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Morphological and Karyological Comparison of Garlic Clones between the Center of Origin and the Westernmost Area of Distribution

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Introduction

Vavilov[14] mentioned that Central Asia including northwest India, Afghanistan, Tajikistan, Uzbekistan, and western Tien Shan Mountains was the third center of the origin of cultivated plants. He suggested that garlic was one of the cultivated plants which originated there, spreading to the world. He noticed different forms of garlic, for example, the large-size forms in the Mediterranean area, which was postulated as a secondary center of origin of garlic[13].

Garlic had been known as a typical sterile plant. However, Etoh[4] stated that a big amount of fertile garlic clones were collected in the Central Asia, especially around the Tien Shan Mountains. And he identified this area around the Tien Shan Mountains as the most probable center of origin of garlic. On the other hand, in the west of Central Asia, no fertile clone was found except a few in Caucasus[6]. In the western Europe, without spread to the north, garlic has been grown around the Mediterranean area probably since prehistoric time[11]. In Iberian Peninsula of the westernmost area in the old continent, bolting-type clones exist while no bolting-type clones are left in other Mediterranean areas[11]. The fertility of garlic clones has not been detected in this area so far. In this study, some bolting garlic clones were collected in the Iberian Peninsula, the westernmost area of the old continent, in the summer of 1996 for search of fertile clones. The purpose of this study was to examine the possibility of existence of fertile clones in this area, and further to compare these clones with the garlic clones collected in the Central Asia.

This is a part of Hong's Ph.D thesis presented to United Graduate School of Kagoshima University in 1999.

Materials and Methods

Plant materials

Garlic clones collected in the Iberian Peninsula (Spain and Portugal) in 1996 (Table 1) were examined in this study. Clones No. 419 to No. 450 were kindly offered by Mr. F. Mansilla of Spanish Gene Bank, and No. 452 to 457 were purchased in the markets. No. 460 to No. 470 were kindly offered by Dr. R. Farias of Braga Gene Bank in Portugal. According to these Gene Bank researchers in charge of garlic, all of the bolting-type garlic clones in this area are included in the present collection. All the collected Iberian clones had dry flower-stalks when

Table 1. Morphological characteristics in the garlic clones from Spain and Portugal

Clone No.	Origin	Average length of longest leaf-blade (cm) March/June	Average width of longest leaf-blade (cm) March/June	Bolting habits
No. 419	Spain(410/86)	31.8/55.5	1.3/1.6	Incomplete-bolting
No. 422	Spain(879/86)	31.0/64.8	1.7/1.6	Incomplete-bolting
No. 423	Spain(A.Campo)	35.0/53.7	1.6/1.4	Incomplete-bolting
No. 424	Spain(A.Ianez)	29.2/50.8	1.6/1.4	Incomplete-bolting
No. 425	Spain(Alpujarras)	27.2/52.0	1.2/1.2	Incomplete-bolting
No. 427	Spain(Cabra Monturque)	30.6/51.7	1.8/1.5	Incomplete-bolting
No. 430	Spain(C.Rica)	35.0/56.1	1.5/1.3	Incomplete-bolting
No. 432	Spain(D.Ramos)	33.0/57.9	1.5/1.4	Incomplete-bolting
No. 433	Spain(E.Garcia)	30.8/42.9	1.4/1.4	Incomplete-bolting
No. 434	Spain(Frio)	33.4/61.6	1.6/1.6	Incomplete-bolting
No. 435	Spain(In vitro)	33.6/54.9	1.4/1.5	Incomplete-bolting
No. 436	Spain(Isidoro Diaz)	34.2/54.0	1.6/1.3	Incomplete-bolting
No. 437	Spain(J.Corral)	30.1/44.4	1.1/1.0	Incomplete-bolting
No. 438	Spain(J.Garcia)	31.2/54.0	1.2/1.4	Incomplete-bolting
No. 442	Spain(M.G.Victoria)	28.2/45.9	1.5/1.4	Incomplete-bolting
No. 444	Spain(Morado de Cordoba)	32.6/52.9	1.8/1.6	Incomplete-bolting
No. 445	Spain(N.Mora)	21.2/54.2	1.1/1.8	Incomplete-bolting
No. 447	Spain(Rojo de Cuenca)	30.2/53.7	1.6/1.5	Incomplete-bolting
No. 448	Spain(Rojo de Falces)	31.2/76.8	1.7/1.8	Incomplete-bolting
No. 450	Spain(S.Moreno)	34.5/55.5	1.6/1.2	Incomplete-bolting
No. 452	Spain(Ajo Rojo)	36.1/72.1	1.8/1.7	Incomplete-bolting
No. 453	Spain(Alcazar)	28.2/51.3	1.8/1.4	Incomplete-bolting
No. 454	Spain(Alcazar)	33.2/63.2	1.6/1.7	Incomplete-bolting
No. 457	Spain(Segovia)	24.8/48.2	2.2/2.0	Incomplete-bolting
No. 460	Portugal(20/96A)	25.0/58.6	1.4/1.6	Incomplete-bolting
No. 461	Portugal(21/96A)	28.3/52.5	1.5/1.7	Incomplete-bolting
No. 462	Portugal(22/96A)	26.2/48.9	1.3/1.1	Incomplete-bolting
No. 463	Portugal(23/96A)	31.2/60.3	1.6/1.8	Incomplete-bolting
No. 468	Portugal(36/96A)	21.0/42.6	1.5/2.0	Incomplete-bolting
No. 470	Portugal(40/96A)	23.2/54.7	1.2/2.7	Incomplete-bolting

they were collected. This fact means that all the collected clones were the bolting-type garlic. Only No. 442 clone had short, thin flower-stalks, showing incomplete-bolting type garlic. Some of the garlic clones[7] collected in the Central Asia in the summer of 1994 were also examined for comparison(Table 2).

Morphological research

All of the clones collected in the Iberian Peninsula had scape-scar, and therefore, they

Table 2. Morphological characteristics in the garlic clones from Central Asia

Clone No.	Origin	Length of scape (cm) June	Average length of longest leaf-blade (cm) March/June	Average width of longest leaf-blade (cm) March/June	Bolting habits
No. 362	China	-	45.8/-	3.4/-	Bolting
No. 365	China	-	33.2/-	3.2/-	Non-bolting
No. 366	China	-	34.2/-	2.3/-	Bolting
No. 367	Kazakhstan	-	34.5/-	2.7/-	Bolting
No. 370	Kazakhstan	-	21.4/-	2.0/-	Bolting
No. 371	Kazakhstan	-	16.8/-	2.3/-	Bolting
No. 372	Kazakhstan	-	26.4/-	2.8/-	Bolting
No. 373	Kazakhstan	-	24.2/-	2.3/-	Bolting
No. 375-1	Kazakhstan	95.5	21.8/50.2	2.2/2.4	Bolting
No. 375-2	Kazakhstan	-	34.4/-	2.8/-	Bolting
No. 378	Kazakhstan	-	45.6/-	4.6/-	Bolting
No. 379	Kazakhstan	102.3	18.8/0.0	1.4/1.4	Bolting
No. 381	Kazakhstan	-	19.0/-	2.2/-	Bolting
No. 384	Kazakhstan	92.5	19.8/33.4	1.7/1.2	Bolting
No. 385	Kazakhstan	87.3	22.8/38.8	2.8/2.8	Bolting
No. 387	Kazakhstan	87.3	26.0/32.5	1.4/1.6	Bolting
No. 388	Kazakhstan	-	20.4/-	2.4/-	Bolting
No. 389	Kazakhstan	70.8	23.2/25.9	2.8/2.3	Bolting
No. 390-1	Kazakhstan	115.8	17.2/60.2	1.8/2.0	Bolting
No. 390-2	Kazakhstan	89.7	24.8/28.0	1.6/1.8	Bolting
No. 391-1	Kazakhstan	118.9	19.4/55.8	2.3/1.8	Bolting
No. 391-2	Kazakhstan	-	31.6/-	2.9/-	Bolting
No. 392	Kazakhstan	95.8	17.8/29.6	2.2/3.1	Bolting
No. 393-1	Kazakhstan	110.8	18.2/70.5	2.8/1.7	Bolting
No. 393-2	Kazakhstan	90.1	16.0/40.2	1.0/1.7	Bolting
No. 394	Kazakhstan	-	22.8/-	2.2/-	Bolting
No. 395-1	Kazakhstan	88.7	22.4/36.3	2.5/2.9	Bolting
No. 395-2	Kazakhstan	110.7	24.2/30.2	2.0/1.9	Bolting
No. 397	China	-	28.2/-	2.8/-	Bolting
No. 398	China	82.0	19.2/60.7	1.8/1.4	Bolting

were identified as bolting clones. Among them, 30 clones were used in this study. Besides those, 30 clones collected in the Central Asia were also used for comparison. These clones were grown in Kagoshima University from the autumn of 1996 to the following summer. The morphological investigations were carried out twice in March and June, at the beginning and the end of growth after winter, respectively, in 1997. The following items were examined in those clones: length of scape, length of the longest leaf, and width of leaf blade, bolting habit, date of blooming, number of flower buds per inflorescence, color of anther, and pollen fertility. Three

plants were examined in respective clones, and the average of the data is shown.

Karyotype

Twenty-five clones from the Central Asia and twenty-nine clones from the Iberian Peninsula, respectively, were used in this study. The root tips were picked out and washed by water, and then pretreated in 2mM 8-hydroxyquinoline at 20℃ for 4 hours. After washed by water, the root tips were fixed in acetic acid-alcohol fluid (acetic acid 25%, alcohol 75%), and then placed at room temperature for 24 hours. They were washed by water again, and then macerated in 1 N of HCl at 60℃ for 6 min. They were stained by fuchsine sulfite-potassium pyrosulfite fluid, and then squashed in 45% acetic acid. Finally they were observed under microscope.

Results

Morphological characteristics

In Kagoshima, the clones from Spain and Portugal did not bolt at all, and consequently, no investigations could be carried out concerning scape-length and floral characteristics. Table 1 and 2 show morphological characteristics of those clones from the Iberian Peninsula and the Central Asia, respectively. Table 3 shows the floral characteristics of those clones from the Central Asia.

Garlic clones did not grow so well in the late-period of growth probably owing to some unsuitable climate conditions. The scape length of clones from the Central Asia ranged from 70.8 cm (No. 389) to 118.9 cm (No. 391-1) in June, the average was 95.9cm, and the mean absolute deviation was 10.5. The lengths of the longest leave blade ranged from 16.0 cm (No. 393-2) to 45.8 cm (No. 362) in March, 25.9 cm (No. 389) to 70.5 cm (No. 393-1) in June, averages were 25.0 cm and 42.1 cm, and the mean absolute deviations were 6.6 and 11.6, respectively. The widths of the leaf-blade ranged from 1.0 cm (No. 393-2) to 4.6 cm (No. 378) in March, 1.2 cm (No. 384) to 3.1 cm (No. 392) in June, their averages were 2.4 cm and 2.0 cm, and the mean absolute deviations were 0.6 and 0.5, respectively. Those from Spain and Portugal showed that the lengths of the longest leaf blade ranged from 21.0 cm (No. 468) to 36.1 cm (No. 452) in March, and from 42.6 (No. 468) to 76.8 cm (No. 448) in June. Their averages were 30.0 cm and 54.9 cm, and the mean absolute deviations were 3.2 and 5.2, respectively. The widths of the leaf blade ranged from 1.1 cm (No. 437) to 2.2 cm (No. 457) in March, and from 1.0 cm (No. 437) to 2.7 cm (No. 470) in June. Their averages were 1.5 cm and 1.6 cm, and the mean absolute deviations were 0.2 and 0.2, respectively.

Comparing the morphological characteristics of the Central Asian clones with those of the Iberian ones, the wider diversities were found in the clones from the Central Asia (Table 4). The mean absolute deviations of the lengths of the longest leaf blade, and the widths of leaf blade of the clones from the Central Asia were almost twice of those from Spain and Portugal. The longest leaf blade (54.9 cm) of those from Spain and Portugal was much longer than that (42.1 cm) of the Central Asian clones. The clones from the Central Asia always showed wider leaf blade than those from Spain and Portugal. Their values were 2.4 cm and 1.5 cm in March, 2.0 cm and 1.6 cm in June, respectively.

Table 3. Floral characteristics in the garlic clones from Central Asia

Clone No.	Number of florets per inflorescence	Color of anther	Pollen fertility (%)	Number of seeds	Date of flowering Month/Day
No. 362	-	-	-	-	-
No. 365	-	-	-	-	-
No. 366	-	-	-	-	-
No. 367	-	-	-	-	-
No. 370	-	-	-	-	-
No. 371	-	-	-	-	-
No. 372	-	-	-	-	-
No. 373	-	-	-	-	-
No. 375-1	118	purple	59.0	0.0	-
No. 375-2	-	-	-	-	-
No. 378	-	-	-	-	-
No. 379	170	yellow	0.0	-	7/ 2
No. 381	-	-	-	-	-
No. 384	162	yellow	0.0	0.0	7/ 3
No. 385	152	purple	70.0	0.0	7/ 2
No. 387	172	yellow	0.0	0.0	7/ 2
No. 388	-	-	-	-	-
No. 389	180	purple	73.0	0.0	-
No. 390-1	312	purple	94.0	0.0	7/ 3
No. 390-2	215	yellow	0.0	0.0	6/13
No. 391-1	241	purple	90.3	0.0	7/ 1
No. 391-2	-	-	-	-	-
No. 392	132	purple	64.3	0.0	7/ 4
No. 393-1	162	purple	34.0	0.0	7/ 4
No. 393-2	152	yellow	0.0	0.0	7/ 7
No. 394	-	-	-	-	-
No. 395-1	182	purple	84.7	0.0	6/22
No. 395-2	168	yellow	0.0	0.0	7/ 1
No. 397	-	-	-	-	-
No. 398	292	purple	-	0.0	6/30

Karyotypes

The basic karyotype of garlic is shown as follows:

$$K(2n) = 10m + 2sm_1^{sc} + 2sm_2^{sc} + 2sm$$

This was revealed by Etoh[3]. It includes ten long median chromosomes, two pairs of SAT-chromosomes, and one pair of short submedian chromosomes. The ten median chromosomes are different from one another in length. Both two pairs of SAT-chromosomes have big satellites and short proximal segments. The chromosomes of sm_1^{sc} are longer than those of sm_2^{sc}. The shorter pair of the SAT-chromosomes have bigger satellites than the longer pair.

Table 4. Average and mean absolute deviation of morphological characteristics in Central Asian garlic clones and Iberian garlic clones

		Clones from Central Asia		Clones from Spain and Portugal	
		Average (cm)	Mean absolute deviation	Average (cm)	Mean absolute deviation
Length of scape	March	-	-	-	-
	June	95.9	10.5	-	-
Length of longest leaf-blade	March	25.0	6.0	30.0	3.2
	June	42.1	11.6	54.9	5.2
Width of longest leaf-blade	March	2.4	0.6	1.5	0.2
	June	2.0	0.5	1.6	0.2

Table 5 and 6 shows the karyotypes of the examined garlic clones which were collected in the Iberian Peninsula and in the Central Asia, respectively. The basic karyotype was found in 20 clones out of the 25 examined clones from the Central Asia, and in 12 clones out of the 29 examined clones from the Iberian Peninsula. All the observed cells showed only the basic karyotype in the 12 clones out of the 25 Central Asian clones, and in the 2 clones of the 29 Iberian clones. The non-basic karyotypes were observed in the 13 clones of the 25 Central Asian, and in the 27 clones out of the 29 Iberian clones. Both of the basic and the non-basic karyotypes were observed in the 8 clones out of the 25 Central Asian clones, and in the 10 clones out of the 29 Iberian clones. The basic karyotype was more frequently observed in the Central Asian clones than in Iberian clones.

Discussion

Morphological characteristics and karyotypes were examined in a large number of garlic clones collected in the Central Asia and in the westernmost area of the old continent. In the previous report[7], morphological types were studied concerning the garlic clones collected in the Central Asia, and abundant fertile clones were found. In this study, 30 clones of those were selected to examine. The clones from Spain and Portugal were obtained in the summer of 1996, and they were grown in Kagoshima. According to the Spanish Gene Bank[10], these clones developed scapes about 50-60 cm long, with smaller inflorescence, and the spathes were generally left to be closed. When the spathe opened, a small bulbil developed in each flower bud of the inflorescence. Under unsuitable growing conditions, sometimes those plants grew too weakly to develop scapes, or even when they developed scapes, the scapes were too small to show themselves out, remaining inside the pseudostems[10]. According to Etoh and Ogura[2], sterile garlic plants frequently produced abnormal flowers, including bulbils within flowers.

Those Iberian clones planted in Kagoshima showed morphological characteristics of sterility. Etoh[4] suggested that the growth habit was an index to distinguish fertile garlic clones from sterile ones. The fertile clones from the Central Asia showed a long rest of growth

Table 5. Karyotypes in the garlic clones collected in Spain and Portugal

Clone No.	Number of cells		Total
	Karyotypes		
	Basic[1]	Non-basic	
No. 419	0	1(11m+2sm$_1^{sc}$+3sm), 2(10m+2sm$_1^{sc}$+4sm)	3
No. 422	4		4
No. 423	0	1(12m+2sm$_2^{sc}$+2sm), 2(10m+2sm$_1^{sc}$+4sm)	3
No. 425	1	1(11m+1sm$_1^{sc}$+2sm$_2^{sc}$+2sm)	2
No. 427	2	1(11m+2sm$_1^{sc}$+3sm)	3
No. 430	1	1(8m+1sm$_1^{sc}$+2sm$_2^{sc}$+5sm)	2
No. 432	2	1(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm)	2
No. 433	2		2
No. 434	0	2(10m+2sm$_2^{sc}$+4sm), 2(10m+1sm$_2^{sc}$+5sm)	4
No. 435	0	1(10m+1sm$_1^{sc}$+2sm$_2^{sc}$+3sm), 1(12m+2sm$_2^{sc}$+2sm)	2
No. 436	1	1(10m+1sm$_1^{sc}$ +5sm)	2
No. 437	0	1(10m+1sm$_1^{sc}$+5sm), 1(11m+2sm$_1^{sc}$+3sm)	2
No. 438	0	1(10m+1sm$_1^{sc}$+5sm)	1
No. 442	0	1(8m+2sm$_1^{sc}$+1sm$_2^{sc}$+5sm)	1
No. 444	0	2(10m+1sm$_1^{sc}$+2sm$_2^{sc}$+3sm)	2
No. 445	0	1(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm), 2(10m+2sm$_1^{sc}$+4sm)	3
No. 447	3	2(10m+2sm$_1^{sc}$+4sm)	5
No. 448	0	3(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm), (8m+2sm$_1^{sc}$+6sm)	4
No. 450	0	1(10m+1sm$_1^{sc}$+2sm$_2^{sc}$+2sm)2), 1(12m−2sm$_2^{sc}$+2sm)	2
No. 451	0	1(11m+2sm$_1^{sc}$+3sm), 1(10m+1sm$_1^{sc}$+5sm)	2
No. 453	0	2(10m+2sm$_2^{sc}$+4sm)	2
No. 454	0	1(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm), 1(10m+2sm$_1^{sc}$+4sm) 1(10m+1sm$_1^{sc}$+2sm$_2^{sc}$+3sm)	3
No. 457	1	(10m+2sm$_1^{sc}$+4sm)	2
No. 460	0	2(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm)	2
No. 461	3	1(12m+1sm$_1^{sc}$+1sm$_2^{sc}$+2sm)	4
No. 462	1	1(10m+2sm$_1^{sc}$+4sm)	2
No. 463	0	2(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm),2(11m+1sm$_1^{sc}$+1sm$_2^{sc}$+3sm)	4
No. 468	0	1(11m+1sm$_1^{sc}$+1sm$_2^{sc}$+3sm), 1(9m+2sm$_1^{sc}$+2sm$_2^{sc}$+3sm)	2
No. 470	1	1(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm)	2

[1]: Basic karyotype: K(2n)=10m+2sm$_1^{sc}$+2sm$_2^{sc}$+2sm [2]: 2n=15

during winter, and the sterile ones from Spain and Portugal kept growing during winter. After the rest of growth, the clones from the Central Asia grew again, and kept vigorous growth till summer, while the growth of those from Spain and Portugal became slower and more weakened in June. Such a tendency as this was not observed in the longest leaf blade. In both of March and June, fertile clones showed shorter leaves than those of sterile ones. These results supported the viewpoint of Etoh[4] describing that fertile clones produced shorter leaf blades in comparison with sterile garlic clones. This fact also might be considered as a

Table 6. Karyotypes in the garlic clones collected in Central Asia

Clone No.	Number of cells		
	Karyotypes		Total
	Basic	Non-basic	
No. 362	2		2
No. 370	3		3
No. 371	5		5
No. 372	1		1
No. 373	1	1(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm)	2
No. 375-1	2		2
No. 375-2	0	3(10m+2sm$_2^{sc}$+4sm)	3
No. 379	0	1(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm), 1(10m+1sm$_2^{sc}$ +5sm) 1(10m+2sm$_2^{sc}$+4sm)	3
No. 381	2		2
No. 385	2		2
No. 387	1	2(10m+2sm$_1^{sc}$+4sm)	2
No. 388	0	1(10m+2sm$_1^{sc}$+4sm), 1(10m+2sm$_2^{sc}$+4sm)	2
No. 389	2	1(11m+2sm$_1^{sc}$+1sm$_2^{sc}$+2sm)	3
No. 390-1	2	1(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm)	3
No. 390-2	2		2
No. 391-1	4	1(10m+1sm$_1^{sc}$+1sm$_2^{sc}$+4sm)	5
No. 391-2	0	1(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm), 3(10m+2sm$_1^{sc}$+4sm)	4
No. 392	2	1(10m+2sm$_1^{sc}$+4sm), 1(11m+1sm$_1^{sc}$+4sm)	4
No. 393-1	2		2
No. 393-2	1	1(10m+2sm$_1^{sc}$+4sm), 1(10m+2sm$_2^{sc}$+4sm)	3
No. 394	0	1(10m+2sm$_1^{sc}$+4sm), 1(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm)	2
No. 395-1	4		4
No. 395-2	1	1(10m+2sm$_1^{sc}$+1sm$_2^{sc}$+3sm)	2
No. 397	2		2
No. 398	3		3

morphological characteristic of fertile clones. Those clones from Spain and Portugal did not bolt completely in Kagoshima. Some of them could not develop even scapes, and several clones developed only short ones. These scapes were so short that they could not show themselves out and were left remaining inside. Therefore, it may be reasonable that we should consider these clones as incomplete-bolting type.

From the present research, another result was obtained. Judged by morphological characteristics and karyotypic analysis, greater variation of garlic is assumed to exist in the Central Asian clones than the Iberian clones. DNA analysis was carried out in preparation for publication, and a higher level of genetic variation was shown in the Central Asian clones. A wider variation existed also in the morphological characteristics. Polymorphisms among the Central Asian garlic clones were previously observed in fertility, such as fertile ones, weak fertile ones, male-sterile ones, and sterile ones[4,5], and also in some morphological characteristics

such as the lengths of leaf blade. Mean absolute deviations of these morphological characteristics in the Central Asian clones were almost twice of the Iberian clones. This means that there is a much greater variation in the clones from the Central Asia than in those from Iberian Peninsula.

The native home of garlic was previously discussed by several researchers, and they presumed it to be the mountainous regions of the Central Asia, such as mountains in Turkmenia, Pamir-Alai and Tien Shan regions[1, 8, 12, 16]. According to Etoh[3], the basic karyotype of garlic was observed most frequently in this area. The heterokarytypes were reported besides the homokaryotype by different researchers[9, 13, 15]. One possibility was that the basic karyotype changed into various heterokaryotypes in garlic, and the modification of karyotype was accelerated by the vegetative propagation of garlic[3]. However, among the 25 examined clones from the Central Asia, the basic karyotype was observed in 20 clones, especially in the pollen fertile clones. All the examined cells showed only the basic karyotype in the 11 pollen fertile clones, and the basic karyotype was observed in all the pollen fertile clones. In the clones from Spain and Portugal, the basic karyotype was not observed so frequently, and non-basic karyotypes existed more commonly. The karyotype may have changed with the spreading of garlic from the center of origin to the west, accompanied with translocation, deletion, replication, recombination, or inversion of chromosomes, and so on.

In the west of the Central Asia, no fertile clones were discovered except for a few found in Caucasus[6]. The Iberian Peninsula is the westernmost area of the continent from the Central Asia, and some bolting-type garlic clones have been known to exist there. There was a slight possibility that some fertile clones still survived in this area. However, the present study clearly gave the evidence that there existed no fertile clones in Iberian and probably in Mediterranean areas because no fertile clones were found in other Mediterranean areas[5), 6]. From the Central Asia to the west, garlic fertility may have become gradually weakened, then it might have been lost completely or only the sterile clones might have spread to the Mediterranean area. Morphological characteristic variation may also have been gradually reduced with the species spreading out, and the karyotype may have changed more frequently.

Summary

In Iberian Peninsula situated at the westernmost Europe, bolting-type garlic clones exist, while no bolting-type ones are left in other Mediterranean areas. In this study, bolting clones were collected in the Iberian Peninsula, the westernmost area of the continent, for search of fertile clones. The morphological characteristics and the karyotype of these clones were compared with those fertile clones collected from the Central Asia in order to examine the possibility of existence of fertile garlic clones in this area, and further in order to identify the distribution limit of fertile clones in the west. Those Iberian clones did not bolt in Kagoshima. Their growth might have been affected by the climate factors because the traces of scapes were noticed when they were collected. No fertile clones had ever been collected in Iberian Peninsula, though bolting-type clones were reported in this area. The average of scape-lengths of the Central Asian clones was 95.9 cm in June, and the mean absolute deviation was 10.5. In the Central Asian clones, the average lengths of the longest leaf blade in March and June were 25.0 cm and 42.1 cm, and the mean absolute deviations were 6.6 and 11.6, respectively. The average widths of the leaf blade in March and June were 2.4 cm and 2.0 cm, respectively. On

the other hand, the average lengths of the longest leaf blade in the Iberian clones were 30.0 cm in March and 54.9 cm in June, and the mean absolute deviations were 3.2 and 5.2, respectively. The averages of widths of leaf blade in March and June were 1.5 cm and 1.6 cm, respectively. The basic karyotype of garlic was found in the 20 clones out of the 25 examined clones from the Central Asia, and it was found in the 12 clones out of the 29 examined clones from Iberian Peninsula. Comparing the Central Asian clones with the Iberian clones, wider diversities in morphological characteristics were found in the clones from the Central Asia. And the basic karyotype of garlic was more frequently observed in the clones from the Central Asia too. By now, any fertile clones have not been reported in this area, and it is reasonable for us to consider that there is no fertile clone in the Mediterranean areas.

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