JARQ 28, 124-132 (1994)

Characteristics of Populations of Tall Fescue (*Festuca arundinacea Schreb.*) Collected from Morocco and Portugal

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Abstract
Populations of tall fescue (*Festuca arundinacea* Schreb.) collected from Morocco and Portugal were evaluated at Kyushu National Agricultural Experiment Station. Moroccan populations displayed early or medium maturity, longer culms and panicles than cv. Nanryo. Portuguese populations except for population 86280 exhibited a late maturity, shorter culms and longer panicles than Nanryo. Most of the Moroccan populations showed a low vigor in the first year, while most of the Protuguese populations showed a low vigor in the second and third years. The early spring vigor of the Moroccan populations was superior to that of the Portuguese ones and Japanese cultivars, and some of the Moroccan populations showed a high vigor in summer, comparable to that of Nanryo, or even superior. Most of the Portuguese populations spread markedly and exhibited rhizomaty. Cluster analysis based on these characters indicated that the Moroccan and Portuguese populations except for population 86280 were isolated from each other and differed from the Japanese cultivars in these characters.

Discipline: Grassland
Additional key words: ecotype, evaluation, germplasm, Mediterranean cultivar

Introduction

Tall fescue, *Festuca arundinacea* Schreb., is a temperate perennial grass used for pasture and soil conservation in the warm temperate zone of Japan. This species is distributed spontaneously throughout Europe and North Africa extending to western Siberia[2]. As the populations derived from southern Europe and the cultivars bred in North America display a good adaptability under the Japanese climatic conditions with hot and humid summer and mild winter[9], the cultivars used predominantly in Japan are bred from these germplasm accessions. On the other hand, tall fescue of Mediterranean origin is attracting a great deal of interest because it exhibits superior growth under cool temperature and short day conditions and is resistant to crown rust[5].

Japanese exploration team collected populations of tall fescue in Morocco and Portugal in 1986. The objective of our study was to determine the variability of the agronomic characters of the populations in these areas and to evaluate their use as breeding materials.

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Materials and methods

Among the populations collected in 1986, 16 populations from Morocco and 16 ones from Portugal were selected for evaluation (Table 1). Accessions of Moroccan populations were separated into two geographic groups. Five

Table 1. Collection sites or breeding sites of accessions

Entry no.	Accession or cultivar	Collection or breeding site	Notes
1	86251	Ourika, 33 km SE of Marrakesh, Morocco	Alt. 900 m
2	86254	55 km SE of Marrakesh, Morocco	Alt. 900 m, roadside
3	86255	32 km SE of Marrakesh, Morocco	Alt. 800 m
4	86257	Sadi Brahim, Morocco	Alt. 1,000 m, near water
5	86258	Joukak, Morocco	Alt. 900 m, cultivated field, under trees
6	86260	Lahri, Morocco	Alt. 750 m, near cultivated field
7	86261	Lahri, Morocco	Alt. 750 m, near water, small colony
8	86263	Azrou-Khenifra, Morocco	Alt, 1,050 m
9	86264	Sidi Addi, Morocco	Alt. 950 m
10	86265	Ain Leuh, Morocco	Alt. 1,250 m, cultivated field
11	86266	Ifrane, Morocco	Alt. 1,500 m, woodland
12	86267	3 km of Ifrane, Morocco	Alt. 1,500 m
13	86268	Imouzzer-Kandar, Morocco	Alt. 1,050 m
14	86269	Dait Oua, Morocco	Alt. 1,350 m
15	86272	20 km of Zaouit Ech Cheikh, Morocco	Alt. 2,000 m
16	86273	39 km of Midelt, Morocco	Alt. 2,000 m
17	86275	Malveira-Torres Vedras, Portugal	Hill
18	86278	4 km of Caldas da Rainha, Portugal	Natural grassland
19	86279	Caldas da Rainha-Alcobaca, Portugal	
20	86280	Caldas da Rainha-Alcobaca, Portugal	
21	86281	Nazare, Portugal	Roadside
22	86282	Nazare, Portugal	Near dock, 50 m of wharf
23	86283	Nazare-Leiria, Portugal	
24	86284	Nazare-Marinha Grande, Portugal	
25	86286	Leiria, Portugal	Near paddy field, eucalyptus woods
26	86288	Cantanhede-Mira, Portugal	Alt. 100 m, pine woods
27	86292	Torreira-Ovar, Portugal	
28	86293	Viana do Castelo-Porto, Portugal	
29	86294	Viana do Castelo-Porto, Portugal	Pine woods
30	86295	Viana do Castelo-Porto, Portugal	Roadside, large population
31	86296	Aveiro, Portugal	Alt, 0 m, near wharf
32	86297	Aveiro-Coimbra, Portugal	
33	Maris Kasba	Cambridge, U.K.	Mediterranean type
34	Maris Jebel	Cambridge, U.K.	Mediterranean type
35	Gazelle	Montpellier, France	Mediterranean type
36	Gloria	Montpellier, France	Mediterranean type
37	Lironde	Montpellier, France	Mediterranean type
38	Djebebina	Tunis, Tunisia	Mediterranean type
39	Hokuryo	Sapporo, Japan	Bred at Hokkaido N.A.E.S.
40	Nanryo	Kumamoto, Japan	Bred at Kyushu N.A.E.S.

populations (accession numbers 1 to 5) were collected from the southern part of the Haut Atlas, and the other Moroccan populations from the Moyen Atlas. Of the two regions in the latter, the annual rainfall is much more abundant than in the former. Accessions of Portuguese populations were collected from the coastal region from N latitude 39° to 42°. They were separated into two groups: eight populations (accession numbers 17 to 24) were collected from the southern part and eight populations (accession numbers 25 to 32) from the northern part where the annual rainfall is more abundant than in the southern part. Six Mediterranean and two Japanese cultivars were included in the accessions for comparison.

Seeds of the accessions were sown in paper pots in November 1986. Seedlings were transplanted into the field in March 1987. Ten plants were randomly selected from each population or cultivar and each plant was divided into six ramets as clone. Then they were transplanted again in the experimental field of Kyushu National Agricultural Experiment Station in November 1987. The experimental design consisted of a randomized complete block with three replications. Each plot consisted of 20 plants (10 clones × 2 ramets) with a spacing of 75 cm between rows and 50 cm within row.

Measurements and observations were recorded for the clones after the summer of 1988 according to the methods described below and were averaged for a plot. Vigor was scored based on the amount of leaves in individual plants in March, September and November where 1 = high, 9 = low. Heading date was scored when the second panicle was observed. Culm and panicle length was measured after the heading stage. Spreading of individuals was scored based on the degree of spread of tillers or developing rhizomes where 1 = wide, 9 = narrow. Resistance to crown rust was scored based on the severity of the lesions formed on leaves where 1 = low, 9 = high.

Results

Heading date, culm and panicle length of the accessions recorded in 1989 and 1990 are shown in Table 2. The heading dates of the Moroccan populations ranged from 15 to 30 April and those of the Portuguese populations from 29 April to 9 May except for 86280. The maturity of the Moroccan populations ranked early or medium, and that of the Portuguese populations except for 86280, which matured early, ranked late compared with the maturity of the other cultivars.

The culm and panicle length of the accessions varied with the geographic origin. The Portuguese populations except for 86280 had shorter culms and longer panicles than the other populations or cultivars. Many Moroccan populations showed longer culm and panicles than Nanryo. Correlation coefficients among the scores of spring, summer and fall vigor are shown in Table 3. The vigor in 1988 showed a low correlation with that in 1989 and 1990. Distribution of the scores of average vigor in late summer and fall of 1988, 1989 and 1990, as well as that in early spring and late summer of 1989 and 1990 is shown in Fig. 1. In 1988, the Japanese cultivars showed the highest scores while most of the Moroccan populations the lowest. In 1989 and 1990, most of the Portuguese populations showed lower scores for vigor than the other accessions. Most of the Moroccan populations and Mediterranean cultivars showed better growth in early spring than Nanryo, while some of them in late summer.

In November of 1988 and 1989, the spreading of individuals was scored. Correlation between the values of the two years was high (0.88**). The Portuguese populations except for 86280 spread remarkedly. However the Moroccan populations showed upright and few rhizomes unlike the other cultivars.

In November 1990, severe crown rust was observed. The Japanese cultivars were highly

Table 2. Characters of populations collected in Morocco and Portugal and comparative cultivars

Entry no.[a)]	Heading date[b)]	Culm length[c)]	Panicle length[c)]	Spread of individual[d)]	Resistance to crown rust[e)]
Moroccan populations					
1	23.9	123.2	27.9	7.5	1.6
2	15.8	146.2	38.1	6.0	1.7
3	17.7	152.9	35.5	7.1	1.7
4	26.4	150.2	32.3	7.2	3.1
5	16.3	139.1	29.5	5.9	2.4
6	15.1	132.7	29.8	7.4	1.5
7	13.4	142.9	36.1	7.3	1.8
8	24.8	148.5	32.3	7.2	4.2
9	23.1	160.2	36.6	7.3	1.2
10	27.9	134.8	28.7	7.5	4.0
11	30.2	134.9	31.1	7.4	3.7
12	30.5	136.7	29.1	7.5	6.3
13	27.6	153.8	32.6	7.3	5.3
14	27.2	153.5	30.5	7.3	4.9
15	29.7	132.7	35.4	6.5	2.6
16	17.8	140.6	36.5	7.3	2.3
Mean	23.2	142.7	32.6	7.1	3.0
Portuguese populations					
17	38.7	100.3	34.3	3.4	2.6
18	30.3	100.8	29.9	4.1	2.6
19	31.2	101.1	32.4	3.6	1.7
20	15.4	120.2	25.8	7.0	6.4
21	30.0	107.9	33.3	3.6	1.9
22	31.5	104.4	33.2	3.1	2.4
23	38.4	109.9	33.5	4.6	1.8
24	30.1	114.6	35.7	5.4	1.8
25	30.3	106.8	32.5	3.0	1.4
26	31.3	115.4	30.7	3.4	3.3
27	32.3	115.3	32.7	4.0	1.8
28	36.8	111.8	30.5	3.3	2.7
29	38.2	104.7	30.5	3.4	2.6
30	29.4	117.4	31.5	4.0	2.4
31	36.3	108.8	34.7	4.4	4.3
32	33.5	115.6	30.0	3.1	2.8
Mean	32.2	109.7	32.0	4.0	2.6
Mediterranean cultivars					
33	26.4	160.4	35.4	7.0	1.7
34	29.9	150.9	32.4	7.3	3.2
35	10.3	139.6	35.1	7.2	1.6
36	18.3	139.9	35.8	6.4	1.1
37	9.6	136.5	38.1	6.7	1.7
38	12.2	132.9	40.1	6.3	1.6
Mean	17.8	143.1	36.3	6.8	1.8
Japanese cultivars					
39	33.7	136.7	36.4	6.5	5.7
40	8.6	134.9	26.3	6.5	5.8
L.S.D. (5%)	2.28	5.07	2.08	0.77	1.06

a): Numbers correspond to the populations or cultivars shown in Table 1.
b): Average number of days to head emergence from April 1, 1989 and 1990.
c): Average of data measured (cm) in 1989 and 1990.
d): Average of scores recorded in Nov. 1988 and 1989. 1 = wide, 9 = narrow.
e): Score recorded in October 1990. 1 = resistant, 9 = susceptible.

Table 3. Correlation coefficients among scores of vigor evaluated in 1988 – 1990 (n = 40)

No.	Character	2	3	4	5	6	7
1	Vigor on 14 Sep. 1988	0.81**	0.18	0.39*	0.20	−0.14	0.36*
2	Vigor on 11 Nov. 1988	–	0.43**	0.34*	0.36*	0.01	0.23
3	Vigor on 10 Mar. 1989		–	0.60**	0.78**	0.82**	0.35*
4	Vigor on 11 Sep. 1989			–	0.74**	0.66**	0.88**
5	Vigor on 27 Nov. 1989				–	0.78**	0.53**
6	Vigor on 17 Mar. 1990					–	0.53**
7	Vigor on 23 Sep. 1990						–

*,** Significant at the 0.05 and 0.01 probability levels, respectively.

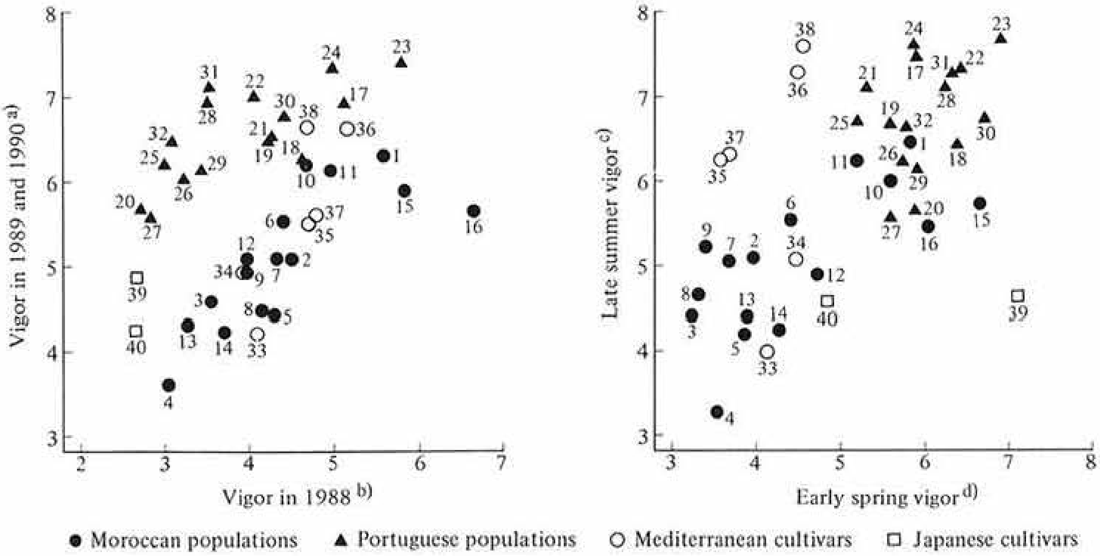

Fig. 1. Distribution of scores of vigor in initial growth stage, in perennial growth stage, early spring vigor and late summer vigor in accessions

Numbers with symbols correspond to the accessions shown in Table 1.

a): Average of vigor evaluated in September 1989, November 1989 and in September 1990. 1 = high, 9 = low.

b): Average of vigor evaluated in September and in November 1988. 1 = high, 9 = low.

c): Average of vigor evaluated in September 1989 and 1990. 1 = high, 9 = low.

d): Average of vigor evaluated in March 1989 and 1990. 1 = high, 9 = low.

susceptible, the Moroccan populations 86267, 86268 and the Portuguese population 86280 were also susceptible, while most of the other accessions were highly resistant.

Correlation coefficients were calculated among these characters in all the accessions, 16 Moroccan populations and 16 Portuguese populations, respectively (Table 4). The correlation coefficients of the Moroccan populations were different from those of the Portuguese ones.

To analyze the relations among accessions, the accessions were classified by cluster analysis based on vigor in 1988, including early spring vigor, late summer vigor, heading date, culm and panicle length, spread of individuals

Table 4. Correlation coefficients among characters based on the data of all accessions, 16 Moroccan populations and 16 Portuguese populations

No.	Character	2	3	4	5	6	7	8
All accessions; n=40								
1	Vigor in 1988[a)]	0.12	0.36*	-0.10	-0.01	0.34*	0.20	-0.48**
2	Early spring vigor[b)]	-	0.57**	0.63**	-0.74**	-0.20	-0.57**	0.15
3	Late summer vigor[c)]		-	0.32*	-0.76**	0.16	-0.61**	-0.38*
4	Heading date[c)]			-	-0.53**	-0.17	-0.58**	0.12
5	Culm length[c)]				-	0.24	0.85**	0.13
6	Panicle length[d)]					-	0.07	-0.46**
7	Spread of individual[e)]						-	0.24
8	Resistance to crown rust[f)]							-
Moroccan populations; n=16								
1	Vigor in 1988[a)]	0.83*	0.74**	-0.05	-0.66**	0.10	-0.07	-0.32
2	Early spring vigor[b)]	-	0.71**	0.36	-0.75**	-0.21	-0.09	0.02
3	Late summer vigor[c)]		-	-0.14	-0.69**	-0.15	0.22	-0.24
4	Heading date[c)]			-	-0.09	-0.37	0.35	0.68**
5	Culm length[c)]				-	0.54*	-0.03	0.09
6	Panicle length[d)]					-	-0.33	-0.42
7	Spread of individual[e)]						-	0.32
8	Resistance to crown rust[f)]							-
Portuguse populations; n=16								
1	Vigor in 1988[a)]	0.50*	0.74**	0.37	-0.41	0.56*	0.04	-0.43
2	Early spring vigor[b)]	-	0.36	0.27	0.03	0.06	0.18	0.13
3	Late summer vigor[c)]		-	0.05	-0.35	0.71**	-0.18	-0.39
4	Heading date[c)]			-	-0.46	0.57*	-0.64**	-0.50*
5	Culm length[c)]				-	0.54*	-0.03	0.09
6	Panicle length[d)]					-	-0.33	-0.42
7	Spread of individual[e)]						-	0.32
8	Resistance to crown rust[f)]							-

*,** Significant at the 0.05 and 0.01 probability levels, respectively.
a): Average of vigor evaluated in September and in November of 1988. 1=high, 9=low.
b): Average of vigor evaluated in March 1989 and 1990. 1=high, 9=low.
c): Average of vigor evaluated in September 1989 and 1990. 1=high, 9=low.
d): Average of data measured in 1989 and 1990.
e): Average of scores recorded in November 1988 and 1989. 1=wide, 9=narrow
f): Score observed in October 1990. 1=resistant, 9=susceptible.

and crown rust resistance. Fig. 2 shows the dendrogram of the accessions obtained by the group average method. The accessions were classified into four groups. Cluster I consisted of the Moroccan populations and Mediterranean cultivars. They were classified again into four sub-groups. Cluster Ia consisted of five populations which showed a lower vigor in every season than that of Ib, Ic and Id (Table 5). Cluster Ib consisted of two populations and four cultivars which showed an early maturity and were markedly depressed in summer. Clusters Ic and Id showed good growth in early spring and summer and taller culms, and the accessions belonging to cluster Id were characterized by a medium-late maturity and crown rust susceptibility. Cluster II consisted of the Portuguese populations except for 86280. They were classified again into sub-groups, too. Cluster IIa consisted of three populations

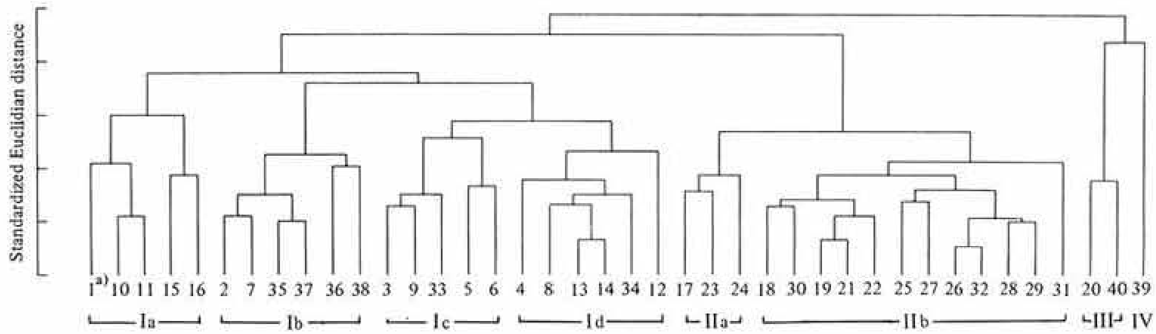

Fig. 2. Dendrogram of accessions obtained by cluster analysis (group average method) based on vigor in early growth stage, early spring vigor, late summer vigor, heading date, culm and panicle length, spread of individual and crown rust resistance
a): Numbers correspond to the accessions shown in Table 1.

Table 5. Mean values[a] of accessions belonging to respective clusters based on cluster analysis

Cluster[b]	Number of accessions	Vigor in 1988	Early spring vigor	Late summer vigor	Heading date	Culm length	Panicle length	Spread of individual	Resistance to crown rust
Ia	5	5.6	5.9	6.0	25.9	133.2	30.5	7.2	2.8
Ib	6	4.8	4.0	6.3	13.3	139.6	27.7	6.7	1.6
Ic	5	4.1	3.8	4.7	19.7	149.1	29.1	6.9	1.7
Id	6	3.7	4.0	4.4	27.7	148.9	32.1	7.3	4.5
IIa	3	5.4	6.3	7.6	35.7	108.2	36.3	4.5	2.1
IIb	12	3.7	6.0	6.7	32.6	109.2	34.9	3.6	2.5
III	2	2.7	5.4	5.1	12.0	127.5	20.7	6.8	6.1
IV	1	2.7	7.2	4.7	33.7	136.7	38.9	6.5	6.7

a): Characters correspond to those in Table 4.
b): Marks correspond to clusters shown in Fig. 2.

collected from the southern part. Their vigor was lower than that of the other populations belonging to cluster IIb. Cluster III consisted of Nanryo and 86280. Cluster IV included only Hokuryo.

To conclude, the Moroccan populations and Portuguese populations except for 86280 were isolated from each other and were distantly related to the Japanese cultivars.

Discussion

Borrill et al.[1] studied the characters of *Festuca* species collected from Europe and the Mediterranean region. As the populations of Morocco showed distinctive morphological and cytological characteristics it was deemed appropriate to treat them separately. In this study, the results of cluster analysis did not enable to discriminate all of the Moroccan populations from the Mediterranean cultivars.

It was reported that introductions from North Africa showed superior winter growth, although they were nonproductive during the summer[6,7,9]. The Moroccan populations and Mediterranean cultivars which were classified into clusters Ib, Ic and Id, displayed a good growth potential in early spring. In some of the accessions which were classified into clusters Ic and Id, summer growth was better than that of Nanryo. A more uniform seasonal growth distribution and extension of the growing period can be expected by using these germplasm accessions as breeding materials. Although the correlation coefficients between vigor in the first year and that in the second and third years in all the accessions were generally low, those in the Moroccan populations were highly significant (Table 4). The correlation coefficients between vigor and culm length in the Moroccan populations were also significant. These findings suggest that long culm plants from the Moroccan populations could be selected for improvement of the growth in the growing season. However the Moroccan populations and Mediterranean cultivars showed a poorer growth than Nanryo in the first year. Since the survival rate of the populations was correlated to summer growth[9], summer growth should be improved in the initial stage in the case of the Moroccan populations and Mediterranean cultivars for using them in the warm region of Japan. Since hybrids between Mediterranean and European or North American populations are sterile, we could not use the Mediterranean populations directly for the improvement of adapted cultivars to Japan[4,7]. These observations indicate that it may be difficult to improve the initial growth of the Mediterranean populations from only the materials with growth as good as that of Japanese cultivars, although variations in this character were detected in the Moroccan and Mediterranean populations.

It was reported also that the North African populations were highly resistant to crown rust[7,10], although the populations and cultivars classified into cluster Id were susceptible. The correlation coefficient between the heading date and crown rust resistance in the Moroccan populations was significant, suggesting that the variation in the crown rust resistance among the North African populations was wide, and was related to their maturity. We should note that most of the Portuguese populations were also resistant.

The populations of North West Iberia possessed a complex of characters associated with rhizomaty, and the geographical boundary of the sub-group was clearly defined[1]. It was considered that the populations from Portugal except for 86280 belonged to that group, because they showed a wide spreading habit. The use of genotypes capable of spreading vegetatively into open spaces and competing successfully with other species may improve the stand persistence in areas marginal for tall fescue adaptation[3]. However, the Portuguese populations showed a low vigor in 1989 and 1990 under the current field conditions. The productivity of the late maturing cultivars was lower than that of the early or medium ones[8] and the poor growth of the Portuguese populations may be ascribed to their late maturity. Collection sites of the Moroccan populations were in the same range of latitudes as Kyushu. Since Portugal is located at higher latitudes than Morocco, most of the Portuguese populations may require a longer daylength for heading than the Moroccan ones. The collection sites of the Portuguese populations were located in lower plains and warmer regions among the habitats of tall fescue in the world. Most of the collection sites of the Moroccan populations were located in mountainous districts. We observed that most of the populations originating from the lowland area of the south of France and Italy displayed an early maturity, and were adapted to the warm region of Japan[9]. It was considered that the population 86280 showed similar characters to those of the southern French and Italian populations. We could not determine why the Portuguese populations except for 86280 were different from them, and why the late maturing populations without adaptability to Japanese conditions were predominant in Portugal.

The results of cluster analysis indicated that the Moroccan populations and Portuguese populations except for population 86280 were isolated from each other and were distinctly different from the Japanese cultivars. Portuguese populations except for 86280 and 86295 were classified again into sub-groups nearly depending on their geographic origin. On the other hand, the Moroccan populations and Mediterranean cultivars were classified into subgroups independently of their origin. This may be due the fact that the Moroccan populations were collected from sites at various altitudes compared with the Portuguese ones. Also the Moroccan populations may display various levels of ploidy[1], although cytological studies were not carried out.

In conclusion, tall fescue populations in Morocco and Portugal display a genetic variability depending on their geographic origin, and the use of tall fescue could be enhanced through the utilization of these accessions in our breeding program.

References

1) Borrill, M., Tyler, B. & Lloyd-Jones, M. (1971): Studies in *Festuca*. 1. A chromosome atlas of *bovinae* and *scariosae*. *Cytologia*, **36**, 1-36.
2) Buckner, R. C. & Bush, L. P. (ed.) (1979): Tall fescue. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Inc. Pub., Madison, WI, USA.
3) D'Uva, P., Bouton, H. J. & Brown, R. H. (1983): Variability in rooted stem production among tall fescue genotypes. *Crop Sci.*, **23**, 385-386.
4) Hunt, K. L. & Sleper, D. A. (1981): Fertility of hybrids between two geographic races of tall fescue. *Crop Sci.*, **21**, 400-404.
5) Nelson, C. J., Treharne, K. J. & Cooper, J. P. (1978): Influence of temperature on leaf growth of diverse populations of tall fescue. *Crop Sci.*, **18**, 217-220.
6) Robson, M. J. (1967): A comparison of British and North African varieties of tall fescue (*Festuca arundinacea* Schreb.). 1. Leaf growth during winter and the effects on it of temperature and daylength. *J. Appl. Ecol.*, **4**, 475-484.
7) Ueyama, Y. & Sato, S. (1989): Improvement of seasonal growth and resistance to crown rust of tall fescue through hybridization between Mediterranean populations and adapted cultivars in Japan. *In* Proc. 16th Int. Grassl. Congr., 385-386.
8) Ueyama, Y., Sato, S. & Nakajima, K. (1991): Heading habit, herbage yield and seasonal growth of tall fescue (*Festuca arundinacea* Schreb.) cultivars and synthetics in the warm temperate zone of Japan. *J. Jpn. Grassl. Sci.*, **37**, 1-9 [In Japanese with English summary].
9) Ueyama, Y., Sato, S. & Nakajima, K. (1992): Variation of seasonal growth and some characters in tall fescue (*Festuca arundinacea* Schreb.) populations and cultivars originated in Central and South Europe, North Africa and West Asia. *J. Jpn. Grassl. Sci.*, **37**, 435-443 [In Japanese with English summary].
10) Wofford, D. S. & Watson, Jr., C. E. (1982): Inheritance of crown rust resistance in tall fescue. *Crop Sci.*, **22**, 510-512.

(Received for publication, Oct. 21, 1993)