Present Status of *Sasa* Resource in Japan and Examination of Suitable Period for Its Grazing Use

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Sasa (Bamboo grass or dwarf bamboo) species are representative native wild grass in Japan together with *Miscanthus sinensis* and *Zoysia japonica*, all of which are main species constituting semi-natural grasslands. Most of *Sasa* species are distributed endemically in the Far East. In Japan there are many species of *Sasa* and they cover an area of about 50% of mountainous regions, which occupy about 70% (25 million ha) of the whole land area of Japan. Judging from the status that the mountainous area used for grazing is only 500,000 ha at present, it is estimated that *Sasa* resource to be utilized for livestock feed is still very abundant in Japan. Moreover, *Sasa* is evergreen plant and is able to be used even in winter season. From that viewpoint, it is considered that the *Sasa* plant in Japan is one of the most promising resources as roughage for livestock.

In this report the author attempts to give a review on species, distribution, feeding value and biomass of *Sasa* plant in Japan, and also to examine the suitable period for grazing use of *Sasa* resource.

Species and distribution

According to Flora of Japan[12] 11 species are reported as endemic species belonging to genus *Sasa*. Among them, *Sasa kurilensis, S. palmata, S. nipponica* and *S. borealis* are main species distributed widely in Japan. Their distribution and ecological characteristics are shown in Table 1, which indicates that the genus *Sasa* is mainly distributed from cool-temperate zone to subarctic zone. Generally, the distribution area of genus *Sasa* shows an increasing trend with higher latitude, for example, the genus *Sasa* accounts for an area of about 90% of the national forest land in Hokkaido[14]. According to Suzuki[16] and Usui[18], *S. nipponica* and *S. borealis* are mainly distributed in the Pacific Sea side, whereas *S. kurilensis* and *S. palmata* in the Japan Sea side in the northern part (Kanto district and northward) of the country. Such an ecolo-

Table 1. Ecological distribution and characteristics of main *Sasa* species in Japan

Species	Distribution		Ecological characteristics			
	Climatic zone	Main region	Plant height (m)	Winter bud position on culm	Depth of rhizome	Life span of culm (year)
Sasa kurilensis	Cool temperate and subarctic	Japan Sea side in northern region (Kanto and northward)	1.0—3.0	Upper part	Shallow	7—10
Sasa palmata	Cool temperate and subarctic	Japan Sea side in northern region (Kanto and northward)	1.0—1.5	Whole part	Shallow	3— 6
Sasa nipponica	Cool temperate and subarctic	Pacific side in northern region (Kanto and northward)	0.3—1.0	Basal part	Deep	1— 2
Sasa borealis	Cool temperate and subarctic	Pacific side in northern region (Kanto and northward)	1.0—2.0	Upper part	Shallow	3— 6
Arundinaria pygmaea	Warm temperate	Southem region (Tokai and southward)	1.0—3.0	Upper part	Deep	1— 3

gical distribution of genus *Sasa* can also be found out in mountainous zones with elevations higher than 700–800 m, which permit deciduous broad-leaved forests even in the southern region, south of Kanto district. As to this different distribution by species, Usui[18] and Suzuki[16] indicated that the ecological distribution of species is influenced mainly by snow-depth, and is most closely related to the relation between snow-depth and height of winter buds formed on culms (life form), among many ecological characteristics.

Sasa is floor (shade-enduring) plant in deciduous broad-leaved and coniferous forests. But if these forests are once destroyed by cutting, fire etc., it grows rapidly and maintains pure community for long time, although it is in a serial stage of plant succession. Especially, widespread, pure and dense communities of *Sasa* are formed at slopes of volcanoes in the northern part of Honshu.

Apart from the genus *Sasa* mentioned above, there is *Arundinaria pygmaea*, dwarf bamboo, in Japan (Table 1). *A. pygmaea* is distributed widely in hilly areas of warm temperature zone, southward from the Tokai district. It's distribution is within a range of 0–800 m and is replaced by genus *Sasa* over 800 m in elevation. As *A. pygmaea* forms a sun plant community, it's growth is not well in the forest floor or in the forest margin. In areas lower than 300 m in elevation, it is semi-deciduous in winter, but it becomes deciduous at elevations higher than 500 m. *A. pygmaea* has been used for roughage from old time in a similar way as genus *Sasa*. Particularly, at Aso and Kujyu highlands in Kyushu district typical *Sasa* grasslands of dwarf bamboo have been formed by grazing use for many years.

Feeding value of *Sasa*

There is not many study as to feeding value of *Sasa*. Table 2 shows the result of leaf analysis on *Sasa nipponica* by Ohara[11], together with that of orchardgrass (*Dactylis glomerata*) for reference. Contents of crude protein, crude fat and soluble non-nitrogen compounds in *Sasa* leaf are almost similar to those of orchardgrass. However, *Sasa* leaf contains more crude ash and less crude fiber than those of orchardgrass. Also Ohara[11] reported that content of vitamin C in *S. nipponica* is very high. Moreover, in grazing experiment on *S. palmata* grassland with cow, Mitamura[7] reported 0.66–0.88 kg/day of daily gains. These results suggest that the feeding value of *Sasa* leaf is not inferior to that of orchardgrass.

Biomass of *Sasa* community

To utilize *Sasa* plants as livestock feed, it is necessary to make clear the biomass (total plant substance) in communities of *Sasa* species. The biomass of *Sasa* community in Japan differs with species and environmental conditions. Table 3 shows the summarized result on above-ground biomass of *Sasa* species reported upto date in Japan. All of these values were obtained from high density communities. As shown in Table 3, the above-

Table 2. Comparison of feeding value between *Sasa nipponica* and orchard grass (*Dactylis gromelata*)

Species	Crude protein (%)	Crude fat (%)	Soluble non-nitrogen compounds (%)	Crude fiber (%)	Crude ash (%)
Sasa nipponica (Winter season)	11.34	4.36	39.83	28.90	15.57
Dactylis gromelata (Headind stage)	12.10	3.88	40.29	33.98	9.70

% based on dry matter

ground biomass differs remarkably with species. For instance, the biomass of *S. kurilensis* community shows 10 times that of *S. nipponica*. As there is no great differences in leaf amount among *Sasa* species, it is evident that the biomass differences are mainly caused by different culm amounts. As can be estimated from Table 1, the culm amounts of *Sasa* species are closely related to longevity of culms and plant height[14].

Incidentally, in the case of *Sasa* plant, only leaf blade is used as the feed for livestock. Consequently, it can be said that there are no large differences in leaf biomass as feed among species. As shown in Table 3, leaf biomass in dense *Sasa* communities under favourable environmental conditions is in the range of 230–573 g/m^2. However, there are two types of seasonal variations of leaf biomass, namely, one with leaf biomass varying with season and the other with leaf mass kept constant throughout the year. *S. nipponica*, belonging to the former, has a short life span (1–2 years) of leaf and culm, and other many *Sasa* species belonging to the latter, have longer ones (over 2 years). The leaf biomass of *S. nipponica* is reduced in winter to about a half that in summer season (Fig. 1).

However, as compared to the differences in biomass observed among species, differences in leaf area index (LAI) among species are very small. It suggests that annual net production may not differ so much among different species. Oshima[14] reported that *S. kurilensis* community and *S. nikkoensis* community showed about the same annual net

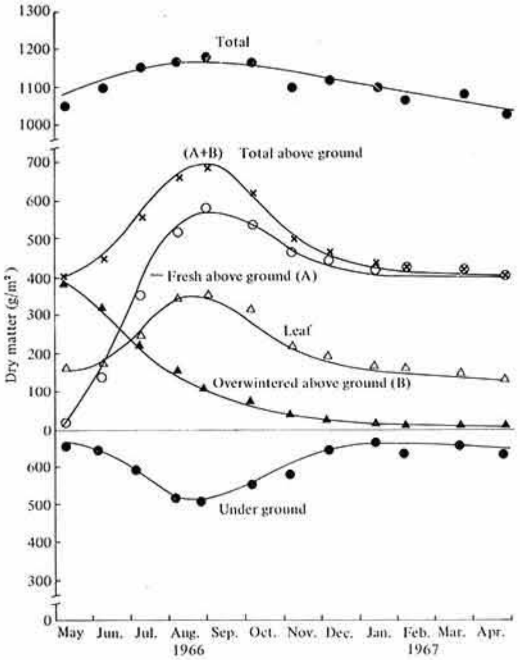

Fig. 1. Seasonal variations of dry weight (g/m^2) of each plant part in *Sasa nipponica* community

Table 3. Biomass of leaf, culm and total above ground, and LAI of communities of some *Sasa* species in Japan

Species	Sampling site (prefecture)	Researcher	Leaf weight (g/m^2)	Culm weight (g/m^2)	Above ground biomass (g/m^2)	LAI (m^2/m^2)
Sasa kurilensis	Mt. Waisuhorun (Hokkaido)	Oshima[14]	465	7,430	7,895	5.2
Sasa kurilensis	Kamisaibara (Okayama)	Saijoh et al.[15]	572	8,000	8,572	6.4
Sasa palmata	Kawatabi (Miyagi)	Naito et al.[9]	229	541	770	4.5
Sasa oseana	Ozegahara (Fukushima)	Oshima[14]	250	1,158	1,408	4.1
Sasa nikkoensis	Mt. Yatsugatake (Nagano)	Oshima[14]	318	1,574	1,892	5.0
Sasa nipponica	Mt. Kirigamine (Nagano)	Oshima[14]	256	490	746	4.5
Sasa nipponica	Mt. Asama (Nagano)	Agata et al.[1]	345	347	692	6.2
Sasa nipponica	Shibahara (Fukushima)	Akiyama et al.[4]	229	477	706	5.0
Sasa nipponica	Mt. Sefuri (Fukuoka)	Agata et al.[2]	298	812	1,110	6.4
Sasa borealis	Chidanemachi (Hyogo)	Nishida et al.[10]	573	1,749	2,322	5.7
Arundinaria pygmaea	Kujyu (Oita)	Iwaki et al.[5]	230	228	458	4.0
Arundinaria pygmaea	Kujyu (Oita)	Numata et al.[5]	230	479	709	5.2

production in spite of that the above ground biomass of the former was about 4 times that of the latter. This result gives an evidence that there is no difference in annual net production of *Sasa* communities of different species under favourable environmental conditions. Such annual net production of *Sasa* community is not so low as compared with that of other native grass communities, such as *Miscanthus sinensis*[6], *M. sacchariflorus*[6], *Arundinella hirta*[6] and *Zoysia japonica*[13] etc. Although the *Sasa* plant is not advantageous for plant matter production owing to its low photosynthetic ability[14] and productive structure of drooping leaf type[3,14] its annual net production is almost similar to other native grasses, depending on the fact that it is an evergreen plant and continues production throughout the year.

Thus, the differences of biomass observed among *Sasa* species can be understood. However, biomass of *Sasa* community varys with environmental conditions, such as solar radiation, air temperature etc. Therefore, the author investigated the relation between annual solar radiation (x) at the floor of various kinds of forest and above ground biomass (y) in *Sasa nipponica* community, and obtained a close relation as follows[1]:

$$y = 6.9x + 53.4 \ (r = 0.943^{**})$$

Furthermore a high positive relation between elevation (x) which is closely related to air temperature and leaf biomass (y) in *Sasa nipponica* community was also obtained as follows[1]:

$$y = -0.19x + 578.3 \ (r = -0.989^{**})$$

Examination of suitable period for grazing use of *Sasa* grassland

For grazing use of *Sasa* grassland for successive years, it is desirable to maintain above-ground biomass constant for many years. But, above-ground biomass in *Sasa* community tends to decrease year after year when it is utilized by grazing for successive years. To keep biomas to be constant every year, it is important to establish a rational method of grazing use based on annual growth pattern and cutting response of biomass. The author carried out the following study[3] with *Sasa nipponica*, which is superior in palatability and intake among *Sasa* species.

1) Annual growth pattern

Monthly changes of dry matter of each organ obtained from the dense community of *Sasa nipponica* are shown in Fig. 1. Above-ground biomass increased rapidly from spring to summer, reaching a maximum in late August, and then decreased gradually towards the next spring. When the above-ground biomass was divided into the fresh one (newly produced in the year) and the overwintered one, it was found that new culms sprouted in May produced the fresh biomass, which exceeded the overwintered biomass in June, and then most of the biomass was dominated by the fresh one in August.

Contrastingly, the under-ground biomass showed the trends of decrease from mid-spring to summer and of increase towards late autumn. The decrease until summer and the increase after summer correspond to the rapid increase of fresh biomass and the supply of assimilate from the fresh biomass, respectively. Thus, the total of above and underground biomass is kept almost constant throughout the year. Such a seasonal change has been recognized in other *Sasa* species[4,14], indicating that annual growth pattern of *Sasa* community is not so different with species.

Moreover, it was made clear that numbers of winter buds on rhizomes and of new rhizomes also showed seasonal variations[3] and time of their formation differs each other owing to their differential response to day length[3].

2) Biomass response to cutting

Influence of time and frequency of cutting on biomass was studied with *Sasa nipponica*[3]. The results are shown in Fig. 2 and Fig. 3. As shown in Fig. 2, monthly cutting resulted

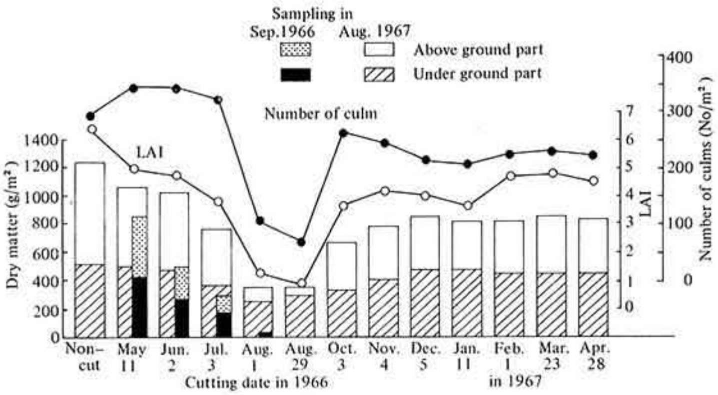

Fig. 2. Influence of cutting time on biomass (g/m²) of the whole plant, above- and under-ground parts, number of culms (No./m²), and leaf area index in *Sasa nipponica* community

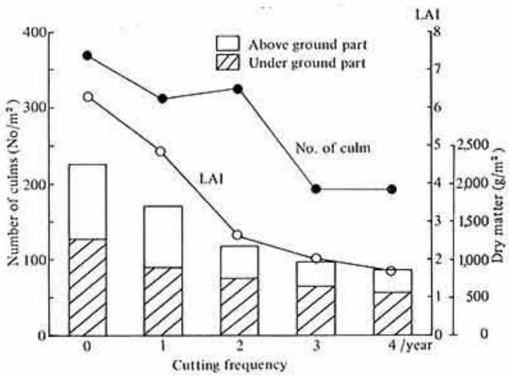

Fig. 3. Influence of cutting frequency on biomass (g/m²) of the whole plant, above- and under-ground parts, number of culms (No/m²), and leaf area index in *Sasa nipponica* community on Sept. 26, 1968. (Cutting treatment was carried out during summer growing season in 1967)

in above ground biomass less than 60% of the non-cutting treatment (control). Summer cutting, in general, decreased the biomass more seriously than autumn-spring cutting, especially cutting in August induced drastic decrease.

The under ground biomass, number of culms and LAI were affected by the cutting treatment similarly to the above-ground biomass. Such results were also observed with *Sasa palmata*[20], *S. borealis*[18] and *Arundinaria pygmaea*[17].

Regarding the remarkable reduction in above-ground biomass caused by August cutting, it was confirmed that the decreased under-ground part and retarded winter bud formation in autumn were responsible for it[3].

Fig. 3 shows the effect of cutting frequency. The biomass above and under-ground, number of culms and LAI were remarkably decreased in parallel to the increase of cutting frequency.

3) *Suitable grazing period*

From the results shown above, it can be concluded that the suitable period for grazing which enables utilization of biomass year after year is from November to April, because reserve substances and winter buds are sufficiently prepared in rhizomes by this periods, and also the amount of above-ground biomass taken away by grazing is less than that in other months. However, as the biomass of *Sasa* community tended to decrease by grazing as well as cutting, the most desirable method of utilization is to adopt a rotational grazing or no grazing at an interval of 2 or 3 years. On the other hand, to convert *Sasa* grassland to other uses, such as tame grassland and afforestation, summer season, especially, August is the most suitable period to do it, because *Sasa* community is destructed most effectively.

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