Habitat Segregation in *Aster subulatus* and Three Species of *Erigeron* Due to Soil Moisture*

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Introduction

As a means of ecological analysis of the structure of weed communities, the concept of habitat segregation becomes the most important problem to be solved.

The phenomenon of habitat segregation of weeds is divided into two groups based on their relationship between the life form and the growing field of plants. The one is the homogenous habitat segregation and the other is the heterogenous habitat segregation. The former is that in which the same species occurs in different life forms and different habitats, while the latter is that in which some different species occur in different habitats and, in many cases in, different life forms³⁾.

The purpose of the present paper is to investigate ecologically and morphologically a heterogenous habitat segregation between *Aster subulatus* Michx, and the three species of *Erigeron* (*E. sumatrensis* Retz, *E. canadensis* L. and *E. bonariensis* L.), both of which belong to the same life form and growing period, and also to investigate a homogenous habitat segregation in *A. subulatus*.

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Area and Method of Study

Field surveys were carried out at the growing habitats of *Aster subulatus* and

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Erigeron spp. on the wayside, ditch-wall and vacant ground in Sendamachi, Hiroshima city in the summer of 1951, '52 and '53.

1). Study of vegetation: Analyses of plant communities of *A. subulatus* and *Erigeron* spp. on road-sides and ditch-walls were made by the systematic sampling by belt transects of 0.2–1.0 m in width or quadrats of 1.0 m². Ecological features of the communities were expressed by the floristic list, coverage and frequency of the occurring plants.

2). Examination of the bed soil of communities: The water content of bed soil at the road-side communities and the pure communities was considered with respect to the soil sample of 20 g and measured after the dryness at 110 C° for 20 hours. For the pure communities, the chemical components of bed soil were determined, too. In this determination, total nitrogen and humus were measured by the Kjeldahl's method and the Turin's method respectively, and in the other tests of soil was made use of the Prof. Yagi's soil tester.

3). Morphological study of subterraneous parts of *A. subulatus*: The subterraneous parts of *A. subulatus* in its pure communities and in the *Erigeron* communities were studied morphologically and anatomically for the comparison in both communities.

Data and Discussion

I. Heterogenous habitat segregation between *A. subulatus* and three species of *Erigeron*:

1) Roadside communities and their soil moisture

For the vegetation developed in and by a green belt zone of road in front of the Western gate of the Hiroshima University, investigations were carried out in September, 1951. To facilitate the investigation, the vegetation was divided into 7 transversal zones A~E from a physiognomical view point (Fig. 1, Tab. I). At the A zone (0.3 m in width) nearer to the side of the high speed vehicle road-way, *A. subulatus* is most dominant in coverage and frequency. But the opposite B' zone is dominated by *E. sumatrensis* and is very few in *A. subulatus*. On the C, C', and D

Fig. 1. Diagrammatic beisect through a green belt zone vegetation
A, *Aster subulatus*; E, *Erigeron* spp.

zones which are adjoined to the bare land and influenced by the traffic of vehicles, *Digitaria ascendens* Henr., *D. violascens* Link. and *Eleusine indica* Gaerten are abundant³⁾.

As to the topography of the habitat, the road-surface is generally flat, but the high speed vehicle way is slightly convex and is a little depressed at the adjoined to the green zones. Namely, the part touching the green belt zone exhibits a slope of 5° to 10° at the place of 0.3-0.4 m apart from the paving-stone (near the boundary-line between **A** and **B** zones) and is favoured with the richness of soil moisture and rubbish. On the other hand, the opposite **B'** zone is subjected to the accumulation of soil and slightly raised. In consequence, rain-water on the **B'** zone runs down to the opposite edge of the road:

Table I. Structure of the vegetation in and by a green belt zone in the 113 road-way at Sendamachi, Hiroshima city (showing coverage and frequency obtained from the 10 quadrats with 1 m² area in each zone)

Division of Vegetation Species	A		B		B'		C		C'		D		E	
	C. d.	Fq.	C. d.	Fq.	C. d.	Fq.	C. d.	Fq.	C. d.	Fq.	C. d.	Fq.	C. d.	Fq.
<i>Aster subulatus</i>	5.0	100	0.7	50	—	—	—	—	—	—	—	—	—	—
<i>Erigeron sumatrensis</i>	0.7	40	4.1	100	4.6	100	—	—	—	—	—	—	1.0	30
<i>E. canadensis</i>	0.7	50	3.7	100	2.1	90	0.2	20	—	—	—	—	2.6	70
<i>E. bonariensis</i>	0.2	10	3.2	90	2.0	80	0.2	10	—	—	—	—	1.2	40
<i>Cynodon Dactylon</i>	1.3	30	1.0	20	—	—	1.1	30	—	—	0.6	20	—	—
<i>Setaria viridis</i>	0.2	10	0.5	30	0.1	10	0.3	20	—	—	—	—	1.0	10
<i>Euphorbia sapina</i>	0.2	10	—	—	0.2	10	—	—	—	—	—	—	—	—
<i>Polygonum longisetum</i>	0.1	10	—	—	—	—	—	—	—	—	—	—	—	—
<i>Kummerovia striata</i>	—	—	0.1	10	—	—	—	—	—	—	—	—	—	—
<i>Cyperus rotundus</i>	—	—	0.3	10	—	—	—	—	0.3	10	—	—	—	—
<i>Digitaria ascendens</i>	—	—	0.5	40	0.2	10	1.2	30	—	—	0.2	20	1.7	70
<i>D. violascens</i>	—	—	—	—	2.0	80	4.6	100	0.9	50	0.8	50	4.2	100
<i>Eleusine indica</i>	—	—	—	—	0.2	20	1.2	70	4.9	100	4.6	100	—	—
<i>Eragrostis multicaulis</i>	—	—	—	—	—	—	—	—	—	—	0.1	10	—	—

The results of the determination of soil water content were shown in Tab. II. From this table it is apparent that the soil water content for the sample on the 8th of September*, which is just before a day of rain-fall, is far smaller in every zone than that on the 11th of Sep., which is two days after the rain-fall day. But in both cases, there can be seen a remarkable difference between *E. sumatrensis*-zone (**B, B'**) and *A. subulatus*-zone (**A**), the latter of which has the highest water content.

2) Analysis of ditch wall community

In Sendamachi of Hiroshima city, there is a ditch which is about 5 m in width and 2.6 m in depth. The water level of the ditch is always changeable and shows a conspicuous rise even when it encounters a very small rain-fall. There grows a

* While the investigation was going on in 1951, the rainfall was very little from the 17th July to the 10th September.

Table II. Soil water content of each zone in and by a green belt zone showing the mean value of three samples in each zone, and the depth of soil sample portion 10 cm

Division of vegetation							
Soil sampling time	A	B	B'	C	C'	D	E zone
Just before rain-fall the 9th Sep. '51	7.5	5.9	5.4	4.5	4.4	4.5	3.4 %
Soon after rain-fall the 11th Sep. '51	17.7	15.1	14.6	11.9	13.1	13.9	8.5

dense community of *A. subulatus* and *Erigeron* spp. on the wall. It is observed at a glance that *A. subulatus* grows near the water's edge and *Erigeron* spp. becomes more frequent toward higher part of the wall. To analyse the community 22 belt transects, each of which is 0.2 m in width, were set with every 1 m interval at right angle to the stream. Furthermore, quadrats of 0.2 m² were set on each transect and the individual number was carefully investigated with respect to each species. The results are shown in Figs. 2~4. The figures clearly show the heterogenous habitat segregation between *A. subulatus* and *Erigeron* spp. The communities of the respective genus are separated at the place of 1.8~2.0 m high above the water level.

Fig. 2. Ditch wall vegetation constituted with *Aster subulatus* and three species of *Erigeron* (the 25th Sep. 1951).

Fig. 3. Diagrammatic beisect through a ditch wall vegetation
A, *Aster subulatus*
E, *Erigeron* spp.

- 3) The pure communities at vacant ground
- a. A comparison between accompanying species. In each of the pure communities of *A. subulatus* and of *E. sumatrensis*, 10 quadrats of 1 m² were set accord-

Fig. 4. Micro growing ranges of the main plants on a ditch wall

ing to the systematic sampling, and the accompanying species (which had been divided into 3 groups*: the wetter, middle and drier groups, according to their general character for a soil moisture condition) were compared between the two pure communities with respect to the percentage of species number, coverage and frequency. In the community of *A. subulatus*, the floristic percentage is 47% in the wetter, 29% in the middle and 24% in the drier group, while in the *E. sumatrensis* community, the wetter group is not found, and the drier one shows such a higher value as 80%. Furthermore, for their total coverage and frequency percentage the same tendency as in the case of the floristic percentage is observed. By the preliminary survey in September 1951 nearly the same results were obtained.

b. Comparison of the chemical components and the water content of the soil between the two communities. As it is clear in Table V, the results of chemical analyses of the soil show not very remarkable differences between the two pure communities in total nitrogen, humus, pH, P_2O_5 and CaO. On the other hand, although the soil belongs to the sandy roam type and humus were very few in both habitats, the maximum water holding capacity as well as the soil water contents both soon after and 3 days after a rain-fall shows higher values in *A. subulatus* community than *Erigeron* communities.

From the results mentioned above, it becomes clear that the *A. subulatus* and the *Erigeron* spp. communities exhibit a distinct heterogenous habitat segregation which is due to the soil moisture condition.

* These three groups are not those which are divided according to the so-called plant geographical view point^{6, 7)} but comparatively classified ones in view of the weed communities.

Table. III. A comaprison of accompanying species between two pure communities (I).

Species	<i>A. subulatus</i> community			Species	<i>E. sumatrensis</i> community		
	Character for moisture	C. d.	Freq.		Character for moisture	C. d.	Freq.
<i>Panicum Crusgalli</i> L. var. <i>submutica</i>	W	1.8	90	<i>Digitaria ascendens</i>	D	2.2	90
<i>Polygonum longisetum</i>	M	1.4	60	<i>Setaria viridis</i>	D	1.1	70
<i>Eclipta prostrata</i>	W	0.9	50	<i>Trifolium repens</i>	D	1.0	40
<i>Juncus tenuis</i>	M	0.8	40	<i>Oxalis corniculata</i>	D	0.9	70
<i>Rorippa islandica</i>	W	0.6	30	<i>Sagina japonica</i>	D	0.6	60
<i>Polygonum nodosum</i>	M	0.6	40	<i>Gnaphalium affine</i>	D	0.4	40
<i>Bidens tripartita</i>	W	0.5	30	<i>Artemisia asiatica</i>	D	0.4	10
<i>Polypogon fugax</i>	W	0.4	20	<i>Hydrocotyle martiana</i>	M	0.3	20
<i>Plantago asiatica</i>	M	0.4	20	<i>Euphorbia supina</i>	D	0.3	20
<i>Hydrocotyle maritima</i>	M	0.3	10	<i>Juncus tenuis</i>	M	0.3	20
<i>Digitaria ascendens</i>	D	0.2	20	<i>Chenopodium album</i>	D	0.2	20
<i>Chenopodium album</i>	D	0.2	20	<i>Fatoua villosa</i>	D	0.2	20
<i>Cyperus microiria</i>	W	0.2	20	<i>Stellaria neglecta</i>	M	0.2	20
<i>Alopecurus amurensis</i>	W	0.1	10	<i>Sonchus oleraceus</i>	M	0.2	20
<i>Rumex japonicus</i>	W	0.1	10	<i>Oxalis Martiana</i>	M	0.1	10
<i>Portulaca oleracea</i>	D	0.1	10	<i>Aster subulatus</i>		0.2	10
<i>Achyranthes japonica</i>	D	0.1	10	<i>Erigeron sumatrensis</i>		4.8	100
<i>Aster subulatus</i>		5.0	100	<i>E. canadensis</i>		2.1	80
<i>Erigeron sumatrensis</i>		0.6	50	<i>E. bonariensis</i>		0.5	30
<i>E. canadensis</i>		0.1	10				
<i>E. bonariensis</i>		0.1	20				

W, Wetter; D, Drier and M, Middle group.

Table IV. A comparison of accompanied plants between two pure communities (II).

Groups by character for moisture	<i>A. subulatus</i> community (17 spp.)			<i>E. sumatrensis</i> community (15 spp.)		
	Numb. of spp. %	Total c. d. %	Total freq. %	Numb. of spp. %	Total c. d. %	Total freq. %
Wetter	47	53	55	—	—	—
Middle	29	40	32	20	9	12
Drier	24	7	13	80	91	88

The subject species not shown here: *A. subulatus*, *E. sumatrensis*, *E. canadensis* and *E. bonariensis*.

II. Homogenous habitat segregation of *A. subulatus* due to the soil moisture.

From the results of the field survey mentioned above, it is clear that there is a habitat segregation due to the soil moisture between the communities of *A. subulatus* and *Erigeron* spp. Namely, the main growing range of *A. subulatus* is always connected with higher moisture. There is often found a pure community of *A. subu-*

Table V. Chemical components and soil water content of the bed soil

Comm- unity	Sampling portion	Total nitrogen	Hu- mus	pH	P ₂ O ₅	CaO	Soil water contents		
							Soon after a rain-fall	3 days after a rain-fall	Maximum water capacity
<i>A. subulatus</i>	0— 5 cm	0.29 %	1.26 %	5.5	200 p.p.m.	less than 0.07	19.7 %	17.9 %	38.4 %
	5—10	0.22	1.88	5.5	200	0.07—0.12	19.5	15.3	39.1
	10—15	0.22	1.66	6.5	200	less than 0.07	19.5	16.1	44.6
	15—20	0.14	1.32	7.0	150	less than 0.07	20.4	16.9	48.3
	20—30	0.10	1.12	7.0	150	less than 0.07	20.5	19.5	51.4
<i>E. sumatrensis</i>	0— 5	0.29	1.22	6.0	200	0.07—0.12	15.7	12.0	37.7
	5—10	0.14	1.17	6.3	200	over 0.17	16.4	12.7	36.2
	10—15	0.07	1.12	7.0	100	over 0.17	17.5	12.5	37.6
	15—20	0.15	1.07	7.2	50	0.07—0.12	19.5	12.7	35.8
	20—30	0.11	1.01	7.5	20	0.07—0.12	18.9	13.8	39.5

Table VI. Anatomical comparison of subterraneous part of *A. subulatus* from drier and wetter habitat (measuring individual number was 25 in each)

Root form (Habitat)	S (Drier)	Re or Br (Wetter)	Significancy
Root diameter mm	3.9±0.34	4.1±0.42	—
Cortex thickness μ	250±64	780±133	+
Ct.-Q.	14±3.2	36±4.6	+
Diameter of wood parts mm	2.8±0.35	2.2±0.33	+
Radial number of vessel arrangement	24±3.6	20±4.4	+
Largest vessel diameter μ	106±29.3	74±17.9	+
Smallest vessel diameter	14±4.2	14±5.4	—
Vessel concentration (in 1 mm ²)	23±5.4	19±5.0	+
Intercellular space in cortex	none	presence	
Hardness of wood parts	hard	little soft	

Significancy of the differences: —none-significant, +significant at 1% level

latus where the *Erigeron* plants can hardly invade*. On the other hand, in the drier stand just adjoined to the wetter ground, a dense community of *Erigeron* spp. is found. This community is sometimes accompanied by a few individual plants of *A. subulatus*. With regard to the root form⁴⁾ of *A. subulatus*, it is observed that plants of *A. subulatus* mixed in the *Erigeron* community show a straight root form (S) in the same manner as in the case of *Erigeron* spp., but those of *A. subulatus* in its pure community show a reticulate form (Re) or branched root form (Br) (Fig. 5).

* According to the survey made on the 6th July, 1953, it was observed that the *A. subulatus* community encountered a flood owing to a long rain for 12 days and that some individuals of the accompanying *E. sumatrensis* and *E. canadensis* suffered several injuries, for example, the leaves were withered and the epidermis of roots were blacked and becoming off.

Fig. 5. Showing root form and anatomical features of *A. subulatus* from different habitats. **A** from wetter habitat (in its pure community) shows a reticulate root form, and **B** from drier habitat (accompanying individuals in *E. sumatrensis* community) shows a straight form. **A'** and **B'** are cross sections of the roots of **A** and **B** respectively at nearly the same parts in diameter. **A** and **B** $\times \frac{1}{4}$, **A'** and **B'** $\times \frac{1}{55}$

Furthermore, *A. subulatus* of the two communities exhibits clear differences in the anatomical features of root such as **Ct.-Q***, the radial number of vessel arrangements, the diameter of the largest vessels, the diameter of wood parts, the vessel

* **Ct.-Q.** (=Cortex thickness-Quotient) represents the percentage of the cortex thickness for the root diameter of the same individuals; that is,

$$\text{Ct.-Q.} = \frac{\text{cortex thickness}}{\text{root radius}} \times 100$$

concentration, etc. Moreover, remarkable differences are found in regard to the presence of intercellular space in cortex and the hardness of wood parts.

On the relation between the root form and relative abundance in the plants in the treated area, the results as shown in Table VII were obtained.

Table VII. Root form and relative abundance in the plants in the treated area

Species \ Habitat	Wetter stand		Drier stand	
	Root form	Abundance	Root form	Abundance
<i>A. subulatus</i>	Re (Br)	abundant	S	seldom present
<i>E. sumatrensis</i>	—	—	S	very abundant
<i>E. canadensis</i>	—	—	S	abundant
<i>E. bonariensis</i>	—	—	S	present

Summary

1. The author experimentally ascertained a heterogenous habitat segregation due to the soil moisture between *Aster subulatus* and three species of *Erigeron*, *E. sumatrensis*, *E. canadensis* and *E. bonariensis*, both of which belong to the same life form and growing period.

2. The main growing range of *A. subulatus* is usually connected with higher soil moisture, but there is found a few individuals of *A. subulatus* accompanying in the community of *Erigeron* spp. which grows in drier habitat. The root form of *A. subulatus* in the *Erigeron* community shows a straight root form (S) as well as in the three species of *Erigeron*. On the other hand, the root form of *A. subulatus* in its pure community shows a reticulate form (Re) or branched root form (Br).

3. As to the anatomical features of root of *A. subulatus* from both communities, the pure communities of *Aster* and *Erigeron*, differences are clearly found in Ct-Q., presence of intercellular space, largest vessel diameter, etc., and the author recognized a homogenous habitat segregation between individuals of *A. subulatus*. Among the plants of *Erigeron* spp. were not found so notable differences as in *Aster subulatus*.

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