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Distribution Pattern of *Carex kobomugi* OHWI Growing on Sandy Beaches of Shimane Prefecture, San'in Region

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Distribution pattern of *Carex kobomugi* OHWI was investigated with reference to the distance from seashore line in three sandy beaches including five stands of Shimane Prefecture, San'in Region. Contagious distribution denoting the statistically significant departure from randomness was observed in all stands. A definite correlation could not be recognized between the degree of contagiousness of distribution and the distance from the seashore line. Twin type of clumps were detected in four-fifths of eighteen distance-classes established in five stands. The smaller scale of clump was estimated to be $0.32\,m^2$, while that of the larger one was to be $1.28\,m^2$–$5.12\,m^2$. The frequency distribution of the actual clump sizes followed the lognormal distribution. The smaller scale of clump corresponded with the maximum total clump area as a whole.

Introduction

There exist two phases in the distribution pattern of individuals in a plant population or community: one is that it is rigidly represented by the intrinsic nature of the species, and another is that it changes pliably by the influence of inorganic environmental factors, particularly edaphic ones or such agencies from other organisms as competition and allelopathy. Although it is desirable to segregate clearly the two phases in the study on the distribution pattern, such a attemp have been tried hardly except for a few studies (PHILLIPS 1954, ANDERSON1961, KERSHAW 1962, ZINKE 1962, KITAMOTO 1972), because of difficulty and complication in the measurements of environmental factors.

Carex kobomugi OHWI is one of the most representative species growing on sand dunes and sandy beaches in the warm-temperate zone of Japan. It is well-known as xerophytic and psamophilous plant as well as *C. pumila, Ischaemum anthephroides, Zoysia macrostachya*, etc. It provides us a good experimental material for the study on the distribution pattern because it grows forming often pure stands under comperatively homogeneous edaphic condition, and its rhizome and root system under the ground surface can be easily dug.

The objective of this study is to clarify the distribution pattern of the

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aboveground shoots of the species with reference to the distance from the seashore line in some sandy beaches. Comparision between the distribution pattern and edaphic factors by means of an excavation survey will be reported in the next paper.

Study Area

We performed field survey in three habitats including five stands of *Carex kobomugi*, Shimane Prefecture, San'in Region, west Japan (Fig. 1). The first habitat is Mochiishi Beach of Masuda City, which locates 2 km westward from the mouth of Takatu River. Seashore line consisting of small shingles follows pure stand of *C. kobomugi* population, which ends at the sand defending fens. The second is Asari Beach of Gōtsu City, 5 km eastward from the mouth of Gōnokawa River. Wider stand than the first is replaced by that of *Calystegia soldanella* or *Ixeris repens*, at the further distance from the seashore line.

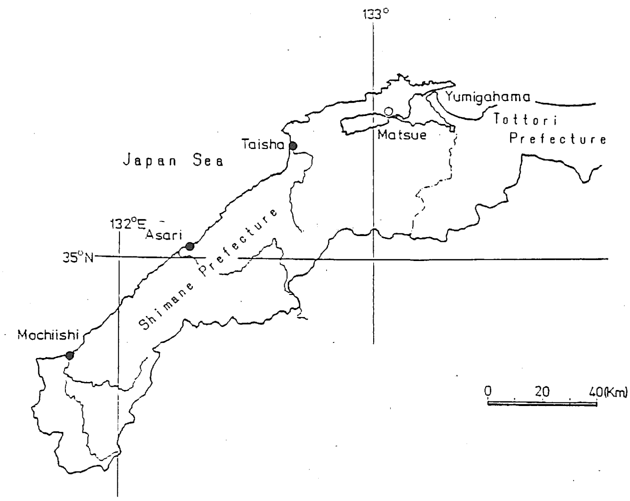

Fig. 1. Geographical map showing the habitats of *Carex kobomugi*, Shimane Prefecture, San' in Region. Darked circles represent the actual localities investigated.

The last is Taisha beach, Taisha Chō, near the mouth of Kandogawa River. Here we sampled three stands: the two, situated at the north-side of the river mouth were called "Minatohara" and "North Minatohara" according to the distance from the river mouth. That of the south-side was called "South Minatohara". In both stands, North and South Minatohara, the populations ended inlandward at the sand defending fens. Minatohara stand was well-developed and presented the most natural and typical physiognomy.

Methods

In each stand, we set up several transect lines of 50 m in length across the stand inlandward from the seashore line. We established arbitorarily some quadrats 3.2 m ×3.2 m in size along each transect line and mapped the projected figure of clumps with various sizes on a section paper. The quadrat size on the paper was 32 cm× 32 cm in size, which was subdivided into grids of 6400. The minimum grid size was 4 mm×4 mm in size, which was counted as one shoot of the species. Met with clumps protruded from the quadrat, we sketched only ones having its center within the quadrat (Fig. 2).

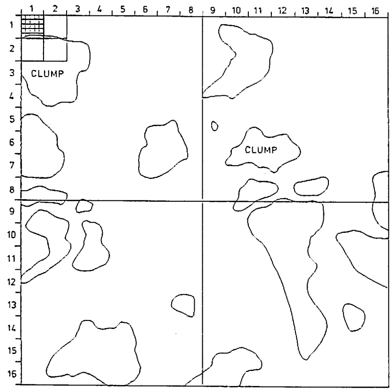

Fig. 2. Shape and size of quadrat. A quadrat 3.2 m×3.2 m in size was subdivided into 6400 grids, one of which was 4 cm×4 cm. Outlines of clumps within the quadrat were sketched on a section paper.

The number of quadrats established were 13 in Mochiishi Beach, 10 in Asari Beach, 25 in Minatohara, 13 in North Minatohara, 6 in South Minatohara, respectively. Using Iδ-method (MORISTITA 1959a), we diagnosed the distribution pattern of shoot distribution. When the contagious distribution was detected, its clump size was estimated by means of Iδ(s)/Iδ(2s)-curve. Iδ-method is available because Iδ-value is influenced neither by the average number of shoots or individuals nor by the number of grids and is adaptable to any types of the distribution pattern. Field survey was carried out from late April to the middle of October, 1983.

Results and Discussion

Figs. 3–7 show Iδ-and Iδ(s)/Iδ(2s)-curves obtained by changing successively grid size with reference to the distance from the seashore line. The values are represented as the average for some quadrats between every distance-class of 5 m interval. As is clear from the figures, we can easily recognize the contagious

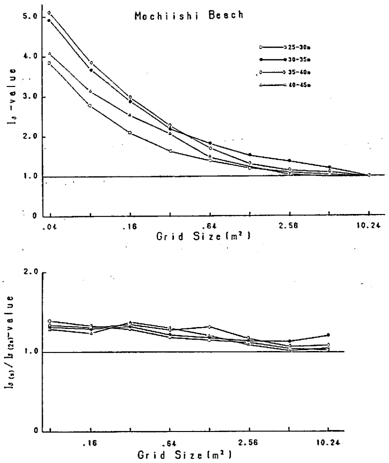

Fig. 3. Iδ-and Iδ(s)/Iδ(2s)-curves with reference to the distance from seashore line in Mochiishi Beach, Masuda City. All Iδ-values except for one at the largest grid size indicated the highly significant departure from randomness.

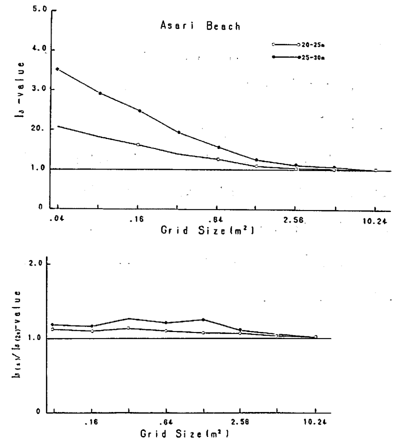

Fig. 4. Iδ-and Iδ(s)/Iδ(2s)-curves with refernce to the distance from seashore line in Asari Beach, Gōtu City.

distribution in all distance-classes, though the degree of contagiousness is somewhat different from place to place. All Iδ-values except for one at the largest grid size denoted the statistically significant departure from randomness over the whole range of grid sizes in every stand.

In Mochiishi Beach, Iδ-curves of 30 m–35 m and 35 m–40 m from the seashore indicated the almost similar trend, while those of 25 m–30 m and more than 40m did the rather lower contagiousness over the whole range of grid sizes. Clump size was estimated to be 0.32 m^2 in three distance-classes, except for the nearest one to the seashore line which assumed to posses the clump size less than 0.08 m^2. The most inland distance-class showed the larger clump size of 1.28 m^2 together with the smaller clump of 0.32 m^2 (Fig. 3).

In Asari Beach, we can recognize the lower contagiousness not in the most inland class but in the nearer one to the seashore line. The former had the twin type of clumps, i.e. 0.32 m^2 and 1.28 m^2, while the latter did only single clump, i.e. 0.32 m^2 in size (Fig. 4). In Minatohara,the further is the distance from the seashore line, the higher contagiousness in the pattern we can fine. Three distance-classes except for the most inland one indicated the clump size of 0.32 m^2. Out of them, the distance class of 40 m–45 m had also the larger clump of 1.28 m^2. The most inland distance class was judged to have a larger and loose clumps ranging from 0.64 m^2 to 1.28 m^2 (Fig. 5).

In North Minatohara, the most inland distance-class denoted the highest

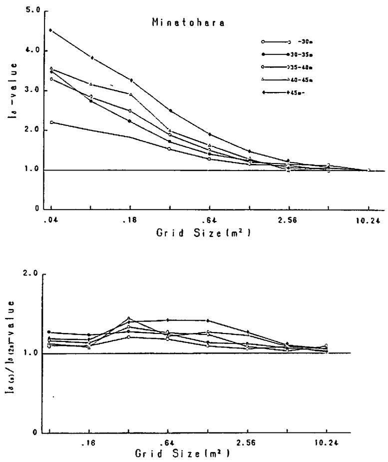

Fig. 5. Iδ-and Iδ(s)/Iδ(2s)-curves with reference to the distance from seashore line in Minatohara, Taisha Beach, Taisha Chō.

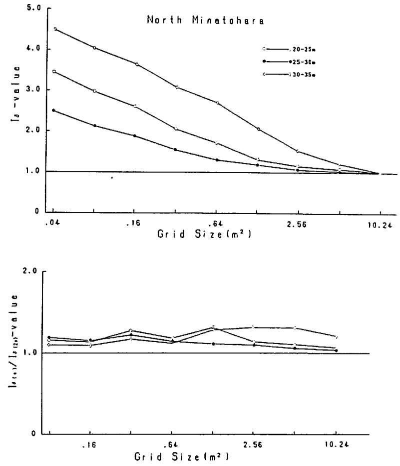

Fig. 6. Iδ-and Iδ(s)/Iδ(2s)-curves with reference to the distance from seashore line in North Minatohara, Taisha Beach, Taisha Chō.

contagiousness, while that of 25 m–30 m did the lowest contagiousness. The distance-class on the side of the seashore line denoted the intermediate contagiousness. The first and last classes had the twin type of clumps: the former had clumps of 0.32 m^2 and 2.56 m^2–5.12 m^2, and the latter had clumps of 0.32 m^2 and 1.28 m^2 (Fig. 6). In South Minatohara, the contagiousness decreased regularly and successively at the range of smaller grid sizes from the seashore line to the inland. Independently of the distance from the seashore line, every distance-class had the common clump size of 0.32 m^2. Out of them, the nearest distance to the seashore line and the most inland one had another clump size, i.e. 1.28 m^2 in addition to the above-mentioned clump size. But, compactness of clump seemed to be somewhat loose (Fig. 7).

As described previously, shoots of *C. kobomugi* populations indicated the contagious distribution without exception. This is well accordance with the results reported in the same species by NOBUHARA (unpublished, cited by NUMATA 1959) and TAGAWA (1963). Taking into consideration of the growth-form and rhizome performance, NUMATA and NOBUHARA (1952) suggested that the contagiousness of distribution may originate from its rhizome propagation. They also stated that a coefficient of individual homogeneity proposed by NUMATA (1949) decreases along the gradient from the inland to the seashore line, i.e. the contagiousness of shoot distribution tends to decrease along the gradient. In this study, however, we could not detect the definite correlation between the contagiousness and the distance from the seashore line. In Minatohara, for example, the contagiousness decreased toward the seashore line from the inland, while it changed reversely in South Minatohara. The difference like this may take place due to partly the existence of the sand defending fens. But, as

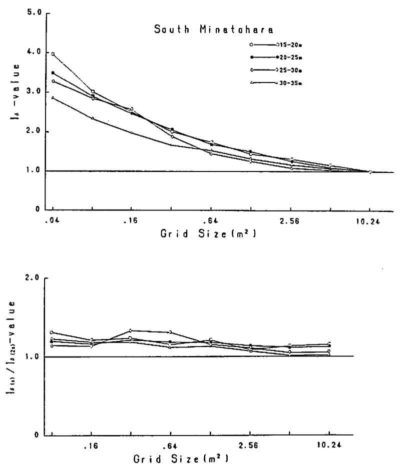

Fig. 7. Iδ-and Iδ(s)/Iδ(2s)-curves with reference to the distance from seashore line in South Minatohara, Taisha Beach, Taisha Chō.

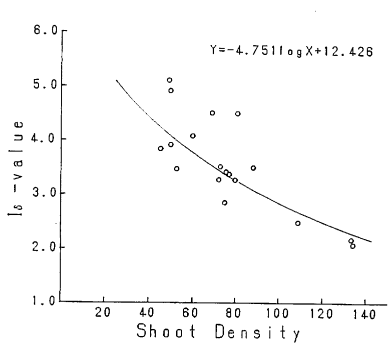

Fig. 8. Showing the correlation between Iδ-values and densities. The values from eighteen distance-classes in five stands were used for analysis.

in North and South Minatohara where the fens were provided, the most inland distance-class exhibited the quite different contagiousness with reference to the distance from the seashore line. Consequently, we could not evalute exactly its effect on the distribution pattern. Such a problem would be reserved for the further detailed investigation, e.g. the excavation survey of the rhizome and root system in the underground.

It seems that the contagiousness depends rather directly on the shoot density than the distance from the seashore line. Fig. 8 shows the relationsip between Iδ-values at the minimum grid size (0.04 m^2) and the shoot densities. Iδ-values were resulted from all distance-classes in five stands. It is well-known that the contagiousness of distribution in many plant populations decreases with increase of shoot or individual density (TAGAWA 1965, MIYATA 1977). This trend is particularly strengthened in the species populations which propagate by the colonial growth of rhizome performance (WATT 1945, CAIN and EVANS 1952, TAGAWA 1965).

Table 1 represents the frequency distribution of average clump sizes estimated in eighteen distance-classses including five stands with reference to the distance from the seashore line. Four-fifths of them has a clump of 0.32 m^2 in size and, in addition to this, about one half of fifteen distance-classes has another larger clumps of 1.28 m^2 or 5.12 m^2 in size. Namely, it was suggested that the twin type of clumps are very commonly observed in *C. kobomugi* population. This fact was already pointed out by TAGAWA (1963) who reported two scales of pattern, i.e. 1/16 m^2 and 1 m^2. The difference in clump sizes between the present study and TAGAWA's may be probably due to the difference in environmental condition or sampling methods.

Table 1. Frequency distribution of clump size estimated by Iδ(s)/Iδ(2s)-curve. Twin type of clumps were observed in four-fifths of eighteen distance-classes in five stands.

Habitat	Distance from seashore line (m)	Clump size (m^2) 0.04	0.08	0.16	0.32	0.64	1.28	2.56	5.12	10.24
Mochiishi Beach	25-30									
	30-35				○				○	
	35-40				○		○			
	40-45				○					
Asari Beach	20-25				○					
	25-30				○		○			
Minatohara	-30				○				○	
	30-35				○					
	35-40					○				
	40-45				○					
	45-					○				
North Minatohara	20-25				○		○			
	25-30				○					
	30-35				○				○	
South Minatohara	15-20				○		○			
	20-25				○					
	25-30				○					
	30-35				○		○			

When the number of clumps is represented against clump size-classes on an octave scale, it draws a normal distribution with comparatively good fitness (Table 2). This lognormal distribution of actual clump sizes was also reported by TAGAWA (1963). He stated that the smaller (primary) scale of pattern (1/16 m^2) is determined by "decision by majority", i.e. it is in full accord with the mode of the frequency distribution of clump sizes, while the larger (secondary) scale of pattern (1 m^2) is done by "decision by much", i.e. it is in accord with the maximum total clump area. In this study, however, the smaller scale of pattern did not coincide quite with the mode of the frequency distribution of clump sizes or the average clump size.

In three stands, Mochiishi Beach, Minatohara and North Minatohara, the maximum total clump size occurred at the clump size of 0.16 m^2, which is less one class than 0.32 m^2. Therefore, it is safely said that the smaller scale of pattern is determined by the maximum toal clump area as a whole. Unfortunately, the origin of larger scale of pattern was unclear in this study. It may or may not correspond with "family", a complex colonies, called by NUMATA and NOBUHARA (1952). Such a problem would be also clarified by the excavation survey of rhizome and root system.

We carried out the preliminary survey on the underground structure of the species and some soil characters in Minatohara. Fig. 9 represents the vertical distribution of fragments of rhizomes and roots,soil moisture and pH from the ground

Table 2. Frequency distribution of the actual clump size and the total clump area. Clump size-classes are taken on the octave scale. The actual clump sizes follow the log-normal distribution as a whole.

Habitat	Clump size (m^2)	Frequency	Total clump area (cm^2)
Mochiishi Beach	~0.005	10	448
	0.005~0.01	34	2704
No. of clumps=454	0.01~0.02	75	11424
Total clump area	0.02~0.04	96	27728
=31.832 m^2	0.04~0.08	101	57536
Mean area=0.070 m^2	0.08~0.16	88	97792
S. D=0.076	0.16~0.32	41	84880
	0.32~0.64	9	35808
	0.64~1.28	0	0
Asari Beach	~0.005	15	608
	0.005~0.01	25	1920
No. of clumps=225	0.01~0.02	24	3712
Total clump area	0.02~0.04	30	8432
=29.685 m^2	0.04~0.08	38	20912
Mean area=0.132 m^2	0.08~0.16	44	50608
S. D=0.244	0.16~0.32	26	59520
	0.32~0.64	14	64320
	0.64~1.28	8	60880
	1.28~2.56	1	25936
	2.56~5.12	0	0
Minatohara	~0.005	16	448
	0.005~0.01	8	688
No. of clumps=219	0.01~0.02	16	2720
Total clump area	0.02~0.04	32	8944
=30.909 m^2	0.04~0.08	43	25088
Mean area=0.141 m^2	0.08~0.16	47	52353
S. D.=0.199	0.16~0.32	28	57856
	0.32~0.64	21	85920
	0.64~1.28	8	75072
	1.28~2.56	0	0
North Minatohara	~0.005	4	192
	0.005~0.01	23	1824
No. of clumps=244	0.01~0.02	26	3856
Total clump area	0.02~0.04	38	10976
=35.170 m^2	0.04~0.08	48	28592
Mean area=0.144 m^2	0.08~0.16	46	51552
S. D.=0.238	0.16~0.32	32	69392
	0.32~0.64	18	84400
	0.64~1.28	5	44592
	1.28~2.56	4	56320
	2.56~5.12	0	0
South Minatohara	~0.005	6	256
	0.005~0.01	17	1344
No. of clumps=134	0.01~0.02	22	3072
Total clump area	0.02~0.04	19	5616
=12.237 m^2	0.04~0.08	22	12752
Mean area=0.091 m^2	0.08~0.16	29	34288
S. D.=0.129	0.16~0.32	11	23040
	0.32~0.64	5	20512
	0.64~1.28	3	20816
	1.28~2.56	0	0

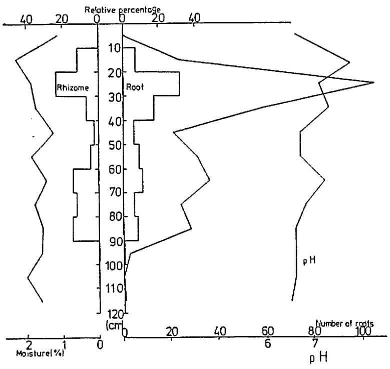

Fig. 9. Vertical distribution of the number of rhizome and root fragments, soil moisture and pH in Minatohara.

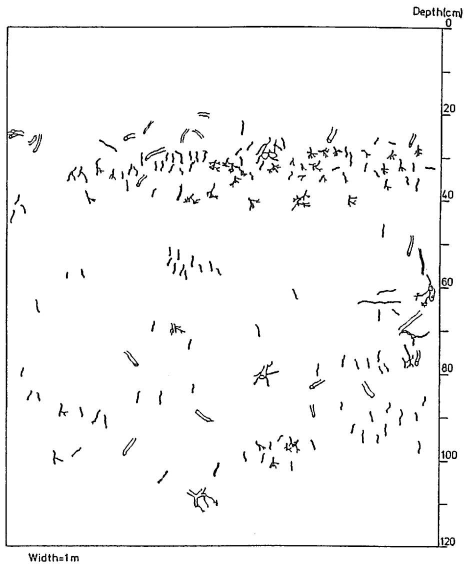

Fig. 10. Soil profile including fragments of rhizome and root. White parts of fragments express rhizomes including bulbous nodes formed at the base of leaf sheath, and black parts express roots.

surface to 120 cm in depth at the point 50 m away from the seashore line. The maximum values of the number of both fragments, rhizomes and roots, were observed at 20 cm–30 cm layer (Fig. 10). The greater part of rhizome fragments at this layer included a number of bulbous nodes, which are usually formed at the base of leaf sheath and become the origin of new shoots. Soil moisture and pH showed the highest value at 10 cm–20 cm layer. The vertical values of pH changed somewhat proportionally with the number of roots.

Some physical and chemical characters of soil including grain size distribution, salinity of soil water, soil moisture, ignition loss and pH were compared between the area covered with shoots and the bare area in Minatohara (Table 3). Except for salinity of soil water, other characters did not denote the definite difference between both areas. Salinity was higher at the upper (0 cm–15 cm) layer than at the under (15 cm–30 cm) layer in both areas. Therefore, we judged that it is difficult for salt to permeate into soil in the vegetation area than in the bare area, and the higher values of pH at 10 cm–20 cm layer may be resulted from the higher salinity at this layer.

In the next paper, we will report the more detailed results of the excavation survey on the undergound structure and its vertical transition of *Carex kobomugi* populations.

Table 3. Comparision of some soil characters between the area covered with shoots and the bare area in Minatohara.

Distribution of grain size							
Site	Depth (cm)	Grain size (10^{-3}mm) -2000	2000-840	840-420	420-210	210-105	105-
Vegetation area	0-15	0.04	7.66	48.69	34.21	9.11	0.28
	15-30	0.19	9.27	53.18	29.20	7.26	0.89
Bare area	0-15	0.20	6.45	50.43	34.68	8.07	0.16
	15-30	0.22	8.56	50.92	29.67	7.79	0.82

Some physical and chemical soil characters					
Site	Depth (cm)	Soil moisture (V/V%)	Salinity of soil water (%)	Ignition loss (W/W%)	pH
Vegetation area	0-15	2.88	8.53	0.45	7.52
	15-30	4.28	6.39	0.43	7.54
Bare area	0-15	2.74	7.55	0.42	7.90
	15-30	4.30	4.97	0.40	7.25

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