Geographical Distribution of Landrace Groups Classified by
Hybrid Pollen Sterility in Foxtail Millet,
Setaria italica (L.) P. BEAUV.¹⁾

Makoto KAWASE and Sadao SAKAMOTO

Plant Germ-plasm Institute, Faculty of Agriculture,
Kyoto University.

Mozume, Muko, Kyoto 〒 617

Eighty-three strains of *Setaria italica* collected from various areas throughout Eurasia were crossed with three tester strains from Japan (tester A), Lan Hsü Island of Taiwan (B) and Belgium(C). The F₁ hybrids were obtained in 224 of the 249 cross combinations tried. The pollen fertility of the F₁ hybrids ranged widely from almost sterile (8.2%) to highly fertile (99.1%) while there was a little variation among the individual F₁ plants of the same cross combination. The 62 strains, which successfully produced F₁ hybrids with all of the three testers, could be clearly classified into six types, designated as types A, B, C, AC, BC and X. Pollen fertility of more than 75% was regarded as normal. The strains of types A, B and C were those which produced F₁ hybrids having normal pollen fertility when crossed with testers A, B and C, respectively. When both F₁ hybrids from the crosses with two testers, A and C, or B and C, showed normal pollen fertility, the strain was classified as type AC or BC. The strains whose F₁ hybrids always showed pollen fertility of less than 75% in all three cross combinations were designated as type X. There was no strain whose F₁ hybrids always showed normal pollen fertility in the cross combinations with all three testers or both testers A and B. These types classified are thought to reflect the landrace groups phylogenetically differentiated, because hybrid sterility occurs as the results of genetic differentiation between strains. Most type A strains were distributed in East Asia including Japan, Korea and China. Type B strains were narrowly found in Taiwan and in the southwestern part of the Nansei Islands of Japan. Most European strains were found to be type C. Strains of types AC and BC were distributed in Afghanistan and India, respectively. Types AC and BC are thought to be less specialized genetically than A, B or C. The geographical distribution of these landrace groups suggests that *S. italica* was first domesticated in an area ranging from Afghanistan to India, and then dispersed both eastward and westward from there.

KEY WORDS : *Setaria italica*, foxtail millet, hybrid sterility, landrace groups, phylogenetical differentiation

Introduction

Foxtail millet, *Setaria italica*, is a minor cereal often cultivated as a relict crop in various local areas while it was once one of the major food crops in the early agriculture of Eurasia. The place of domestication, the dispersal and the differentiation of this crop have not been clear. Many endemic landraces still cultivated in their local areas will provide a great deal of information on these problems. They might also provide some general knowledge on crop evolution, because *S. italica* is a typical summer-grown, annual and diploid cereal with a wide geographical distribution. DE WET *et al.* (1979) divided *S. italica* into two races based on the morphological characters. We have already reported the studies on variation, geographical distribution and genetic analysis of two biochemical characters, phenol color reaction and esterase isozymes (KAWASE and SAKAMO-

Received August 20, 1986.

¹⁾ Contribution No. 39 from the Plant Germ-plasm Institute, Faculty of Agriculture, Kyoto University.

TO, 1982 ; 1984).

Intraspecific hybrid sterility is one of the critical indicators of genetic differentiation. Since Iso (1928) first reported the hybrid sterility for Asian cultivated rice, *Oryza sativa*, between the varieties of Taiwan and Japan, this phenomenon has been studied in detail by many workers. KATO *et al.* (1928) divided *O. sativa* into two types, japonica and indica, based on the hybrid sterility among varieties. Two major varietal groups, so called japonica and indica types, and some minor groups were classified not only by several morphological, physiological and biochemical characters but also by hybrid sterility (OKA, 1958). Very little information on the hybrid sterility is available for *S. italica*. Concerning the artificial hybridization between *S. italica* and *S. viridis*, both fully fertile hybrids (KIHARA and KISHIMOTO, 1942) and a semi-fertile one (LI *et al.*, 1945) have been reported. *S. viridis* is the closest relative and the presumed wild ancestor of *S. italica*, and these two species are thought to belong to a single biological species.

The present study was, therefore, made in order to classify the landrace groups by intraspecific hybrid sterility in *S. italica* and to clarify their geographical distribution.

Materials and Methods

Strains used

A total of 86 strains of foxtail millet, *Setaria italica* (L.) P. BEAUV., collected from various areas in Eurasia were used in the present study. They were originally collected from Japan (16 strains), Korea (9), China (10), Taiwan (14), the Philippines (5), Indonesia (2), Thailand (1), Nepal (3), India (10), Afghanistan (5), the USSR (3), Germany (1), Belgium (3), France (3) and Spain (1). All strains used have been maintained at the Plant Germ-plasm Institute, Kyoto University. Eighty-three of the 86 strains were used as female parents in the cross experiment. They were called as code Nos. 1 to 83 in the present study. The remaining three strains were used as male parents, designated as testers A, B and C, which were collected from Japan, Lan Hsü Island of Taiwan, and Belgium, respectively. According to the preliminary experiment, the F_1 hybrids between these three tester strains showed a relatively high degree of pollen sterility (Table 1).

Cross experiment

Emasculation was carried out just during anthesis which usually occurred at midnight and in the early morning. The anthers were removed with a forceps or sucked with a thin nozzle (0.5 mm ϕ) of an air-pump under a stereoscopic microscope immediately before their dehiscence. Then, the florets were pollinated with a tester as soon as possible. Anthocyan pigmentation, color of lemma and palea and/or esterase isozymes were used

Table 1. Pollen fertility (%) of F_1 hybrids between the tester strains

♀ Tester (Region)	♂		
	Tester A	Tester B	Tester C
	Mean (No.) ¹⁾	Mean (No.)	Mean (No.)
A (Japan)	—	43.4 (1)	42.4 (1)
B (Taiwan)	30.9 (1)	—	32.1 (3)
C (Belgium)	32.7 (1)	59.1 (1)	—

¹⁾ No.: The number of F_1 plants examined.

as marker characters to ascertain whether true hybrids were obtained or not.

Estimation of pollen fertility and seed set

The F_1 hybrids and their parental strains were grown in a glasshouse. Pollen grains of each F_1 hybrid plant were collected from at least ten different florets on a panicle during anthesis and were stained by glycerine carmine solution. They were classified into normally stained pollen grains, empty grains and several degrees of intermediates between them. The pollen fertility was calculated from the frequency of normally stained pollen grains among at least one thousand pollen grains observed for each sample. The pollen fertility of each parental strain was also estimated by the same procedure for one plant per strain.

Each spikelet of *S. italica* has two florets, a bisexual fertile one and a degenerated sterile one. The seed set of the F_1 hybrid was calculated from a single plant for each cross combination as the frequency of the fully ripened grains in more than five hundred spikelets that had flowered on at least three branches randomly chosen from a panicle. When there were less than five hundred spikelets in a panicle, two panicles were observed per plant. The seed set of each parental strain was also measured in the same way.

Results

A total of 628 mature F_1 plants were obtained in 224 of the 249 cross combinations tried. Almost all the F_1 plants grew vigorously showing an intermediate nature of parents or sometimes heterosis. No morphological hybrid weakness was observed.

A very wide variation of pollen fertility was found among the F_1 hybrids, that is from 8.2% (almost sterile) to 99.1% (highly fertile) (Table 2). In most cases, there was a little variation observed among the individual plants of each cross combination. The distribution of the pollen fertility of the F_1 hybrids and their parental strains is shown by the histograms in Fig.1. Since the pollen fertility was more than 75% in almost all the parental strains, the F_1 hybrids having the pollen fertility of more than 75% were classified as normal. The fact that no F_1 plant showed 0% pollen fertility (complete pollen sterility) indicates the intraspecific nature of the genetic differentiation involved.

Fig. 1. Distribution of pollen fertility in the F_1 hybrids (a) and their parental strains (b). The pollen fertility of more than 75% was taken as normal.

Fig. 2. Distribution of seed set in the F_1 hybrids (a) and their parental strains (b).

Table 2. Pollen fertility (%) of F₁ hybrids between 83 strains and 3 testers in *S. italica*.
The pollen fertility of more than 75% is shown in **bold type**

Code No.	Strain tested (♀)		Tester strain (♂)			Type
	Region	Locality (Source)	Tester A Mean(No.) ¹⁾	Tester B Mean(No.)	Tester C Mean(No.)	
1	Japan	Iwate Pref.	— ²⁾	17.2 (2)	31.6 (1)	? ³⁾
2		Nagano Pref.	95.4 (3)	19.9 (3)	39.6 (2)	A
3		Yamanashi Pref.	97.9 (4)	26.7 (2)	40.7 (3)	A
4		Toyama Pref.	96.1 (1)	25.5 (2)	35.5 (2)	A
5		Kanagawa Pref.	96.1 (2)	38.9 (1)	—	?
6		Nara Pref.	80.0 (1)	42.4 (3)	37.4 (2)	A
7		Hyogo Pref.	77.5 (3)	—	—	?
8		Kochi Pref.	98.2 (1)	29.0 (4)	25.5 (2)	A
9		Kumamoto Pref.	82.3 (1)	29.3 (4)	—	?
10		Tsushima Is.	98.1 (2)	37.8 (2)	56.9 (2)	A
11		Kagoshima Pref.	41.1 (1)	17.2 (3)	8.2 (1)	X
12		Ikema Is.	—	—	44.9 (2)	?
13		Ishigaki Is.	13.9 (4)	88.5 (3)	36.8 (3)	B
14		Iriomote Is.	20.0 (3)	81.9 (2)	29.6 (1)	B
15		Hateruma Is.	11.5 (2)	77.8 (3)	54.2 (3)	B
16	Korea	Kangwon-do	83.1 (4)	14.2 (1)	25.6 (1)	A
17		Kyonggi-do	93.4 (2)	17.9 (1)	19.6 (2)	A
18		Chungchong-pukto	92.3 (2)	41.2 (4)	53.4 (3)	A
19		Chungchong-namdo	91.9 (1)	28.2 (4)	20.0 (1)	A
20		Kyongsang-pukto	90.9 (4)	28.2 (3)	33.8 (3)	A
21		Kyongsang-namdo	92.6 (1)	20.4 (2)	27.5 (1)	A
22		Cholla-pukto	89.7 (2)	24.2 (4)	46.2 (4)	A
23		Cholla-namdo	99.1 (4)	37.8 (4)	57.7 (1)	A
24	China	Cheju-do	98.1 (4)	24.4 (2)	48.2 (2)	A
25		(110001) ⁴⁾	93.7 (2)	11.8 (2)	—	?
26		(110002) ⁴⁾	93.4 (4)	42.0 (2)	46.8 (1)	A
27		(110003) ⁴⁾	93.6 (1)	39.3 (3)	39.2 (4)	A
28		(110005) ⁴⁾	20.2 (4)	9.2 (2)	13.1 (3)	X
29		(110007) ⁴⁾	68.9 (4)	—	—	?
30		(110008) ⁴⁾	88.2 (4)	58.1 (2)	42.9 (1)	A
31		(110009) ⁴⁾	93.3 (2)	34.2 (4)	—	?
32		(110012) ⁴⁾	94.7 (3)	19.4 (4)	33.5 (3)	A
33		Hunan Prov.	16.9 (2)	—	20.1 (2)	?
34	Taiwan	Yunnan Prov.	70.4 (4)	35.2 (4)	74.7 (4)	X
35		Pington	32.9 (4)	77.6 (3)	26.0 (3)	B
36		Pington	25.1 (2)	97.0 (1)	53.9 (3)	B
37		Pington	47.2 (4)	85.4 (2)	55.1 (4)	B
38		Pington	37.9 (4)	86.5 (4)	35.5 (4)	B
39		Taitung	33.2 (4)	97.2 (2)	39.9 (1)	B
40		Taitung	34.2 (4)	92.8 (3)	42.6 (4)	B
41		Hwalien	65.9 (3)	54.4 (3)	22.1 (4)	X
42		Nantou	32.8 (3)	94.6 (3)	55.9 (4)	B
43		Nantou	—	34.4 (3)	37.2 (4)	?
44		Lan Hsü Is.	48.7 (2)	40.4 (2)	17.8 (3)	X

Table 2. (continued)

Code No.	Strain tested (♀)		Tester strain (♂)			Type
	Region	Locality (Source)	Tester A Mean(No.)	Tester B Mean(No.)	Tester C Mean(No.)	
45	Taiwan	Lan Hsü Is.	41.5 (4)	23.8 (4)	21.6 (3)	X
46		Lan Hsü Is.	66.7 (2)	44.8 (4)	33.2 (3)	X
47		Lan Hsü Is.	38.5 (2)	46.1 (4)	—	?
48	Philippines	Itbayat Is.	36.2 (4)	51.9 (3)	59.4 (1)	X
49		Batan Is.	20.2 (4)	29.8 (4)	66.7 (4)	X
50		Batan Is.	45.6 (4)	48.5 (4)	42.1 (1)	X
51		Batan Is.	45.2 (4)	46.3 (4)	18.7 (3)	X
52		Batan Is.	50.7 (3)	38.2 (1)	28.5 (1)	X
53	Indonesia	Halmahera Is.	—	—	75.4 (4)	?
54		Sulawesi Is.	40.5 (3)	68.3 (1)	73.5 (2)	X
55	Thailand	near Cheng-mai	16.8 (1)	50.4 (2)	38.6 (3)	X
56	Nepal	Dhunché	—	30.8 (3)	66.9 (4)	?
57		Bhargu	26.5 (2)	31.4 (3)	86.3 (4)	C
58		Bhargu	31.2 (3)	37.8 (4)	—	?
59	India	(ISC-5) ⁵⁾	38.1 (4)	77.2 (3)	92.9 (4)	BC
60		(ISC-19) ⁵⁾	40.5 (4)	90.8 (4)	78.7 (4)	BC
61		(ISC-282) ⁵⁾	50.5 (4)	78.2 (4)	86.5 (4)	BC
62		(ISC-294-B) ⁵⁾	49.5 (1)	—	89.4 (3)	?
63		(ISC-300-B) ⁵⁾	58.6 (4)	82.5 (3)	95.3 (4)	BC
64		(ISC-713) ⁵⁾	49.1 (4)	41.0 (4)	73.9 (4)	X
65		(ISC-1) ⁶⁾	52.6 (4)	87.2 (1)	93.9 (2)	BC
66		(ISC-80) ⁶⁾	55.5 (2)	41.1 (2)	—	?
67		(ISC-109) ⁶⁾	54.1 (3)	—	97.3 (3)	?
68		(SI 76/4) ⁶⁾	98.4 (4)	26.9 (2)	47.9 (1)	A
69	Afghanistan	Jabalsalaj-zenya	63.9 (1)	31.5 (3)	85.9 (2)	C
70		Takhar	95.9 (2)	—	85.8 (3)	?
71		Takhar	96.4 (4)	33.1 (2)	93.8 (3)	AC
72		Badakhshan	95.0 (4)	48.6 (2)	96.5 (2)	AC
73		Badakhshan	—	19.0 (2)	65.8 (3)	?
74	USSR	Kirghizia ⁷⁾	63.3 (2)	45.2 (4)	57.1 (3)	X
75		Uzbekistan ⁷⁾	82.3 (2)	43.5 (4)	62.3 (2)	A
76		Primorskaya Prov. ⁷⁾	96.3 (4)	—	67.8 (1)	?
77	Germany	(unknown) ⁸⁾	30.0 (3)	9.3 (4)	36.3 (4)	X
78	Belgium	(unknown) ⁹⁾	47.2 (3)	31.3 (3)	91.0 (3)	C
79		(unknown) ⁹⁾	31.0 (4)	19.7 (4)	76.7 (4)	C
80	France	Cuon	65.2 (4)	48.6 (4)	88.2 (2)	C
81		Cuon	56.9 (3)	58.9 (4)	—	?
82		Cuon	57.3 (3)	56.7 (3)	96.1 (1)	C
83	Spain	Canges de Narcea	62.0 (2)	38.2 (4)	92.7 (3)	C

1) : Number of F₁ plants observed.2) : No F₁ hybrid has been obtained yet.

3) : The strain has not been classified yet.

4) : Strains obtained from National Institute of Agricultural Science, Japan.

5) : Strains obtained from University of Agricultural Sciences, Bangalore, India.

6) : Strains obtained from Tamil Nadu Agricultural University, Coimbatore, India.

7) : Strains obtained from the N. I. Vavilov All-Union Institute of Plant Industry, Leningrad, USSR.

8) : Strains obtained from Karl-Marx-Universität, Leipzig, DDR.

9) : Strains obtained from Dienst voor Parken en Plantsonen, Antwerpen, Belgium.

The histograms in Fig. 2 show the distribution of the seed set in the F_1 hybrids and their parental strains. The difference in the seed set of the parental strains was much broader than that in pollen fertility. The seed set might be influenced more largely by some environmental conditions. Hybrid sterility was more clearly recognized in pollen fertility than in seed set.

The seed set of the F_1 hybrids was significantly correlated with pollen fertility, especially in cross combinations with testers A ($r=0.82$) and B ($r=0.80$). The correlation coefficient among the F_1 hybrids from the crosses with tester C ($r=0.53$) was less than the other values.

Assuming that the strain belongs to the same type as the tester when the pollen fertility of the F_1 hybrid between a given strain and a tester is normal ($>75\%$), most of the strains used could be classified into at least six types. The strains which produced F_1 hybrids having normal pollen fertility only when crossed with a certain tester were classified as type A, B or C after the tester's code name. When both F_1 hybrids from the crosses with two testers, A and C, or B and C, showed normal pollen fertility, the strains were designated as type AC or BC. There was no strain whose F_1 hybrids were always normal in the cross combinations with all of the three testers or with both testers A and B. Therefore, 62 strains, of which all the three kinds of F_1 hybrids were available in the present study, were clearly classified into types A, B, C, AC, BC and other type(s) (shown as X) (Table 2). Type X strains always showed the pollen fertility of less than 75% in the F_1 hybrids from all the three cross combinations. The remaining 21 strains could not be classified, since their F_1 hybrids were not yet obtained in one or two cross combinations. Some of these strains were, however, suspected to belong to certain types. For example, the strains of code Nos. 5, 9, 25 and 31 might be type A, and code No. 70 might be type AC.

Discussion

Intraspecific hybrid sterility in *S. italica*

Hybrid sterility was observed in particular cross combinations of strains in *Setaria italica*. In the preliminary studies, regular chromosome pairing of nine bivalents was observed at the first metaphase of the meiosis in the pollen mother cells of some F_1 plants which showed a high degree of pollen sterility. The F_1 hybrids between the three tester strains always showed pollen sterility, although the degrees of sterility were somewhat different in the reciprocal crosses between testers B and C (Table 1).

There was a relatively high correlation between pollen fertility and seed set in F_1 hybrids. The seed set of the parental strains, however, showed a much broader variation than the pollen fertility (Figs. 1 and 2). The pollen fertility of the parental strains was usually more than 75%. The individual F_1 plants of each cross combination showed in most cases only a little difference of the pollen fertility. Therefore, hybrid pollen sterility, compared with hybrid seed sterility, will serve as a more reliable and direct indicator for the measurement of the phylogenetic differentiation among local strains.

Geographical distribution of landrace groups in *S. italica*

Among the 83 strains of *S. italica* used in the present experiment, 62 strains successfully

produced F_1 hybrids with all of the three testers. They could be classified into types A, B, C, AC, BC and X by means of intraspecific hybrid pollen sterility. Hybrid pollen sterility occurs as the result of genetic differentiation between strains. Therefore, these types classified are thought to reflect the phylogenetically differentiated landrace groups. Each of these landrace groups showed a rather limited geographical distribution, and was often found endemic to a small area.

Most strains of type A are distributed in Honshu Island, Shikoku Island and Kyushu Island of Japan, and in Korea and China. The strains of *S. italica* in these regions are thought to be closely related with one another and are clustered as a single landrace group. This corresponds with the fact that almost all the strains in these regions belonged to a negative phenotype in the phenol color reaction (KAWASE and SAKAMOTO, 1982). Furthermore, the variation in esterase isozymes of mature grains showed that these regions, especially China, are a center of diversity (KAWASE and SAKAMOTO, 1984). Outside of these regions, only two strains of type A were found; one in India and another in Uzbekistan of the USSR. Another phylogenetic group might be distributed in South China because the strains from Hunan and Yunnan Provinces (code Nos. 33 and 34) were not type A.

The strains of type B are narrowly distributed in the mountainous areas of Taiwan and in the southwestern part of the Nansei Islands (Okinawa Prefecture) of Japan in the neighborhood of Taiwan. This strongly suggests that the strains of southwestern part of the Nansei Islands were introduced from Taiwan. This hypothesis might be supported by the fact that some strains from the Nansei Islands exceptionally showed a positive phenol color reaction among Japanese strains, and more than half of the strains from Taiwan also belonged to the positive phenotype (KAWASE and SAKAMOTO, 1982). It is interesting to note that no type B strain was found from Lan Hsü Island of Taiwan except tester B. This fact suggests that the strain used as tester B is endemic to Taiwan and was recently introduced from Taiwan to Lan Hsü Island.

Type C is found especially in most European strains. This indicates that the European strains also form a distinct landrace group. Genetic analysis of esterase isozymes revealed that the *Est-2^b* allele is almost endemic to Europe, which also suggests the phylogenetic relationship of this group (KAWASE and SAKAMOTO, 1984).

Type AC strains are distributed in Afghanistan and type BC in India. These types are thought to be less specialized genetically than type A, B or C.

Type X might include more than one type, because different kinds of pollen fertility arrays in the three cross combinations are recognized among the strains classified as type X (Table 2). For example, two Chinese strains of type X, code Nos. 28 and 34, are quite different in the pollen fertility arrays of the F_1 hybrids. No. 28 showed 20.2%, 9.2% and 13.1% while No. 34 showed 70.4%, 35.2% and 74.7% in the cross combinations with testers A, B and C, respectively. The type X strains from Lan Hsü Island of Taiwan and the Batan Islands of the Philippines might belong to a single landrace group, because these islands are located in a close vicinity. Some strains of type X might have been originated in different ways, since they are sporadically distributed in different regions. In order to elucidate these problems on type X, further cross experiments are now in

progress.

The above-mentioned indigenoussness of these six landrace groups differentiated with one another implies a long history of cultivation of *S. italica* in each region.

It is interesting to point out some similarities in the intraspecific differentiation between *S. italica* and the Asian cultivated rice, *Oryza sativa*. In *O. sativa*, two major varietal groups, so called japonica and indica types, and several minor groups have been classified by hybrid sterility and some morphological, physiological and biochemical characters (OKA, 1958). These groups of *O. sativa* also show specific distributions. The differentiation of landrace groups in *S. italica* is thought to have occurred along with the dispersal from the place of domestication as is the case for *O. sativa*. The more specialized landrace groups (types A, B and C) and the less specialized ones (AC and BC) of *S. italica* are recognized in the present study. Similarly, various degrees of genetic specialization have been shown by hybrid sterility among *O. sativa* varieties (OKA, 1958). The landrace groups of *S. italica* might be rather more distinct than *O. sativa*, because the former has a much wider geographical distribution throughout Eurasia than the latter. Moreover, the indigenoussness of landrace groups in *S. italica* has been less disturbed by modern breeding or systematic introduction than in *O. sativa*.

Domestication of *S. italica*

The place of domestication of *S. italica* is not yet clear. VAVILOV (1926) states that the principal center of diversity in *S. italica* is Eastern Asia, including China and Japan, where it is cultivated as a cereal for food. The genetic diversity of esterase isozymes in Chinese strains is not conflict with VAVILOV's statement (KAWASE and SAKAMOTO, 1984). The large diversity in East Asia could have resulted merely from the intensive cultivation of the landrace group of type A for a long period to the present.

The possibility of independent domestication of *S. italica* in China and Europe has been suggested by DE WET and HARLAN (1975) and DE WET *et al.* (1979), mainly based on the archaeological evidence. It might be difficult to explain the present findings of the six landrace groups in Eurasia by this hypothesis. The distribution of genetically less specialized landrace groups, i. e. type AC in Afghanistan and type BC in India, may provide another possibility: *S. italica* was first domesticated within the area ranging from Afghanistan to India, and from there it was dispersed both westward and eastward being gradually differentiated genetically. This possibility is supported by the fact that the Afghan strains show several morphologically primitive characteristics such as short plant height and exceptionally abundant tillers with very small panicles (SAKAMOTO, 1987). Based on this assumption, the archaeological remains of *S. italica* from the Neolithic sites in both Europe and China are easily comprehensible, except for the lack of direct archaeological evidence from the presumed area of the domestication.

Literature Cited

- DE WET, J. M. J. and J. R. HARLAN 1975. Weeds and domesticates: evolution in man-made habitat. *Econ. Bot.* **29**: 99~107.
- , L. L. OESTRY-STIDD and J. I. CUBERO 1979. Origins and evolution of foxtail millet (*Setaria italica*). *Journ. d'Agric. Trad. et de Bota.* **26**: 53~64.
- ISO, N. 1928. Researches on the Formosan rice plants with special reference to the plant breeding and culture (in Japanese). *Rep. Dept. Agr. Govern. Res. Inst. Formosa Jpn.* **37**, pp. 315.

- KATO, S., H. KOSAKA and S. HARA 1928. On the affinity of rice varieties shown by the fertility of hybrid plants (in Japanese with English summary). Rep. Bul. Fak. Terkult, Kyushu Imp. Univ. 3 : 132~147.
- KAWASE, M. and S. SAKAMOTO 1982. Geographical distribution and genetic analysis of phenol color reaction in foxtail millet, *Setaria italica* (L.) P. BEAUV. Theor. Appl. Genet. 63 : 117~119.
- and —— 1984. Variation, geographical distribution and genetical analysis of esterase isozymes in foxtail millet, *Setaria italica* (L.) P. BEAUV. Theor. Appl. Genet. 67 : 529~533.
- KIHARA, H. and E. KISHIMOTO 1942. Bastarde zwischen *Setaria italica* und *S. viridis* (in Japanese with German summary). Bot. Mag. 20 : 63~67.
- LI, H. W., C. H. LI and W. K. PAO 1945. Cytogenetical and genetical studies of the interspecific cross of the cultivated foxtail millet, *Setaria italica* (L.) BEAUV., and the green foxtail millet, *S. viridis*. J. Amer. Soc. Agron. 37 : 32~54.
- OKA, H. I. 1958. Intervarietal variation and classification of cultivated rice. Ind. J. Genet. Plant Breed. 18 : 79~89.
- SAKAMOTO, S. 1987. Origin and phylogenetic differentiation of cereals in southwestern Eurasia. In "Wheats and herd" TANI, Y. (ed.) (in preparation)
- VAVILOV, N. I. 1926. Studies on the origin of cultivated plants. Inst. Appl. Bot. Plant Breed., Leningrad, pp. 248.

系統間雑種の花粉不稔性によって分類されたアワの地方品種群の地理的分布について

河瀬 真琴・阪本 寧男

(京都大学農学部附属植物生殖質研究施設, 向日市, 〒 617)

ユーラシア各地から収集されたアワ 83 系統を供試系統 (♀) に選び, 日本, 台湾の蘭嶼, ベルギーの 3 系統をそれぞれテスター A, B, C (♂) として交配した. 交配にはピンセット乃至は吸入ポンプを用いて効率的に除雄を行なうことができた. 試みた 249 組み合わせのうち 224 組み合わせにおいて系統間雑種を得ることができ, その雑種第一代および供試系統の自殖個体の花粉稔性と種子稔性を調査した. 雑種第一代の花粉稔性は 8.2% から 99.1% まで観察され様々な程度の不稔性が見られたが, 同じ交配組み合わせから得られた雑種の個体間では不稔性の程度に大きな差はなく, その不稔性の出現は遺伝的なものと考えられる. ほとんどすべての供試系統自殖個体の花粉稔性が 75% 以上であることから, 雑種の花粉稔性においても暫定的に 75% 以上をもって正常と判定した. 3 種類すべてのテスターとの雑種を得ることのできた 62 系統はその花粉不稔性にもとづいて 6 種類の型に分類することができた. テスター A, B, C のうち, 特定のひとつのテスターとの雑種だけが正常な花粉稔性を示す系統をそれぞれ A 型, B 型, C 型と分類した. また, テスター A との雑種もテスター C との雑種も正常な花粉稔性を示す系統は AC 型, テスター B との雑種もテスター C との雑種も正常なものは BC 型と分類した. どのテスターとの雑種も正常な花粉稔性を示さない系統は X 型と分類した. AB 型あるいは ABC 型と分類されるような系統は見い出されなかった. 種子の不稔性にも同様の傾向が認められたが, 不明瞭であり花粉不稔性の方が系統間の遺伝的分化をより直接的に反映していると考えられる. 分類された各型はそれぞれ特異的な地理的分布を示した. A 型は日本, 韓国, 中国の系統に高い頻度で見られ, これらの地域のアワが互いに緊密な関係にあることが示唆された. B 型は台湾本島山間部と日本の南西諸島の系統に, C 型は特にヨーロッパの系統に, それぞれ集中して見い出された. 遺伝的により未分化な段階にあると考えられる AC 型と BC 型の系統はそれぞれアフガニスタンとインドに分布している. X 型の系統は台湾の蘭嶼やフィリピンのバタン諸島に集中して見られたほか各地に点在しており, さらにいくつかの型に分類できるかもしれない. このように各型の分布は明瞭な地理的独自性を示し, 各地域に特異的な地方品種群が成立していることが明らかとなった. 各型の地理的分布と穎果のフェノール着色反応性やエステラーゼ・アイソザイムの分布との間にいくつかの対応関係が見い出された. また, 台湾から南西諸島へアワの導入された可能性がフェノール着色性の系統の分布から示唆されていたが両地域における B 型系統の分布はそれを裏付けるものである. 遺伝的により未分化と考えられる AC 型と BC 型の分布はアワの起原を考えるうえで非常に重要である. すなわち, アワがアフガニスタンからインドにかけての地域で起原し, 遺伝的に分化しながら東西に伝播していった可能性が示唆される. この可能性はアフガニスタンの系統が草丈が低くきわめて旺盛に分けつし小型の穂をもつといった原始的特徴を示すこととも一致している.