shape index (*Y*/*X*)	Range of leaf shape index
3	24	12.2	7.7	1.58	1.28–1.92
5	21	10.6	6.8	1.56	1.30–1.82
7	21	10.7	7.2	1.49	1.22–1.98
10	10	6.5	4.3	1.51	1.20–1.91
11	24	5.0	3.5	1.43	0.91–1.86

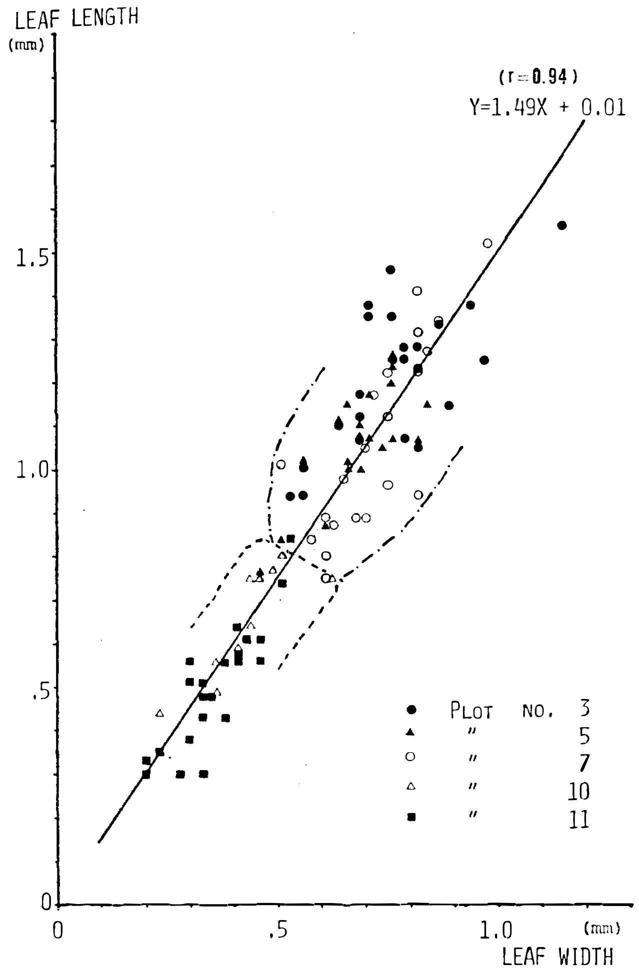

Fig. 5. Correlation between the leaf length (Y) and the leaf width (X) of the leaves from the lower or the upper parts of an innovation shoot.

Table 2. Variation of the morphological characters of leaves from the middle part of an innovation shoot.

Plot No.	Number of sample	Mean of leaf length (0.1 mm) (*Y*)	Mean of leaf width (0.1 mm) (*X*)	Mean of leaf shape index (*Y*/*X*)	Range of leaf shape index
3	30	16.8	8.8	1.90	1.55–2.31
5	20	14.4	7.6	1.89	1.50–2.19
7	24	18.0	8.4	2.14	1.67–2.81
10	11	11.2	5.8	1.93	1.50–2.20
11	26	9.2	4.8	1.91	1.58–2.41

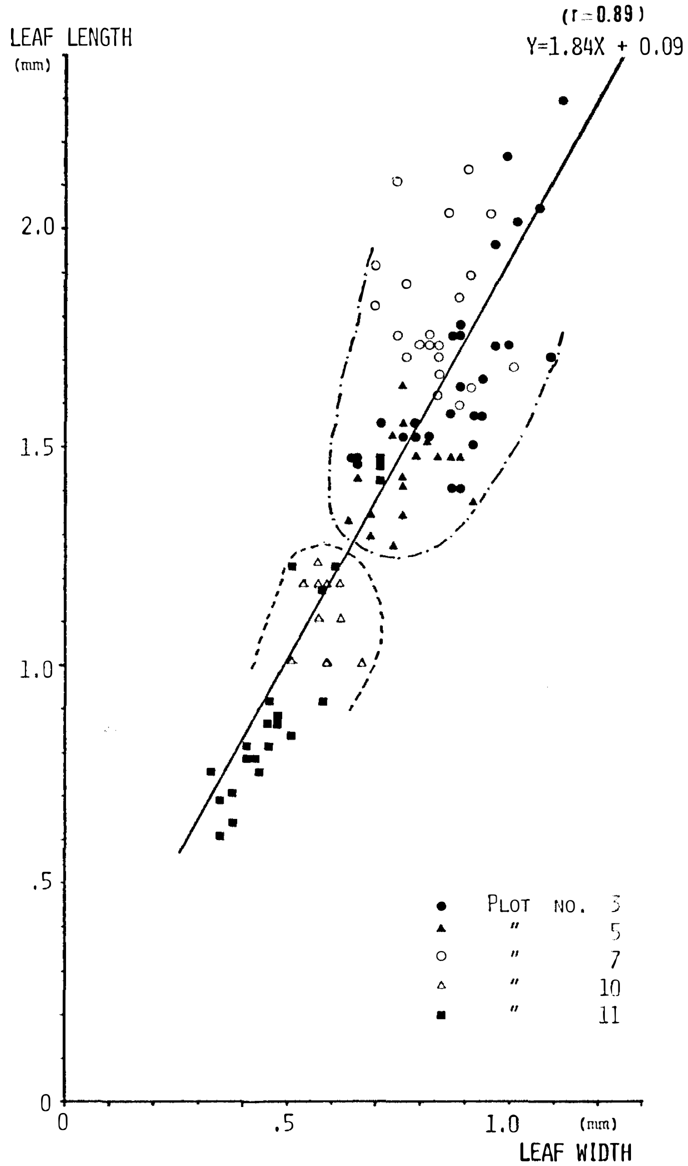

Fig. 6. Correlation between the leaf length (Y) and the leaf width (X) of the leaves from the middle part of an innovation shoot.

regardless of their habitat condition. As a whole, in the former case the correlation shows $Y=1.49X+0.01$ with the correlation coefficient 0.94, and in the latter case it shows $Y=1.84X+0.09$ with the correlation coefficient 0.89. The former means that the leaf shape is ovate in which the length is one and a half times as much as the width. The latter means that the leaf shape is elliptic or oblong in which the length is about two times as much as the width. There is a decided difference between them.

It is clear from this examination that the leaf shape and leaf size show a good deal of variability according to the position in one innovation shoot of an individual plant.

3.2. Relationship between the variation of leaf characters and habitat condition

It is often observed in the ice-free areas that the water condition has a principal effect on the growth of mosses among habitat factors. Considering such fact, it seems that there may be expected some correlation between the variation of leaf characters and the water availability in their habitat.

In fact, as known from Tables 1 and 2 and Figs. 5 and 6, the length and the width of the leaves are different from plot to plot. Especially, there is a distinct difference between plots Nos. 3, 5, 7 and plots Nos. 10, 11. The leaves of plants growing on moist habitats are greater than those on arid sand bank. However, the leaf shape index represented by the ratio of the leaf length to leaf width is not different from plot to plot.

Then, the author examined the variation of leaf shape and leaf size in various habitats where the water availability is different. The results regarding the leaf size are shown in Tables 3 and 4, respectively. The results on the leaf shape index are shown in Table 5.

It seems that there is a tendency that the leaf size decreases with the poverty of

Table 3. Variation of leaf length in every habitat along the gradient of water availability.

Plot No.	Condition of substratum	Total number of sample	Mean value (0.1 mm)	Variance	Standard deviation
2	Submerged by running water	81	12.0	1.50	1.23
3	〃	344	14.8	6.14	2.48
4	〃	136	12.9	6.81	2.61
5	〃	194	12.1	3.09	1.76
6	Moist sand	74	11.7	5.89	2.42
7	〃	261	14.3	9.63	3.10
8	〃	98	11.3	4.77	2.18
10	Sandy bank	155	9.9	9.02	3.00
11	〃	215	8.7	13.98	3.74

Table 4. Variation of leaf width in every habitat along the gradient of water availability.

Plot No.	Condition of substratum	Total number of sample	Mean value (0.1 mm)	Variance	Standard deviation
2	Submerged by running water	72	7.5	0.84	0.92
3	〃	343	8.5	1.91	1.38
4	〃	119	7.6	1.92	1.38
5	〃	202	7.0	0.84	0.92
6	Moist sand	68	7.3	1.20	1.10
7	〃	262	8.0	1.76	1.33
8	〃	87	6.4	1.32	1.15
10	Sandy bank	148	5.4	1.46	1.21
11	〃	226	4.9	3.18	1.78

Table 5. Variation of the leaf shape index in every habitat along the gradient of water availability.

Plot No.	Condition of substratum	Total number of sample	Mean value	Variance	Standard deviation
2	Submerged by running water	72	1.62	0.03	0.18
3	〃	319	1.77	0.08	0.28
4	〃	67	1.66	0.04	0.21
5	〃	182	1.73	0.05	0.22
6	Moist sand	67	1.62	0.05	0.22
7	〃	263	1.80	0.09	0.30
8	〃	87	1.78	0.06	0.26
10	Sandy bank	143	1.83	0.08	0.29
11	〃	212	1.76	0.09	0.30

water availability, whereas, the leaf shape index is invariable independently of the habitat condition.

In order to verify such conclusion, the statistical test is made for every plot. The test of statistical hypothesis is of the difference of mean of a certain character in two populations with normal distribution (KITAGAWA and INABA, 1960). By means of this test, one can know whether the two populations belong to the same population on the character in question or not. In this test the value less than 2.58 means that two populations are considered to belong to the same population, and the value more than 2.58 indicates that there is a very significant difference between two populations.

Table 6. Statistical test on the mean of the characters on leaf size among the plots.

Plot No.		[Leaf length]								
		2	3	4	5	6	7	8	10	11
[Leaf width]	2		14.81	3.46	**0.50**	**1.00**	10.00	2.69	7.50	11.37
	3	8.33		7.31	15.00	10.00	**2.17**	14.00	18.10	21.00
	4	**0.63**	6.43		4.44	3.87	6.08	6.40	11.11	14.48
	5	4.17	16.67	4.29		**1.29**	9.56	3.20	7.85	12.14
	6	**1.17**	8.00	**1.67**	**2.14**		7.64	**1.11**	4.86	7.89
	7	3.84	4.54	2.67	10.00	4.67		10.34	14.20	17.50
	8	6.87	15.00	6.67	4.28	5.00	10.67		4.24	7.64
	10	15.00	25.80	13.75	14.54	11.87	20.00	6.25		3.42
	11	16.25	25.70	15.90	16.15	13.33	22.10	8.82	**0.33**	

Table 7. Statistical test on the mean of the leaf shape index among the plots.

Plot No.	2	3	4	5	6	7	8	10	11
11	5.00	**0.38**	3.33	**1.15**	4.24	**1.53**	**0.61**	**2.26**	
10	6.77	**2.00**	5.15	3.33	5.83	**1.00**	**1.39**		
8	4.84	**0.33**	3.52	**1.61**	4.32	**0.64**			
7	6.92	**1.00**	5.00	4.00	5.80				
6	**0.24**	5.00	**1.17**	3.54					
5	4.23	**2.00**	**2.50**						
4	**0.75**	3.92							
3	5.76								
2									

The results obtained from the statistical test are shown in Tables 6 and 7. In the statistical tests on leaf length and leaf width, only five pairs of populations show that every pair is belonging to the same population and the rest indicate that every pair differs significantly with each other. In the tests on leaf shape index, however, seventeen pairs of populations (*ca.* 50% of all the pairs) show that every pair is not different significantly one another but belonging to the same population.

From the results of these tests, it is considered that the leaf length and leaf width are variable according to the habitat condition becoming smaller with the decrease of water supply, while the leaf shape is not so variable as seen in the leaf length and the leaf width but rather definite independently of water condition in their habitat.

There is recognized another notable phenomenon. The variance and the standard deviation of the leaf size are larger at plot No. 11 than at other plots, but those of the leaf shape are almost similar to each other. These facts would suggest that the characters on leaf size show a wide range of variability in the places which are apt to be exposed to aridity although the shape of leaf is almost uniform.

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