Exploring Subtropical Grasses Adapted to Low Temperature from Asian Countries

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Species ecology of native grasses in Japan

Japan is situated in the middle of the north latitue and belongs to the Asian monsoon climatic zone.

A mixed up aspect of northern element with the southern one can be observed on the grasses of this country in the same way as cold current meets with the warm one around the Japanese mainland.

The southern element (*Miscanthus*, *Zoysia* etc.) is sweepingly dominant over almost the area of Japan, while the northern element (*Sasa*, *Calamagrostis* etc.) is dominant over the northern area of the island of Hokkaido.

Here subfamily *Panicoideae* and *Eragrostoideae* are designated as the southern element, and the species of *Festucaideae* is designated as the northern element (Kawanabe 1968).

Among the southern element, a few of the genera or species originated in the tropics or subtropics of Asia had been adapted to low temperature and might have developed their distribution to the north of the Japanese mainland.

Genus *Miscanthus* to which *Miscanthus sinensis* belongs will be discussed hereunder as a representative species in the Japanese grassland.

This genus seems to have been derived from genus *Saccharum* which distributes in the tropics. Among six species of *Miscanthus* distributed in Japan, *M. floridulus* and *M. candensatus* are distributed only in the southern area, the former has been distributed in the subtropics while the latter has developed its distribution in the southern warm temperate zone. The former is regarded as the ancestor of the many species of genus *Miscanthus* (Lee 1964). *M. floridulus* is an evergreen species and *M. condensatus* is a half evergreen species. All other *Miscanthus sp.* are of summer green.

The fact that many of the annual grass species of the southern element are distributed in the northern area, and the relation between the distribution and phenological type mentioned above suggest as follows; that is, most of the southern element species have no tolerance for cold weather and are confined to the tropics and subtropics, but a few of the species have acquired the adaptability for low temperature and developed its distribution to the northern area in Japan.

Cultivated grasses in Japan

Sown grasslands in Japan can be roughly classified into two types; one is paddy or upland field where annual grasses have been cultivated mostly in short rotation, and the other is the permanent pasture of hilly land where perennial grasses have been cultivated. As for the annual grasses, *Lolium multiflorum* (Italian rye grass) has been much cultivated. *Chlories gayana*, a perennial grass in the tropics, has been cultivated as an annual grass and recently the test cultivation of *Eleusine indica* var. *Coracane* and *Paspalum distichum* was carried out.

As for the perennial grass, the temperate grass such as *Dactylis glomerata* (orchard grass) and *Fertuca arundinacea* (tall fescue) are the majority, and the subtropical grass such as *Paspalum dilatatum* (Dallis grass) is cultivated only in a small area.

In southern Japan, the decline of summer production, the shortening of persistency; namely, the damage of summer depression are unavoidable for temperate grasses which belong to the group of the northern element described above. Growing the grasses, which belong to the northern group, in the area where the southern element is dominant seems very rare.

Furthermore the temperate grasses, which originated in the Mediterranean region and have been bred in Europe and America are cultivated in Japan while the species originated in Japan which are not used utterly must be very rare. Some Japanese ecologists criticized such present situation from the point of view that the indigenous species are most adaptable to the land.

Significance of the introduction of subtropical grasses

Some examinations on indigenous grass had been made in Japan. A certain effort had been made on the cultivation of *Miscanthus sinensis* (Susuki), *Pueraria Thunbergiana* (Kuzu), and *Lespedeza bicolor* (Hagi) etc. But the difficulty of the multiplication by seeds, short growing period, low increase rate of yield in response to fertilizer and low ablity of regrowth after cutting or grazing are the common defects of these plants.

Though it is not so much as the case of general crop plants, the cultivation environment of grass is greatly different from the natural one, that is, fertilizer is applied, cutting and grazing are repeated and sometimes soil is turned over with plough. No species of grasses grown in natural environment can adapt to such artificial environment. This may be the cause that native grass cannot give good result. And the fact that species grown in a certain environment is not the only one which is most adaptable to that environment also is a good reason for the important introduction (Kawanabe 1967).

Even the species, which possesses the potential to grow up in an environment, could not grow in that environment because of its distribution prevented by isolation. This can be substantiated the existence of many cosmopolitan varieties of weeds or ruderals which had been distributed widely according to the development of communication and transportation, and isolation may be clarified by geohistory.

Experiments on the responses of subtropical grasses against low temperature

Low temperature adaptability is always the first target for the exploration of perennial or annual grasses which are suitable for cultivation in the warm regions of Japan. As to the low temperature adaptability, there are two points to be considered, one is the good growing ability in low temperature region and the other is winter survival. The former is needed for annual grasses and the latter is especially necessary for the perennial.

These two characters are incompatible with each other, for example, in *Medicags sativa* (Alfalfa), the winter hardy variety is suitable for cultivation in cold area but its growth declines soon in autumn and comes into dormancy, while non-hardy variety which is suitable for warm region shows a contrary trend.

An example of the study on the low temperature adaptability with respect to *Chloris gayana* and *Setaria sphacelata* which orginated from different altitudes is introduced hereunder (Neal-Smith C. A. and S. Kawanabe).

1) Chloris gayana

This is the grass originated in East Africa and is suitable for cultivation in warm

Table 1. Origin and growth form of cultivars of *Chloris gayana*

Cultivar	Origin	Altitude (m)	Growth form
Serere	The natural, unselected variety from Serere reserch station, Uganda	1.170	Stemy
Mpwapwa	Detected near Iringa, Tanganyika	1.730	Leafy
Nzoia	A diploid variety of suspected S. African origin, First recorded near Kitale	2.000	Leafy
Mosaba	A variety from Endebess, Kenya	2.270	Stemy

region. Growth under low temperature in the phytotron was compared with four cultivars from Kenya and one Australian commercial variety (Table 1).

The maximum distribution limit in altitudes of this grass is 2,700 meters in Kenya, but the majority is found in altitudes below 2,000 meters.

As to the climatic condition of this area, day length and temperature are scarcely variable through out the year because this area is situated just under the line, but diurnal range is very large. In the area of the maximum distribution limit in altitude, the mean value of daily maximum temperatures seems to be 21 to 22°C, and that of daily minimum temperature may be 4 to 5°C. Summer is not so hot and winter is not so cold. The climate is very mild.

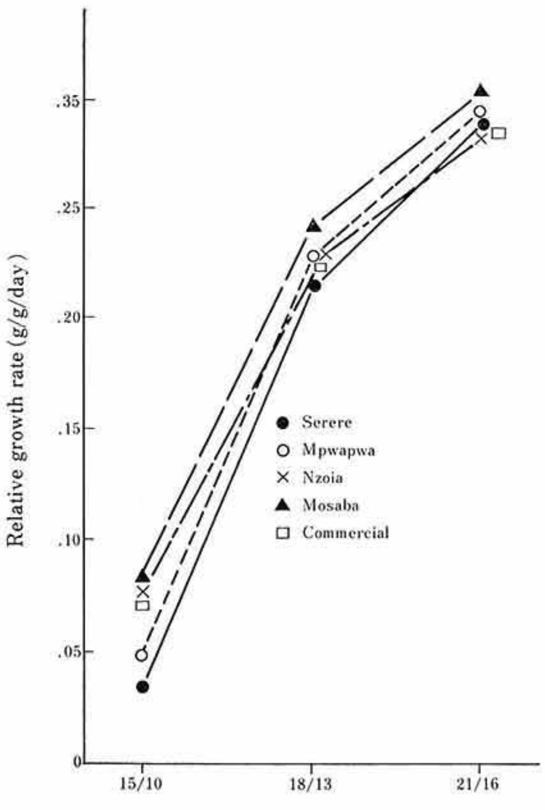

Fig. 1. Comparison of relative growth rate of five cultivars in *Chloris gayana* originated from varied altitudes

Fig. 1 shows the relative growth rate (RGR) of young plants of each cultivar grown in the plytotron under the temperature of 15°/10°, 18°/13° and 21°/16° (day/night °C). RGR of commercial variety and that of Nzoia and Mosaba both of which originated in high altitude are higher than those of Serere and Mpwapwa which originated in low altitude.

The grasses grown under the temperature of 15°/10°C had pale green leaves and showed very little growth because this temperature was the minimum limit for the growth of subtropical grasses. The cultivar originated in high altitude, however, showed fairly good growth. Clausen et al. (1948) have revealed that there is a close relation between the climate of habitat and the temperature response of the plant grown there. This principle can be applicable to the grasses too.

2) Setaria sphacelata

This grass has not been cultivated in Japan but it is an important species in Australia. This genus is an interesting source for exploration because many differentiations of this genus can be found in crop plants and weeds. Fig. 2 shows field comparison of the winter survival and yield among five varieties originated from different altitudes.

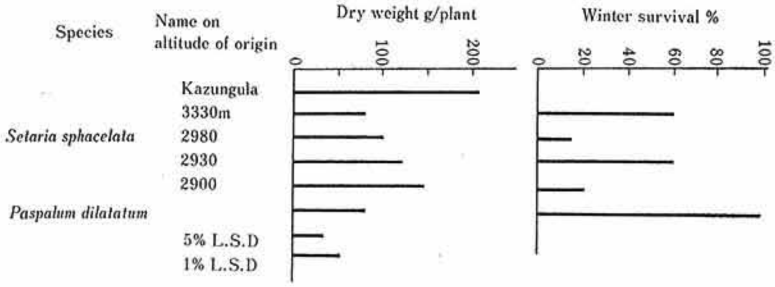

Fig. 2. Dry weight and winter survival of five varieties of *Setaria sphacelata*, comparing with *Paspalum dilatatum*

This grass also grows naturally in Kenya and its distribution limit in altitude is 3,330 meters in the maximum which is higher than that of *Chloris;* therefore, there may be the possibility to contain higher cold resistant varieties in this strain.

As is shown in the figure, the winter survival rate of the varieties originated in the altitude of 3,330 meters or 2,930 meters was 60%, while that of Kazungula (a commercial variety) was 0%. Therefore, it is observed that there are good winter-survival varieties in the strain originated from the high altitude region. In this experiment, the winter-survival rate of *Paspalum dilatatum* was 100% and that of all the *Chloris gayana* varieties was 0%. From these results, it is inferred that the *Setaria sphacelata* strain includes comparatively good winter-survival varieties.

As to the yield per individual, the Kazungula yield is the highest and that of the varieties originated from high altitude is low. The *Paspalum dilatatum* yield was the same as the variety originated in the 3,330 meter altitude. It was also observed that the varieties originated in high altitude are small in plant height and they are less vigorous. So far as the varieties collected here are concerned, the winter survival and yield cannot be compatible. If this is true, the next step of study shall be transferred from introduction to breeding.

Exploring genetic resources in Asia

The experiment described here is only one more step into the study on the introduction. It is desirable, furthermore, that the investigation on many species or strains of grasses is advanced from the points of ecology, physiology and biochemistry (Kawanabe 1971).

The results described above, however, are sufficient to point out the importance of the examination on the climatic condition of natural habit for exploration and introduction. Therefore, it may be necessary to investigate the habitat previously for exploring and introducing the species and strain of grasses.

Though the genetic resources of subtropical grasses in Japan are very poor, that of foreign tropical and subtropical countries are very abundant.

The grass resources in Africa are fairly well known from many data, and some investigations have been also carried out by Japanese recently. But studies on grasses in tropical Asia are really not very good. Whyte (1970) has proposed a worldwide investigation on the grass resources and it seems necessary especially for Asia.

Vavilov (1951) had indicated that plants of original area are rich in variability. Hartley reported that south Asia is a differentiation center of some *Andropogoneae* (*Saccharum*, *Miscanthus* etc.).

Therefore, the investigation on Asian grasses must be important. In Asia as well as in other continents, the tropical mountainous areas must be investigated at first because that areas seem to be the differentiation center of plants (Axelrod, 1960).

References

1) Axelrod, D. I.: The evolution of flowering plants, Tax (ed.), Evolution after Darwin. 1, 227–305, Chicago Univ. (1960).
2) Clausen, J., Keck, D. D. & Hiesey, W. M.: Experimental studies on the nature of species. III. Environmental responses of climatic races of Achillea. *Publs. Carnegie Instn.* 581, 129 (1948).
3) Hartley, W.: Studies on the origin, evolution and distribution of the Gramineae. I. The tribe Andropogoneae. *Aust. J. Bot.*, **6**, 116–128 (1958).
4) Kawanabe, S.: Significance and method of exploration and introduction of new pasture species. *Nogyo gijutsu* (Agr. techniques), **9**, 6–11 (1967). [In Japanese]
5) Kawanabe, S.: Temperature responses and systematics of the Gramineae. *Proc. Jap. Soc. Plant Taxo.*, **2**, 17–20 (1968).
6) Kawanabe, S.: Some problems on ecology, cultivation and utilization of tropical and subtropical pasture species. *Chikusan no kenkyu* (Anim. husbandry), **25**, 1181–1185, 1315–1318, 1442–1444, 1570–1574 (1971). [In Japanese]
7) Lee, Y. N.: Taxonomic studis on the genus *Miscanthus* (3). Relationships among the section, subsection and species. I. *J. Jap. Bot.*, 38, 196–204 (1964).
8) Neal-Smith, C. A. & Kawanabe, S.: [Unpublished data]
9) Vavilov, N. I.: The origin, variation, immunity and breeding of cultivated plants. The Ronald Press, New York (1951).
10) Whyte, R. O.: The archaeology, history and taxonomic geography of the *Gramineae*. *Plant Introduction Newsletter*, No. 24, 32–36 (1970).