Variation and Evolution in the Karyotype of *Lycoris*, Amaryllidaceae

VI. Intrapopulation and/or intraspecific variation in the karyotype of *L. sanguinea* Max. var. *kiushiana* and *L. sanguinea* Max. var. *koreana* (Nakai) Koyama

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L. sanguinea var. *kiushiana* is distributed in the lower or middle part of montane zone at the south of province Musashi to the north of province Satsuma, but it is found more commonly in south-western regions such as Shikoku and Kyushu. Typical individuals of *L. s.* var. *kiushiana* can easily be distinguished from those of *L. s.* var. *sanguinea* by some characters. For example; 1) The size of flowers of *L. s.* var. *kiushiana* is larger than that of *L. s.* var. *sanguinea*, namely the mean length of perianth lobes of the former is 10.0 cm and that of the latter is 5.5 cm. 2) The length of stamens of *L. s.* var. *kiushiana* ($\bar{x}=11.5$ cm) is longer than that of its perianth lobes and, in addition to this, each perianth lobe recurves, so the stamens distinctly protrude beyond perianth lobes. On the other hand, stamens of *L. s.* var. *sanguinea* is not exerted from corolla. 3) The length of style of *L. s.* var. *kiushiana* ($\bar{x}=12.0$ cm) is about twice as long as that of *L. s.* var. *sanguinea* ($\bar{x}=5.5$ cm). 4) The length of scape and the width of perianth lobe of *L. s.* var. *kiushiana* are also larger than those of *L. s.* var. *sanguinea*; and 5) The anthesis of *L. s.* var. *kiushiana* starts at the beginning of July, while that of *L. s.* var. *sanguinea* starts at the beginning of August. However, the leaves of the former begin to elongate in the later part of February as well as the latter.

L. sanguinea var. *koreana* had been collected at the foot of Mt. Paektu of southern Korea and was registered as a new species, *L. koreana*, by Nakai (1930) at the first, thereafter it was described as a variety of *L. sanguinea* by Koyama (1959). The distribution of this taxon is very restricted. It is only reported in a part of Kyushu, Tsushima Island, and southern Korea. This taxon can be distinguished from *L. s.* var. *kiushiana* by its smaller size of corolla, and from *L. s.* var. *sanguinea* by the long-exserted stamens. The anthesis of the taxon starts at July as well as *L. s.* var. *kiushiana*, but the leaves elongate at the beginning of December and tide over a winter unlike the other two varieties.

The karyotypes of a few bulbs of *L. s.* var. *kiushiana* and *L. s.* var. *koreana* were studied by Takemura (1965) and Yoshida (1972). They reported the karyotypes consisting of twenty-two acrocentric chromosomes in both taxa. The present author examined numerous bulbs from many populations and found various intrapopulation and/or intraspecific variations. The results will be mentioned and discussed in this paper.

Materials and methods

As shown in Table 1, 185 bulbs of *L. sanguinea* var. *kiushiana* from ten localities and seventeen bulbs of *L. sanguinea* var. *koreana* from two localities were examined. Used bulbs were collected randomly in each population and cultivated in unglazed pots at the experimental

garden of Chiba University.

Preparations for karyotype analysis were made by the same methods mentioned in the previous paper (Kurita 1986). The chromosomes in the text figures are aligned in a row according to the length of the long arm of each chromosome in a complement. Black-painted chromosomes in the figures excepting Figs. 2 and 3 indicate the satellite chromosome and some chromosomes which deviate from the standard type.

Table 1. Localities from which the materials were obtained and the number of bulbs examined

Taxa	Localities	Number of bulbs
<i>L. sanguinea</i> var. <i>kiushiana</i>	Tara-dake, Omura, Nagasaki Pref.	100
	Oharatodera, Kyoto, Kyoto Pref.	10
	Kuramakihune, Kyoto, Kyoto Pref.	10
	Kozagawa, Higashimuro, Wakayama Pref.	30
	Kamiyama, Myozai, Tokushima Pref.	5
	Kamisato, Kochi, Kochi Pref.	10
	Chikamy-yama, Imabaru, Ehime Pref.	3
	Ishitedera, Matsuyama, Ehime Pref.	2
	Inosedo, Beppu, Oita Pref.	10
	Kukino, Aso, Kumamoto Pref.	5
	Gokanosho, Izumi, Yatsushiro, Kumamoto Pref.	7
<i>L. sanguinea</i> var. <i>koreana</i>	Hoshikura, Nichinan, Miyazaki Pref.	10
Total	12 populations	202

For simplification of descriptions, following abbreviations are used: *A*, *T'*, *m*, *LG*, *MG*, *SG*, *L1/S1*, *S*, $\bar{x}$, and *r*. The meaning of each abbreviation is just the same with that in the previous papers (Kurita 1987a, 1988c).

Based on the statistical analysis of the karyotype of *L. sanguinea* var. *sanguinea* (Kurita 1987c), the author considers that the disparity more than 0.9 μ m in the long arm length of any given chromosome set in a complement of *L. sanguinea* var. *kiushiana* also indicates the heterozygous condition.

Observations

1) *L. sanguinea* var. *kiushiana*

In the first place, one hundred bulbs from the Tara-dake population were examined cytologically. The representative karyotype which was observed in the majority of the bulbs examined is shown in Figs. 1, 2 and 3. After this, the author will style it as the standard karyotype of this taxon. This karyotype is very similar to the standard karyotype of *L. s.* var. *sanguinea*, but any *A* type chromosome of which arm ratio is higher than 10.0 is not found in this complement. In the standard karyotype of *L. s.* var. *sanguinea*, there are two such *A* type chromosomes (Kurita 1988c). The measurements and calculated numerical value of each chromosome of the standard karyotype of *L. s.* var. *kiushiana* are summarized in Table 2. The numerical value of *L1/S1*, $\bar{x}$ and *S* in the figured cell is 1.3, 10.6 μ m, and 0.9 μ m respectively. The number of nucleoli in an interphase nucleus of these bulbs is one or two, but usually two are observed.

A few, but distinct karyotype variations are found in some bulbs from the Tara-dake population. Details are given under.

A subtelocentric chromosome is observed in many complements of a bulb (Figs. 4, 8). The arm ratio of this chromosome in the figured cell is 4.3. The numerical value of *L1/S1*,

Figs. 1-3. Standard karyotype of *L. sanguinea* var. *kiushiana* from the Tara-dake population. $2n=22=22A$. 1, a prometaphase cell. Arrow heads indicate satellite chromosomes. 2, the cut-out complement from Fig. 1. Bar indicates $10\ \mu\text{m}$. 3, explanatory karyogram for Fig. 2.

Table 2. Measurements and calculated values in a standard karyotype of *L. sanguinea* var. *kiushiana*

Chromosome	Length of arm (μm) short+long=total	Relative length	Arm ratio ^a	Form
1	$1.8+11.8=13.6$	5.1	6.6	A
2	$1.8+11.8=13.6$	5.1	6.6	A
3	$0.3+1.8+11.7=13.5$	5.0	6.5	A*
4	$0.3+1.8+11.7=13.5$	5.0	6.5	A*
5	$1.6+11.6=13.2$	4.9	7.3	A
6	$1.3+11.3=12.6$	4.7	8.7	A
7	$1.6+11.1=12.7$	4.7	6.9	A
8	$1.3+11.1=12.4$	4.6	8.5	A
9	$1.6+10.5=12.1$	4.5	6.6	A
10	$1.4+10.5=11.9$	4.4	7.5	A
11	$1.1+10.5=11.6$	4.3	9.6	A
12	$1.3+10.5=11.8$	4.4	8.1	A
13	$1.1+10.5=11.6$	4.3	9.6	A
14	$1.2+10.5=11.7$	4.3	8.8	A
15	$1.3+10.5=11.8$	4.4	8.1	A
16	$1.3+10.3=11.6$	4.3	7.9	A
17	$1.3+10.0=11.3$	4.2	7.7	A
18	$1.3+10.0=11.3$	4.2	7.7	A
19	$1.0+9.5=10.5$	3.9	9.5	A
20	$1.2+8.9=10.1$	3.8	7.4	A
21	$1.3+8.9=10.2$	3.8	6.9	A
22	$1.3+8.9=10.2$	3.8	6.9	A

* Satellited: A type chromosome.

$\bar{x}$, and S in this complement is 1.4 , $9.6 \mu\text{m}$, and $0.8 \mu\text{m}$, respectively. Such subtelocentrics are also observed in other twelve bulbs. In the complements of a bulb, the length of each long arm of two satellite chromosomes differs clearly (Figs. 5, 9). The difference is $1.1 \mu\text{m}$, and the one is situated in LG and the other is in second half of MG . Such situation of satellite chromosomes is also found in other two bulbs. The numerical value of $L1/S1$, $\bar{x}$, and S in the figured cell is 1.3 , $8.2 \mu\text{m}$, and $0.7 \mu\text{m}$, respectively. One T' type chromosome is observed in

Figs. 4-7. Prometaphase or metaphase cells of four individuals of *L. s. var. kiushiana* from the Tara-dake population. 4, arrow head indicates a subtelocentric chromosome. 5, arrow head indicates heterozygous satellite chromosomes. 6, arrow head indicates a T' type chromosome. 7, arrow head indicates a subtelocentric chromosome and a satellite chromosome.

each complement of six bulbs. In the figured complement (Figs. 6, 10), it is situated in SG . The numerical value of $L1/S1$, $\bar{x}$, and S in this complement is 1.3 , $8.4 \mu\text{m}$, and $0.6 \mu\text{m}$, respectively. In a complement (Figs. 7, 11), a satellite chromosome, a subtelocentric chromosome, and an A type chromosome having rather small short arm are observed. The arm ratio of this subtelocentric chromosome is 4.4 , and that of the A is 10.7 in the figured cell. The numerical value of $L1/S1$, $\bar{x}$, and S in this cell is 1.4 , $8.8 \mu\text{m}$, and $0.7 \mu\text{m}$, respectively. The karyotype including only one visible satellite chromosome is found in fifteen bulbs in toto,

Figs. 8–11. Explanatory karyograms for Figs. 4–7. Figs. 8, 9, 10 and 11 corresponds to Figs. 4, 5, 6 and 7, respectively. Bar indicates 10 μm .

Table 3. Measurements and calculated value in the standard karyotype of triploid

L. sanguinea var. *kiushiana*

Chromosome	Length of arm (μm) short+long=total	Relative length	Arm ratio	Form
1	$0.3+1.3+9.0=10.3$	3.6	6.9	A*
2	$0.3+1.3+9.0=10.3$	3.6	6.9	A*
3	$1.3+8.7=10.0$	3.4	6.7	A
4	$1.3+8.7=10.0$	3.4	6.7	A
5	$1.1+8.7=9.8$	3.4	7.9	A
6	$1.1+8.7=9.8$	3.4	7.9	A
7	$1.1+8.4=9.5$	3.3	7.6	A
8	$1.3+8.4=9.5$	3.3	6.5	A
9	$1.1+8.4=9.5$	3.3	7.6	A
10	$1.1+8.2=9.3$	3.2	7.5	A
11	$1.1+8.2=9.3$	3.2	7.5	A
12	$1.3+8.2=9.5$	3.3	6.3	A
13	$1.1+7.9=9.0$	3.1	7.2	A
14	$0.8+7.9=8.7$	3.0	9.9	A
15	$0.8+7.9=8.7$	3.0	9.9	A
16	$0.8+7.6=8.4$	2.9	9.9	A
17	$0.9+7.6=8.5$	2.9	8.4	A
18	$0.9+7.6=8.5$	2.9	8.4	A
19	$1.3+7.6=8.9$	3.1	5.8	A
20	$1.1+7.6=8.7$	3.0	6.9	A
21	$0.9+7.6=8.5$	2.9	8.4	A
22	$1.1+7.6=8.7$	3.0	6.9	A
23	$0.9+7.6=8.5$	2.9	8.4	A
24	$1.1+7.6=8.7$	3.0	6.9	A
25	$1.1+7.4=8.5$	2.9	6.7	A
26	$1.1+7.4=8.5$	2.9	6.7	A
27	$0.8+7.1=7.9$	2.7	8.9	A
28	$0.8+7.1=7.9$	2.7	8.9	A
29	$1.1+6.6=7.7$	2.7	6.0	A
30	$1.1+6.3=7.4$	2.5	5.7	A
31	$1.1+6.3=7.4$	2.5	5.7	A
32	$1.1+6.1=7.2$	2.5	5.5	A
33	$1.1+6.1=7.2$	2.5	5.5	A

* Satellited: A type chromosome.

but the number of nucleoli in an interphase nucleus of these bulbs is usually two. In other five bulbs, the satellite chromosomes having very large satellite body is observed. Such satellite was also observed in some bulbs of *L. s. var. sanguinea* (Kurita 1986).

Three bulbs which were collected by Dr. Yamazaki at the Tara-dake population have $2n=33$. Namely, they are triploid plants. This is the first record of triploid in this taxon. The

Figs. 12–15. 12, a metaphase cell of triploid *L. s. var. kiushiana*, showing $2n=33=33A$. 13, a metaphase cell of tetraploid *L. s. var. kiushiana*, showing $2n=44=42A+2T'$. 14 and 15, explanatory karyogram for Figs. 12 and 13.

Table 4. Measurements and calculated value in the standard karyotype of tetraploid
L. sanguinea var. *kiushiana*

Chromosome	Length of arm (μm) short+long=total	Relative length	Arm ratio	Form
1	1.3+7.6=8.9	2.6	5.8	A
2	1.3+7.6=8.9	2.6	5.8	A
3	1.3+7.6=8.9	2.6	5.8	A
4	1.3+7.4=8.7	2.6	5.7	A
5	0.8+7.4=8.2	2.4	9.3	A
6	1.1+7.4=8.5	2.5	6.7	A
7	1.2+7.1=8.3	2.4	5.9	A
8	1.3+7.1=8.4	2.5	5.5	A
9	1.3+7.1=8.4	2.5	5.5	A
10	1.1+7.1=8.2	2.4	6.5	A
11	1.1+7.1=8.2	2.4	6.5	A
12	1.1+6.8=7.9	2.3	6.2	A
13	0.9+6.8=7.7	2.3	7.6	A
14	1.1+6.8=7.9	2.3	6.2	A
15	1.3+6.8=8.1	2.4	5.2	A
16	1.1+6.8=7.9	2.3	6.2	A
17	1.1+6.8=7.9	2.3	6.2	A
18	1.1+6.8=7.9	2.3	6.2	A
19	0.3+6.8=7.1	2.1	22.7	T'
20	0.3+6.8=7.1	2.1	22.7	T'
21	0.8+6.8=7.6	2.2	8.5	A
22	1.1+6.8=7.9	2.3	6.2	A
23	1.1+6.6=7.7	2.3	6.0	A
24	1.1+6.6=7.7	2.3	6.0	A
25	1.1+6.6=7.7	2.3	6.0	A
26	1.1+6.6=7.7	2.3	6.0	A
27	1.1+6.6=7.7	2.3	6.0	A
28	1.1+6.6=7.7	2.3	6.0	A
29	1.1+6.6=7.7	2.3	6.0	A
30	1.1+6.6=7.7	2.3	6.0	A
31	1.1+6.6=7.7	2.3	6.0	A
32	1.1+6.6=7.7	2.3	6.0	A
33	1.1+6.6=7.7	2.3	6.0	A
34	1.1+6.6=7.7	2.3	6.0	A
35	1.3+6.3=7.6	2.2	4.9	A
36	1.1+6.3=7.4	2.2	5.7	A
37	1.1+6.3=7.4	2.2	5.7	A
38	1.1+6.3=7.4	2.2	5.7	A
39	0.8+6.1=6.9	2.0	7.6	A
40	1.1+5.5=6.6	1.9	5.0	A
41	1.1+5.5=6.6	1.9	5.0	A
42	1.3+5.5=6.8	2.0	4.2	A
43	1.1+5.5=6.6	1.9	5.0	A
44	1.1+5.3=6.4	1.9	4.8	A

karyotype of this triploid is shown in Figs. 12 and 14. Though there are three nucleoli in each interphase nucleus, the author can not find out three satellite chromosomes but two as shown in the figure. The numerical value of $L1/S1$, $\bar{x}$, and S in the figured cell is 1.5, 7.8 μm , and 0.8 μm , respectively. The measurements and calculated value of each chromosome in a complement are summarized in Table 3. The shape of flowers of this triploid plant slightly differs from that of the diploids. The width of perianth segment of triploid is wider than that of the diploid (Fig. 16). Moreover, the size of stomata of the former is larger than that of

the latter as is also recorded in the triploid plants of *L. s. var. sanguinea* (Kurita 1988c).

One tetraploid plant having $2n=44$ was collected in the Tara-dake population, too. The complement of this plant consists of forty-two *A* types and two *T'* type chromosomes as shown in Figs. 13 and 15. Though the satellite chromosomes are obscure in the figured cell, four satellite chromosomes have been observed clearly in other cells of this bulb. Therefore, the number of nucleoli in an interphase nucleus is four at maximum. The numerical value of *LI/SI*, $\bar{x}$, and *S* in the figured cell is 1.5, 6.7 μm , and 0.6 μm , respectively. Measurements and calculated value of each chromosome of this cell are summarized in Table 4. Intraindividual chromosomal interchanges have not been observed in the Tara-dake population so far as the present investigation is concerned.

Intrapopulational karyotype variations which are similar to those observed in the Tara-dake population have also been found in almost all examined populations. In the population at Oharatodera, Kyoto City, ten bulbs had been collected. Three bulbs out of ten have a karyotype which is almost accordant with the standard karyotype. In the complement of the rest seven bulbs, one *T'* type chromosome is included (Figs. 17, 20). And in this complement,

Fig. 16. Flowers of triploid plant of *L. s. var. kiushiana* from Mt. Tara-dake, showing broader perianth lobes and exserted stamens.

one *A* type chromosome having a smaller short arm than that of the standard is also found. The arm ratio of this chromosome in the figured cell is 10.0. The numerical value of *LI/SI*, $\bar{x}$, and *S* in the figured complement is 1.5, 10.0 μm , and 1.4 μm , respectively. A karyotype which is just like that found in Oharatodera was observed in all bulbs from the Kuramakifune population (Fig. 19).

In the Kozagawa population, thirty bulbs have been gathered. The greater part of examined bulbs have a karyotype which is almost accordant with the standard type, but an *A* type chromosome having high arm ratio is found in the complement of four bulbs (Fig. 21). The arm ratio of this chromosome in the figured cell is 16.7. The numerical value of *LI/SI*, $\bar{x}$, and *S* in this cell is 1.3, 7.5 μm , and 0.6 μm , respectively.

At Mt. Kumosoan, five bulbs had been collected by the late Mr. Y. Kato. The karyotype of these bulbs is similar to that of the bulbs from the Kuramakifune population. Namely one T' type chromosome is included in the complement (Fig. 22). The numerical value of $L1/S1$, $\bar{x}$, and S in this complement is 1.4, 9.3 μm , and 0.8 μm , respectively.

Figs. 17–20. 17, a prometaphase cell of *L. s. var. kiushiana* from Kuramakifune. Arrow head indicates a T' type chromosome and a A type chromosome having fairly large arm ratio. 18, a metaphase cell of *L. s. var. kiushiana* from Ishitadera. Arrow heads indicate two T' type chromosomes. 19, karyotype of a bulb of *L. s. var. kiushiana* from Oharatodera. Bar indicates 10 μm . 20, explanatory karyogram for Fig. 17.

Ten bulbs were collected in the Kamisato population. Seven of them have a karyotype which is almost accordant with the standard type. In three bulbs, however, one A type chromosome having very high arm ratio is observed (Fig. 23). The numerical value of $L1/S1$, $\bar{x}$, and S

S in the figured cell is 1.4, 10.2 μm , and 0.9 μm , respectively.

The author examined three bulbs which were collected at Chikamiyama, Imabaru City. The karyotype of these bulbs is almost accordant with the standard type, but the length of long arms of both satellite chromosomes in the complement of one bulb slightly differs in each other (Fig. 24). The numerical value of $L1/S1$, $\bar{x}$, and S in the figured cell is 1.4, 8.4 μm and 0.7 μm , respectively.

Figs. 21–28. Eight karyotypes of *L. s. var. kiushiana* (cf. text). Bars indicate 10 μm . 21, karyotype of a bulb from Kozagawa. No. 21 chromosome has high arm ratio. 22, karyotype of a bulb from Kumosozan. 23, karyotype of a bulb from Kamizato. 24, karyotype of a bulb from Chikamiyama. 25, explanatory karyogram for Fig. 18. 26, karyotype of a bulb from Ishitedera. 27, karyotype of a bulb from Inosedo. 28, karyotype of a bulb from Kukino population,

Figs. 29–37. Karyotypes of *L. s. var. koreana* (cf. text). Bars indicate 10 μm. 29, a metaphase cell of a bulb from Gokanoshō. Arrow head indicates a *T'* type chromosome and a subtelocentric chromosome. 30, a metaphase cell of a bulb from Gokanoshō. Arrow head indicates a *m* type chromosome. 31, a metaphase cell of a bulb from Hoshikura. Arrow head indicates *T'* type chromosome. 32, a prometaphase cell of a bulb from Hoshikura. Arrow head indicates *m* type chromosome. 33, standard karyotype of *L. s. var. koreana* from Hoshikura. 34, 35, 36 and 37 are explanatory karyograms for Figs. 29, 30, 31 and 32, respectively.

Two bulbs from the Ishitedera population were examined. A complement of a bulb is shown Figs. 18 and 25. Two T' type chromosomes are found and only one satellite chromosome is observed in this complement, though two nucleoli are usually counted in each interphase nucleus. The numerical value of $L1/S1$, $\bar{x}$, and S in the figured cell is 1.4, 7.4 and $0.6 \mu\text{m}$ respectively. One satellite chromosome and two T' type chromosomes are also observed in the complement of another bulb, but the size and form of the shortest chromosome (no. 22) differ from those of the former bulb as shown in Fig. 26. The length of long arm of the no. 22 is $5.8 \mu\text{m}$, while the length of no. 21 is $6.8 \mu\text{m}$. Moreover, the size of the short arm of the no. 22 is twice as large as that of the no. 21. Namely the no. 22 is a subtelocentric chromosome and its arm ratio is 3.7. Accordingly the calculated value of $L1/S1$ in this complement is 1.7, which is larger than that of the standard type. The numerical value of $\bar{x}$, and S of the figured complement is $8.2 \mu\text{m}$ and $0.9 \mu\text{m}$, respectively.

Table 5. Measurements and calculated value of a representative complement of *L.sanguinea* var. *koreana*

Chromosome	Length of arm (μm) short+long=total	Relative length	Arm ratio	Form
1	$1.3+8.7=10.0$	5.2	6.7	A
2	$1.1+8.7=9.8$	5.1	7.9	A
3	$0.3+1.3+8.4=9.7$	5.0	6.7	A*
4	$0.3+1.1+8.4=9.5$	4.9	7.6	A*
5	$1.1+8.2=9.3$	4.8	7.5	A
6	$1.1+8.2=9.3$	4.8	7.5	A
7	$1.1+8.2=9.3$	4.8	7.5	A
8	$1.1+7.9=9.0$	4.7	7.2	A
9	$1.3+7.9=9.2$	4.8	6.1	A
10	$1.3+7.6=8.9$	4.6	5.8	A
11	$1.3+7.6=8.9$	4.6	5.8	A
12	$1.1+7.4=8.5$	4.4	6.7	A
13	$1.1+7.4=8.5$	4.4	6.7	A
14	$1.3+7.4=8.7$	4.5	5.7	A
15	$1.1+7.4=8.5$	4.4	6.7	A
16	$1.1+7.4=8.5$	4.4	6.7	A
17	$1.1+7.4=8.5$	4.4	6.7	A
18	$1.1+7.1=8.2$	4.3	6.5	A
19	$1.1+6.6=7.7$	4.0	6.0	A
20	$1.2+6.6=7.8$	4.0	5.5	A
21	$1.1+6.6=7.7$	4.0	6.0	A
22	$1.1+6.3=7.4$	3.8	5.7	A

* Satellited: A type chromosome

Ten bulbs collected in the Inosodo population were examined. Excepting one bulb, all have a karyotype which is almost accordant with the standard type. In the complement of the rest one bulb, however, there are two satellite chromosomes of which long arm length slightly differs each other and one subtelocentric chromosome having $r=4.3$ (Fig. 27). Moreover, in this complement there is one A type chromosome having rather small short arm than the standard. The arm ratio of this chromosome is 10.7. And the length of long arm of the no. 22 chromosome is about $1 \mu\text{m}$ shorter than that of the no. 21 in the figured complement. The numerical value of $L1/S1$, $\bar{x}$ and S in this cell is 1.5, $8.5 \mu\text{m}$, and $0.8 \mu\text{m}$, respectively.

In the Kukino population, five bulbs had been collected. All bulbs have a karyotype which is very similar to the standard type, but in a bulb the long arm of the no. 22 chromosome is slightly shorter than that of the no. 21 as shown in Fig. 28. The numerical value of $L1/S1$,

$\bar{x}$, and S in the figured cell is 1.4, 10.2 μm , and 0.8 μm , respectively.

2) *L. sanguinea* var. *koreana*

Seventeen bulbs of this taxon were collected from two populations as shown in Table 1. Some intrapopulation karyotype variations and intraindividual chromosomal interchanges were also observed.

In the Gokanosho population, seven bulbs were collected. The karyotype of five bulbs out of seven is almost in accordance with the standard type of *L. s.* var. *kiushiana*. The measurements and calculated value of each chromosome in a representative complement (Fig. 33) are summarized in Table 5. The numerical value of $L1/S1$, $\bar{x}$, and S in this figured cell is 1.4, 7.6 μm , and 0.7 μm , respectively. On the other hand, in the complements of the rest two bulbs, a T' type chromosome and a subtelocentric chromosome are observed (Figs. 29, 34). The arm ratio of the subtelocentric chromosome in the figured cell is 4.1. Two satellite chromosomes are observed in the complement of all bulbs examined. The numerical value of $L1/S1$, $\bar{x}$, and S in this figured complement is 1.4, 8.9 μm , and 0.6 μm , respectively. An intraindividual chromosomal interchange is found in a bulb. Namely, one m type chromosome is included in a complement (Figs. 30, 35) as observed in some bulbs of *L. s.* var. *sanguinea* (Kurita 1988c). Moreover, the condensability of some chromosomes in this figured cell is partially abnormal, so the configuration of each chromosome in the complement fairly differs from that of the normal cell. For reference, the numerical value of $L1/S1$, $\bar{x}$, and S in this figured complement is 16.3, 12.9 μm , and 3.1 μm , respectively.

Ten bulbs from a population at Hoshikura, Nichinan City, were examined. Six out of ten bulbs have a karyotype which is almost in accordance with the standard type of *L. s.* var. *kiushiana*, but one T' type chromosome is included in the complements of the rest four bulbs. One of such complements is shown in Figs. 31 and 36. The numerical value of $L1/S1$, $\bar{x}$, and S in this cell is 1.3, 9.0 μm , and 0.7 μm respectively. Two satellite chromosomes are observed in each complement of eight bulbs, but the complements of the rest two bulbs included only one satellite chromosome. The number of nucleoli in an interphase nucleus of these bulbs, however, is one or two, and usually two are counted. An intraindividual chromosomal interchange is also found in this population. As it is observed in a bulb from the Gokanosho population, one m type chromosome is included in a complement of one bulb (Figs. 32, 37). The numerical value of $L1/S1$, $\bar{x}$, and S in this aberrant cell is 7.3, 9.6 μm , and 2.0 μm , respectively.

Discussion

Takemura (1965) is the first cytologist who counted the chromosome number of *L. s.* var. *kiushiana*. He found twenty-two A type chromosomes in this taxon, and he stated that this karyotype could not be distinguished from that of *L. s.* var. *sanguinea*. Yoshida (1972) also reported $2n=22=22A$ in *L. s.* var. *kiushiana*, and he found two satellite chromosomes in his complement.

On the other hand, there was no cytological study on *L. s.* var. *koreana* but the Takemura's oral report (Takemura 1965). He reported a karyotype consisting of twenty-two A type chromosomes which is exactly alike in the karyotype of *L. s.* var. *kiushiana* and *L. s.* var. *sanguinea*.

At the present investigation, the majority of examined bulbs of both taxa have the karyotype which consists of twenty-two A type chromosome as shown in Figs. 1, 2, 3 and 29. This result accords with the previous reports fundamentally. Though the previous records on the karyotype of these taxa contain no mention on the intraspecific karyotype variations, various

structural and numerical chromosomal changes were found by the present author.

In the Taradake population, several karyotypic variations or deviations from the standard type were observed as mentioned above. Besides 77% standard satellite chromosome combination, as shown in a pie chart (Fig. 38, left), there are some aberrant combinations. Namely a combination in which the length of each long arm of two satellite chromosomes differs obviously takes 3% share, and a combination of two satellite chromosomes of which one has fairly large satellite takes 5% share, and the complements in which only one satellite chromosome is observed take 15% share. On the other hand, as shown in another pie chart (Fig. 38, right), 80% individuals have the complements consisting of *A* type chromosome alone. In the complements of 13% individuals, there is one subtelocentric chromosome at the least. Such subtelocentrics may be produced by the reciprocal translocation or pericentric inversion in *A* type chromosomes. The complements including one *T'* type chromosome are observed in 6% individuals, and two *T'* type chromosomes are found in the complement of 1% individual. Such *T'* type chromosomes may be produced from *A* type chromosomes by means of pericentric inversion or deficiency. The results mentioned above are not so different from those obtained in *L. s. var. sanguinea* population at Noro (Kurita 1988c).

Fig. 38. Frequency of satellite chromosome combination (left: pie chart) and arm ratio variation (right: pie chart) in the complements of 100 bulbs of *L. s. var. kiushiana* from Tara-dake population (cf. text).

Similar variations in the karyotype are also found in almost all examined population of *L. s. var. kiushiana* and *L. s. var. koreana*.

The shortening of short arm of the standard *A* type chromosomes which resulted in *T'* type chromosomes was also observed in some bulbs from seven populations. They are the Kuramakifune, Oharatodera, Kamiyama, Kamisato, Ishitedera, Gokanoshō, and Hoshikura populations. The percentage of the individuals carrying *T'* type chromosome in these populations is as follows: It is 70.0% in Oharatodera, 100% in Kuramakifune and Ishitedera, 38.6% in Gokanoshō, 50.0% in Kamiyama, 33.3% in Kamisato and 40% in Hoshikura. In Ishitedera population, all bulbs carry *T'* type chromosomes homozygously in their complement. Therefore, the *T'* type chromosome

is observed in 60.0% of the examined populations of *L. s. var. kiushiana* and in all of *L. s. var. koreana*. These percentages are apparently larger than that (21.0%) in *L. s. var. sanguinea* (Kurita 1988c).

The elongation of the short arm resulting the subtelocentric chromosomes was observed in some bulbs from three populations. They are the Ishitedera, Inosedo and Gokanoshō populations. The percentage of individuals carrying the subtelocentrics in these populations is as follows: It is 50.0% in Ishitedera, 100% in Inosedo, and 38.6% in Gokanoshō population.

The *m* type chromosome was observed in two bulbs of *L. s. var. koreana* as an intercellular chromosomal rearrangement. This chromosome may be produced from the standard *A* type chromosome by large paracentric deficiency in the long arm.

The heterozygous combination in the long arm length of satellite chromosomes was also found in the complements of 14.0% bulbs from Chikamiyama and in 10.0% bulbs from Hoshikura population. Such combination was already reported in some bulbs of *L. s. var. sanguinea* (Kurita 1988c).

The triploid and tetraploid plants of *L. s. var. kiushiana* may be the autopolyploid judging from the gross morphology and karyotype, though their meiotic division has not been examined yet.

As stated above, various types of chromosomal interchange were found in *L. s. var. kiushiana* and *L. s. var. koreana*. Similar karyotypic variations have been reported *L. s. var. sanguinea*, too (Kurita 1988c). The role of these interchanges in the karyotype evolution of the genus *Lycoris* will be discussed fully in the forthcoming paper.

Summary

Intraspecific variation of the karyotype of *L. sanguinea* var. *kiushiana* and *L. sanguinea* var. *koreana* was studied. Almost all plants of both taxa examined were diploid having $2n=22$, but three triploid bulbs ($2n=33$) and one tetraploid bulb ($2n=44$) were found in *L. s. var. kiushiana* from the Taradake population. The absolute arm length, relative length, and r value of each chromosome of the representative karyotype of these taxa have been summarized in Tables. The standard karyotype of diploid plants consists of twenty-two A type chromosomes of which two are satellite chromosomes.

Though the frequency is low, various intraspecific and intercellular chromosome rearrangements were observed in the diploid. They are as follows: 1. Some subtelocentric chromosomes and T' type chromosomes were observed. They must have originated from the standard A type chromosomes by means of deficiency or pericentric inversion. 2. The m type chromosome was found in some cells of *L. s. var. koreana*. It must have originated from the A by means of a break at the proximal region of the long arm. 3. A few instances of heterozygous combination of satellite chromosomes were observed.

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