# Ecology of Grassland Weeds in Japan

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It is difficult to eradicate weeds in grasslands mechanically. Furthermore, the use of herbicides is undesirable because of their influence on livestock and of their high costs. Consequently, it is important to elucidate the ecology of weeds in grasslands and to control them by a proper management i.e. ecological control of weeds. The authors surveyed weeds of sown grasslands in Japan in order to make clear the ecological characteristics and methods of ecological control of weeds.

In this paper, grassland weeds are defined as plants other than those generally classified as grass and legume.

## Places and methods of the survey

The survey was carried out over four years, from 1971 to 1974. The localities of surveyed places are shown in Fig. 1.

Survey site No. 1 is located in a subarctic region, Nos. 2～5 in a cool temperate region and Nos. 6～10 in a warm temperate region.

A representative unit area with average topography and vegetation was selected for

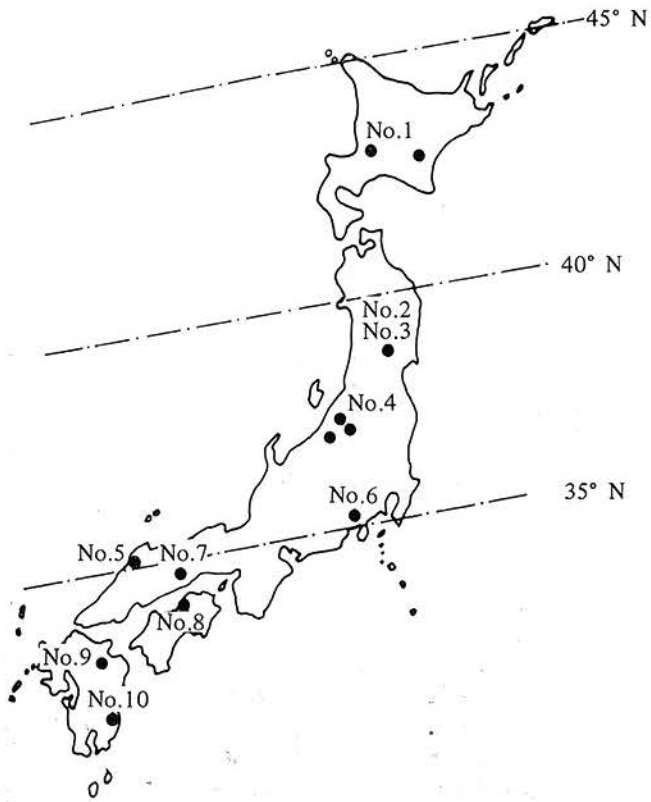


Fig. 1. Localities of the survey sites

survey in each grassland, and the coverage and sociability of each species within each unit area were recorded according to the Braun-Blanquet method.[5] Each survey area, although slightly differing in size depending upon the vegetation type, was about 3 m×3 m.

## Species and grouping of grassland weeds

*1) Weed species*

The number of species of grassland weeds amounted to 258 species belonging to 61 families in Northern Japan, 252 species belonging to 65 families in Southern Japan, 373 species belonging to 78 families in the whole of Japan. There were many species belonging to the families of *Gramineae* and *compositae*.

*2) Life-form of weeds*

The life-form spectra of grassland weeds of 98 species observed more than five times in Northern Japan and of 87 species found more than four times in Southern Japan are shown in Fig. 2. To compare with these species in grasslands, the life-form spectra of the main weed species of upland farm fields (hereafter referred to upland fields[2]) and of *Zoysia japonica* type grassland,[6] semi-natural grassland in grazing lands, at Yunotai, Aomori Prefecture are also shown in Fig. 2.

In dormancy form spectrum, grassland weeds differ from both the weeds of upland fields and the species of *Zoysia japonica* type grasslands. The ratio of "Th" increases in the following sequence; upland field>grassland>*Zoysia japonica* type. Conversely, the ratio of "G" and "H" increases in the following sequence; *Zoysia japonica* type>grassland>upland field. Grassland weeds are midway between weeds of upland field and species of *Zoysia japonica* type when classified into annuals (including biennials) and perennials. Grassland weeds in Southern Japan are placed higher in ratio of "Ph" than in Northern Japan, which is based on the fact that there are more shrubs in Southern Japan.

In disseminule form spectrum, the ratio of "$D_1$"+"$D_2$"+"$D_3$" (mobile plants) increases in the following sequence; *Zoysia japonica* type> grassland>upland field. Notably, there is a small difference between grasslands and upland fields, but a large difference between grasslands and *Zoysia japonica* type.

In radicoid form spectrum, the ratio of "$R_{1-3}$" increases in the following sequence; grassland> *Zoysia japonica* type>upland field, and indicates that grassland weeds are highly capable of radical propagation.

In growth form spectrum, grassland weeds represent the characteristics similar to upland field weeds, but differ a little from species of *Zoysia japonica* type. Thus, judging from life-form spectrum, the characteristics of grassland weeds are situated between those of upland field and those of *Zoysia japonica* type.

*3) Local difference of weed species*

Species of grassland weeds vary not only by climatic factors but also by other factors. The main species of weeds at each site are shown in Table 1. Although *Agrostis alba* and *Holcus lanatus*, which are pasture plants in themselves, are not recognized as sown grasses, and were treated as weeds.

The species occuring at highest frequencies in the whole of Japan were *Rumex obtusifolius*, *Plantago asiatica*, *Erigeron annuus*, *Miscanthus sinensis*, *Erigeron canadensis*, *Stellaria media*, *Rumex acetocella* and *Pteridium aquilinum*.

As for local character, Miyagi Prefecture B (No. 3) area has wild plants which constituted the previous *Miscanthus*-meadow, semi-natural grassland type in hay-land. Hokkaido (No. 1), Miyagi Prefecture A (No. 2) area and Shizuoka Prefecture (No. 6) involve the previous upland field weeds. In Kagawa Prefecture (No. 8) and Miyazaki Prefecture (No. 10), the thorny weeds (i.e. *Smilax china* and *Rosa wichuraiana*) are found more often.

Such a difference among regions is assumed to be due to the previous vegetation and the environmental conditions.

*4) Grouping of weed by community component*

Grassland weeds essentially occur not only in grasslands but also in other plant communities. Grassland weeds are divided into five components,[2,3,7] that is arable land weed component, *Miscanthus sinensis-Zoysia japonica* type com-

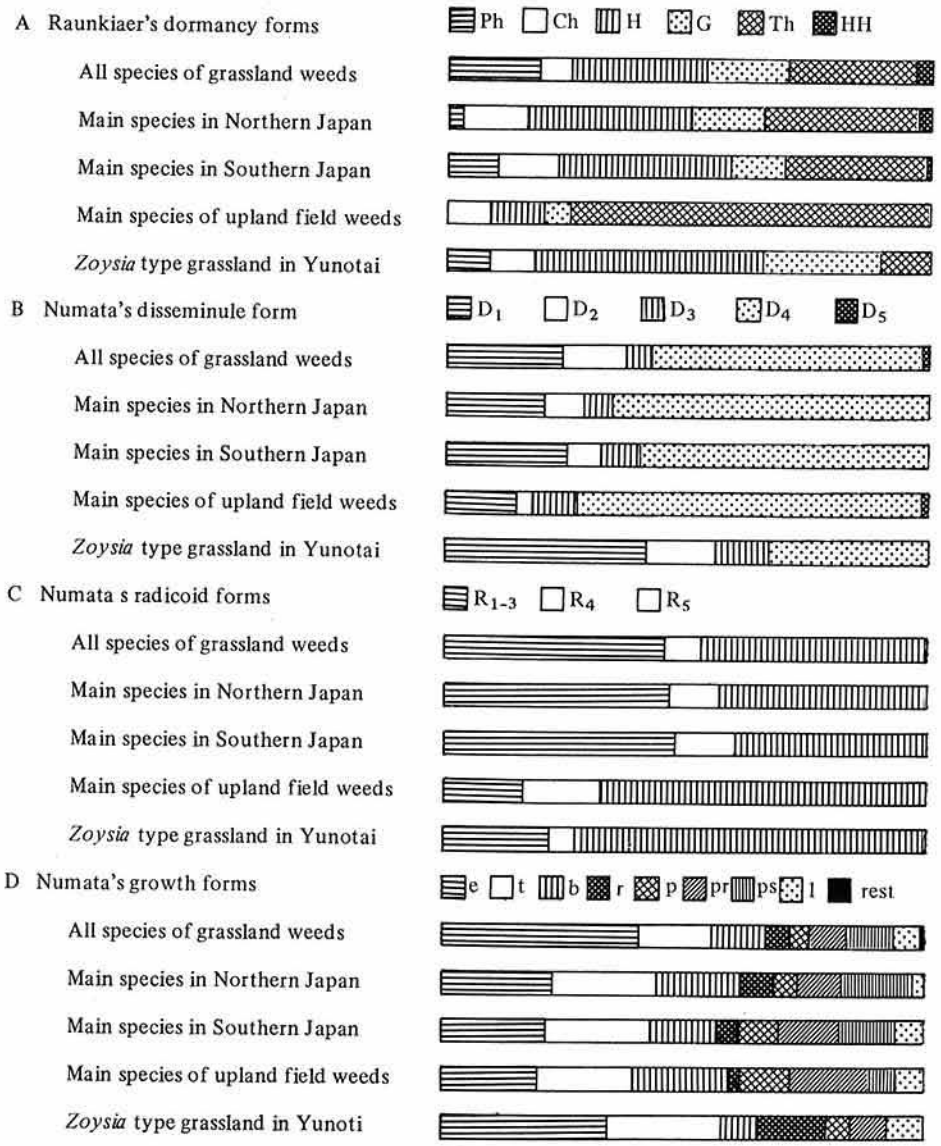


Fig. 2. Comparison of life-form spectra of grassland weeds with upland field weed
Note: The life-form spectra are examined according to the species percentage

ponent, roadside weed component, road weed component and others. The main species in each component are shown in Table 2.

The constituent of these components in the whole weeds occurred corresponds to the environmental factors and the managements of grasslands etc., and indicates the conditions of the grassland.

## Grassland weeds in relation to establishment and utilization of grassland

*1) Weeds and soil condition*

The mixed vegetation composed of *Dactylis glomerata* and *Trifolium repens* is a typical grassland in the cool temperate zone in Japan.

**Table 1. Comparison of appearance of main species of weeds**

| Weed species | Place of survey | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No.1 | No.2 | No.3 | No.4 | No.5 | No.6 | No.7 | No.8 | No.9 | No.10 |
| *Rumex obutusifolius* | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + |
| *Plantago asiatica* | ++ | ++ | + | + | + | ++ | ++ | ++ | ++ | + |
| *Erigeron annuus* | ++ | ++ | | + | ++ | + | ++ | ++ | ++ | ++ |
| *Miscanthus sinensis* | + | + | + | ++ | + | + | + | ++ | ++ | ++ |
| *Erigeron canadensis* | + | + | + | ++ | ++ | + | + | + | + | ++ |
| *Rumex acetosella* | + | ++ | ++ | + | + | + | + | + | + | + |
| *Pteridium aquilinum* | + | + | ++ | ++ | + | + | | ++ | + | + |
| *Agrostis alba* | ++ | ++ | + | ++ | | + | | + | + | ++ |
| *Artemisia princeps* | | ++ | ++ | + | ++ | + | ++ | + | + | ++ |
| *Polygonum Blumei* | ++ | + | | + | ++ | ++ | | + | + | + |
| *Stellaria media* | ++ | + | + | | + | ++ | + | ++ | + | |
| *Stellaria Alsine undulata* | + | + | + | + | | ++ | | + | + | + |
| *Digitaria adscendens* | + | + | | + | + | ++ | + | + | + | |
| *Ixeris dentata* | | + | ++ | + | | + | + | ++ | + | ++ |
| *Potentilla freyniana* | | + | ++ | + | + | + | | ++ | + | + |
| *Taraxacum officinale* | ++ | | | + | | | | | | |
| *Chenopodium album* | ++ | + | | + | + | | + | + | | |
| *Geranium thunbergii* | + | ++ | | | + | + | | | + | |
| *Anthoxanthum odoratum* | + | ++ | + | + | | | | + | + | |
| *Carex nervata* | | | ++ | + | | + | + | | ++ | |
| *Carex lanceolata* | | | ++ | + | | | | + | | |
| *Weigela hortensis* | | | ++ | + | | | | | | |
| *Erigeron sumatrensis* | | | | + | ++ | + | ++ | ++ | ++ | ++ |
| *Smilax china* | | | + | + | | | ++ | ++ | | ++ |
| *Youngia japonica* | | + | | | | + | + | ++ | | ++ |
| *Rosa wichuraiana* | | | | | | | + | ++ | + | ++ |
| *Arundinella hirta* | | | + | + | | + | | ++ | + | ++ |
| *Imperata cylindrica* | | | | | + | | | + | + | ++ |

++ Frequency of appearance was valued more than 30%
+ Frequency of appearance was valued less than 30%

**Table 2. Classification of main grassland weeds by community components**

| Community component | | | | |
|---|---|---|---|---|
| *Miscanthus–Zoysia* type | Arable land weed | Roadside weed | Road weed | Others |
| *Agrostis clavata* | *Acalypha australis* | *Agrostis alba* | *Carex incisa* | *Aralia elata* |
| *Arundinaria pygmaea* | *Amaranthus patulus* | *Anthoxanthum odoratum* | *Carex nubigera subsp. albata* | *Cirsium nipponicum var. shikokianum* |
| *Arundinella hirta* | *Capsella bursapastoris* | *Artemisia montana* | *Eragrostis ferruginea* | *Cocculus trilobus* |
| *Aster ageratoides var. ovatus* | *Cerastium glomeratum* | *Artemisia princeps* | *Juncus tenuis* | *Dioscorea japonica* |
| *Carex lanceolata* | *Cerastium vulgatum* | *Erigeron sumatrensis* | *Plantago asiatica* | *Erechtites hieracifolia* |
| *Carex nervata* | *Chenopodium album* | *Geranium thunbergii* | *Poa annua* | *Lonicera japonica* |
| *Cirsium japonicum* | *Commelina communis* | *Gnaphalium affine* | *Polygonum aviculare* | *Macleaya cordata* |
| *Haloragis micrantha* | *Digitaria adscendens* | *Holcus lanatus* | *Sagina japonica* | *Paederia scandens* |

In the mixed vegetation at Miyagi Prefecture A area, the weeds in *Dactylis*-dominant vegetation and those in *Trifolium*-dominant vegetation were compared. In the former, there are many weeds which are often found in the land deficient in nitrogen (*Rumex acetosella*, *Petasites japonicus*, etc.) or in arid soil (*Plantago lanceolata*, *Aster ageratoides*, etc.), while in the latter weeds which occur in nitrogen rich soil (*Stellaria media*, *Polygonum Blumei*, etc.) or in humid soil (*Carex incisa*, etc.) are pervasive.

2) *Weeds in relation to the method of grassland establishment*

Comparing weeds in the grasslands established by the complete plowing method and the incomplete plowing method in Miyagi Prefecture B, the following results were obtained. In the former, weed had been very few for four years after establishment; number of weed species was from 9 to 13, the coverage of weeds was less than 1% and also very small in weight. On the other hand, in the latter, where some wild plants of the previous *Miscanthus* type grassland remained, weed species numbered from 28 to 33, the coverage was about 10% and dry matter weight ranged from 350 kg to 860 kg per hectare. In the grasslands established by the incomplete plowing, weeds suppress frequently the growth of grasses and legumes, but if the number of species and the weight of weeds are within the range mentioned above, the growth of grasses and legumes is not inferior compared with complete plowing.

3) *Weeds in pastures and meadows*

Comparing weeds in pastures and meadows in Miyagi Prefecture A, the characteristics of weeds dominant in the pastures are as follows;

(1) Low palatability to livestock (*Rumex obtusifolius*, *Geranium thunbergii*, *Pennisetum alopeculoides*, etc.)
(2) Resistant to stamping (*Plantago asiatica Pennisetum alopeculoides*, etc.)
(3) Short plant height and propagation by rhizome (*Equisetum arvense*, *Rumex acetosella*, etc.)
(4) Dispersion through adhesion to livestock (*Pennisetum alopeculoides*, etc.) or through the feces of livestock (*Digitaria adscendens*, *Rumex obtusifolius*, etc.)
(5) Annual weeds (*Digitaria adscendens*, *Polygonum Blumei*, etc.)

## Weeds and the stages of grassland succession

To measure the degree of succession, P-A index (number of species of pernnial weeds minus number of species of annual and biennial weeds) was introduced. The stage of succession, in general, proceeds with increasing P-A index.

The relationships between the successional stages represented by P-A index and weeds in Miyagi Prefecture A are indicated in Table 3. In this table, the successional stages are divided into five groups according to P-A index. Weed species of the group A appear in the early and intermediate stage. Group B appears in the intermediate and late stages. Group C appears in the final stage. The species of group D and E appear frequently in a wide range of serial stages, from the initial stage to the final stage. The weeds belonging to these last two groups seem to be typical grassland weeds in Miyagi Prefecture A.

The relationships between the successional stages and the life-form of weeds are shown in Fig. 3. This figure indicates the species number of weeds in each life-form which emerged in each successional stage of I~V in Table 3. The number of species of weeds appearing in each stage are 13.4 in stage I, 8.7 in stage II, 9.8 in stage III, 11.7 in stage IV and 20.9 in stage V as a mean value per surveyed plot, respectively. In the initial stage, the number of species is relatively high, but in the intermediate stage decreases and thereafter increases toward the end of succession.

As is evident from Fig. 3, in dormancy form, the number of species of "Th" is high in the initial stage and decreases with the proceeding of succession, while the number of species of "H", "G", "Ch" and "Ph" are low in the initial, but increases toward the final stage. In disseminule form, the number of species of mobile plants ("$D_1$"+"$D_2$"+"$D_3$") increases in the final stage. The number of species of "$D_1$" greatly increases in the stage V, almost as many

Table 3. Grouping of main weed species by successional stages, which are specified by P–A index, and number of surveyed plots on which the species has a coverage value larger than 1.

| Group of weed species | Species of weeds | Sucessional stage | | | | |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | V |
| | | Range of P–A index | | | | |
| | | −11∼−2 | −1∼3 | 4∼8 | 9∼13 | 14∼25 |
| A | *Polygonum Persicaria* | 2 | | | | |
| | *Commelina communis* | 3 | | | | |
| | *Digitaria adscendens* | 5 | | | | |
| | *Stellaria media* | 5 | 3 | | | |
| B | *Polygonum cuspidatum* | | 1 | 1 | 1 | |
| | *Carex nubigera* | | 1 | | 1 | |
| | *Geranium thunbergii* | | | | 2 | |
| C | *Hydrocotyle ramiflora* | | | 2 | 1 | 5 |
| | *Miscanthus sinensis* | | | | 1 | 4 |
| | *Aster ageratoides* | | | | | 5 |
| | *Ixeris dentata* | | | | | 5 |
| | *Cirsium japonicum* | | | | | 3 |
| | *Pteridium aquilinum* | | | | | 2 |
| D | *Plantago asiatica* | 3 | 3 | 5 | 2 | |
| | *Rumex obtusifolius* | 3 | 7 | 6 | 2 | |
| | *Agrostis alba* | 3 | 12 | 19 | 7 | |
| | *Rumex acetosella* | 1 | | 1 | 2 | |
| | *Erigeron annuus* | | 1 | 2 | 1 | |
| | *Pennisetum alopeculoides* | | 1 | 3 | 3 | |
| E | *Artemisia princeps* | | 2 | 1 | 2 | 5 |
| | *Anthoxanthum odoratum* | | 1 | 8 | 5 | 6 |
| Number of surveyed plots | | 11 | 18 | 25 | 10 | 6 |

as that of "$D_4$." In radicoid form, the number of species of rhizome plants ("$R_{1-3}$") increases and that of "$R_5$" decreases with the proceeding of the succession and in the final stage both of them increase.

The number of species of each community component of weeds in each serial stage is shown in Fig. 4 (which represents the study result in Miyagi Prefecture A as in Fig. 3). In the initial stage, the number of species of arable land weed component is highest and roadside weed component is the second. In the intermediate stage, arable land weed component decreases and roadside weed component becoming the most abundant. As the succession proceeds toward the final stage, *Miscanthus-Zoysia* type component increases remarkably and roadside weed component decreases slightly. From the relationships between the serial stages and weeds, the sown grassland ecosystem seems to be situated between the arable land ecosystem and the *Miscanthus-Zoysia* type (semi-natural grassland) ecosystem.

## Diagnosis of grassland by weeds

Species and amount of weeds in grasslands change with the succession of grasslands. There fore, the information on species and coverage of grassland weeds may be useful on evaluating the quality of grasslands. It may be possible to estimate the quality of grasslands by putting together the number of weed species, P-A index, soil fertility weed index (number of weed species specified in fertile conditions minus number of

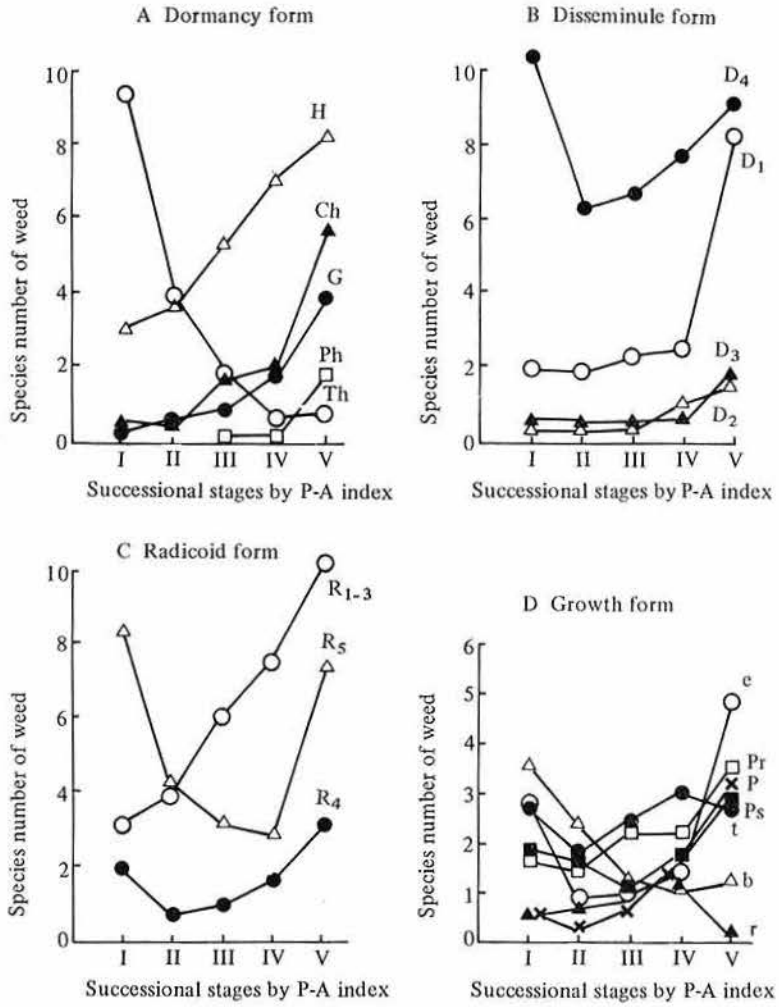


Fig. 3. Relations between successional stages of grassland and life-form of grassland weeds

weed species specified in infertile conditions), indicator species and the life-form spectrum of weeds. Furthermore, it may also be possible to estimate the condition of grasslands by applying a plant sociological method[4] which had been conducted by the study on semi-natural grasslands and sown grasslands[9][10][11].

From the previous surveys by the authors, following species of weeds are specified as indicators for diagnosis of grasslands;

*1) Indicator species of pastures*

The main indicator species of pastures are road weeds (*Plantago asiatica*, *Juncus tennuis*, etc.), annual arable land weeds (*Digitaria adscendens*, *Stellaria media*, etc.), *Geranium thunbergii* and *Pennisetum alopeculoides*.

*2) Indicator species of serial stages*

In the initial stage, the weeds of group A listed on Table 3 appear. In the intermediate stage, group B or a part of group D and E appear, and in the final stage, group C appear.

*3) Indicator species of soil fertility*

In fertile grasslands, the arable land weeds are dominant and in infertile grasslands, *Miscanthus-Zoysia* type component. The main indicator species of each conditions are listed in Table 4.

*4) Indicator species of soil moisture conditions*

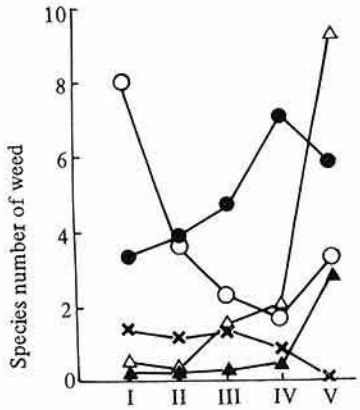


Fig. 4. Relations between successional stage of grassland and community components
Notes: ○ Arable land weed component
● Roadside weed component
× Road weed component
△ *Miscanthus-Zoysia* type component
▲ Other component

**Table 4. Indicator species of soil fertility**

| Indicator species of fertile soils | Indicator species of infertile soils |
|---|---|
| *Amaranthus patulus* | *Agrostis alba* |
| *Capcella bursa pastoris* | *Equisetum arvense* |
| *Chenopodium album* | *Geranium thunbergii* |
| *Echinochloa crus-galli* | *Hypochoeris radicata* |
| *Elsholtzia ciliata* | *Hydrocotyle ramiflora* |
| *Phalaris arundinacea* | *Metaplexis japonica* |
| *Poa annua* | *Oenothera parviflora* |
| *Polygonum aequale* | *Phragmites communis* |
| *Polygonum aviculare* | *Plantago lanceolata* |
| *Polygonum Blumei* | *Rubus parvifolius* |
| *Polygonum nodosum* | *Rumex acetosella* |
| *Rumex obtusifolius* | *Spiranthes sinensis* |
| *Solanum photeinocarpum* | |
| *Stellaria media* | |

In hygroric condition, *Carex nubigera* subsp. *albata*, *Polygonum hydropiper*, *Juncus effusus* are observed. In xeric condition, *Rumex acetosella*, *Erigeron canadensis*, *Anthoxanthum odoratum*, *Petasites japonicus*, *Plantago lanceolata*, etc. are found.

## Control of weeds in grassland

More than 300 weed species occur in sown glasslands in Japan, but only a few of them suppress severely the growth of grasses or poison livestocks. The common species found throughout the country are *Rumex obtusifolius*, *Pteridium aquilinum*, *Rumex acetosella*, *Plantago lanceolata*, *Hydrocotyle ramiflora*, *Erigeron annuus*, *Digitaria adscendens* and *Polygonum* sp.. *Rumex obtisifolius* is the most noxious weed among these plants, and the method of its control will be mentioned later. *Pteridium aquilinum* poisons cattle (Panmyelopathy). Since 1961, poisoning by brackens has been found in the pastures of Japan. Damage by weeds in sown grasslands is more severe and more difficult to eradicate in the warm temperate region than in the cool temperate and subarctic regions. Therefore, the necessity of weed control is more urgent in grasslands in the warm temperature region.

For the ecological control of weeds in grasslands in the early stage after establishment, as shown by the results of the previous studies by the authors, the preferable methods of establishment are in the order of effectiveness; complete plowing>incomplete plowing>hoof cultivation, likewise in sowing time; autumn sowing>spring sowing. likewise in sowing density; dense sowing>sparse sowing, and likewise in fertilization; more nitrogen>less nitrogen.

Weeds increase with the proceeding of succession of grasslands, so it is important to maintain grasslands in the intermediate stage, through preventing succession progress, by conducting adequate management, as well as to consider each weed control. For this reason, it is necessary to carry out appropriate management by considering the environmental conditions.

As to the chemical control of weeds, herbicides used in grasslands are Asulam, MDBA, DNBP, MCPB, DPA, DBN.

*Rumex obtusifolius*[1], which is mostly found in temperate region of the world and is the most noxious weed in grasslands, is hard to eradicate under usual management. It was introduced to Japan with grasses from Europe and America about 100 years ago. At the beginning, it distributed in Hokkaido and Tohoku districts, but, at present, distributed throughout the country. Investigations for its control methods are mostly concerned with utilization of herbicides[8,9]. Concerning the control of *Rumex*

*obtusifolius*, firstly, the seed examination of grasses, secondly, prevention of seed dispersion by clipping (adequate clipping time is before flowering), thirdly, removing by plowing and grubbing up, and fourthly, utilization of herbicides are adopted. Recently, MCPB has been used in one year old grasslands and Asulam in grasslands more than two years old.

## References


1) Cavers, P. B. & Harper, J. L.: *Rumex obtusifolius* L. and *R. crispus* L.. *J. Ecology*, **52**, 737–776 (1964).
2) Kasahara, Y.: Weeds of Japan illustrated. Yokendo, Tokyo, 518p. (1968) [In Japanese].
3) Miyawaki, A.: Trittgesellschaften auf der Japanischen inseln. *Bot. Mag. Tokyo*, **77**, 365–374 (1964).
4) Miyawaki, A. & S. Okuda: Handbook of Japanese vegetation. Shibundo, Tokyo, 69–88 (1978) [In Japanese].
5) Numata, M.: Illustrated plant ecology. Asakura Shoten, Tokyo, 286p (1969) [In Japanese].
6) Numata, M.: Ecological judgement of grassland condition and trend. *J. Jap. Grassl. Sci.*, **11**(1), 20–33 (1965) [In Japanese with English summary].
7) Okuda, S. & Numata, M.: Relationships between succession of *Miscanthus sinensis* community and its productivity based on phytosociological analysis. *JIBP Synthesis*, **13**, 45–50 (1975).
8) Otake, S. et al.: Ecological studies on the control of broad leaf dock, *Rumex obtusifolius* L., in the grassland. *Bull. Hiroshima Pref. Agr. Exp. Sta.*, **33**, 69–74 (1974) [In Japanese with English summary].
9) Sakai, H. et al.: Floristic composition and the dynamics of weeds of sown grassland in Okinawa. *J. Weed Soc. Japan*, **21**(3), 101–106 (1976) [In Japanese with English summary].
10) Sakai, H. et al.: Floristic composition and the dynamics of weeds of sown grassland in Japan. III. Classification of weed communities in sown grasslands in Akita and Yamagata Prefectures. *J. Weed Soc. Japan*, **25**(1), 17–24 (1980) [In Japanese with English summary].
11) Sakai, H. et al.: Floristic composition and the dynamic of weeds of sown grassland in Japan. IV. Dynamics of weed communities in sown grasslands in Akita and Yamagata Prefectures. *J. Weed Soc. Japan*, **25**(1), 24–29 (1980) [In Japanese with English summary].


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