Karyotype Analysis in *Tulipa* VII

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チューリップ属植物の核型分析 VII

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Introduction

The earliest study of the chromosomes in the genus *Tulipa* was carried out by Guignard (1900). In 1925 De Mol made reference to the chromosome number of the genus *Tulipa*. This seems to be one of the earlier and somewhat detailed reports concerning the chromosome number of *Tulipa*. Since then, chromosome studies of various species and races in the genus have been made by many investigators e. g. Newton (1926), De Mol (1926a, '27c, '28b, '28c, '28d), Newton and Darlington (1929), Darlington (1929b), Hall (1929), Darlington and Ammal (1932), Upcott and La Cour (1936), Woods (1937), Bellow and Bamford (1941), and Sisa and Sakurai (1954) and others. In *Tulipa* there are many species and races. The karyotypes of them have not been analysed. Since 1955 the present author and his collaborators have carried out observations on the karyotypes of 114 races of *T. gesneriana*, and a race of *T. edulis* was reported (Takusagawa et al. 1955, '56, '57, '58, '59, '60). Moreover, the author made the karyotype analysis in thirty one races of *T. gesneriana*. The present paper deals with the results of this investiigation.

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Materials and Methods

Thirty one races of *Tulipa gesneriana* were used as the material for this study. They were cultivated in the experimental garden of the Shimane Agricultural College. Their names of races used are listed in table 1. In this list the races used were classified according to the classifications of Sisa, Hazu, Sakurai and Kimura (1955), and the Royal General Dutch Society (1958).

A method slightly modified from that of Tjio and Levan (1950b) was employed for making preparations. Root-tips were treated with 0.002 mol 8-oxyquinoline solution for about four hours. After having been washed in running water for thirty minutes, each of the tips was kept in n-HCl at 60°C from fifteen to twenty seconds, brought into a drop of acetic orcein on a slide-glass, and then squashed into one cell layer between a slide and a

cover-glass.

The measurements of the chromosomes were made by the same method as was used by Tjio and Hagberg (1951).

The figures of chromosomes were drawn from the photomicrographs which were made by using the temporary preparations.

Table 1. The names of the races of *Tulipa gesneriana* used in this study their chromosome numbers and karyotypes observed.

Plant name	2n	Karyotype	Figs.
I. Early Flowering Tulips.			
* Single Early Tulips.			
1. race *Couleur de Cardinal.*	24	A−2	(18)
* Mendel Tulips.			
2. race *Superba.*	24	A−2	(15)
* Triumph Tulips.			
3. race *Prominence.*	24	A−4	(21)
4. race *Olaf.*	24	B	(26)
5. race *Aureola.*	24	A−2	(10)
6. race *Gretha Benkemper.*	24	B	(24)
7. race *Finland.*	24	A−1	(1,32)
II. Late Flowering Tulips.			
* Cottage Tulips.			
8. race *Golden Harvest.*	24	B	(27)
9. race *Henri Correvon.*	24	B	(28,39)
10. race *Mount Erebus.*	24	C	(29)
11. race *Gay Hussar.*	24	C	(30,36)
12. race *Chappaqua.*	24	D	(31,35)
* Lilly-Flowered Tulips.			
13. race *White Cross.*	24	A−1	(7)
14. race *The Bride.*	24	A−1	(2)
15. race *Mildred.*	24	A−1	(4)
16. race *Maytime.*	24	A−1	(3)
17. race *Beverley.*	24	A−1	(8)
* Breeder Tulips.			
18. race *Papago.*	24	A−2	(9,33)
19. race *Saginaw.*	24	A−1	(5)
20. race *Winnetou.*	24	A−2	(14)
* Ideal Darwin Tulips.			

21. race *Cum Laude.*	24	A−2	(16,38)
* Darwin Tulips.			
22. race *Neerlandia.*	24	B	(23)
23. race *Ceylon.*	24	A−2	(11)
24. race *Darlington.*	24	A−3	(19)
25. race *Black Eagle.*	24	A−4	(20,37)
26. race *Reliance.*	24	A−2	(17)
27. race *Pride of Harrlem.*	24	B	(22)
28. race *Sweet Harmony.*	24	B	(25,34)
29. race *Pieter de Hoogh.*	24	A−2	(12)
* Parrot Tulips.			
30. race *Thérèse.*	24	A−2	(13)
* Double Late Tulips.			
31. race *Nizza.*	24	A−1	(6)

Results of Observations

For the descriptions of morphology of chromosomes in this report, the terms : median, submedian, subterminal etc, F% and TF% are used. F% denotes the percentage of the ratio of the length of a short arm to the whole length of the chromosome.

The relations between the terms : median, submedian, subterminal and terminal, and the values of F% are as follows : median=F% 50, submedian=F% from 49 to 34, subterminal F% from 33 to 11, terminal from 10 to 1. A relative length of each chromosomes is expressed as the percentage of the total sum of the lengths of all chromosomes of complement at metaphase.

1. *Tulipa gesneriana* race *Couleur de Cardinal.* 2n=24 (A−2) (Fig. 18 Table 2).

This race has 24 chromosomes in its somatic cell. As shown in Fig. 18 and Table 1, these chromosomes are composed of twelve pairs which may be classified into nine groups. The first group includes one pair of the largest chromosomes of the complement (chromosomes, nos. 1 and 2). They have each a subterminal constriction. The second group consists of one pair of large chromosomes with submedian constrictions (3 and 4). The third group includes one pair of subterminally constricted chromosomes (5 and 6). The fourth group includes one pair of chromosomes of middle size with submedian constrictions (7 and 8). The fifth group includes one pair of chromosomes of middle size with subterminal constrictions (9 and 10). The sixth group includes one pair of chromosomes of middle size with subterminal constrictions (11 and 12). The seventh group includes one pair of chromosomes with subterminal constrictions (13 and 14). They are a little smaller than chro-

mosomes 11 and 12. The eighth group includes two pairs of chromosomes with subterminal constrictions (15, 16, 17 and 18). They were observed to be curved.

The ninth group includes three pairs of chromosomes with subterminal constrictions (19, 20, 21, 22, 23 and 24). These six chromosomes of the smallest size are almost similar in size and shape to each other.

Table 2. Measurements of length of somatic chromosomes in *Tulipa gesneriana* race *Couleur de Cardinal.*

Chromosomes	Long arm (μ)	Short arm (μ)	Whole length (μ)	Relative length	F%	TF%
1,2	13.3	2.5	15.8	5.8	16	
3,4	8.7	5.3	14.0	5.1	38	
5,6	10.1	3.3	13.4	4.9	25	
7,8	8.7	4.7	13.4	4.9	35	
9,10	10.0	3.3	13.3	4.9	25	
11,12	8.7	2.0	10.7	3.9	19	
13,14	8.0	2.0	10.0	3.7	20	
15,16	7.7	2.2	9.9	3.6	22	
17,18	7.7	2.1	9.8	3.6	21	
19,20	6.7	2.0	8.7	3.2	23	
21,22	6.7	2.0	8.7	3.2	23	
23,24	6.7	1.9	8.6	3.2	22	24

2. *Tulipa gesneriana* race *Superba.* 2n=24 (A−2) (Fig. 15 Table 3).

This race has twelve pairs of somatic chromosomes. They may be classified into ten groups. The first group includes one peir of the chromosomes of the largest size (1 and 2). They have each a subterminal constriction. The second group includes one pair of chromosomes with subterminal constrictions (3 and 4). The third group inclides one pair of chromosomes with submedian constrictions (5 and 6). The fourth group includes one pair of chromosomes with subterminal constrictions (7 and 8). The chromosomes of these three pairs are almost the same in size. The fifth group includes two pairs of chromosomes with subterminal constrictions (9, 10, 11 and 12). They are almost the same in size and shape. The sixth group includes one pair of chromosomes with subterminal constrictions (13 and 14). The seventh group consists of one pair of chromosomes (15 and 16), which are curved and have subterminal constrictions. The eighth group includes one pair of chromosomes with subterminal constrictions (17 and 18). The ninth group includes two pairs of chromosomes with subterminal constrictions (19, 20, 21 and 22). The tenth group includes one pair of chromosomes with subterminal constrictions (23 and 24). They are much smaller in size than the chromosomes 21 and 22.

Table 3. Measurements of length of somatic chromosomes in *Tulipa gesneriana* race *Superba*.

Chromosomes	Long arm (μ)	Short arm (μ)	Whole length (μ)	Relative length	F%	TF%
1,2	13.4	6.7	20.1	6.0	33	
3,4	13.3	3.4	16.7	5.0	20	
5,6	10.0	6.7	16.7	5.0	40	
7,8	13.3	2.0	15.3	4.5	13	
9,10	10.0	4 7	14.7	4.4	32	
11,12	10.0	4.7	14.7	4.4	32	
13,14	10.0	3.4	13.4	4.0	25	
15,16	10.0	3.3	13.3	4.0	25	
17,18	10.0	3.3	13.3	4.0	25	
19,20	10.0	2.0	12.0	3.6	17	
21,22	8.7	2.0	10.7	3.2	19	
23,24	5.3	2.0	7.3	2.2	27	26

3. *Tulipa gesneriana* race *Prominence*. 2n=24 (A−4) (Fig. 21 Table 4).

There were twenty four chromosomes in the root-tip cell of this race. The twenty four somatic chromosomes may be classified into ten groups by their shape, size and position of constrictions (Fig. 21 Table 4). The first group includes one pair of chromosomes with subterminal constrictions (1 and 2). The second group includes one pair of chromosomes each of which is rod-shaped and has a subterminal constriction (3 and 4).

Table 4. Measurements of length of somatic chromosomes in *Tulipa gesneriana* race *Prominence*.

Chromosomes	Long arm (μ)	Short arm (μ)	Whole length (μ)	Relative length	F%	TF%
1,2	13.3	4.0	17.3	5.9	23	
3,4	12.0	4.0	16.0	5.5	25	
5,6	10.0	3.4	13.4	4.6	25	
7,8	8.7	4.7	13.4	4.6	35	
9,10	10.0	2.0	12.0	4.1	17	
11,12	8.7	3.3	12.0	4.1	28	
13,14	10.0	2.0	12.0	4.1	17	
15,16	8.0	3.3	11.3	3.9	29	
17,18	6.7	3.3	10.0	3.4	33	
19,20	6.7	2.7	9.4	3.2	29	
21,22	6.7	2.7	9.4	3.2	29	
23,24	6.7	2.7	9.4	3.2	29	27

The third group includes one pair of chromosomes with subterminal constrictions (5 and 6). The fourth group includes one pair with submedian constrictions (7 and 8). The fifth group includes one pair of chromosomes with nearly terminal constrictions (9 and 10). The sixth group consists of one pair of chromosomes with subterminal constrictions (11 and 12). The seventh group consists of one pair of chromosomes with nearly terminal constrictions (13 and 14). The eighth group includes one pair of chromosomes with subterminal constrictions (15 and 16). These four pairs of chromosomes are almost the same in length. The ninth group includes one pair of chromosomes with subterminal constrictions and small satellites (17 and 18). The tenth group includes three pairs of chromosomes of the smallest size with subterminal constrictions (19, 20, 21, 22, 23 and 24). The chromosomes of this group seemed to be similar in size and shape to each other.

4. *Tulipa gesneriana* race *Olaf*. 2n=24 (B) (Fig. 26 Table 5).

The twenty four chromosomes of this race may be classified into seven groups by their shape, size and position of constrictions. The first group includes two pairs of chromosomes with subterminal constrictions (1, 2, 3 and 4). The second group includes one pair of chromosomes with subterminal constrictions (5 and 6). The short arms of the chromosomes of this group are a little shorter as compared with those of the chromosomes of the first group. The third group includes two pairs of chromosomes of median size with subterminal constrictions (7, 8, 9 and 10). No exact difference of size could be observed between them. The fourth group includes two pairs of chromosomes with subterminal constrictions (11, 12. 13 and 14). But the short arms of the chromosomes 11 and 12 seem to be a little larger than those of chromosomes 13 and 14. The fifth group includes one pair of chromosomes with submedian constrictions (15 and 16).

Table 5. Measurements of somatic chromosomes in *Tulipa gesneriana* race *Olaf*.

Chromosomes	Long arm (μ)	Short arm (μ)	Whole length (μ)	Relative length	F%	TF%
1,2	10.0	3.3	13.3	6.0	25	
3,4	10.0	3.3	13.3	6.0	25	
5,6	10.0	2.0	12.0	5.3	17	
7,8	6.7	3.3	10.0	4.5	33	
9,10	6.7	3.3	10.0	4.5	33	
11,12	6.7	2.1	8.8	3.9	24	
13,14	6.7	2.0	8.7	3.9	23	
15,16	4.7	3.3	8.0	3.6	41	
17,18	5.3	2.6	7.9	3.5	33	
19,20	5.3	2.0	7.3	3.3	27	
21,22	5.3	2.0	7.3	3.3	27	
23,24	3.0	2.0	5.0	2.2	40	29

The sixth group includes three pairs of chromosomes with subterminal constrictions (17, 18, 19, 20, 21 and 22). They are almost similar in size and shape. The seventh group consists of one pair of chromosomes with submedian constrictions (23 and 24). They are smaller in size than the chromosomes 21 and 22. Owing to the fact that all the chromosomes which were shown in the figures seem to have heavily shortened themselves, the description of the morphology of the chromosomes of this race is not so exact as sxpected.

5. *Tulipa gesneriana* race *Aureola.* 2n=24 (A−2) (Fig. 10 Table 6).

This race has twelve pairs of chromosomes which are classified into ten groups by their shape, size, and position of constrictions. The first group includes two pairs of chromosomes with subterminal constrictions, one of which can be distinguished from the other by the difference of form. In the chromosomes (1 and 2) the long arms are curved, while in the other (7 and 8) the long arms are of rod shape. The second group includes one pair of chromosomes with submedian constrictions (3 and 4). The third group includes one pair with submedian constrctions (5 and 6). The fourth group includes one pair with submedian constrictions (9 and 10). The fifth group includes one pair with subterminal constrictions (11 and 12). The sixth group includes one pair with submedian constrictions (13 and 14). The seventh group includes two pairs. Of these pairs, one pair has the long arms which are curved in S-shape, while the other has the short arms attached at right angles with long arm, their constrictions being subterminal (15, 16, 17 and 18). The eighth group includes one pair with subterminal constrictions (19 and 20). The ninth group includes one pair with subterminal constrictions (21 and 22). The tenth group includes one pair of the smallest size with subterminal constrictions (23 and 24).

Table 6. Measurements of length of somatic chromosomes in *Tulipa gesneriana* race *Aureola.*

Chromosomes	Long arm (μ)	Short arm (μ)	Whole length (μ)	Relative length	F%	TF%
1,2	13.3	3.4	16.7	5.7	20	
3,4	10.0	6.7	16.7	5.7	40	
5,6	10.7	6.0	16.7	5.7	36	
7,8	13.3	3.4	16.7	5.7	20	
9,10	8.0	4.7	12.7	4.4	37	
11,12	8.7	3.3	12.0	4.1	28	
13,14	6.7	4.7	11.4	3.9	41	
15,16	6.7	3.3	10.0	3.4	33	
17,18	6.7	3.3	10.0	3.4	33	
19,20	6.7	2.0	8.7	3.0	23	
21,22	5.3	2.7	8.0	2.8	34	
23,24	4.0	2.0	6.0	2.1	33	32

6. *Tulipa gesneriana* race *Gretha Benkemper*. 2n=24 (B) (Fig. 24).

This race has twelve pairs of somatic chromosomes. The first and second pairs of chromosomes (1, 2, 3 and 4) are larger than the other chromosomes of the complement. They are similar size and shape and have subterminal constrictions. The third and fourth pairs of chromosomes (5, 6, 7 and 8) are similar in length, having subterminal constrictions. The fifth pair of chromosomes (9 and 10) resembles the fourth pair, being a little shorter than the latter. The sixth pair of chromosomes (11 and 12) have median constrictions. The seventh pairs of chromosomes (13 and 14) have subterminal constrictions. The eighth pair of chromosomes (15 and 16) have subterminal constrictions. The ninth and tenth pairs of chromosomes (17, 18, 19 and 20) have subterminal constrictions. The eleventh and twelfth pairs of chromosomes (21, 22, 23 and 24) have subterminal constrictions, being the smallest in the complement.

7. *Tulipa gesneriana* race *Finland*. 2n=24 (A−1) (Figs. 1 and 32 Table 7).

Chromosome measurements for this species are given in Table 7. The chromosomes vary in length from 15.3 microns to 6.7 microns. The twenty four chromosomes may be classified into seven groups by their shape, size and position of constrictions. The first group consists of one pair of chromosomes which is the longest in the complement, and has nearly terminal constrictions. The second group includes two pairs of chromosomes (3, 4, 5 and 6) with subterminal constrictions. The third group comprises one pair of chromosomes with median constrictions. The fourth group includes three pairs of chromosomes with subterminal constrictions (9, 10, 11, 12, 13 and 14). They are almost similar in length. The fifth group includes two pairs of chromosomes with subterminal constrictions (15, 16, 17 and 18).

Table 7. Measurements of length of somatic chromosomes in *Tulipa gesneriana* race *Finland*.

Chromosomes	Long arm (μ)	Short arm (μ)	Whole length (μ)	Relative length	F%	TF%
1,2	13.3	2.0	15.3	5.7	13	
3,4	10.0	3.4	13.4	5.0	25	
5,6	10.0	3.4	13.4	5.0	25	
7,8	6.7	6.7	13.4	5.0	50	
9,10	10.0	2.0	12.0	4.4	17	
11,12	10.0	2.0	12.0	4.4	17	
13,14	10.0	2.0	12.0	4.4	17	
15,16	6.7	3.3	10.0	3.7	33	
17,18	6.7	3.3	10.0	3.7	33	
19,20	6.5	2.0	8.5	3.1	24	
21,22	6.5	2.0	8.5	3.1	24	
23,24	4.7	2.0	6.7	2.5	30	26

The short arms in this group are longer than those in the former group. The sixth group includes two pairs of chromosomes with subterminal constrictions. (19, 20, 21 and 22). They are of the same size and shape. The seventh gronp includes one pair of chromosomes with subterminal constrictions. (23 and 24). They are smaller than those of the former group, the relative length of the latter being 2.5 and that of the former 3.1.

8. *Tulipa gesneriana* race *Golden Harvest.* 2n=24 (B) (Fig. 27).

The twenty four somatic chromosomes may be classified into eight groups. All the chromosomes have subterminal constrictions. The chromosomes vary in length from 19.3 microns to 8.7 microns. This race bears a resemblance in karyotype to *T. gesneriana* race *Olaf* which is described above. The majority of chromosomes of both races have subterminal constrictions.

9. *Tulipa gesneriana* race *Henri Correvon.* 2n=24 (B) (Fig. 28 and 39).

There are twenty four chromosomes in the root-tip cell of this race. As shown in Fig. 28, these chromosomes are found to be composed of twelve pairs which are classified into seven groups by their shape, size and position of constrictions. All the chromosomes have subterminal constrictions. The chromosomos vary in length from 18.0 mcrons to 7.3 microns. The karyotype of this race bears a resemble in general to that of race *Pride of Haarlem.* But there are some differences betveen them. The eleventh pair of chromosomes of this race have subterminal constrictions, but those of *Pride of Haarlem* have submedian ones.

10. *Tulipa gesneriana* race *Mount Erebus.* 2n=24 (C) (Fig. 29 Table 8).

There are twenty four chromosomes in the root-tip cell of this race. As shown in Fig. 29 and Table 8, these chromosomes are found to be composed of twelve pairs which are sorted into ten groups by their shape, size and position of constrictions.

The first group includes one pair of very long chromosomes with submedian constrictions (1 and 2). The second group comprises one pair of chromosomes with two constrictions (3 and 4). The third group includes one pair of chromosomes with two constrictions (5 and 6). The arms outside of the centromere in this pair are shorter as compared with those of the second pair. The fourth group includes one pair of chromosomes (7 and 8) with subterminal constrictions. The fifth group consists of one pair of chromosomes (9 and 10) with two constrictions, one of which is subterminal and the other terminal. The latter may be a secondary constriction. The part outside of this constriction may be a satellite. The sixth group includes a pair of chromosomes with submedian constrictions (11 and 12). The seventh group includes two pairs of chromosomes with two constrictions (13, 14, 15 and 16). The eighth group includes one pair of chromosomes with subterminal constriclions (17 and 18).

The ninth group comprises two pairs of chromosomes of the same size with subterminal constrictions (19, 20, 21 and 22). The tenth group includes one pair of chromosomes with subterminal constrictions (23 and 24). The chromosomes of this pair are much smaller as compared with the chromosomes of the ninth group.

Table 8. Measurements of length of somatic chromosomes in *Tulipa gesneriana* race *Mount Erebus*.

Chromosomes	Long arm (μ)	Short arm (μ)	Whole length (μ)	Relative length	F%	TF%
1,2	19.0	10.0	29.0	8.3	34	
3,4	10.0+6.7	3.3	20.0	5.7	17	
5,6	10.0+4.7	3.3	18.0	5.2	18	
7,8	12.0	5.3	17.3	5.0	31	
9,10	10.4	5.3	15.7	4.5	34	
11,12	10.4	5.3	15.7	4.5	34	
13,14	6.7+3.3	3.3	13.3	3.8	25	
15,16	6.7+3.3	3.3	13.3	3.8	25	
17,18	8.0	2.0	10.0	2.9	20	
19,20	6.7	1.3	8.0	2.3	16	
21,22	6.7	1.3	8.0	2.3	16	
23,24	4.7	1.3	6.0	1.8	22	24

11. *Tulipa gesneriana* race *Gay Hussar*. 2n=24 (C) (Figs. 30 and 36).

This race has twelve pairs of chromosomes which may be classified into seven groups. The chromosomes vary in length from 14.7 microns to 7.3 microns. The first pair of chromosomes (1 and 2) have subterminal constrictions. The second pair of chromosomes have two constrictions, having large satellites. The third and fourth pairs are almost the same in size and shape, having subterminal constrictions. The fifth pair of chromosomes were observed to be curved, having subterminal constrictions. The sixth pair of chromosomes have submedian constrictions. All the other pairs of chromosomes have subterminal constrictions. The karyotype of this race resembles in some respects that of race *Mount Erebus*, but there are some differences between them.

12. *Tulipa gesneriana* race *Chappaqua*. 2n=24(D) (Figs. 31 and 35)

This race has twelve pairs of chromosomes. The chromosomes are comparatively smaller as compared with those of other races. The chromosomes vary in length from 10 microns to 5.3 microns. The chromosomes may be classified into eight groups by their shape, size and position of constrictions. The first group includes one pair of chromosomes (1 and 2) with subterminal constrictions. The second group comprises one pair of chromosomes with

subterminal constrictions. The third group comprises one pair of ohromosomes (5 and 6) with submedian constrictions. The fourth group includes one pair of chromosomes with nearly terminal constrictions. The fifth group inclludes three pairs of chromosomes (9, 10, 11, 12, 13 and 14) with submedian constrictions. They are similar in length. The sixth group includes one pair of chromosomes with median constrictions (15 and 16). The seventh group includes one pair of chromosomes with nearly terminal constrictions. The eighth group comprises three pairs of chromosomes. (19, 20, 21, 22, 23 and 24) with submedian constrictions.

The karyotype of this race seems to differ in many respects from others, but owing to the heavy shortening of chromosomes due to the influence of 8-oxyquinoline, it was impossible to observe the karyotype precisely.

13. *Tulipa gesneriana* race *White Cross.* 2n=24 (A−1) (Fig. 7).

This race has twelve pairs of chromosomes. The karyotype of this race resembles in many respects that of race *Finland.* But they differ from each other in some respects. The largest chromosomes of this race have subterminal constrictions, but the homologous chromosomes of *Finland* have nearly terminal ones. The chromosomes of the twelfth pair of this race are as large as those of the eleventh pair, but those of the twelfth pair of *Finland* are smaller as compared with those of the eleventh pair of the same race.

14. *Tulipa gesneriana* race *The Bride.* 2n=24 (A−1) (Fig. 2).

This race has twelve pairs of somatic chromosomes. The chromosomes vary in length from 13.3 microns to 7.3 microns. The karyotype of this race resembles that of the race *Finland.* But there are some differences between the karyotypes of the two races. The chromosomes of the first pair of this race have subterminal constrictions. Their short arms are larger than those of homologous ohromosomes of race *Finland.* The chromosomes of twelve pairs of this race is the equal in size to the chromosomes of eleventh pair while the chromosomes of twelfth pair of *Finland* are smaller than those of eleventh pair of the same race.

15. *Tulipa gesneriana* race *Mildred.* 2n=24 (A−1) (Fig. 4).

This race has twelve pairs of somatic chromosomes. The karyotype of this race is quite similar to that of the race *Finland,* which is mentioned above.

16. *Tulipa gesneriana* race *Maytime.* 2n=24 (A−1) (Fig. 3).

This race has the same chromosome number and the same karyotype as the race *Mildred.*

17. *Tulipa gesneriana* race *Beverley*. 2n=24 (A−1) (Fig. 8).

The karyological features concerning the chromosome number and karyotype of this race are the same as those of the race *Maytime*.

18. *Tulipa gesneriana* race *Papago*. 2n=24 (A−2) (Figs. 9 and 33).

This race has twelve pairs of somatic chromosomes. The chromosomes of the first pair, the largest chromosomes of the complement, are fairly larger than those of the second pair. The morphology of the other chromosomes of this race are almost the same as those of the race *Aureola*.

19. *Tulipa gesneriana* race *Saginaw*. 2n=24 (A−1) (Fig. 5).

This race has twelve pairs of somatic chromosomes. Three pairs of large chromosomes (1, 2, 3, 4, 5 and 6) each have subterminal constrictions. The fourth pair of chromosomes (7 and 8) have submedian constrictions. All the other chromosomes have subterminal constrictions except the chromosomes of the tenth pair, which have submedian constrictions. The karyotype of this race seems to be almost the same as to that of the race "*The Bride*", although the chromosomes of the former appeare to be larger than those of the latter.

20. *Tulipa gesneriana* race *Winnetou*. 2n=24 (A−2) (Fig. 14).

This race has twelve pairs of somatic chromosomes. The first pair of the chromosomes are of the largest size and have subterminal constrictions. The second and third pairs of chromosomes have submedian constrictions. All the other chromosomes have subterminal constrictions. The chromosomes of the twelfth pair are smaller as compared with those of the eleventh pair. The karyotype of this race resembles that of the race *Aureola*.

21. *Tulipa gesneriana* race *Cum Laude*. 2n=24 (A−2) (Figs. 16 and 38).

This race has twelve pairs of chromosomes. They are classified into seven groups. The chromosomes vary in length from 21.0 microns to 12.0 microes. The karyotype of this race resembles in many respects that the race *Superba*. But in some respects there are differences between them. In this race there is a pair of chromosomes of middle size with submedian constrictions, while in *Superba* there are no such chromosomes of middle size. The chromosomes of the twelfth pair are a little smaller than those of the eleventh pair in this race, but in *Superba* the chromosomes of the twelfth pair are much smaller as compared with those of the eleventh pair.

22. *Tulipa gesneriana* race *Neerlandia.* 2n=24 (B) (Fig. 23).

This race has twelve pairs of chromosomes. All the chromosomes have a subterminal constriction. The karyotype of this race is very similar to that of the race *Olaf.*

23. *Tulipa gesneriana* race *Ceylon.* 2n=24 (A−2) (Fig. 11).

The twelve pairs of chriomosomes of this race may be classified into seven groups. The first group includes one pair of chromosomes of the largest size with subterminal constrictions (1 and 2). The second group comprises one pair of chromosomes with submedian costrictions (3 and 4). The third group includes one pair of chromosomes with subterminal constrictions (5 and 6). The chromosomes of these pairs were observed to be curved. The fourth group includes two pairs of chromosomes with subterminal constrictions (7, 8, 9 and 10). The fifth group includes one pair of chromosomes with terminal constrictions. The sixth group consists of two pairs of chromosomes with subterminal constrictions. All the other chromosomes have terminal constrictions. The karyotype of this race has some similarities to that of the race *Aureola.*

24. *Tulipa gesneriana* race *Darlington.* 2n=24 (A−3) (Fig. 19).

The twelve pairs of chromosomes of this race may be classified into seven groups. The first group includes one pair of the largest chromosomes (1 and 2) with subterminal constrictions. They were observed to be by far longer than the other chromosomes. The second group consists of one pair of chromosomes with subterminal constrictions (3 and 4). The third group comprises one pair of chromosomes with submedian constrictions (5 and 6). The fourth group includes one pair of chromosomes with subterminal constrictions (7 and 8). The fifth group includes four pairs of chromosomes of middle size with subterminal constrictions. The sixth group consists of three pairs of chromosomes with subterminal constrictions. The seventh group includes one pair of chromosomes with subterminal constrictions and they were observed to be a little shorter than those of the eleventh pair.

25. *Tulipa gesneriana* race *Black Eagle.* 2n=24 (A−4) (Figs. 20 and 37).

This race has twelve pairs of chromosomes. The chromosomes vary in length from 22.0 microns to 10.0 microns. The chromosomes of the first pair are the largest in the complement and have almost terminal constrictions. The chromosomes of the second pair are a little shorter than those of the first pair and have subterminal constrictions. The chromosomes of the third pair have subterminal constrictions. The chromosomes of the fourth pair have median constrictions. The chromosomes of the fifth pair have subterminal constrictions.

The chromosomes of the sixth pair have nearly submedian constrictions. The chromo-

somes of the seventh pair have subterminal constrictions. The chromosomes of the eighth pair are as large as those of the seventh pair, but the former are a little smaller in size than the latter. The chromosomes of the ninth pair have each a subterminal constriction and a small satellite at the end of the short arm. The chromosomes of the tenth pair have subterminal constrictions. The chromosomes of the eleventh pair have subterminal constrictions, but the short arms of these chromosomes are a little larger than those of the tenth pair. The chromosomes of the twelfth pair are a little smaller than those of the eleventh pair. The karyotype of this race is similar to that of the race *Prominence.*

26. *Tulipa gesneriana* race *Reliance.* 2n=24 (A−2) (Fig. 17).

This race has twelve pairs of chromosomes. The chromosomes vary in length from 22.0 microns to 12.0 microns. The chromosomes of the first pair have subterminal constrictions. The chromosomes of the second and third pairs are almost the same in length, but the chromosomes of the second pair have subterminal constrictions, while the chromosomes of the third pair have submedian ones. The chromosomes of the fourth pair have subterminal constrictions. All the other chromosomes except one pair have a subterminal constriction. The karyotype of this race resembles that of *Superba,* although there are differences in two pairs of chromosomes (17, 18, 23 and 24).

27. *Tulipa gesneriana* race *Pride of Haarlem.* 2n=24 (B) (Fig. 22).

This race has twelve pairs of chromosomes. The karyotypes of this race is similar to that of the race *Neerlandia.* But the differences between them may be pointed out : the twelfth pair of chromosomes of *Neerlandia* are smaller than the eleventh pair, while the twelfth pair of chromosomes of this race are almost as large as those of the eleventh pair.

28. *Tulipa gesneriana* race *Sweet Harmony.* 2n=24 (B) (Figs. 25 and 34).

This race has twelve pairs of chromosomes. Its karyotype is almost the same as that of the race *Neerlandia.*

29. *Tulipa gesneriana* race *Pieter de Hoogh.* 2n=24 (A−2) (Fig. 12).

This race has twelve pairs of chromosomes. The karyotype of this race is similar to that of the race *Ceylon.*

30. *Tulipa gesneriana* race *Thérèse.* 2n=24 (A−2) (Fig. 13)

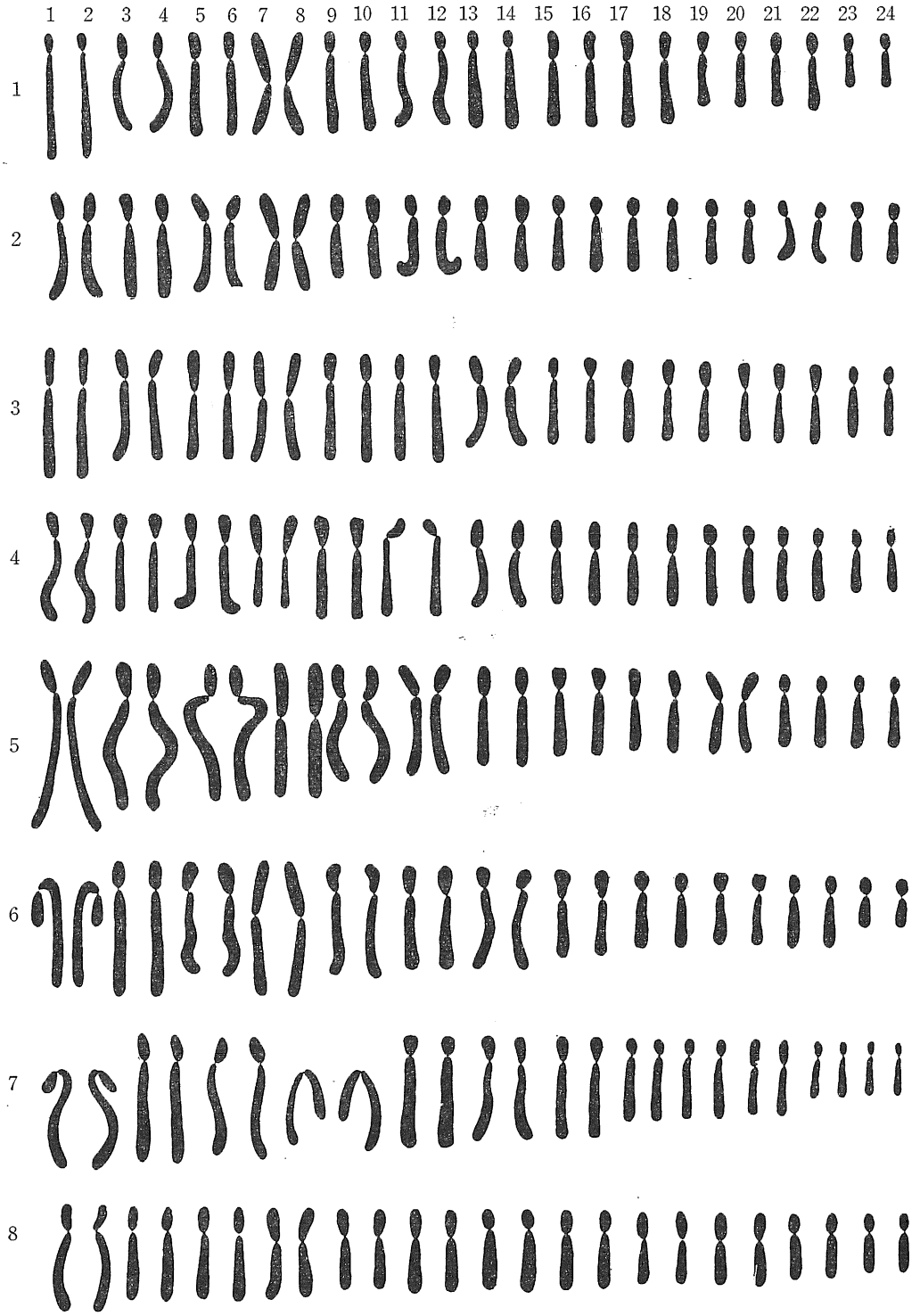
This race has twelve pairs of chromosomes. The karyotype of this race almost fully coincides with that of race *Aureola.* But one pair of chromosomes of the middle size of

Aureola has a submedian constriction, while the chromosomes of this race which correspond to them have subterminal constrictions.

31. *Tulipa gesneriana* race *Nizza*. 2n=24 (A−1) (Fig. 6).

This race has twelve pairs of chromosomes. The karyotype of this race is quite similar to that of race *Finland* except that the chromosomes of the first pair of this race have subterminal constrictions, while those of *Finland* have nearly terminal constrictions.

A－1　Type



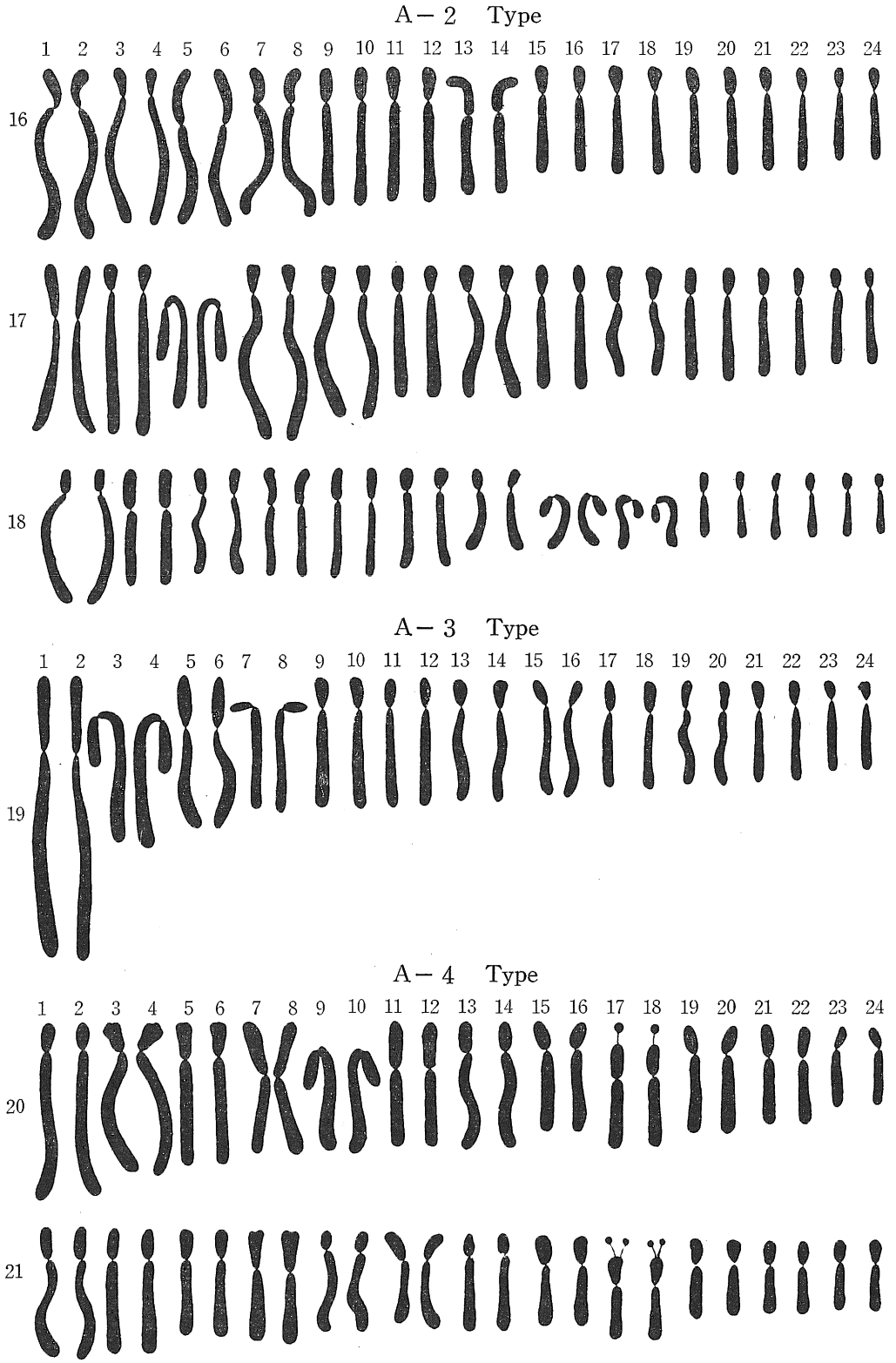
Figs. 1－8. Somatic chromosomes of eight races in *Tulipa gesneriana*.

1. *Finland*.　2. *The Bride*.　3. *Maytime*.　4. *Mildred*.
5. *Saginaw*.　6. *Nizza*.　7. *White Cross*.　8. *Beverley*.　(ca.×1220)

A－2 Type

Figs. 9－15. Somatic chromosomes of seven races in *Tulipa gesneriana*.

9. *Papago.* 10. *Aureola.* 11. *Ceylon.* 12. *Pieter de Hoogh.*
13. *Therese.* 14. *Winnetou.* 15. *Superba.* (ca.×1220)



Figs. 16–21. Somatic chromosomes of six races in *Tulipa gesneriana.*

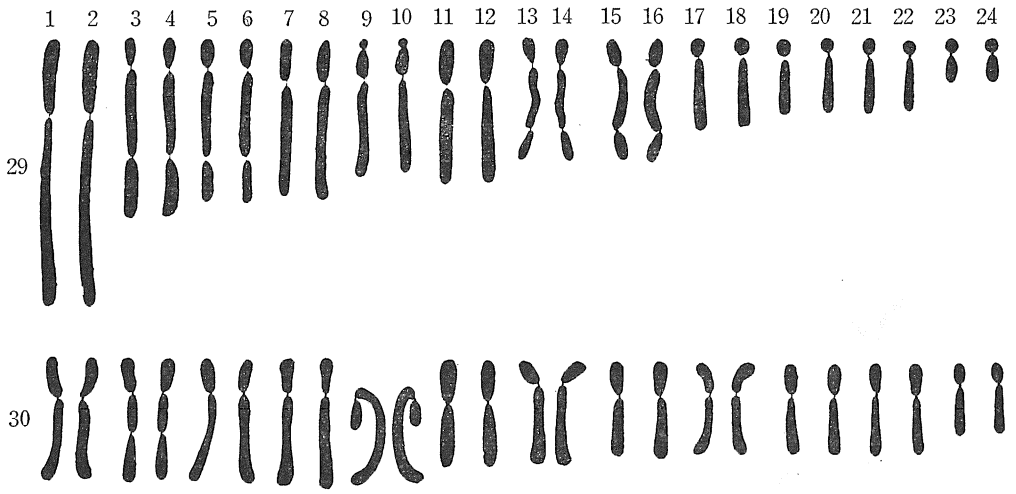
16. *Cum Laude.*　17. *Reliance.*　18. *Couleur de Cardinal.*
19. *Darlington.*　20. *Black Eagle.*　21. *Prominence.*　(ca.×1220)

Figs. 22–28. Somatic chromosomes of seven races in *Tulipa gesneriana*.

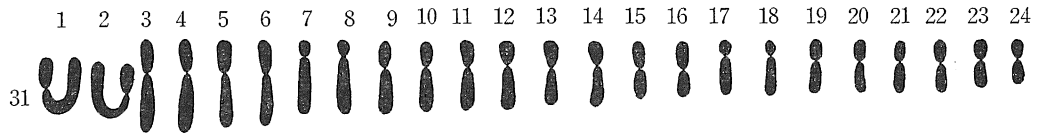
22. *Prid of Haarlem.* 23. *Neerlandia.* 24. *Gretha Benkemper.*
25. *Sweet Harmony.* 26. *Olaf.* 27. *Golden Harvest.* 28. *Henri Correvon.*

(ca.×1220)

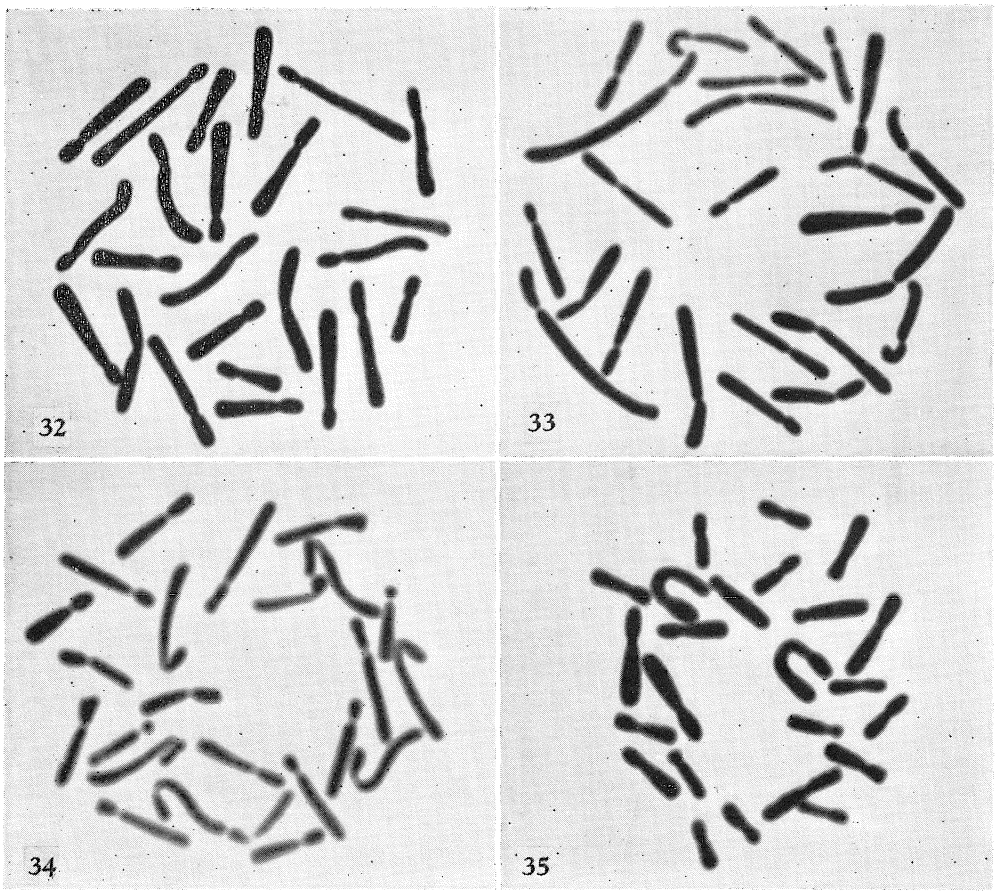
C Type



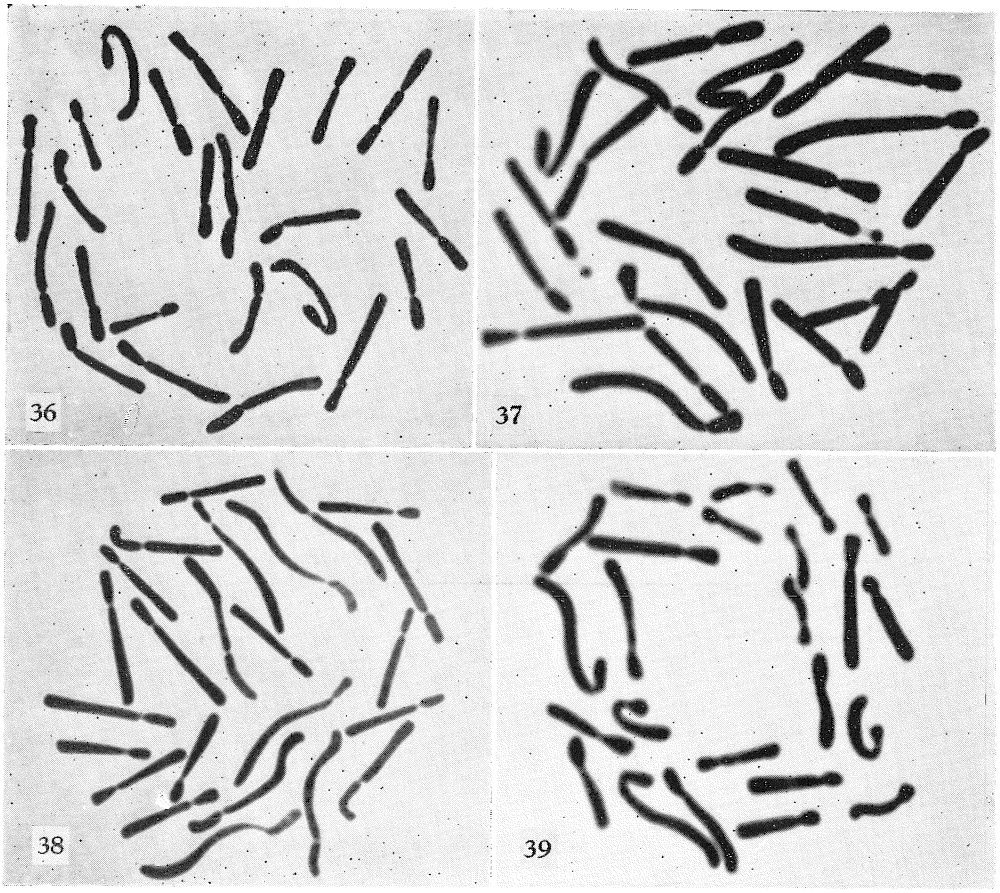
D Type



Figs. 29–31, Somatic chromosomes of three races in *Tulipa gesneriana*.
29. *Mount Erebus.*　30. *Gay Hussar.*　31. *Chappaqua.*　(ca.×1220)



Figs. 32–35. Photomicrographs of somatic chromosomes of four races in *Tulipa gesneriana*.
32. *Finland.* 33. *Papago.* 34. *Sweet Harmony.* 35. *Chappaqua.*
(ca. ×1220)



Figs. 36–39. Photomicrographs of somatic chromosomes of four races in *Tulipa gesneriana*.
36. *Gay Hussar*　37. *Black Eagle.*　38. *Cum Laude.*　39. *Henri Correvon.*
(ca.×1220)

Considerations of the karyotypes of the diploid races in *Tulipa gesneriana*

The results of the observations of the present investigation on the chromosomes in thirty one races of *Tulipa gesneriana* have revealed that the races studied were diploid, having 24 somatic chromosomes, and that karyotypes of some races were quite or almost similar to each other, while those of others were different. Of the karyological facts concerned with the karyotypes obtained, those which seem to be noteworthy may be pointed out as follows: (1) In all the races studied there was the largest chromosome with a subterminal constriction in each chromosome set. (2) In a chromosome set of many races, chromosomes of the large size were found three or four in number. One of them had a median or submedian constriction, while the others had subterminal ones. (3) Most of the chromosomes of middle size each had a subterminal constriction. Some races had one or two chromosomes of middle size with a submedian constriction. (4) Each of the chromosomes of small size had a subterminal constriction. In some races one of the chromosomes of small size was much smaller than the others. (5) In some races all the chromosomes of a chromosome set had subterminal constrictions. (6) In two races there were found chromosomes which had two constrictions. (7) In two races there were found two chromosomes which had a satellite.

As the representative types of the karyotypes in the thirty one races used in this study seven types were determined. The characteristics of them are as follows.

A−1 type : the first pair with a subterminal constriction, second and third pairs with subterminal constriction, fourth pair with a median or submedian constriction and the rest with subterminal constrictions.

A−2 type : the first pair with subterminal constriction, second or third, or rarely both, with a submedian constriction, almost all the other pairs with a subterminal constriction.

A−3 type : this type is almost similar to type A−2. The first pair is much longer than others.

A−4 type : this type is almost similar to type A−1. The nineth pair of chromosomes which possess a setellite in the short arm.

B type : all the pairs with subterminal constrictions.

C type : several pairs of chromosomes have two constrictions.

D type : the chromosomes are smaller as compared with those of the other types. Two or three pairs with submedian constrictions.

From the view point of the types of karyotypes the races used in this study may be classified as follows :

A−1 type : *Finland, White Cross, The Bride, Mildred, Maytime, Beverley, Saginaw, Nizza.*

A−2 type : *Superba, Aureola, Papago, Winnetou, Ceylon, Pieter de Hoogh, Thérèse, Couleur de Cardinal, Cum Laude, Reliance.*

A−3 type : *Darlington.*

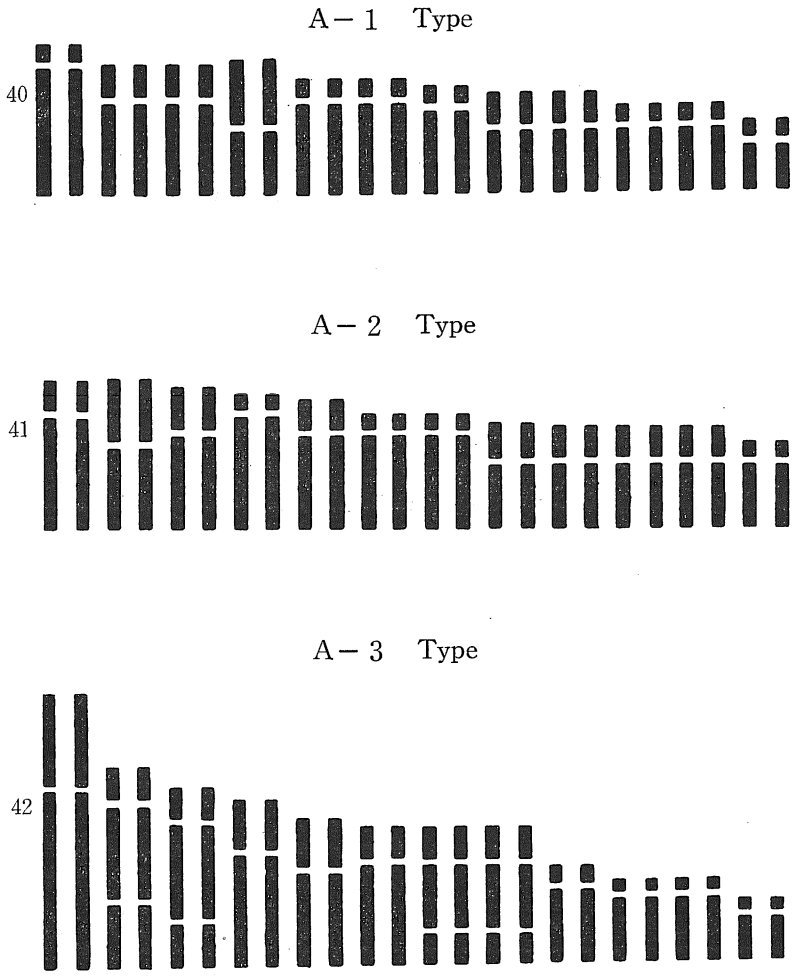
A−4 type : *Prominence, Black Eagle.*

B type : *Olaf, Gretha Benkemper, Golden Harvest, Neerlandia, Pride of Haarlem, Henri Correvon, Sweet Harmany.*

C type : *Mount Erebus, Gay Hussar.*

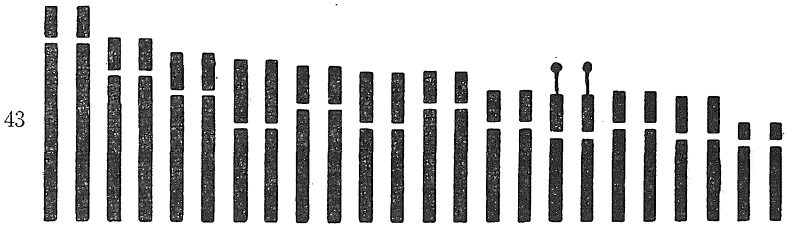
D type : *Chappaqua.*

On this occasion the author took into consideration the karyotypes reported in previous papers. In those papers of the author and his coworkers the karyotypes of one hundred and fifteen races were reported, of which ninety nine races were diploid. The results of these reports wer concerned with only the observations and descriptions of the karyotypes and any classification of the karyotypes of these races have not yet been atempted. Therefore, the classification was made on the karyotypes of those races from the standpoint of the types of the karyotypes which were represented in this study. The results have reveals that all the karyotypes observed in the previous investigations may be classified into the seven types, although the karyotypes belonging to type C seem to be complicated more than those observed in this study. Table 9 lists the horticultural classification and the classification of the karyotypes of all the races in the previous reports together with those in the present study. This table shows that there are some correlations between the horticultural classification and the classification of the karyotypes.

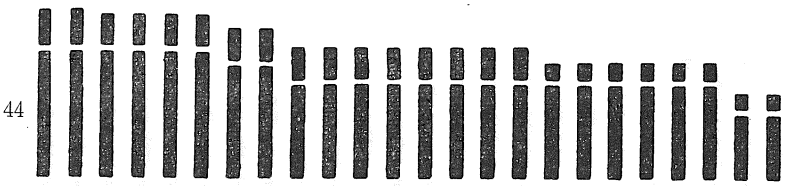


Figs. 40－42. Schemata of three karyotypes in diploid races of *Tulipa gesneriana*.
Fig. 40. Type A－1. race *Finland*. Fig. 41. Type A－2. race *Pieter de Hoogh*.
Fig. 42. Type A－3. race *Darlington*.

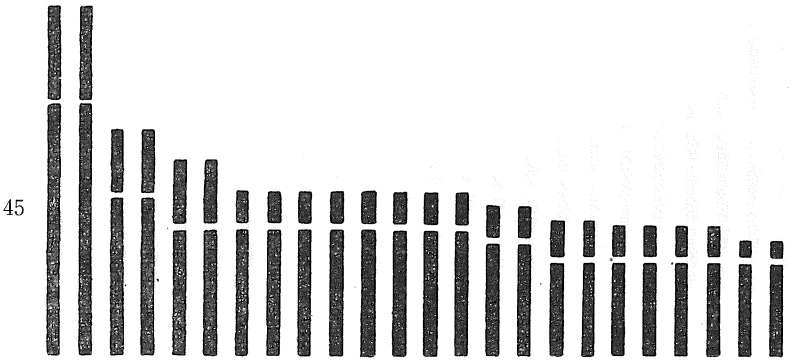
A－4　Type



B　Type



C　Type



D　Type

Figs. 43－46. Schemata of four karyotypes in diploid races of *Tulipa gesneriana*.
Fig. 43. Type A－4. race *Black Eagle*.　Fig. 44. Type B. race *Neerlandia*.
Fig. 45. Type C. race *Mount Erebus*.　Fig. 46. Type D. race *Chappaqua*.

Table 9. The names of all the diploid races of *Tulipa gesneriana* used in the previous and present studies and their karyotype confirmed.

Plant name	2n	karyotype
I. Early Flowering Tulips.		
* Single Early Tulips.		
race *Couleur de Cardinal.*	24	A−2
race *Cramoisie Brilliant.*	24	A−2
race *Diana.*	24	C
race *Enchantress.*	24	C
race *Fredelick Moore.*	24	A−2
race *Princess Helen.*	24	A−2
* Double Early Tulips.		
race *La Candeur.*	24	C
race *Murillo.*	24	C
race *Schoonoord.*	24	B
* Mendel Tulips.		
race *Amidonette.*	24	A−1
race *Erihord.*	24	A−2
race *King of the Reds.*	24	A−1
race *Mozart.*	24	C
race *Superba.*	24	A−2
race *Top Score.*	24	C
race *Van der Earden.*	24	C
* Triumph Tulips.		
race *Alberio.*	24	A−1
race *Aureola.*	24	A−2
race *Edith Eddy.*	24	A−2
race *Finland.*	24	A−1
race *Glory of Noordwijk.*	24	C
race *Gretha Benkemper.*	24	B
race *Hydra.*	24	B
race *Ismari.*	24	A−3
race *Kansas.*	24	A−1
race *Le Horma.*	24	B
race *Lord Carnarvon.*	24	C
race *Marjorie.*	24	C
race *Mississippi.*	24	A−3
race *Mr. Zimmerman.*	24	B
race *Olaf.*	24	B
race *Overdale.*	24	B

race	*Pax.*	24	B
race	*Pierre Monteux.*	24	C
race	*Pink Glow.*	24	C
race	*Preludium.*	24	B
race	*Prominence.*	24	A−4
race	*Roland.*	24	A−1
race	*Viotta.*	24	A−1
race	*Wintergold.*	24	C

II. Late Flowering Tulips.

* Cottage Tulips.

race	*Albino.*	24	C
race	*Anna Pavlova.*	24	B
race	*Argo.*	24	B
race	*Caledonia.*	24	B
race	*Capri.*	24	B
race	*Carrara.*	24	B
race	*Chappaqua.*	24	D
race	*Cocarde.*	24	C
race	*Gay Hussar.*	24	C
race	*Golden Harvest.*	24	B
race	*Golden Measure.*	24	C
race	*Golden Wonder.*	24	C
race	*Grape Fruit.*	24	B
race	*Henri Correvon.*	24	B
race	*Inglescombe Yellow.*	24	C
race	*Majestic.*	24	C
race	*Marshal Haig.*	24	C
race	*Mount Erebus.*	24	C
race	*Saffan.*	24	C
race	*Wall Street.*	24	C
race	*White Pearl.*	24	A−1
race	*Zina.*	24	B

* Lily-flowered Tulips.

race	*Beverley.*	24	A−1
race	*Maytime.*	24	A−1
race	*Mildred.*	24	A−1
race	*Painted Lily.*	24	A−1
race	*The Bride.*	24	A−1
race	*White Cross.*	24	A−1
race	*White Triumphator.*	24	A−2

* Breeder Tulips.

race	*Cunera.*	24	A−4
race	*George Grappe.*	24	C
race	*Indian Chief.*	24	A−2
race	*Jessy.*	24	C
race	*Louis* X IV.	24	C
race	*Papago.*	24	A−2
race	*President Hoover.*	24	C
race	*Saginaw.*	24	A−1
race	*Winnetou.*	24	A−2

* Ideal Darwin Tulips.

race	*Clematis.*	24	A−1
race	*Duke of Wellington.*	24	C
race	*Cum Laude.*	24	A−2
race	*Heliotrope.*	24	C

* Darwin Tulips.

race	*Adagio.*	24	B
race	*Afterglow.*	24	B
race	*Bartigon Maxima.*	24	B
race	*Black Eagle.*	24	A−4
race	*Blue Gem.*	24	C
race	*Centenaire.*	24	A−1
race	*Ceylon.*	24	A−2
race	*City of Haalem.*	24	A−2
race	*Copeland Purple.*	24	C
race	*Darlington.*	24	A−3
race	*Desirée.*	24	C
race	*Dorrie Overall.*	24	C
race	*Drs. Betting.*	24	B
race	*Eminaent.*	24	B
race	*Feu Brilliant.*	24	B
race	*Galant Lady.*	24	B
race	*Hetty Hoos.*	24	A−3
race	*Lord Dunlan.*	24	C
race	*Mamasa.*	24	C
race	*Mantel's Favorite.*	24	B
race	*Martins.*	24	A−3
race	*Miss Blamiss.*	24	A−2
race	*Neerlandia.*	24	B
race	*Palembang.*	24	C
race	*Pieter de Hoogh.*	24	A−2

race	*Pride of Haarlem.*	24	B
race	*Princess Elizabeth.*	24	C
race	*Red Pitt.*	24	B
race	*Reliance.*	24	A−2
race	*Salmon King.*	24	C
race	*Scarlet Sensation.*	24	C
race	*Sweet Harmony.*	24	B
race	*Tindal.*	24	C
race	*Utopia.*	24	B
race	*William Pitt.*	24	C
race	*Yellow Giant.*	24	B
race	*Zwanenburg.*	24	A−4
* Parrot Tulips.			
race	*Cramoisi Brilliant.*	24	A−2
race	*Fire Bird.*	24	A−1
race	*Lutea.*	24	A−2
race	*Lutea Major.*	24	C
race	*Palette.*	24	A−2
race	*Perfecta.*	24	A−1
race	*Taroh.*	24	A−2
race	*Thérèse.*	24	A−2
race	*Yosemite.*	24	A−1
* Double Late Tulips.			
race	*Hermer.*	24	A−2
race	*Nizza.*	24	A−1

Summary

1. The karyotype studies were made on thirty one races in *Tulipa gesneriana.*

2. All the races studied were diploid, having 24 somatic chromosomes.

3. The karyotypes of all the races used were analyzed. It was found that some of the karyotypes are similar to each other while the others are different from each other.

4. From the standpoint of the karyotype the thirty one races may be classified into seven types. A−1 type : *Finland, White Cross, The Bride, Mildred, Maytime, Beverley, Saginaw* and *Nizza.* A−2 type : *Couleur de Cardinal, Superba, Aureola, Papago, Winnetou, Cum Laude, Ceylon, Reliance, Pieter de Hoogh* and *Thérèse.* A−3 type : *Darlington.* A−4 type : *Prominence* and *Black Eagle.* B type : *Olaf, Gretha Benkemper, Golden Harvest, Henri Correvon, Neerlandia, Pride of Haarlem* and *Sweet Harmony.* C type : *Mount Erebus* and *Gay Hussar.* D type : *Chappaqua.*

5. It was ascertained that as to the thirty one races the karyotypical classification supports the horticultural classification.

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