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Cytological Evolution in the Genus *Lycoris* (Amaryllidaceae)

Tae, Kyoung-Hwan and Sung-Chul Ko*
Department of Biology, Hannam University, Taejon 300-791, Koreka

Cytological characters of ten taxa of the genus *Lycoris* were investigated to illustrate their chromosomal evolution. The fusion theory was more appropriate than the fission theory. From the viewpoint of the fusion theory *L. sanguinea* group, diploids with R-shaped chromosomes was the most primitive and they might have diverged into two directions, the diploids with V+R shaped chromosomes and the triploid with V+R shaped chromosomes via triploids with only R-shaped chromosomes.

Keywords: lycoris, chromosome, fusion, fission, evolution

The genus *Lycoris* (Amaryllidaceae) consists of about 20 species, which are limited to moist warm temperate woodlands of eastern Asia (Lawrence, 1951; Creech, 1952; Hutchinson, 1959; Melchior, 1964; Stebbins, 1971; Kurita, 1987a).

For *Lycoris* plants, cytological researches have been mainly concentrated on the chromosome number, shape and evolution by Nishiyams (1928), Takenake (1931), Inariyama (1931, 1953), Sato (1938), Mookerjea (1995), Bose (1960), Koyama (1962a, b), Takemura (1962), Bose and Flory (1963), Yoshida (1972), Khaleel (1978), Nakamura (1978), Fukuda *et al.* (1980), Kurita (1988a, b), Tae and Ko (1991, 1993) etc. Their chromosome evolution has been explained through two theorics, fusion and fission, which are contradictory to each other. The fusion theory is supported by Inariyama (1931, 1932, 1937, 1951, 1953), Stebbins (1971), Jones (1978), Nishikawa *et al.* (1979) and Tae *et al.* (1987), while the fission theory by Darlington (1973), Flory (1977) and Kurita (1988b). According to the fusion theory in the evolution of chromosome number and shape two R-shaped (rod-shape) chromosomes evolved into one V-shaped chromosome by their fusion. On the other hand the fission theory asserts that one V-shaped chromosome evolved into two R-shaped chromosmes by its fission. In *Lycoris* plants only two shapes of chromosome described are observed.

The present study was focused on illustrating chromosome shape evolution of *Lycoris* plants, and cytological relationship between 10 taxa, in which chromosomal features of 4 species and 2 varieties of the Korean plants, and 2 species and 2 varieties of the foreign ones were included. For the Korean plants, chromosome number, karyotype and polyploidy were observed from living materials, and the foreign plants were examined through literatures.

*Corresponding author: Fax +82-42-629-7444

MATERIALS AND METHODS

L. radiata (L' Hérit.) Herb., *L. chinensis* Traub var. *sinuolata* K. Tae et S. Ko, *L. chejuensis* K. Tae et S. Ko, *L. flavescens* M. Kim et S. Lee, *L. squamigera.* Maxim., *L sanguinea* Maxim. var. *koreana* (Nakai) Koyama were collected from Korea from May 1990 to October 1994. *L. sanguinea* Maxim. var. *sanguinea, L. sanguinea* var. *kiushiana* Makino, *L. albiflora* Koidz. and *L. aurea* (L' Herit.) Herb. were refered to literatures.

To examine the chromosome number and the shape, 20-25 individuals in each taxon were used. Somatic chromosomes from the root tip were observed following the method of Tae and Ko (1991). Well-dispersed chromosome sets of metaphase in mitosis were chosen for the analysis of chromosomal morphology, and their length were calculated with the standardized scale improvised for this purpose. Karyotypes were classified into V-shaped chromosome and R-shaped chromosome followed by Bose(1958). Arm ratio and centromeric indices were adopted from Leven *et al.* (1964)

RESULTS

The details of chromosome characters and karyotypes of 6 *Lycoris* plants from Korea are given in

Table 1. Summarized karyo-morphological features of *Lycoris* plants from Korea. 1, Chromosome numbers (2n); 2, Karyotypes; 3, Number of metacentric chromosomes; 4, Number of submetacentric chromosomes; 5, Number of subacrocentric chromosomes; 6, Number of acrocentric chromosomes; 7, Size range in microns; 8, Average chromosome length in microns; 9, Total chromosome length in microns

Taxa	1	2	3	4	5	6	7	8	9
L. radiata	33	33R	-	-	-	33	7.3-10.9	8.8	292.0
	34	33R+1B	-	-	-	34	4.2- 9.7	8.1	277.7
L. chinensis var. *sinuolata*	16	6V+10R	6	2	-	8	7.1-20.3	12.0	192.4
L. chejuensis	30	3V+27R	3	-	-	27	7.5-19.2	9.6	260.6
L. flavescene	19	3V+16R	3	-	-	16	7.4-21.8	10.5	200.7
L. squamigera	27	6V+21R	6	-	-	21	6.0-21.6	10.8	292.4
L. sanguinea var. *koreana*	22	22R	-	-	6	16	5.3- 9.1	7.5	164.4

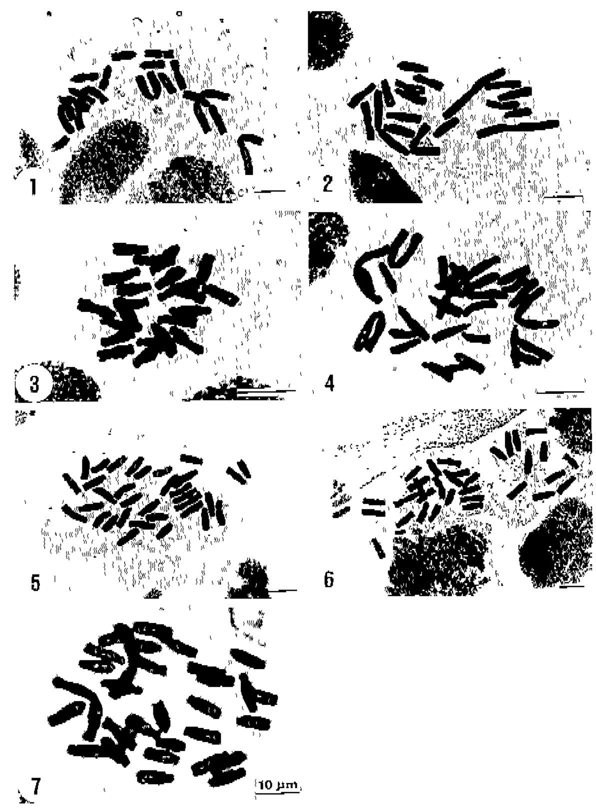

Plate 1.

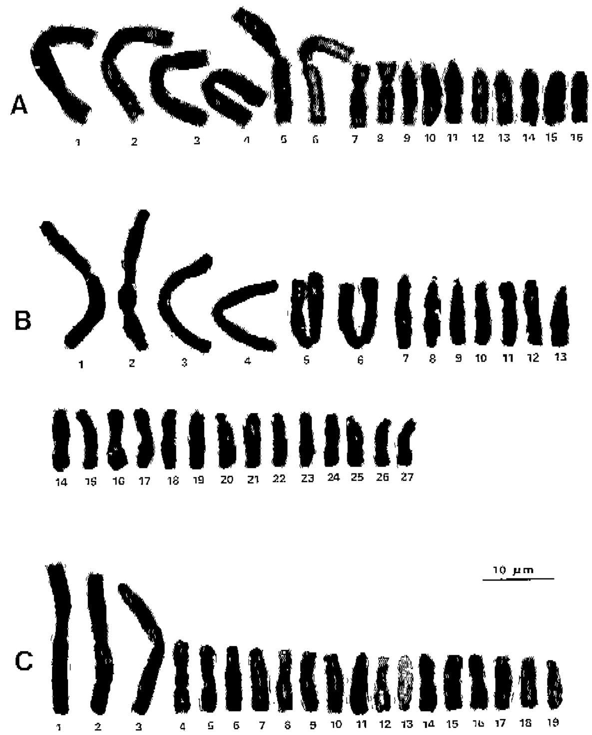

Plate 2.

Table 1 and Plate 1-4, respectively. Ten taxa including the foreign plants can be classified into 2 types in chromosome shape, and also into diploid and triploid in terms of polyploidy level (Table 2).

Chromosome shape

1. V+R type: Total chromosome complement is composed of V-shaped and R-shaped chromosomes. *L. flavescens, L. squamigera, L. chejuensis, L. albiflora, L. aurea* and *L. chinensis* var. *sinuolata* are this type.

2. All R type: All chromosomes in one cell are R-shaped. *L. radiata, L. sanguinea* var. *koreana, L. sanguinea* var. *sanguinea* and *L. sanguinea* var. *kiushiana* fall under this type.

Most of V-shaped chromosomes are metacentric except submetacentric chromosomes in *L. chinensis* var. *sinuolata* and *L. chejuensis.* Plants with all R type have only acrocentric chromosomes except 6 subacrocentric chromosomes in *L. sanguinea* var. *koreana* (Table 1).

Ploidy level

Table 2. Chromosome numbers of the genus *Lycoris*

Taxa	Present study		Previous study			Possible potentialities in rod chromosome
	2n	shape	2n	shape	author and year	
L. radiata	33	33R	15	15R	Mookerjea (1955)	15
	34	33R+1B	22	22R	Mookerjea (1955)	22
			25	25R	Mookerjea (1955)	25
			28	28R	Lee (1967)	28
			32	32R	Mookerjea (1955)	32
			32	1V+31V	Kurita (1987b)	33
			33	33R	Bose (1963a), Bose and Flory (1963), Fukuda *et al.* (1980), Inariyama (1941, '37, '51, '53), Khaleel (1978), Kim and Seo (1979), Koyama (1976), Kurita (1978, '87b), Mookerjea (1955), Nakamura (1978), Nishikawa *et al.* (1979), Nishiyama (1928, '39), Tae *et al.* (1987), Park *et al.* (1989)	33
			33	1V+31R+1B	Bose (1963a)	33
L. chinensis var. *sinuolata*	16	6V+10R	16	6V+10R	Tae *et al.* (1987), Tae and Ko(1993)	22
L. chejuensis	30	3V+27R	30	3V+27R	Tae and Ko (1993)	33
L. flavescens	19	3V+16R	19	3V+16R	Park *et al.* (1989)	22
L. squamigera	27	6V+21R	27	6V+21R	Bose (1963b), Bose and Flory (1963), Inariyama (1931, '32, '37, '51, '53), Koyama (1962b, '78), Kurita (1978, '87b), Nakamura (1978), Nishikawa *et al.* (1979), Sato (1938, '41), Tae *et al.* (1987), Takenaka (1931)	33
			26			?
L. sanguinea var. *koreana*	22	22R	21	21R	Khaleel (1978)	21
			22	22R	Tae and Ko (1991)	22
					Kurita (1978, '88a), Tae *et al.* (1987),	
			33	33R	Tae and Ko (1991)	33
			43	1V+42R	Tae and Ko (1991)	44
L. sanguinea var. *sanguinea*		-	21	21R	Kurita (1989)	21
			22	22R	Inariyama (1931, '37, '51, '53), Kurita (1988a), Nakamura (1978), Nishiyama (1928, '39), Sato (1941) Tae and Ko (1991), Yoshida (1972)	22
			22	22+B	Kurita (1989)	22
			28	28R	Kurita (1989)	28
			32	1V+31R	Kurita (1989)	33
L. sanguinea var. *kiushiana*		-	22	22R	Kurita (1988a), Takemura (1962),	22
			23	23R	Yoshida (1972)	
		-	16	6V+10R	Tae and Ko (1991)	23
L. albiflora			17	5V+12R	Inariyama (1931)	22
					Bose (1960), Base and Flory (1963), Inariyama (1931, '37, '51, '53), Koyama (1962a, b), Kurita (1978, '87b),	22
			18	4V+14R	Nishikawa *et at.* (1979), Yoshida (1972)	
L. aurea		-	12	10V+2R	Inariyama (1931), Kurita (1978, '87b)	22
					Bose (1958), Bose and Flory (1963), Inariyama (1931, '37, '51, '53), Koyama	22
			13	9V+4R	(1962b), Yoshida (1972)	
					Inariyama (1937, '51, '53), Koyama (1967), Nishikawa *et at.* (1979), Yoshida (1972)	22
			14	8V+6R	Bose (1963b), Inariyama (1937, '51, '53), Koyama (1967), Nishikawa *et at.* (1979), Yoshida (1972)	22
			15	7V+8R	Bose (1963b), Bose and Flory (1963), Kurita (1978, '87b)	22
			22	-	Khaleel (1978)	?

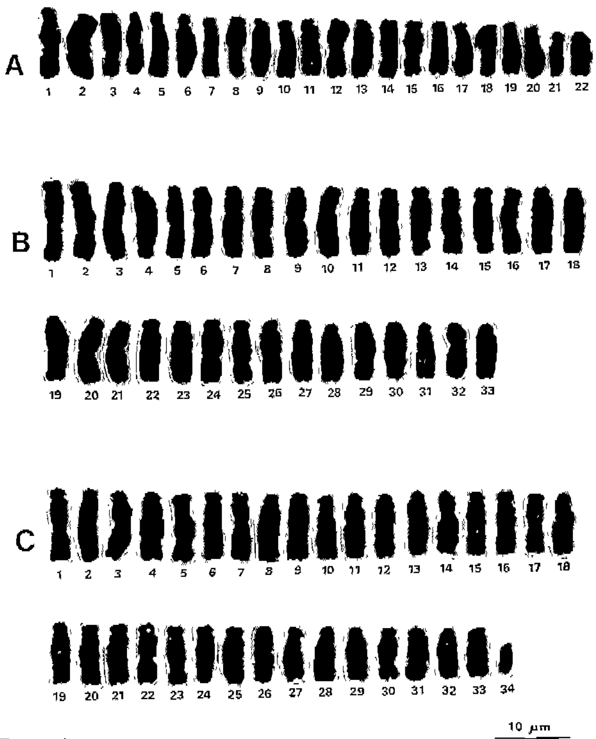

Plate 3.

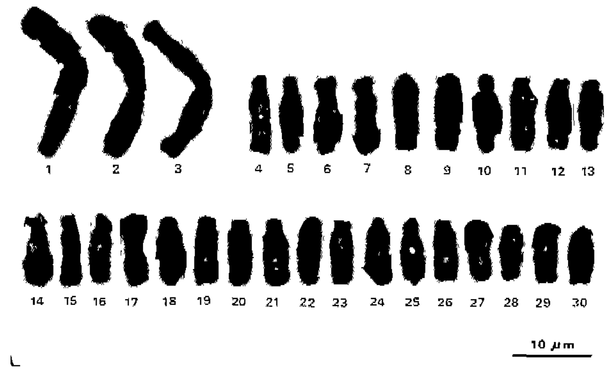

Plate 4.

If one V-shaped chromosome is regarded as two R-shaped chromosomes, ploidy levels of the genus *Lycoris* are classified into two types, diploidy and triploidy (Table 2).

1. Diploidy: basic chromosome number is 2n=22 (x=11) and *L. chinensis* var. *sinuolata, L. albiflora, L. aurea, L. flavescens, L. sanguinea* var. *koreana, L. sanguinea* var. *sanguined* and L. sanguinea var. *kiushiana* come under this type.
2. Triploidy: basic chromosome number is 2n=33 (x=11) and *L. squamigera, L. radiata* and *L. chejuensis* come under this type.

Chromosome number, shape and polyploidy of 6 taxa examined from living materials were consistant with the previous reports. *L. radiata* cells with one accessory chromosome (2n=34=33R+1B) were also observed in the same individuals together with normal cells (Table 1).

DISCUSSION

From the chromosome number and the shape of 6 taxa examined in this study and the previous reports, an induction on the evolution of chromosome shape of the genus *Lycoris* was made.

First, the chromosome number and the shape are constant in each taxon expect *L. radiata, L. sanguinea* var. *sanguinea.* and *L. sanguinea* var. *koreana.* This result was supported by Mookerjea (1995), Bose (1963a), Kurita (1987c, 1989), and Tae and Ko (1991). *L. radiata,* triploid has R-shaped chromosomes (2n=33=33R), but rarely a V-shaped chromosome (2n=32=1V+31R) or an accessory chromosome (2n=34=33R+1B). *L. sanguinea* var. *sanguinea* and *L. sanguinea* var. *koreana* carried R-shaped chromosomes in general (2n=22=22R) but often has accessory chromosome (2n=23=22R+1B), triploidy cells (2n=33R and 2n=1V+31R) or tetraploidy cells (2n=43=1V+42R) (Table 2). The cytological unstabilities, for example, formation of accessory and V-shaped chromosome, and increase of chromosome numbers showed cytological differentiation in the chromosomal evolution.

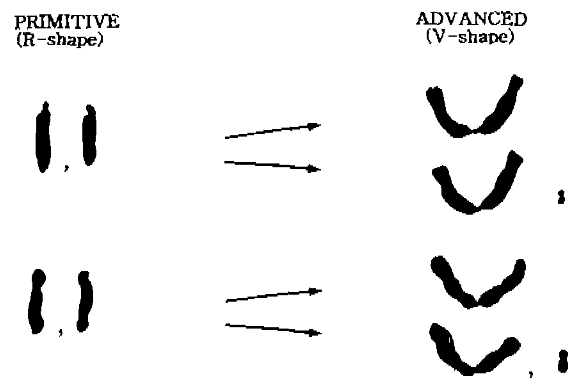

Fig. 1. Fusion from 2R-shaped chromosomes to 1 V-shaped chromosome and formation of accessory chromosome.

The increase in ploidy level seems to be related to the formation of V-shaped chromosome because the V-shaped chromosomes are mostly observed in triploids and tetraploids. Therefore, the V-shaped chromosomes are thought to be formed by the centromeric fusion of acrocentric R-shaped chro-

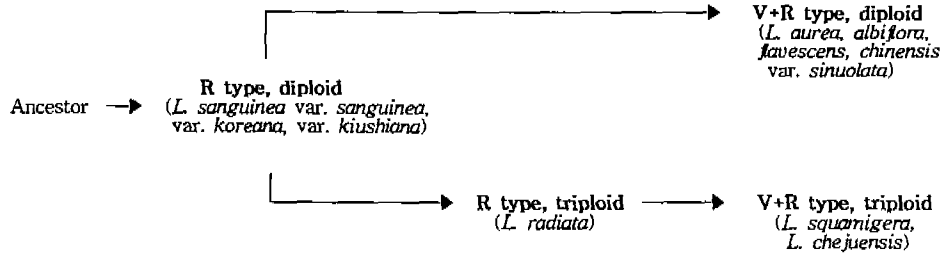

Fig. 2. Cytological evolution scheme of the treated taxa in this study.

mosomes. During this chromosomal behavior accessory chromosomes may be generated by deletion or duplication (Sharma, 1985).

Second, it was shown that there is a close proportionality between total chromosome length and realative DNA content of the nucleus during the chromosomal evolution (Stebbins, 1966; Bullen and Rees, 1972; Cheng and Grant, 1973; Nishikawa *et al.* 1979). Nishikawa *et al.* (1979) reported that longer the total length of chromosomes the larger was the DNA content and that there was much more V-shaped chromosomes in such nuclei. This study also found that one V-shaped chromosome length was longer than two R-shaped chromosomes and the total chromosome length of taxa with V+R shaped chromosomes was longer than that of taxa with all R-shaped chromosome (Table 1). According to these results, the fusion theory is more proper to explain the chromosomal evolution of the genus *Lycoris*, because the taxa with unstability in chromosome shape and number continue to increase in total chromosome length (Table 2). With respect to the fission theory, two R-shaped chromosomes are formed by the fission of a V-shaped chromosome and then contracted to a short length (Kurita, 1987a, Sivarajan, 1991). Since there exists no direct proof about the contraction of chromosomal length after the fission the authors' acceptance of the fission theory need to be waited. Consequently, in the chromosomal evolution of the genus *Lycoris*, V-shaped metacentric chromosome is thought to be formed by the contromeric fusion of acrocentric, subacrocentric and submetacentric chromosomes (Fig. 1). Cytologically, *L. sanguinea* var. *sanguinea, L. sanguinea* var. *koreana* and *L. sanguinea* var. *kiushiana* are the most primitive taxa among the taxa because they are diploids and have only R-shaped chromosomes (2n=22=22R). *L. sanguinea* var. *kiushiana*, especially, is the closest to an ancestor of the above three taxa owing to its cytological stability. It always has 2n=22R with one exception 2n=23R (Tae and Ko, 1991). From the primitive taxa of diploids with R-shaped chromosomes like *L. sanguinea* group, chromosomal evolution of the genus *Lycoris* might have diverged into two directions, diploids with V+R shaped chromosomes, and triploids with R-shaped chromosomes and with V+R shaped chromosomes (Fig. 2). The possibility that triploid with V+R shaped chromosomes was derived from diploid with V+R shaped chromosomes seems very unlikely but can not be excluded.

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