JARQ 27, 106-111 (1993)

Genetic Resources of Orchardgrass (*Dactylis glomerata* L.) and Related Subspecies from Warmer Regions

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Abstract
Characteristics of orchardgrass populations collected in 7 regions in Japan were studied for a period of 5 years. Populations from the Kanto region showed the best performance, indicating a high adaptation to the region. Factors which had contributed to the differentiation of ecotype populations in Kanto were discussed. Characters of several introduced subspecies of *Dactylis glomerata* L. were evaluated in relation to their native habitats. Subsp. *marina* from the sub-tropical coastal region differed from the others by the high degree of greenness in winter. Subspecies *himalayensis* was very late in heading. Subsp. *lusitanica* from Portugal showed good growth under short daylength. Populations of the subspecies of *Dactylis glomerata* L. collected in Morocco and Portugal were evaluated at NGRI, Japan. Fresh weight was low throughout the year in the populations from Morocco and high in those from Portugal. Many populations from Portugal displayed better growth in late autumn. Examination of the characteristics of populations in relation to the local climatic conditions indicated that fresh weight and leaf size increased in accordance to the increase of rainfall in the collection districts.

Discipline: Grassland
Additional key words: adaptation, autumn growth, ecotype population

Introduction

Populations of *Dactylis glomerata* L. are widely distributed in the world and their high genetic adaptability is reflected by the diversity of the environments in which they are growing. Differentiation of diploid and tetraploid subspecies with different habitats has been reported in warmer areas such as Southwestern Europe and North Africa[2,7,8].

Collection of genetic resources of *Dactylis glomerata* L., both within and outside the country has been carried out in recent years by Japanese teams and the evaluation of the collected materials has been pursued at the National Grassland Research Institute (NGRI) in Japan.

Although orchardgrass (*Dactylis glomerata* L. subsp. *glomerata*) is one of the most important grasses in meadows and pastures in Japan, its acreage in warmer regions is not as large as that in cooler regions. As the need for higher forage production in warmer regions is increasing, the use of genetic resources as materials for breeding better adapted cultivars is important. In this paper, recent results of the evaluation at NGRI and discussions from the viewpoints of adaptation of populations are presented.

Ecotype populations from the Kanto region of Japan

Orchardgrass was first introduced to Japan at the beginning of the Meiji era from the United States. Some of the populations were considered to be acclimatized to Japanese environments during nearly 100 years of use in pastures and meadows, and

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materials for breeding works have been obtained from them.

In a national project which started in 1984 for the utilization of the ecotypes of grasses and legumes in Japan, plants and seeds of orchardgrass were collected from pastures, meadows and roadsides throughout the country.

Out of these collections, 28 populations from 7 regions in Japan were evaluated for 5 years at NGRI, located in Nishinasuno in the Kanto region[3]. Significant differences were recognized between populations from the 2nd year harvest and differences between regions became more distinct with the lapse of time (Fig. 1). Populations from Kanto showed the best adaptation to the conditions of the region; the dry matter weight in the 4th year and yield ratio of the 4th year to the 2nd, which reflects the persistency of the yielding ability, were the highest in the populations from Kanto (Plate 1), followed by those from Tokai and Chu-Shikoku and Kyushu. The populations from cool regions could not perform well in Kanto. Populations from Kanto showed a high degree of greenness of leaves from

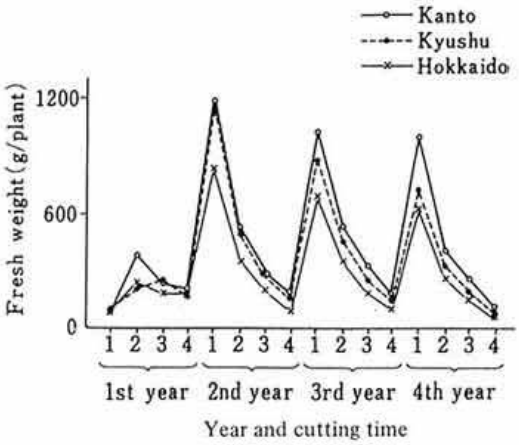

Fig. 1. Changes of fresh weight with the year of harvest in orchardgrass populations collected in Japan (NGRI, 1986-1989)

Plate 1. Vigorous and uniform growth of Kanto populations in the 4th year (NGRI, May 31, 1989)

Table 1. Characteristics of collected populations of orchardgrass, grouped by regions

Regions of collection	Greenness[a]	Dry matter (g/plant)	Persty.[b] (4yr/2yr)	Regr. v.[c] (89.7.27)	Blight[d] (88.9.4)	Heading date (May)	Survival from SH[e]
Hokkaido	2.2	272	77	3.5	4.3	14.4	34.2
Tohoku	2.7	309	68	4.0	4.1	7.8	51.8
Hokuriku	3.2	328	72	4.3	4.1	11.7	38.1
Kanto	3.6	440	81	5.0	2.6	10.8	88.3
Tokai	3.6	382	79	4.5	2.6	10.9	132.9
Chu-Shikoku	3.7	346	74	4.3	3.9	9.6	82.7
Kyushu	3.2	335	63	4.0	3.3	13.5	58.6
C1[f] Sapporo	2.1	354	70	4.2	3.3	21.4	18.0
C2[f] Nishinasuno	2.4	455	90	5.0	3.2	14.2	35.7
C3[f] Kumamoto	3.4	407	71	4.6	3.7	16.9	27.3

a): Degree of greenness in early spring (March); 1 (yellow) - 5 (green).
b): Persistency; Fresh weight ratio(%) of 4th year to 2nd year.
c): Regrowth vigor; 1 (very low) - 9 (very high).
d): Summer blight; 1 (slight) - 9 (very severe).
e): Survival from SH; Number of plants which survived to the spring of the next year (plants/1.5 m^2, from shattered seeds of 5th year).
f): C1-C3; mixture of clones artificially selected at three breeding stations as check strains.

early spring and displayed the highest regrowth vigor in summer (Table 1). Occurrence of summer blight (*Rhizoctonia solani*) was minimal in the populations from Kanto and Tokai. Dry matter weight in the 4th year was correlated with the regrowth vigor in summer and occurrence of summer blight in the previous year, and in the multiple regression analysis, 82% of the among-population variations in dry matter weight were accounted for by using these two characters as independent variables.

As for the reproductive growth, no consistent differences in heading date were recognized between regions. However there was a significant difference in the number of plants which survived to the next year from shattered seeds in the 5th year: the number of surviving plants in the collected populations from warmer regions was apparently larger than that from cool regions and check strains.

Based on these results, the following suggestions were made concerning the factors which had contributed to the differentiation of ecotype populations in the warm region of Japan. Selection in competitive swards under the humid and high temperature conditions of summer was severe, resulting in the death of unadapted genotypes and survival of plants which showed a higher regrowth vigor and disease resistance. The plants which survived intercrossed within a population to form the next generations, and the new adapted population must have been differentiated through repeated intercrossing, seed shattering and selection among the plants which survived. It was inferred that better summer regrowth and resistance to diseases under severe summer conditions were the major factors for the differentiation of ecotype populations in the warmer region of Japan[3,5].

Evaluation of characters of introduced subspecies

Evaluation from 1987 to 1990 included five subspecies of *Dactylis glomerata* L. as follows: subsp. *woronowii*, subsp. *hispanica*, subsp. *marina*, subsp. *lusitanica* and subsp. *himalayensis*[6].

Among the characteristics observed during spring growth, difference in the heading date was recognized among subspecies. Subspecies *woronowii* and *hispanica* were earlier than the other ones and subsp. *himalayensis* was very late in heading. In the morphological characters at the time of the first cutting, subsp. *himalayensis* showed the longest culm, the longest panicle and the largest leaves. On the contrary, subsp. *marina* of the subtropical type showed the shortest culm, panicle and leaf. Subspecies *woronowii* and *hispanica* also had short panicles and narrow leaves. Subsp. *lusitanica* had longer panicles and larger leaves than the subspecies of the Mediterranean type (Table 2).

In autumn growth represented by the plant length and fresh weight at the end of October, the performance of subsp. *lusitanica* was better than that of the others, indicating the high growth ability of this subspecies under short-daylength conditions. In contrast, the growth of subsp. *himalayensis* ceased early in autumn. The degree of greenness in winter was especially high in *marina*, which distinguished this subspecies from the others.

The observed characteristics of these subspecies reflected the differences in the environmental conditions of their habitats. Subsp. *marina* grows in coastal regions of Southwest Europe, North Africa and Atlantic islands[1]. The greenness of the leaves

Table 2. Characteristics of introduced subspecies of *Dactylis glomerata* L.

Subspecies	Heading date[a]	Observed at the 1st cutting				Fresh wt. (g/plant)	
		Culm[b] (cm)	Panicle[b] (cm)	Leaf[b] (cm)	Leaf width (cm)	Oct. '87	May '88
woronowii	Apr. 22	57.3	8.6	13.3	0.73	67	338
hispanica	May 2	80.0	12.6	20.5	0.75	88	440
marina	May 13	45.3	6.3	11.2	0.78	24	159
lusitanica	May 12	79.4	18.6	23.8	1.00	162	524
himalayensis	Jun. 18	123.4	29.3	37.1	1.35	–	282

a): Heading date is the mean of 1987 and 1989.
b): Length of culm, panicle and leaf were measured at heading time in 1989.

of this subspecies during the winter seems to be derived from the warm winter conditions of the native habitats. Subsp. *himalayensis* grows under a continental climate at a high altitude ranging from 1,800 to 4,000 m[7]. The growth of the plants stopped earlier in autumn, probably because their resistance to low temperature under winter conditions was associated with short day-length. On the other hand, subsp. *lusitanica* from Portugal showed good growth in autumn, which may be attributed to the mild climate of its habitat.

Populations of *Dactylis glomerata* L. collected in Morocco and Portugal

In July of 1986, two Japanese researchers (Sato, S. and Turumi, T.) collected genetic resources of forage plants in Morocco and Portugal. From the 101 accessions of *Dactylis glomerata* collected during their exploration, 26 populations from Morocco and 21 populations from Portugal were used for evaluation. Ten subspecies preserved at NGRI and 2 Japanese cultivars (Akimidori and Makibamidori) bred at NGRI were included in the materials for comparison[4].

1) Comparison of characteristics among populations

Populations from Morocco were mostly early in heading and growth during summer was poor, while many populations from Portugal were late-heading and exhibited a higher fresh weight throughout the year. Frequency distribution of populations from Morocco and Portugal (Fig. 2) for the fresh weight clearly illustrated the larger variation in the Portugal populations than that in the Morocco populations. When they were compared with the cultivars from Japan, many populations from Portugal showed a higher fresh weight than the Japanese cultivars in late autumn (4th cutting). The populations from Portugal were peculiar in that they showed a high degree of heading in the aftermath growth of August, strongly resembling the subspecies *lusitanica*.

Among the introduced subspecies, *judaica* was the earliest in heading date, but its regrowth was poor in summer. Other two subspecies of the Mediterranean type, *juncinella* and *mairei*, also showed a poor regrowth. On the contrary, subsp. *lusitanica* which is late-heading, produced many heads in summer regrowth and a high fresh weight in autumn as well as in early spring.

As the populations from Portugal displayed

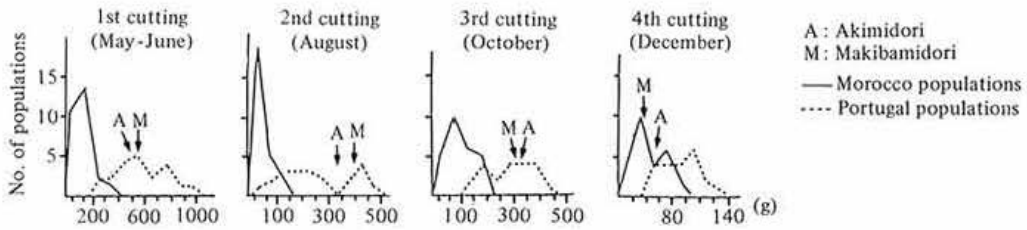

Fig. 2. Frequency distribution of fresh weight in populations collected in Morocco and Portugal (4 cuttings in 1990)

Table 3. Climatic conditions of collection areas and the evaluation station (NGRI)

Area	City	Latitude	Rainfall (mm)		Temperature (°C)		
			Annual	Apr.-Sep.	Yearly mean	Oct.-Mar.	Apr.-Sep. (Aug.)
Morocco	Casablanca	33°34′	493.1	68.5	17.4	14.8	20.0(22.4)
Portugal							
Interior	Campo Maior	39°00′	518.8	135.6	16.5	11.8	21.2
Center coast	Lisbon	38°46′	707.5	154.8	16.6	13.3	19.8(22.5)
North coast	Porto	41°10′	1,149.6	310.5	14.4	11.4	17.5
Japan	Nishinasuno	36°55′	1,631.8	1,208.1	12.3	5.9	21.2(24.8)

interesting characteristics such as good growth in late autumn, the chromosome numbers of five collected populations and a few subspecies were counted. Plants from the subsp. *lusitanica* were diploid as generally recognized. Plants from five Portugal populations were diploid. Four of them were late in heading and resembled *lusitanica* in morphological characteristics, suggesting that most of the populations collected in Portugal may belong to the subsp. *lusitanica*.

2) Relation between characteristics and climatic conditions of the collection areas

Large differences in the fresh weight, leaf size, disease occurrence and degree of heading in summer were recognized among the populations collected in the two countries.

Collection sites were divided into five areas based on the climatic conditions (Table 3 and Fig. 3) and the differences in the means of the characteristics were examined in relation to the climatic conditions (Table 4). Populations from highland areas of Morocco and inland areas of Portugal where summer is dry showed similar growth characteristics in Japan; their fresh weight was low, growth was particularly poor in summer (Plate 2), and leaves were short and narrow. It appears that these populations were not adapted to humid climates and high

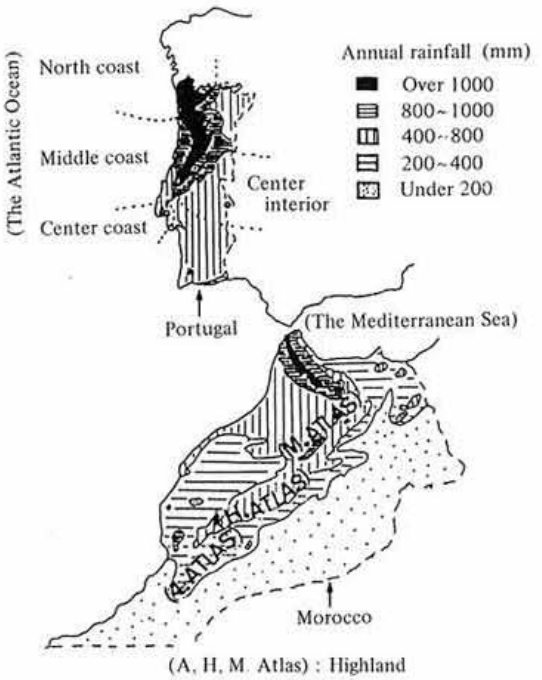

Fig. 3. Local distribution of annual rainfall in Morocco and Portugal
(From World Atlas of Agriculture, 1969)

Table 4. Characteristics of populations grouped by areas under different climatic conditions

Area	Number of pop.	Fresh weight (g/plant)				Leaf size (cm)		Anthracnose[a)]
		1st	2nd	3rd	4th	Length	Width	
Morocco								
Highland	26	134	38	92	53	15.3	0.75	5.4
Portugal								
Interior	2	234	74	156	53	16.7	0.92	4.6
Center coast	5	494	154	261	82	22.7	1.13	2.3
Middle coast	10	573	257	273	90	26.7	1.13	2.4
North coast	4	816	434	368	108	30.8	1.18	1.6
Japan, bred by NGRI								
Nishi- Akimidori	1	518	335	330	70	22.7	1.32	3.7
nasuno Makibamidori	1	533	409	303	46	32.1	1.18	3.4
Subspecies (from Welsh PBS, UK)								
mairei (NE. Algeria)	1	47	21	22	11	13.9	0.50	2.1
santai (W. Alg.-Morocco)	1	88	32	72	35	14.2	0.75	4.8
lusitanica (Portugal)	1	204	166	170	86	23.9	1.21	3.1

a): Degree of occurrence; 1 (very slight) - 9 (very severe).

Plate 2. Poor growth of Morocco populations in summer as compared with Japanese cultivar (Makibamidori) and Portugal populations (plots in the back)

moisture soil conditions. Poor growth in summer suggests the presence of dormancy during the dry season in their indigenous habitats.

In contrast to these two groups, the populations from the Atlantic coast of Portugal were characterized by good growth and large leaves. These features became more pronounced toward the North along with the increase of annual rainfall. Rainfall during the dry season (April to September) is considerably high (Table 3). Hence, it is estimated that the adaptation to these climatic conditions resulted in luxuriant growth when the soil moisture was abundant as in the case of Nishinasuno, Japan. Moreover, the high temperature during the wet season (October to March) seems to have increased their potential for continued growth under short daylength.

Anthracnose (*Colletotrichum graminicola*) occurred severely in populations from Morocco and the inland area of Portugal. The dry climatic conditions may have been the factors which induced the lack of resistance in these populations. The low anthracnose occurrence in populations from the North coast of Portugal seems to reflect the humid summer in these areas.

Based on these considerations, it was concluded that the populations from North Portugal could become promising materials for breeding work in the warmer region of Japan. However further studies such as evaluation under sward competitive conditions and phylogenetic clarification compared with other subspecies may be necessary before these materials can be used in breeding programs.

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(Received for publication, July 5, 1993)