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Response of a *Miscanthus sinensis* Grassland in an Early Successional Old-Field to Fertilization

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The effects of fertilization on the structure and function of an early successional *Miscanthus sinensis* grassland were investigated in an old-field ecosystem at Honjo city, Saitama Prefecture, Japan from 1981 to 1982. Compared to control plot, life form composition of treatment plot was characterized by a decrease of phanerophytes and an increase of hemicryptophytes. Fertilization had a beneficial effect on the growth in aboveground phytomass of *M. sinensis*, the dominant species. However, it did not cause a change in the total number of stems of *M. sinensis*. Annual increment of patch diameter of *M. sinensis* was estimated to be 6-8 cm on an average and there was no significant difference in the growh rate of patch size between fertilized and non-fertilized plots. To estimate the aboveground phytomass of *M. sinensis*, several non-destructive parameters were examined. As a result, the patch size showed a high correlation with aboveground phytomass. Thus the patch size was suggested to be most applicable to its estimation. Diversity indices based on phytomass data of component species were increased slightly by fertilization, because relative dominance of some other species, especially of *Artemisia princeps* increased, while that of *M. sinensis* decreased. Fertilizer application resulted in a decrease in the total number of species.

Key words : fertilization, grassland, phytomass, species diversity, succession

Miscanthus sinensis, a perennial grass, is a dominant species of tall-grass type grasslands in China, Korea and Japan (Numata and Mitsudera, 1969; Park, 1965, 1985). Its seedlings come to establish well either on fertile soils or nutrient poor soils (Yamane and Naito, 1975).

M. sinensis community has usually been considered as the final stage of secondary succession of herbaceous communities in the above regions (Hayashi, 1977, 1987; Hayashi *et al.*, 1981; Park, 1985). However, on nutrient poor soils and bare grounds without buried-seeds, *M. sinensis* can be dominated at the earlier stage of secondary succession. Therefore, this plant seems to be of considerable significance in terms of the revegetation or restoration of exposed areas and wastelands for soil erosion control.

Many ecologists have devoted much effort to ecological studies on the *M. sinensis* community and have greatly contributed to our understanding of this grassland ecosystem. The references are summarized by Numata (1979) and Park (1985). However, information about the dynamics of the establishment process and the effects of fertilization on the structure and function of *M. sinensis* grassland is still insufficient. In the present study, therefore, the author intends to make clear the establishment process and the effects of fertilizer application on the growth of *M. sinensis*. On the other hand, it is known that the establishment of *M. sinensis* is closely related to the nutrient state of soil (Yamane and Naito, 1975). The present study is focused on the response of *M. sinensis* community to fertilization under nutrient poor

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Corresponding author : Fax 82-571-54-5952 soil conditions.

MATERIALS AND METHODS

Study site

The investigation was carried out in a *M. sinensis* grassland on a gently sloping hill with N exposure in the Honjo campus of Waseda University, located 1 km south of Honjo city, Saitama Prefecture, Japan. Phytosociologically the *M. sinensis* community belongs to Arundinario chino-Miscanthetum sinensis Miyawaki 1971.

According to the data (1951-1981) from the Kumagaya Meteorological Observatory (36°09'N and 139° 23'E) situated 20 km SE of the study site, mean annual rainfall is 1284 mm and mean annual temperature is 14.1℃.

Prior to cultivation, the field had been kept as a secondary forest for long period. After that the field had been planted with mulberry (*Morus alba*) or sweet potato (*Ipomoea batatas* var. *edulis*) in most of the years preceding abandonment. It has been abandoned since 1965. However, it had been used as a soil depository for two years (1976-1977) during the construction of the New Zyoetsu Line. Thus the soil quality deteriorated remarkably.

According to the data of soil analysis at the start of the experiment of 1981, original soil type of the field was Kanto-loam containing a volcanic ash above unconsolidated sand and gravel layers. The soil layer is shallow in depth (15-20 cm) and is characterized by high contents of clay and silt (67-69%), and sand and gravel (31-33%). The value of ignition loss was very low (3.99-4.95%), showing lower content of organic matter. Contents of total carbon (0.65-1.02 %) and nitrogen (0.03-0.04%) were relatively low as compared with those of other places on the hill.

Experimental design and treatments

A rectangular, 38×10 m study site was selected from homogeneous parts of the *M. sinensis* grassland and the two treatments were arranged in replicated blocks, consisting of total ninety-five 2×2 m subplots divided by vinyl strings. Among the subplots, thirty-five 2×2 m subplots (CF plot), five rows of 7 contiguous subplots, were applied with chemical fertilizer in early May of 1981 and 1982, and the other sixty 2×2 subplots (C plot), five rows of 12 contiguous subplots, left as a control. The application rates of N, P and K were 5, 5 and 5 g/m^2 in 1981 and 4, 6, 4 g/m^2 in 1982, respectively. Two replicated subplots were set within each plot and were used as permanent quadrats.

Vegetation analyses

Frequencies of occurrence of each component species were investigated from 14 subplots, distributed randomly, in each plot in May 1982.

The numbers of living and dead leaves, and the number and height of stems of *M. sinensis* were measured in the permanent quadrats of each plot once a month during the growing season in 1981. Three patches of *M. sinensis* at each hand of the outside of C and CF plots were also sampled monthly, to estimate the seasonal change in mean dry weight per shoot between the two. The sample patches were clipped at the ground level, taken to the laboratory, and were divided into stems, living and dead leaves. Then, they were dried at 80℃ for 48 hours, and weighted to the nearest 0.01 g. Mean area per leaf was measured by an automatic area meter (AAM-7, Hayashi Denko Ltd.).

Species diversity

Relative dominance (p_i) and diversity indices of the community were calculated based on the data of the dry phytomass obtained from the three duplicate subplots in each plot. Samples for standing crop of component species were clipped at the ground level from the subplots.

Dominance was expressed by Simpson's dominance index (Whittaker, 1975):

$$C = \sum_{i}^{S} (n_i/N),$$

where n_i is the biomass of species i, N is total biomass of the sample, and S is the number of species. Species diversity was expressed using 4 different diversity indices:

1. Species richness: S = number of species in sample
2. Shannon-Wiener's function (Pielou, 1969):

$$H' = -\sum_i p_i \log_2 p_i$$

3. Simpson's diversity (Simpson, 1949):

$$P = 1 - \sum_i p_i^2$$

4. Pielou's evenness (Pielou, 1969): $J' = H'/\log_2 S$

Buried-seed population

At the start of the experiment in 1982, soil samples for analysis of buried-seeds were collected from five points in the study site using steel cans ($10 \times 10 \times 10$ cm). Buried-seeds in the soil were separated by the floating method by Hayashi and Numata (1971) using 50% K_2CO_3 solution. The identification and inspection of viability of separated seeds were made under a binocular microscope.

Patch size

The distribution of *M. sinensis* patches was mapped all over the study site in May 1981. In May and November of 1982, 40 patches from C plot and 29 patches from CF plot were also investigated to estimate annual increase in patch size and patch diameter. The patch size and the patch diameter were determined assuming that the shape of patch is ellipsoid as follows:

PS (patch size) $= [(a \times b)/4] \times \pi$

PD (patch diameter) $= (a + b)/2$

where a = major axes of patch and b = minor axes of patch.

Estimation of the aboveground biomass of *M. sinensis*

In September of 1981, seven patches from C plot and twelve patches from CF plot were sampled to measure aboveground dry weight (DW). Some non-destructive parameters such as height (H), patch size (PS), number of stems (NS), number of living leaves (NDL) and of attached dead leaves (NDL) in each patch were also determined.

RESULTS AND DISCUSSION

Floristic composition, life form and buried-seed population

A total 59 species were present in the 28 subplots of both plots for the investigation of percent frequencies; 43 from C plot and 47 from CF plot. Thirty-one species were common to C and CF plots. *M. sinensis* and *Equisetum arvense* occurred with 100% frequency in both plots. Frequencies of *Amphicarpaea trisperma, Artemisia princeps* and *Erigeron philadelphicus* in C and CF plots were 100% and 91%, respectively. Percent frequencies of seven species, especially of *Poa sphondylodes, Picris japonica, Lespedeza cuneata* and *Inula japonica,* were higher in CF plot than in C plot, but twelve species occurred more often in C plot.

The spectrum of Raunkiaer's dormancy form for each plot was characterized by a predominance of therophytes (Th) in both plots, with 51% (C plot) and 47% (CF plot) of the total number of species. The proportions of hemicryptophytes (H) and geophytes (G) were increased from 21 to 28% and from 9 to 13%, respectively, by fertilization. However, the second highest hemicryptophytes were relatively small compared with the *M. sinensis* grasslands in northern and central Honshu, and Korea (Suganuma and Sugawara, 1975; Hayashi *et al.*, 1981; Park, 1965, 1985), indicating that this grassland is in an early perennial-herb stage of secondary succession. The proportions of phanerophytes (Ph) decreased from 9 to 2% as well as those of therophytes. On the other hand, fertilizer application to CF plot for two years, from 1981 to 1982, resulted in a decrease in the total species from 90 to 75. Most of the species lost were therophytes (8 species) and woody plants (5 species) as suggested in the above life form spectrum.

The total number of the buried-seeds in the uppermost 2 cm layer was $9920/m^2$, and most of which were those of annuals. Seeds of *Polygonum* spp. were the most abundant ($4300/m^2$), followed by *Chenopodium album* ($4240/m^2$), suggesting that the study site once was subjected to the annual herb stage. The number of buried-seeds of *M. sinensis* was very low ($920/m^2$) as compared with the value of about $2000/m^2$ found in various *M. sinensis* grasslands of Japan (Hayashi, 1971).

The dominants of grasslands are altered by various environmental factors, e.g. topography, soil conditions and management practices. The floristic co-

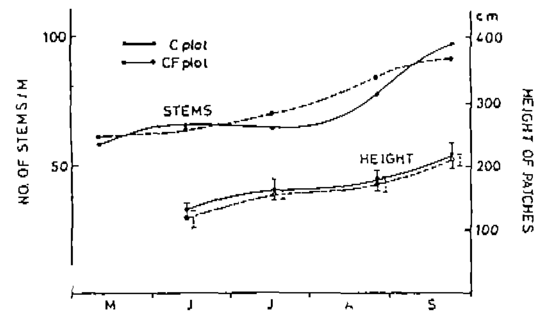

Fig. 1. Seasonal changes in the number of stems and the mean height of *Miscanthus sinensis* patches in C and CF plots during the growing season. In the height, vertical bars are 95% confidence limits.

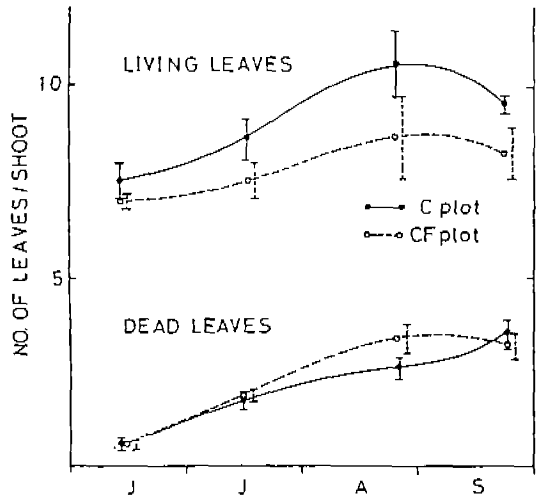

Fig. 2. Seasonal changes in the numbers of living and attached dead leaves per shoot in C and CF plots during the growing season. Vertical bars are 95% confidence limits.

mposition of the buried-seeds in underground soil changes corresponding to the change of aboveground vegetation. However, Hayashi and Numata (1975) pointed out that the difference in the floristic composition between the aboveground vegetation and buried-seeds is commonly seen in the grasslands in Japan. Also, the result of the present study revealed that the seeds of the dominant *M. sinensis* are not always dominated in the soil beneath the stand. This may be related closely to the vegetative reproduction of *M. sinensis*; This plant expands own distributional range mainly by tillering strategy.

Seasonal growth of aboveground part of *M. sinensis*

Seasonal changes in the numbers of stems, living and dead leaves and in the height of *M. sinensis* patches in permanent quadrats were investigated during the growing season in 1981 (Figs. 1 and 2). The seasonal changes in the number of stems including buds and the height of the patches showed no great difference between C and CF plots. Seasonal maximum of the stem number and the height of the patches attained in September together in the two plots.

The number of living leaves was greater in C plot than in CF plot (significant with $p<0.05$), and its seasonal maximum value attained in late August. Instead, the seasonal changes in the mean values of the area per leaf were higher in CF plot than in C plot. The number of attached dead leaves was significantly greater in CF plot than in C plot in late August ($p<0.05$). The higher mortality of leaves in CF plot may be related to the lower light intensity inside the *M. sinensis* patches in CF plot than those in C plot. In relation to this, solar radiation was 16.57± 1.28 $kW \cdot h^{-1} \cdot m^{-2}$ and 11.64± 3.12 $kW \cdot h^{-1} \cdot m^{-2}$, respectively, inside the patches in C and CF plots for the period from 26 August to 23 September, 1981. Meanwhile, mean values of the area per leaf were higher in CF plot than in C plot during the growing season in 1981, but leaf area index (LAI) in September 1982 was the reverse.

The values of average dry weight per shoot in CF plot are greater than those in C plot during the growing season of 1981, indicating a beneficial effect of fertilization on shoot growth. Aboveground standing crops per unit area in the permanent quadrats are estimated based on the number of shoots in the permanent quadrats (Fig. 1) and the mean dry weights per shoot. In both plots, aboveground standing crop began to increase since late April and attained its seasonal peak at the end of August, then declined to the end of the growing season. The seasonal maximum of standing crop in C and CF plots was 600 and 940 g dry $wt \cdot m^{-2}$, respectively.

Estimation of peak aboveground stand biomass by non-destructive method

Since the distribution of patches of *M. sinensis* in the plots was not homogeneous, percent coverages of the patches in 2×2 m subplots were very variable among these subplots. Mean percent coverage of the

Table 1. Increase in the size and the diameter of *Miscanthus sinensis* patches. Values in parentheses are increments between the sampling times (Mean± SE)

(a) Patch size (cm^2)

	C plot (n=40)	CF plot (n=29)	d.f.	T-value	P-value (α)
May	688.9± 71.74	560.5± 38.83	67	1.36^-	0.1
1981	(469.0± 60.83)	(390.0± 47.92)	(67)	(1.02^-)	0.3
May	1157.8± 101.1	950.0± 63.09	67	1.59^-	0.1
1982	(385.0± 50.57)	(419.0± 57.57)	(67)	(0.96^-)	0.3
Nov. 1982	1542.5± 115.73	1369.7± 94.16	67	1.08^-	0.2

(b) Patch diameter (cm)

	C plot (n=40)	CF plot (n=29)	d.f.	T-value	P-value (α)
May	28.84± 1.21	26.47± 0.94	67	1.43^-	0.1
1981	(8.70± 0.96)	(7.90± 0.91)	(67)	(0.91^-)	0.3
May	37.50± 1.48	34.39± 1.17	67	1.55^-	0.1
1982	(5.90± 0.67)	6.80± 0.86	(67)	(0.89^-)	0.3
Nov. 1982	43.40± 1.58	41.20± 1.48	67	1.04^-	0.3

$^-$, Means between the two plots and the sampling times were compared by t-test. All t-values were not significant ($p>0.05$).

patches in May 1981 was 7.2% in C plot with range from 1.6 to 15%, and 8.3% in CF plot with range from 4.1 to 16%. Therefore, many sample quadrats are demanded to estimate stand biomass precisely.

Aboveground biomass of a herbaceous stand is usually estimated by harvesting method. However, the method is very time-consuming and needs many destructive samples. In the present study, therefore, a non-destructive method (Milner and Hughes, 1968) was applied to estimate seasonal peak value of stand biomass, using regressions relating some non-destructive parameters such as H, NDL, NLL, NS and PS to aboveground biomass of *M. sinensis* patches.

There was a great correlation between DW and PS in both C and CF plots. The regression equations relating PS to DW were:

$$DW=0.595PS-25.781 \text{ for C plot} \quad (r=0.995;\ p<0.01)$$

$$DW=0.763PS-6.775 \text{ for CF plot} \quad (r=0.949;\ p<0.01)$$

Since counting the numbers of stems or leaves in *M. sinensis* patches is very laborious work to do though they show high correlations, as compared with measuring patch size, the regression equations between DW and PS were most applicable to estimate aboveground stand biomass of *M. sinensis*. Thus aboveground biomass of *M. sinensis* in all the subplots of C and CF plots was estimated based on the data of patch size in each subplot, using the above simple regression equations. As a result, mean aboveground biomass of C plot in September 1981 was 385.6 g dry $wt \cdot m^{-2}$, which was significantly lower than the value of 623.2 g dry $wt \cdot m^{-2}$ of CF plot.

Coverages of *M. sinensis* patches in May 1981 were not significantly different between C and CF plots ($p>0.05$), but the mean aboveground biomass per unit land area showed a highly significant difference ($p<0.001$) between the two plots. Thus it was concluded that fertilizer application had a beneficial effect on the growth of *M. sinensis*.

Branching pattern of rhizomes and annual increment of patch size

In December 1981, branching pattern of rhizomes of *M. sinensis* was investigated for two patches of *M. sinensis* using the sorting method of Iwaki and Midorikawa (1968). The patches were excavated and rhizomes were separated into age classes. The elongation of the rhizomes occurs radially from the center of the clone and sometimes a dead center is formed in the old stub. The relationships between the dry weight (y) of the rhizomes of various age classes and the age (x) were fitted to logistic function, as follows:

$$y=45.534/(1+67.237\ \exp(-0.888t)) \text{ for patch one}$$

$$y=34.449/(1+134.253\ \exp(-1.197t)) \text{ for patch two}$$

It is suggested that as the rhizomes of *M. sinensis* get older, their growth rates become slow. Eventually the elongation of the patch areas of *M. sinensis* may be largely affected by the growth state of rhizomes. Kobayashi (1979, 1988) pointed out that the number of standing shoots in *M. sinensis* patches relevant to the elongation of the areas increased year by year with a marked seasonal change and after reaching a maximal shoot-number, the patches kept a steady state. From this fact, the *M. sinensis* community in the study site seems to be in younger perennial stage before attained such steady state.

Table 2. Comparisons of community biomass, species richness and diversity indices between C and CF plots. Data are based on measurements of three 2×2 m subplots for each plot in September 1981 and 1982

	1981		1982	
	C plot	CF plot	C plot	CF plot
Biomass (g dry wt·m^{-2})	349	875	425	524
Species richness	18	23	26	25
Simpson's dominance index	0.94	0.63	0.83	0.68
Simpson's diversity	0.057	0.380	0.169	0.322
Shannon-Wiener's function	0.269	1.157	0.659	1.013
Pilou's evenness	0.065	0.256	0.141	0.215

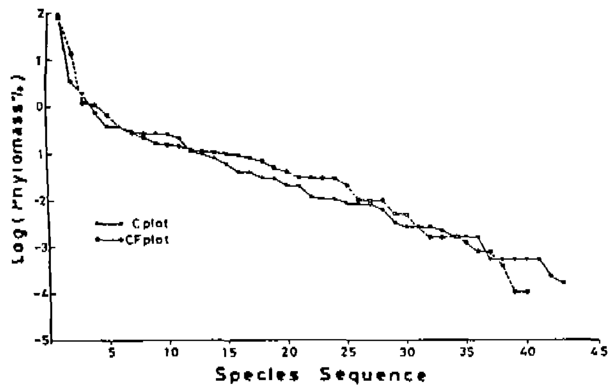

Fig. 3. Dominance-diversity curves for C and CF plots in September 1982 ($\log_{10}$ scale; bit).

The total number of *M. sinensis* patches in the study site in May 1981 amounted to 720 (428 in C plot and 292 in CF plot). More than half of the patches in the both plots were as small as less than 400 cm^2. The percentages of the patches over 1000 cm^2 in size were only 5% and 3.3% for C and CF plots, respectively. This also implies that the *M. sinensis* community in the study site is in earlier perennial stage of secondary succession.

Annual increments in patch size and patch diameter were measured in 1981 and 1982 for 69 *M. sinensis* patches (40 for C plot and 29 for CF plot). Changes of the patch size and patch diameter in 1981 and 1982 are shown in Table 1. Mean annual increment of patch size in 1981 was 469± 61 cm^2 and 390± 48 cm^2 in C and CF plots, respectively. Mean annual increment of patch diameter was 8.7± 1 cm in C plot and 7.9± 0.9 cm in CF plot. There was no significant difference in the rate of patch expansion between C and CF plots in 1981. The size and the diameter of patches were investigated again in November 1982 and they were compared with the data of May 1982. Increment of patch size during this period was 385± 51 cm^2 and 419± 58 cm^2 in C and CF plots, respectively. Increment of patch diameter was 5.90± 0.67 cm in C plot and 6.80± 0.86 cm in CF plot, respectively. Also, there was no significant difference between the two plots. This fact suggests that the growth rate of patch size is not affected by fertilization. According to Kobayashi (1981, 1982, 1988), annual increments in diameter of *M. sinensis* patches showed 8.4 cm in the yearly mean until the patch area amounted to about 1000 cm^2, after which it decreased to nearly 5.4 cm. This conclusion seems to be nearly coincident with the above results, considering that most of the patches in the present study site are below 1000 cm^2 in their areas as stated above.

Species diversity

Since the relative dominance of *M. sinensis* was great, values of diversity indices (H') for the study site were much lower than those for *M. sinensis* grasslands of some other localities of Japan: 1.94-3.03 in Nishime (Iwaki and Midorikawa, 1964), 2.64 in Miyagi (Koike, 1969), 1.13-1.81 in Kawatabi (Shimata *et al.*, 1975) and 3.15 in Sugadaira (Hayashi *et al.*, 1981). The values of diversity indices (species eveness or equitability) in CF plot were higher than those of C plot both in 1981 and in 1982. However, in CF plot the values of diversity indices decreased slightly between 1981 and 1982. In contrast, those of C plot increased much more greatly in 1982 than in 1981. The above results agree approximately with those reported by Muto *et al.* (1985) and Iwaki *et al.* (1985). On the other hand, the number of species (species richness) did not show any significant difference between the two plots (Table 2).

The dominance-diversity curves of C and CF plots were in general of logarithmic series (Fig. 3). As a result of fertilizer application, the relative dominance of *M. sinensis* decreased in CF plot of both years, while those of some other species increased in CF plot. Especially, *Artemisia princeps* was responded to fertilization most favourably with relation to the relative dominance. Thus, the upper portion of the curve in CF plot was less steep than in C plot. It is suggested that the diversity indices are largely a function of dominance rather than of phytomass or productivity. Bakelaar and Odum (1978) found in an old-field ecosystem that fertilization increased relative dominance of the first dominant species of community. This result exhibits contrast with the result obtained in the present study. The reason may be that the site of the present study is very poor in soil fertility and the community is in early perennial stage of secondary succession, as compared with the site investigated by Bakelaar and Odum.

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LITERATURE CITED

Bakelaar, R.B. and E.P. Odum. 1978. Community and population level responses to fertilization in an old-field ecosystem. *Ecology* **59**: 660-665.

Hayashi, I. 1977. Secondary succession of herbaceous communities in Japan. *Jpn. J. Ecol.* **27**: 191-200.

Hayashi, I. 1987. Autecology of the dominant species in early stages of secondary succession: *Miscanthus sinensis* Anderss. *Bull. Sugadaira Montane Res. Cen.* **8**: 9-15.

Hayashi, I. and M. Numata. 1971. Viable buried seed population in the *Miscanthus* and *Zoysia* type grasslands in Japan. —Ecological studies on the buried seed population in the soil related to plant succession VI. *Jpn. J. Ecol.* **14**: 207-215.

Hayashi, I. and M. Numata. 1975. Viable buried seed population in grassland in Japan. *In*, Ecological Studies in Japanese Grasslands with Special Reference to the IBP Area —Productivity of terrestrial communities—, M. Numata (ed.). Univ. of Tokyo Press, Tokyo. pp. 58-66.

Hayashi, I., Y. Hishinuma and T. Yamasawa. 1981. Structure and functioning of *Miscanthus sinensis* grassland in Sugadaira, Central Japan. *Vegetation* **48**: 17-25.

Iwaki, H. and B. Midorikawa. 1964. Standing crop of *Miscanthus sinensis*-type grassland at Nishime, Akita Prefecture. *Bull. Grassl. Ecol. Res. Gr.* **5**: 29-32.

Iwaki, H. and B. Midorikawa. 1968. Principles for estimating root production in herbaceous perennials. *In*, Methods of Productivity Studies in Root Systems and Rhizosphere Organism, M.S. Ghilarov (ed.), Nauka, Leningrad. pp. 72-78.

Iwaki, H., M. Kimura, N. Muto and Y. Oshima. 1985. Species diversity and primary productivity in *Miscanthus sinensis* grasslands 2. Effects of different management practices on species diversity and phytomass. *In*, Origin and Evolution of Diversity in Plants and Plant Communities, H. Hara (ed.), Academica Sci. Book Inc., Tokyo. pp. 345-354.

Kobayashi, K. 1979. Studies on the growth and maintenance of patch of *Miscanthus sinensis* Anderss I. Dynamics of shoot population and its relationships to expansion of patch area. *Jpn. J. Ecol.* **29**: 397-401.

Kobayashi, K. 1981. Studies on the growth and maintenance of patch of *Miscanthus sinensis* Anderss: Formation process of the patch and its ecological characteristic in a warm region. *J. Jpn. Grassl. Sci.* **27**: 71-78.

Kobayashi, K. 1982. Studies on the growth and maintenance of patch of *Miscanthus sinensis* Anderss: Expansion pattern of patch area determined on the base of the distribution of shoots. *Jpn. J. Ecol.* **32**: 219-226.

Kobayashi, K. 1988. Characteristics of the growth of the shoot population in *Miscanthus sinensis* Anderss. *Jpn. J. Ecol.* **38**: 229-242.

Koike, K. 1969. Seasonal change of standing crop and stratification in community of *Miscanthus sinensis*-type grassland. *Bull. Inst. Agr. Res. Tohoku Univ.* **20**: 185-215.

Milner, C. and R.E. Hughes. 1968. Methods for the measurement of the primary production of grassland. IBP Handbook 6. Blackwell Sci. Pub., Oxford. 70 pp.

Muto, N., M. Kimura, Y. Oshima and H. Iwaki. 1985. Species diversity and primary productivity in *Miscanthus sinensis* grasslands 1. Diversity in relation to stand structure and dominance. *Bot. Mag. Tokyo* **98**: 159-170.

Numata, M. 1979. Primary producers in meadows. *In*, Grassland Ecosystems of the World, R.T. Coupland (ed.), Cambridge Univ. Press, Cambridge. pp. 127-138.

Numata, M. and M. Mitsudera. 1969. Efficient environmental factors in relation to growth and production of the *Miscanthus sinensis* meadows in Japan. *Jpn. J. Bot.* **20**: 135-151.

Park, B.K. 1965. Ecological studies on native grassland vegetation in Korea. *J. Kor. Cult. Res. Inst.* **5**: 15-22.

Park, B.K. 1985. Studies on the grasslands in Korea. Ewha Womans Univ. Publ., Seoul. 530 pp.

Pielou, E.C. 1969. An introduction to mathematical ecology. Wiley, New York. 286 pp.

Shimada, Y., H. Iwaki, B. Midorikawa and N. Ohga. 1975. Primary production of the *Miscanthus sinensis* community at the Kawatabi IBP area: Standing crop of aboveground parts. *In*, Ecological Studies in Japanese Grasslands with Special Reference to the IBP Area

—Productivity of terrestrial communities—, M. Numata (ed.), Univ. of Tokyo Press, Tokyo. pp. 110-114.

Simpson, E.H. 1949. Measurement of diversity. *Nature* **163**: 688.

Suganuma, T. and K. Sugawara. 1975. Grassland vegetation of Kawatabi special research area. *In*, Ecological Studies in Japanese Grasslands with Special Reference to the IBP Area —Productivity of terrestrial communities—, M. Numata (ed.), Univ. of Tokyo Press, Tokyo. pp. 13-20.

Yamane, I. and T. Naito. 1975. Soil-plant relation in the Kawatabi grassland. *In*, Ecological Studies in Japanese Grasslands with Special Reference to the IBP Area —Productivity of terrestrial communities—, M. Numata (ed.). Univ. of Tokyo Press, Tokyo. pp. 91-93.

Whittaker, R.H. 1975. Communities and ecosystems. (2nd ed.). Macmillan, New York. 162 pp.

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初期 遷移相 廢耕地 억새草原의 施肥에 대한 反應

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적 요

遷移의 初期相에 있는 억새草原의 構造와 機能에 대한 施肥의 影響이 日本 埼玉縣 本莊市에 있는 하나의 廢耕地에서 2年間 調査되었다. 對照區와 比較할 때, 施肥區의 生活形組成은 地上植物의 減少와 半地中植物의 增加가 觀察되었다. 施肥는 優占種 억새의 地上部 現存量의 增大에 有益한 影響을 미쳤지만, 稈의 總數에는 變化를 일으키지 않았다. 억새의 群斑(patch) 直徑의 年增加는 平均 6-8 cm로 評價되었으나, 施肥區와 對照區 사이에 群斑 크기의 成長率에는 有意한 差異가 나타나지 않았다. 억새의 地上部 現存量의 推定을 위한 非破壞的인 要因 中에서 억새의 群斑 크기는 그것과 높은 相關을 나타내었다. 따라서, 억새의 群斑 크기는 이 종의 地上部 現存量의 評價에 매우 效果的이란 事實을 判明하였다. 構成種의 地上部 現存量 데이타에 의해 計算된 多樣性指數들은 施肥에 의해 약간 增加하였다. 그것은 主로 地上部 現存量에 대한 相對優占度에 있어서 쑥의 增加와 억새의 減少에 起因하였다. 또, 施肥는 種의 總數에 약간의 減少를 야기시켰다.

주요어: 施肥, 草原, 植物現存量, 種多樣性, 遷移

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