

CHROMOSOME NUMBER IN THE PROGENY OF TRIPLOID CLADIOLUS WITH
SPECIAL REFERENCE TO THE CONTRIBUTION OF THE TRIPLOID

By
Robert E. Jones

Thesis submitted to the Faculty of the Graduate School
of the University of Maryland in partial
fulfillment of the requirements for the
degree of Doctor of Philosophy

1942

UMI Number: DP70417

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



UMI DP70417

Published by ProQuest LLC (2015). Copyright in the Dissertation held by the Author.

Microform Edition © ProQuest LLC.

All rights reserved. This work is protected against unauthorized copying under Title 17, United States Code



ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

ACKNOWLEDGMENT

The author wishes to express his appreciation to Dr. Ronald Bamford for his suggestion of the problem and for his advice and direction during the investigation.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
MATERIALS AND METHODS	2
RESULTS AND DISCUSSION	5
SUMMARY	11
BIBLIOGRAPHY	12

INTRODUCTION

In a previous report concerning the chromosome number in Gladiolus (3) and a later one (4) showing the relation of this factor to the hybridization of various species and varieties, one of the important objects in view has been the origin of the present-day commercial varieties. That certain of the species of this genus were concerned in the formation of these types has long been recognized (6), and, as McLean (81) pointed out some time ago, certain characters in the commercial types must have come from the South African species. In terms of chromosome number, this means that certain characters of the commercial tetraploids have been derived from the South African diploid species. Whether this transfer was by means of amphidiploids, which might have been formed spontaneously after hybridization and then crossed again with other tetraploids, or whether triploids were involved, is a question. In the first study (3) it was apparent that triploids did occur among the commercial types and later (4) that the probable origin of these was from either a diploid-tetraploid or reciprocal cross, since over fifty per cent of such attempts were successful. Perhaps the most important observation in the recent study (4), however, was that such triploids were partially fertile when used as the seed parent in further crosses with either of the original parents or with other diploid and tetraploid forms.

Although the thought still persists among many that triploids are sterile, an examination of the literature reveals that such is not the case. Progeny have been produced from crosses involving triploids, mostly as the seed parents, with diploids in apple (11) (34) (15), Petunia (16), Fragaria (48), Oenothera (12), Populus (10) (22),

Tulipa (5) (19) (45), Zea (30), Impatiens (42), Allium (28), Datura (8) (39), Lilium (40), Crepis (33), tomato (27), and potato (36). It has also been reported that progeny have been produced from crosses between triploids and tetraploids in Petunia (16), Phleum (35) (18), and others. It would appear then that Gladiolus is not unusual in this respect.

Preliminary investigations (26) showed that not only did these Gladiolus triploids, when used as the seed parents, behave in a fashion similar to those already reported in the literature (5, 15, 19, 30, 34, 39, 45), but that some other type of chromosome behaviour was taking place. This report presents the occurrence and frequency of these observations.

MATERIALS AND METHODS

With the exception of the previously reported triploid variety Charm (3), the triploids used in this study were produced through reciprocal crosses between various tetraploid commercial varieties and diploid species. Using the triploids as the female parent, seeds were obtained after crossing these with diploid species or some diploid hybrids, and also with tetraploid commercial varieties, as well as some tetraploid hybrids produced as the result of previous hybridization. Some examples illustrating the parentage of these progeny are:

[Prof. Donders (60) x G.hirsutus (30)] x [G.tristis (30)]
 [G.tristis (30) x Prof. Donders (60)] x [G.tristis (30) x G.alatus (30)]
 [Miss Bloomington (60) x G.angustus (30)] x [Dr. Moody (60)]
 [Prof. Donders (60) x G.tristis (30)] x [G.primulinus (60) x
 Princeps (60)]

In all, approximately 500 plants were obtained, and of these it was possible to obtain chromosome counts from 470.

All work was done in the greenhouse during the winter months. Seeds from the triploids were gathered in the late spring and planted in pots the following fall. The corns produced from these seeds were generally planted the next fall, if large enough, in separate pots and root tips collected from each. These tips were fixed in Navashin's solution and prepared for sectioning by the short butyl alcohol method. Tissue-mat was used for the embedding process, and all sections were cut 12 microns thick. Staining was accomplished by the crystal violet-iodine technique. Observations were made with the aid of a 90x, 1.8 apochromatic objective. Drawings were made with a camera lucida. All magnifications are listed with the plates.

In making the chromosome counts, it was impossible in a few cases to obtain a consistent number for some individuals. In recording these, it was necessary to list them as ± the number which was found most frequently. The least inconsistent of these have been included in the graphs, while the more variable ones were entirely eliminated from consideration.

RESULTS AND DISCUSSION

It was presumed in all cases that the diploid male parent contributed only fifteen chromosomes and the tetraploid male only thirty chromosomes, because in all other crosses, such as diploid-diploid, diploid-tetraploid, tetraploid-diploid, and tetraploid-tetraploid, no irregularities in gametic chromosome contribution have been observed from a study of the resultant hybrids.

After the chromosome number of the triploid progeny had been determined, the contribution of the triploid seed parent, when crossed with the diploid, was ascertained by subtracting the haploid number of the

pollen parent. This is shown graphically in Plate I, while the contribution of the triploid, when crossed with the tetraploid as the pollen parent, is shown in Plate II. In Plate III the total contribution in all cases is shown, thus combining the two previous graphs, since the triploid parent was common to both types of crosses.

Throughout the course of the investigation, observations were made to determine whether certain triploids might have reacted differently when crossed with various diploids and tetraploids; but there was no indication of this in the behaviour of any of the triploids in crosses with any one individual variety or species. For this reason, all triploid-diploid or triploid-tetraploid crosses were treated as a group rather than as individuals.

Triploid-Diploid Progeny. It is quite obvious from Plate I that there is a great variance in regard to the chromosome number of the functional gametes of the triploid. From 18 to 55 chromosomes were contributed one or more times. Despite this wide distribution and variation as shown in the charts, it is possible to note three obvious frequencies, which probably indicates three different possible types of behaviour most frequently occurring in the triploid. The frequent contribution of approximately 24 indicates the meiosis must have been nearly normal, the frequency at 30 indicates gametes like those of tetraploids, and 45 the contribution of the full triploid chromosome complement.

In Plate I, which shows the contribution in the triploid-diploid crosses, it is obvious that the $3n/2$ number, or approximately that, was contributed in only a small per cent of the cases. One might expect it to be that of greatest frequency in view of the results previously reported in some other plants. In Tulipa ($n=12$) Bamford et al (5),

Hall (19), and Upcott (45) have found that a triploid, used as the female parent and crossed with a diploid, contributed from 12 to 22 chromosomes and in most cases from 15 to 18, which would be about the $3n/2$ number. Nebel (34) has shown in a $3n \times 2n$ cross in apple ($n=17$) that the chromosome number of the progeny ranged from 35 to 48 with the mode at 40.5, which would indicate that in most cases the triploid contribution would be somewhere near the $3n/2$ number. Capinpin (12) in Oenothera ($n=7$) in a similar cross found the range to be 14 to 21 with the mode at 16, which again approximates the $3n/2$ number from the triploid. Bergstrom (10) and Johnsson (22) in Populus, Dermen (15) in apple, and Levan (28) in Allium all found similar results, with the progeny from $3n \times 2n$ crosses having somatic chromosome numbers ranging from the diploid to the triploid. In all these instances, however, practically all of the triploid progeny fell within this group. In Gladiolus it must be emphasized that such a contribution occurs in only a small portion of the cases, and only a small portion of the progeny would have somatic chromosome numbers ranging from the diploid to the triploid.

The second most obvious contribution of the triploid female in triploid-diploid hybrids of Gladiolus was that of thirty chromosomes, which would make the resulting progeny full triploids with regard to chromosome number. A few such progeny have been found by McClintock (30) and Longley (29) in Zea, Levan (28) in Allium, and Sato (40) in Lilium in crosses involving a triploid parent. Bergstrom (10) in Populus and Dermen (15) in apple also found evidence of similar gametes from the triploid. Navashin (33) in Crepis, in crossing a triploid F_1 inter se and with other sister diploid plants, found that approximately twenty-eight per cent of the progeny were triploids. Then this type of behaviour

is not unusual in the case of triploids.

The contribution in Gladiolus of the full triploid number would seem to be the most common type of behaviour. This would then mean that the progeny receiving this number would be tetraploid in nature. This is not in general accord with the literature, although occasional tetraploid progeny from triploids have been reported. In Solanum (36), Tulipa (45), and Populus (10) (22) infrequent progeny have appeared with the full tetraploid chromosome number. This unusual behaviour of Gladiolus would make it possible to see how diploid characters could be transmitted to the tetraploids if this has been common in the past development of commercial Gladiolus.

Triploid-Tetraploid Progeny. Upon examining the contribution of the triploid (Plate II) in the triploid-tetraploid crosses, it is again obvious that the previous three types of behaviour, as found in the triploid-diploid crosses, still exist. This indicates that the triploid, regardless of the pollen parent used, is consistent in the types of gametes most frequently produced.

The twenty-four and the thirty chromosome contributions again appear in approximately the same proportions as in the triploid-diploid crosses, although the somatic chromosome number of the progeny would be higher because of the thirty chromosome contribution from the pollen parent. Only a limited number of $3n \times 4n$ crosses have been previously reported; but Longley (29) in Zea, Dermen (16) in Petunia, and Gregor and Sansome (18) in Phleum found that the triploid contributed approximately the diploid number when used in such a cross.

The full triploid somatic number again was contributed in most of the cases. This would indicate that the progeny receiving this contribution would be pentaploid with regard to chromosome number. Dermen (16)

in Petunia, in a $3n \times 4n$ cross, found one plant with the full pentaploid number of chromosomes; and Nordenskiöld (35), using Phleum in such a cross, found some of the progeny to be pentaploid. In neither of these cases, however, was the full triploid contribution a general feature of such a cross. This indicates that in Gladiolus, the triploid, regardless of the male parent, most generally contributes the full triploid chromosome number. This is particularly true when, out of 470 progeny observed (Plate III), 129 apparently resulted from such behaviour.

Instances of higher chromosome contribution than forty-five are also shown. This is comparable to the results shown by Nordenskiöld (35) in Phleum.

To explain the results presented above, it is only necessary to remember that failure of pairing, unequal divisions, lagging chromosomes, and the formation of restitution nuclei have repeatedly been described as characteristic of triploids. Stout (43) in Hemerocallis, Capinpin (12) in Oenothera, Dermen (15) in the Baldwin apple, Levan (28) in Allium, McClintock (30) in Zea, Satina and Elakeslee (38) in Datura, Sato (40) in Lilium tigrum, Belling (7) in Hyacinthus, and Skovsted (41) in cotton, and many others have observed these phenomena. Although no extensive observations have been made of the embryo sac behaviour in triploid Gladiolus, those of Westfall (47), Bellows (9), and Satina and Elakeslee (38) in other genera demonstrate that the meiotic and subsequent divisions are similar to the PMC behaviour so often described, although Jensen (21) observed that they are not apt to show such violent irregularities. One of these phenomena, or a combination of them, is all that is necessary to account for the variety and extent of chromosome numbers present in the female gametes produced by the triploid. The number twenty-four could be the result of nearly normal meiosis, while the

number thirty would indicate the contribution of a diploid gamete, which is not uncommon in such hybrids. The numbers 18-23 and 25-27, as well as those from 28 to 29 and 31 to 35 could have resulted from lagging of chromosomes or unequal division of chromosomes during the meiotic and subsequent divisions.

It is apparent that the most frequent method of behaviour in triploid Gladiolus, in contrast to many other observations, is non-reduction or the formation of a restitution nucleus. This is also borne out by Darlington (14) who states, "Nearly all triploids that have been examined, for example, form restitution nuclei whether they are the product of hybridization of two species or of self-fertilizing a diploid." This is not an uncommon behaviour because it has been observed frequently in triploids and in other hybrids by Kostoff (24) in Triticum, Crane and Darlington (13) in Rubus, Andersson and Gairdner (1) in Dianthus, Webber (46) in Nicotiana, Lawrence (25) in Delphinium, Crane (17) in Veronica, and many others. However, the total range from 36 to 55 is due to other phenomena in addition to the formation of restitution nuclei. Lagging and unequal division of chromosomes after non-reduction could account for gametes with chromosome numbers from 36 to 44 and from 44 to 55. It is also possible that lack of pairing, with the resultant irregular behaviour of univalents, might produce a gamete with greater than the diploid or triploid number of chromosomes, as has been suggested by Karpechenko (23). When those progeny receiving the numbers 36 to 44 and 44 to 55 are added to the 129 which received the full 45 chromosomes, it shows that over fifty per cent of all the progeny fell within this group, which basically are the result of the formation of restitution nuclei.

From all this evidence of high chromosome number in the functional gametes of the triploids, it seems entirely possible that the characteristics of the diploids may have been transmitted to the tetraploids through the medium of hybridization which involved the formation of triploid hybrids. Navashin (33) has spoken of "... the tendency of triploids to produce polyploid interspecific hybrids...." during his work on Crepis, and Crane (20) in a recent article states, "We are often unable to say how a particular polyploid arose, but it is clear that the functioning of unreduced germ cells is a frequent method and that in conjunction with hybridization it has played an important part, both in nature and in cultivation, in the origin of new forms and species." Gladiolus, because of its extensive cultivation and hybridization, might well have followed this pattern.

Besides the possibility of embryo sac behaviour determining the chromosome number of these triploid progeny, another occurrence may explain some minor changes. These are the irregularities in somatic cell division illustrated in Plate VI. That these concerned tissues, as well as individual cells, is obvious, because in some cases certain areas in the root tips were found to have different chromosome numbers from that of the surrounding tissue. In one instance the epidermis within a limited area gave a consistent chromosome count of 88, while the area of the cortex between that and the stele contained only 75 chromosomes. In another case the epidermis and cortex continually differed in number throughout the observable portion of the root. There were also instances of single cells which possessed chromosome numbers well over 100. In addition to these irregularities, a persistent nucleolus was found in some cells, as shown in Plate VI. The presence of such a nucleolus has previously been reported in Gladiolus (32).

Cases of premature division of the chromosomes at metaphase also were found. In such cases some of the chromosomes preceded the others in moving toward the poles. Observations of such mitotic irregularities have been made previously by Mensinkai (32) in Gladiclus, Babu (2) in Groundnut, Stout (44) in Hemerocallis, and others; but no special significance seems to be attached to the phenomena. These irregularities may indicate a certain degree of unbalance, either in chromosome number or in the rhythm of cell division.

Summary

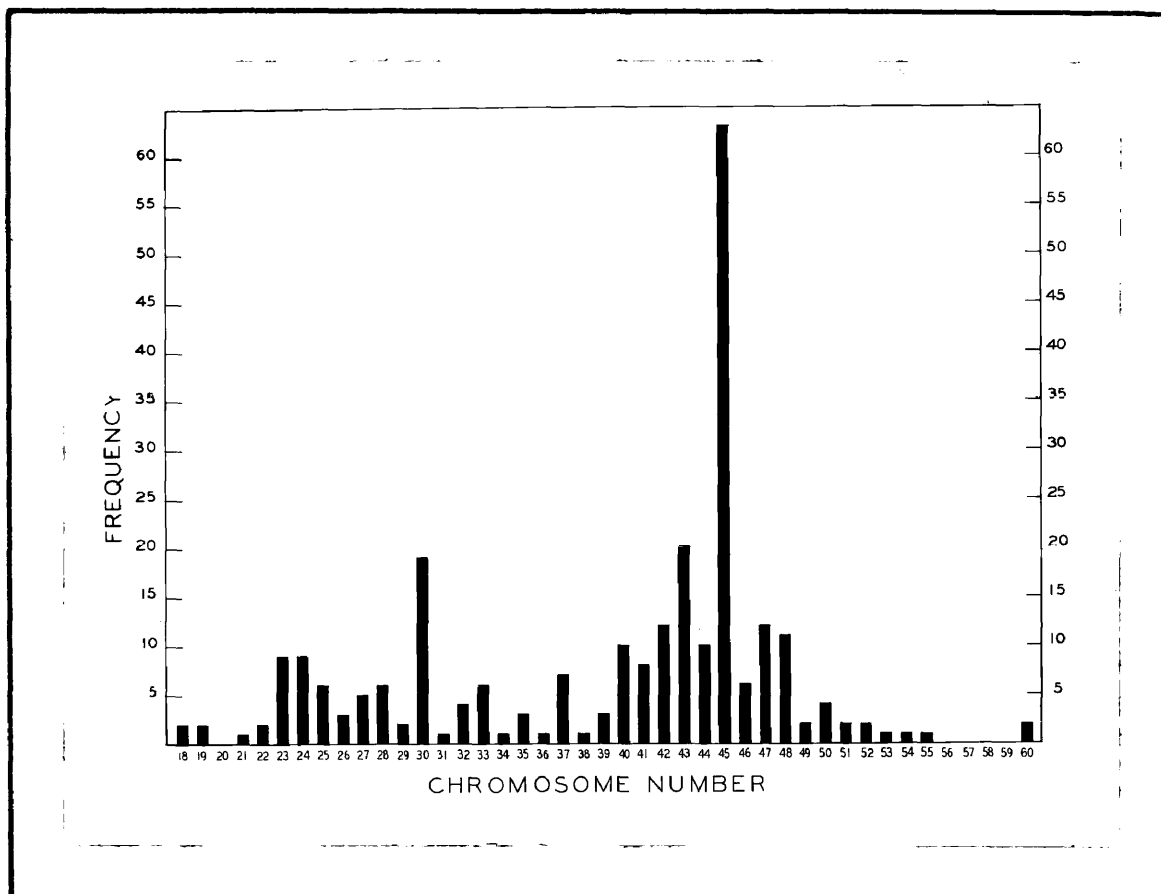
1. Four hundred and seventy progeny were obtained from several triploid Gladiolus, when these were used as the seed parents in crosses with diploids and tetraploids. The somatic chromosome numbers of these progeny were determined to find the contribution of the triploids.
2. The triploids contributed every chromosome complement from 18 to 56 and other sporadic numbers up to 69. The majority of the triploid progeny fell into three main groups, the most important being that where the triploid seed parent contributed its full chromosome complement of 45.
3. This behaviour could have come about through the formation of restitution nuclei during meiosis or subsequent divisions, with the accompanying unequal distribution of chromosomes. Both of these types of behaviour are characteristic of triploids.
4. Such behaviour in the triploid followed by hybridization offers one explanation for the transmission of characters from the diploid species to the tetraploid forms in Gladiolus.
5. Irregularities in mitotic cell division were observed in the root tips of several of the triploid progeny.

OF LITERATURE

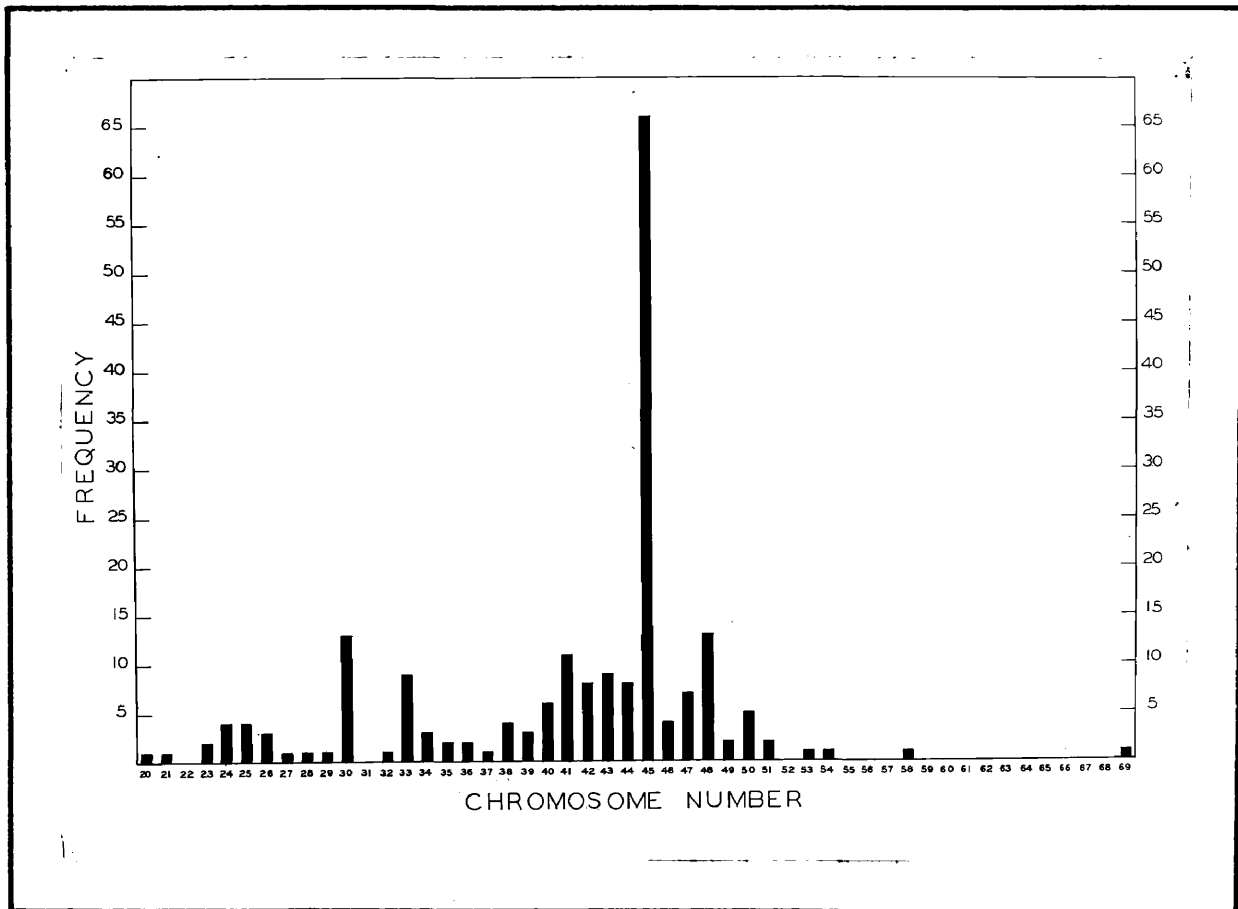
1. Andersson-Kotto, I. and A. E. Wairdner 1931. Interspecific crosses in the Genus Lianthus. Genetica 13: 77-112.
2. Babu, C. N. 1941. Chromatin Bridges in the roottip of Groundnut. Current Science 10: 173-174.
3. Sanford, R. 1935. The Chromosome Number in Cladiolus. Journ. Ag. Research. 51: 945-950.
4. _____ 1941. Chromosome number and Hybridization in Cladiolus. Journ. of Hered. 32: 418-422.
5. _____, Geo. E. Heynard and J. M. Wellows, Jr. 1939. Chromosome number in some Tulip Hybrids. Bot. Gaz. 101: 482-490.
6. Neal, A. C. 1916. Cladiolus Studies. I. Botany, History, and Evolution of the Cladiolus. N. Y. Agr. Col. (Cornell) ext. Bull. 9: 95-188.
7. Pelling, J. 1924. The distribution of chromosomes in the pollen grains of a triploid Hyacinth. Am. Nat. 58: 440-446.
8. _____ and A. F. Flakeslee 1922. The assortment of chromosomes in Triploid Liliaceae. Am. Nat. 56: 359-346.
9. Wellows, J. M. Jr. and Ronald Sanford 1941. Macrogametophyte Development in a Triploid Tulip. Bot. Gaz. 102: 699-711.
10. Bergstrom, I. 1940. On the Progeny of Diploid x Triploid Populus Tremula, with Special Reference to the occurrence of Tetraploidy. Hereditas. 26: 191-201 Ja.
11. _____ 1938. Tetraploid Apple Seedlings Obtained from the progeny of Triploid Varieties. Hereditas. 24: 210-215.
12. Capinpin, J. M. 1935. Studies on the Genetics and Cytology of Triploid Oenotheras. Cytologia 4: 355-426.
13. Crane, M. G. and C. C. Darlington 1927. The Origin of New Forms in Rubus. I. Genetica 9: 241-278.
14. Darlington, C. C. 1937. Recent Advances in Cytology. P. Blakiston Sons and Co., Philadelphia, Penna.
15. Dermen, H. 1936. Fertilization in the Baldwin Apple, a Triploid Variety. Jour. of the Arnold Arb. 17: 106-108.
16. _____ 1931. Polyploidy in Petunia. Am. Jour. Bot. 18: 250-261.

17. Graze, Hildegard 1955. Weitere Chromosomenuntersuchungen bei Veronica-Arten der Sektion Pseudolusimachia Koch. Jahrb. wiss. Bot. 81: 609-632.
18. Gregor, J. W. and F. W. Sansome 1930. Experiments on the Genetics of Wild Populations. II Phleum pratense L. and the hybrid P. pratense L. x P. alpinum L. Jour. Genetics 22: 373-387.
19. Hall, A. D. H. 1937. Polyploidy in Tulipa. Jour. Linn. Soc. Bot. 1: 481-489.
20. Huxley, Julian 1940. The New Systematics. Oxford.
21. Jensen, H. W. 1938. The significance of Meiotic Irregularities in Hybrids. The Theory of Cyto-Nuclear Harmony. Cytologia 8: 481-496.
22. Johnsson, H. 1940. Cytological Studies of Diploid and Triploid Populus Tremula and of Crosses between them. Hereditas 28: 521-552.
23. Karpechenko, G. D. 1927. The production of Polyploid Gametes in Hybrids. Hereditas 9: 549-568.
24. Kostoff, D. 1932. (Triticum dicoccum x Triticum monococcum) x Triticum vulgare Triple hybrid with 42 Chromosomes. Cytologia 3: 186-187.
25. Lawrence, W. J. C. 1936. The origin of new forms in Delphinium. Genetica 18: 109-115.
26. Leavenworth, W. C. 1938. Chromosome Studies in Some Gladiolus Hybrids. Masters Thesis University of Maryland Library, Unpublished Data.
27. Lesley, J. W. 1928. A Cytological and Genetical Study of Progenies of Triploid Tomatoes. Genetics 13: 1-45.
28. Levan, A. 1936. Different results in Reciprocal Crosses between Diploid and Triploid Allium Schoenoprasum L. Nature 138: 508.
29. Longley, A. E. 1934. Chromosomes in Hybrids between Euchlaena perennis and Zea mays. Jour. Ag. Res. 48: 789-806.
30. McClintock, B. 1929. A Cytological and Genetical Study of Triploid Maize. Genetics 14: 180-222.
31. McLean, F. T. 1925. The Value of Gladiolus Species for Hybridizing. Gladiolus Review. 2 (5): 7-9.
32. Mensinkai, S. W. 1939. Cytological Studies in the Genus Gladiolus. Cytologia 10: 59-72.
33. Navashin, M. 1929. Studies on Polyploidy. I. Cytological Investigations Triploidy in Crepis. Univ. of Calif. Pub. Agr. Sci. 2: 377-400.

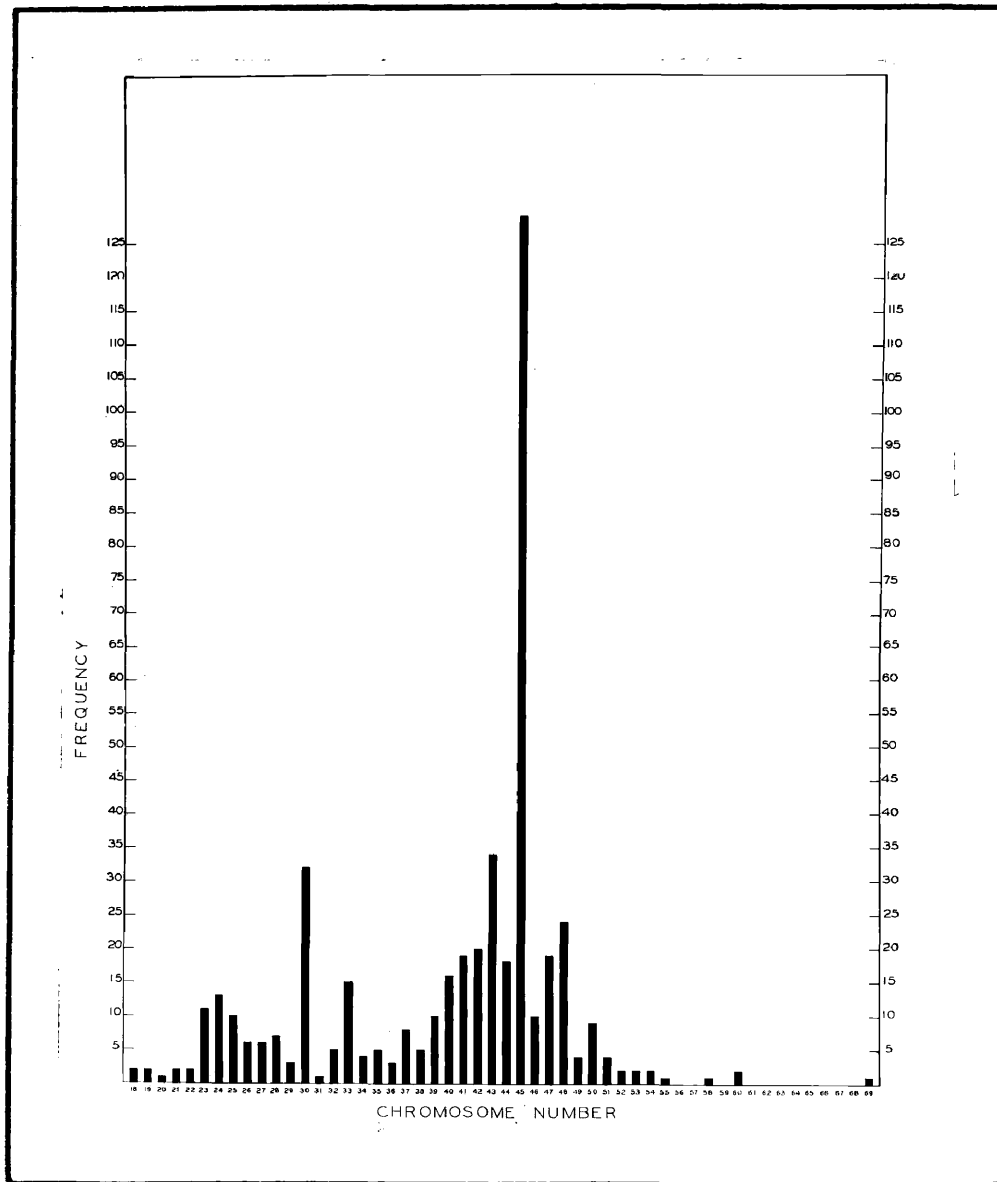
34. Nebel, H. E. 1933. Chromosome numbers in Aneuploid apple seedlings. N. Y. Agr. Exp. Sta. Tech. Bul. 209.
35. Nordenskiöld, E. 1941. Cytological Studies in Triploid Phleum Bot. Bot. 1941; 12-32.
36. Ferlova, R. L. 1940. Production of Tetraploid plants in Triploid Potato species, group andigena, by cultivating in the Pamirs. Compt. Rend. (Doklady) Acad. Sci. U. R. S. S. 27: 55-58.
37. Satina, S. and A. E. Lakeslee 1937. Chromosome behaviour in Triploids of Latura stramonium. I. The Male Gametophyte. Am. Jour. Bot. 24: 519-527.
38. _____ 1937. Chromosome behaviour in Triploid Datura. II. The Female Gametophyte. Am. Jour. Bot. 24: 521-527.
39. _____ and A. E. Avery 1938. Chromosome behaviour in Triploid Datura. III. The Seed. Am. Jour. Bot. 25: 595-602.
40. Sato, M. 1937. Chromosome variation in the progeny of Triploid Lilium tigrinum. Cytologia Fujii Jubilee 1056-1061.
41. Skovsted, A. 1933. Cytological Studies in Cotton. I. The Mitosis Meiosis in Diploid and Triploid Asiatic Cotton. Ann. Bot. 47: 227-251.
42. Smith, F. B. 1938. Reduction Division in Triploid Impatiens. Am. Jour. Bot. 25: 651-654.
43. Stout, A. B. 1932. Chromosome number in hemerocallis, with reference to Triploidy and Secondary Polyploidy. Cytologia 3: 250-259.
44. _____ and Torasaturo Sasa 1929. Chromosome Irregularities in Relation to Sterility in hemerocallis Fulva Clon Europa. Ann. N. Y. Acad. Sci. 31: 1-30.
45. Upcott, W. and James Philp 1939. The Genetic Structure of Tulips. IV. Balance, Selection and Fertility. Jour. of Genetics 38: 91-123.
46. Webber, J. M. 1930. Interspecific Hybridization in Nicotiana. XI. The Cytology of a Sesquidiploid hybrid between Tabacum and Sylvestris. Univ. of Calif. Pub. Bot. 11: 319-354.
47. Westfall, J. J. 1940. Cytological Studies of Lilium tigrinum Bot. Gaz. 101: 550-561.
48. Yarnell, S. B. 1931. A Study of Certain Polyploid and Aneuploid forms in Brassica. Genetics 16: 455-489.



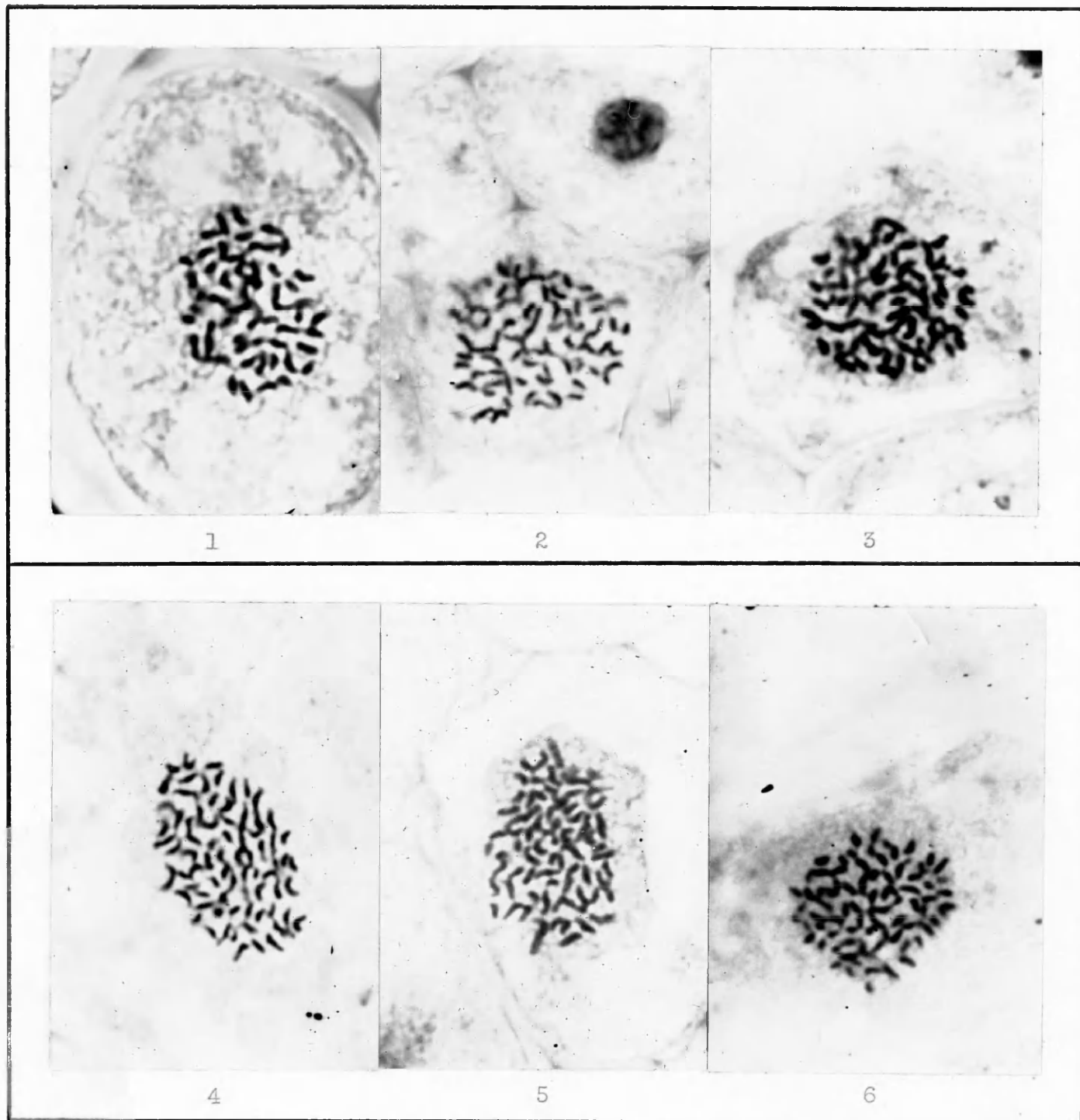
The chromosome contribution of the triploid in the triploid-diploid hybrids.



The chromosome contribution of the triploid in the triploid-tetraploid hybrids.



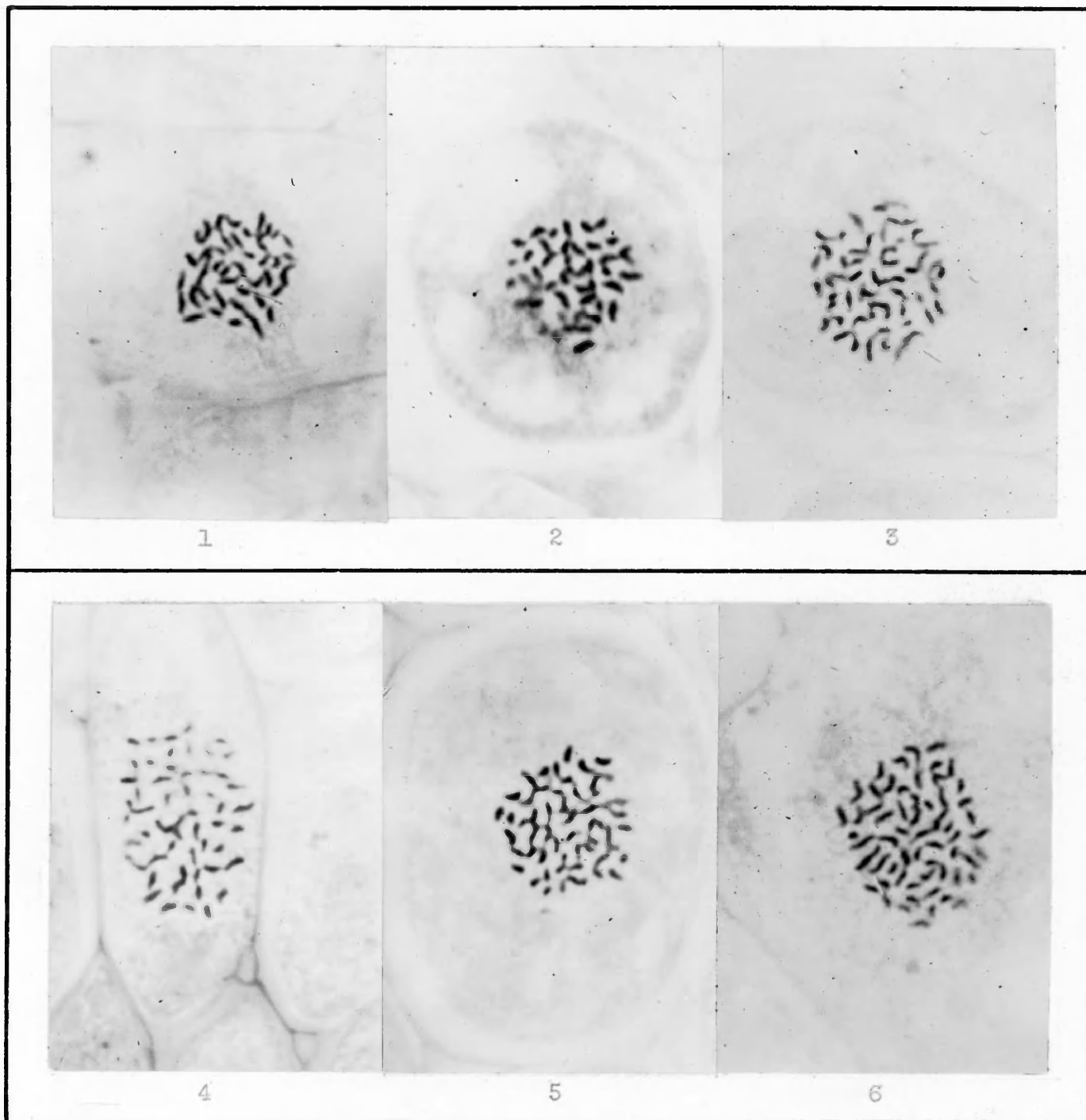
The chromosome contribution of the triploid in both triploid-diploid and triploid-tetraploid hybrids.



Chromosomes from Triploid-Tetraploid Progeny

- Fig. 1. (Edith Mason (60) x *G. cuspidatus* (30)) x (Edith Mason (60)),
55 chromosomes.
- Fig. 2. (Prof. Donders (60) x *G. hirsutus* (30)) x (Dr. Moody (60)),
71 chromosomes.
- Fig. 3. (Prof. Donders (60) x *G. tristis* var. *concolor* (30)) x (Prof.
Donders (60)), 74 chromosomes.
- Fig. 4. (Prof. Donders (60) x *G. undulatus* (30)) x (Mrs. Francis King
(60) x self (60)), 75 chromosomes.
- Fig. 5. (Edith Mason (60) x *G. angustus* (30)) x (Prof. Donders (60)),
77 chromosomes.
- Fig. 6. (Prof. Donders (60) x *G. tristis* var. *concolor* (30)) x (Dr. Moody
(60)), 78 chromosomes.

Mag. Approximately 2500



Chromosomes from Triploid-Diploid Progeny

- Fig. 1. (Joost Vondel (60) x (*G. tristis* var. *concolor* (30) x *G. hirsutus* (30))) x (*G. tristis* var. *concolor* (30) x *G. hirsutus* (30)), 42 chromosomes.
- Fig. 2. (Prof. Donders (60) x (*G. tristis* var. *concolor* (30) x *G. callistus* (30))) x (*G. tristis* var. *concolor* (30) x self (30)), 48 chromosomes.
- Fig. 3. (Prof. Donders (60) x *G. undulatus* (30)) x (*G. tristis* var. *concolor* (30) x *G. watsonius* (30)), 55 chromosomes.
- Fig. 4. (*G. tristis* var. *concolor* (30) x Prof. Donders (60)) x (*G. tristis* var. *concolor* (30) x *G. alatus* (30)), 57 chromosomes.
- Fig. 5. (Prof. Donders (60) x *G. tristis* var. *concolor* (30)) x (*G. tristis* var. *concolor* (30) x self (30)), 60 chromosomes.
- Fig. 6. (*G. tristis* var. *concolor* (30) x Prof. Donders (60)) x (*G. tristis* var. *concolor* (30)), 60 chromosomes.

Mag. Approximately 2500

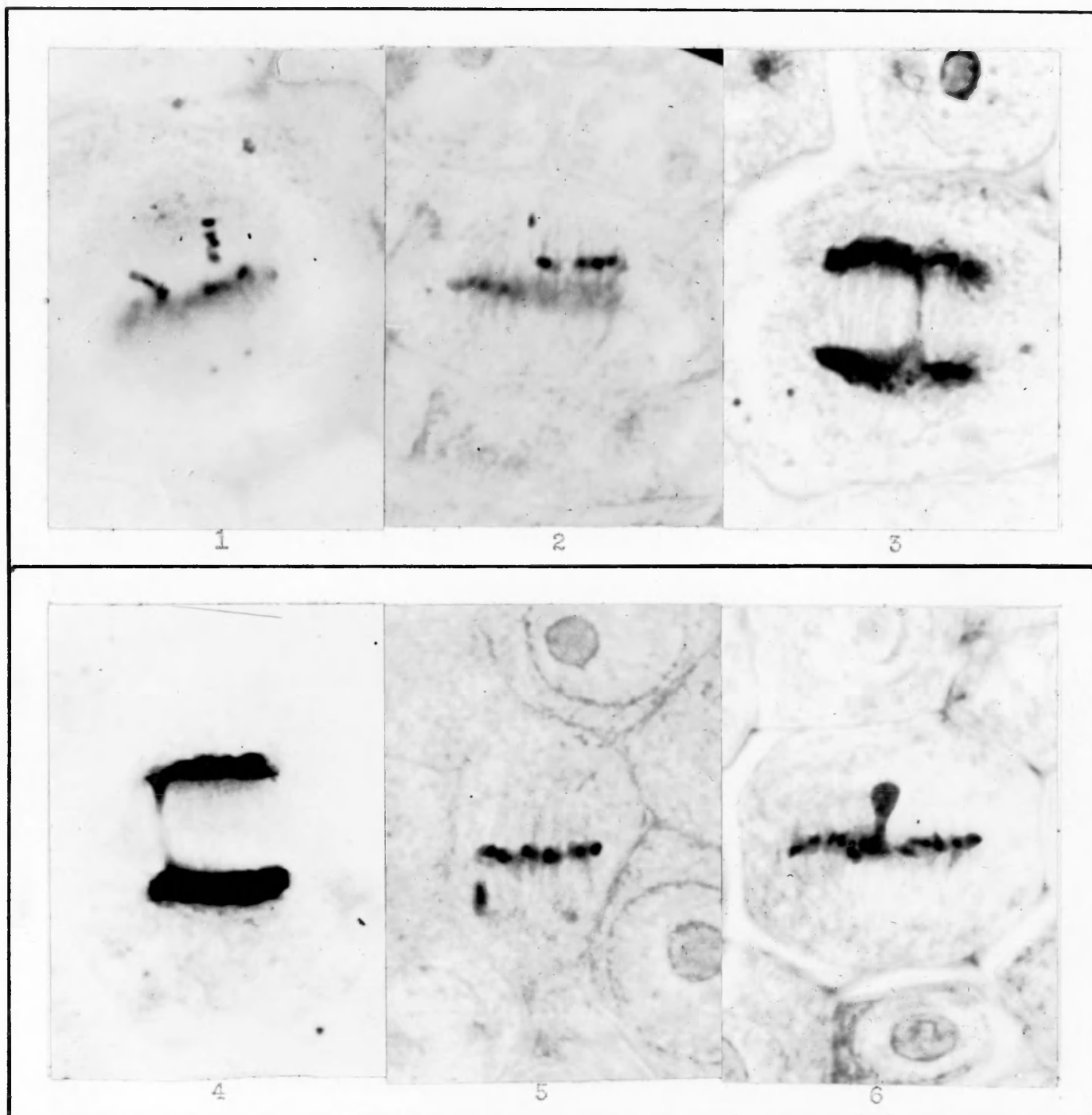


Fig. 1. Irregular mitotic division from the root tip of a triploid-tetraploid hybrid.

Fig. 2. Irregular mitotic division from the root tip of a triploid-diploid hybrid.

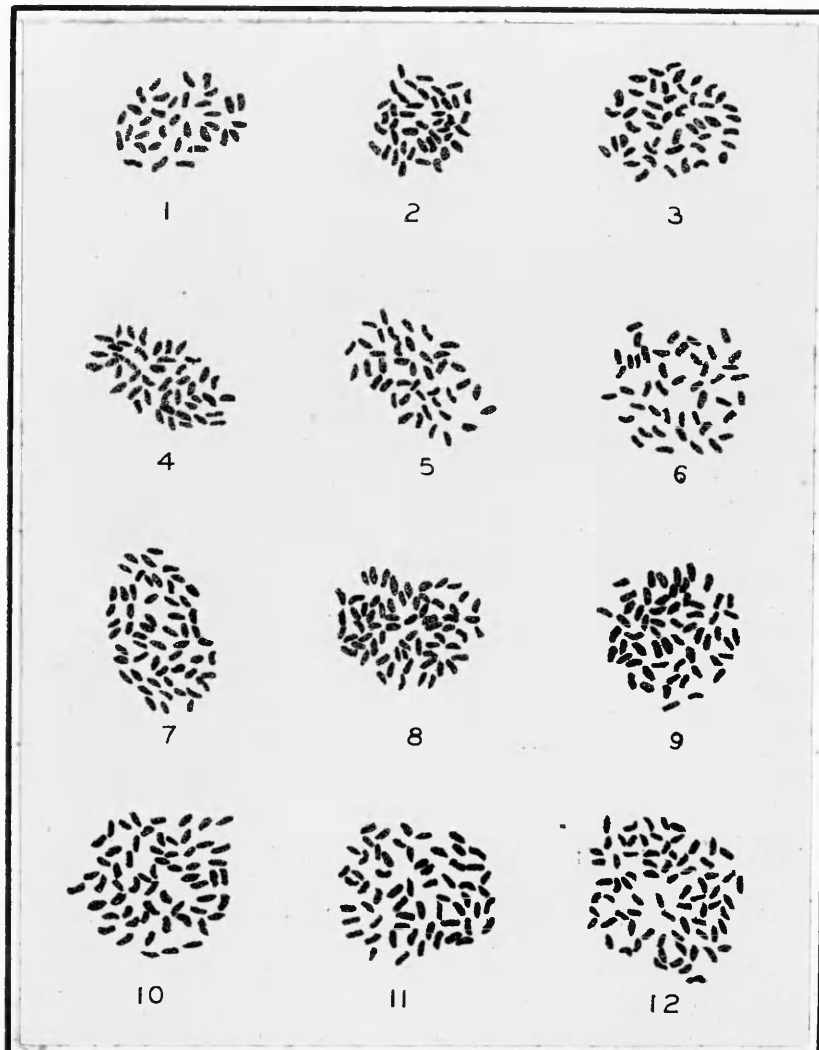
Fig. 3. Chromatin bridge found in the root tip of a triploid-tetraploid hybrid.

Fig. 4. Chromatin bridge found in the root tip of a triploid-tetraploid hybrid.

Fig. 5. Irregular mitotic division from the root tip of a triploid-diploid hybrid.

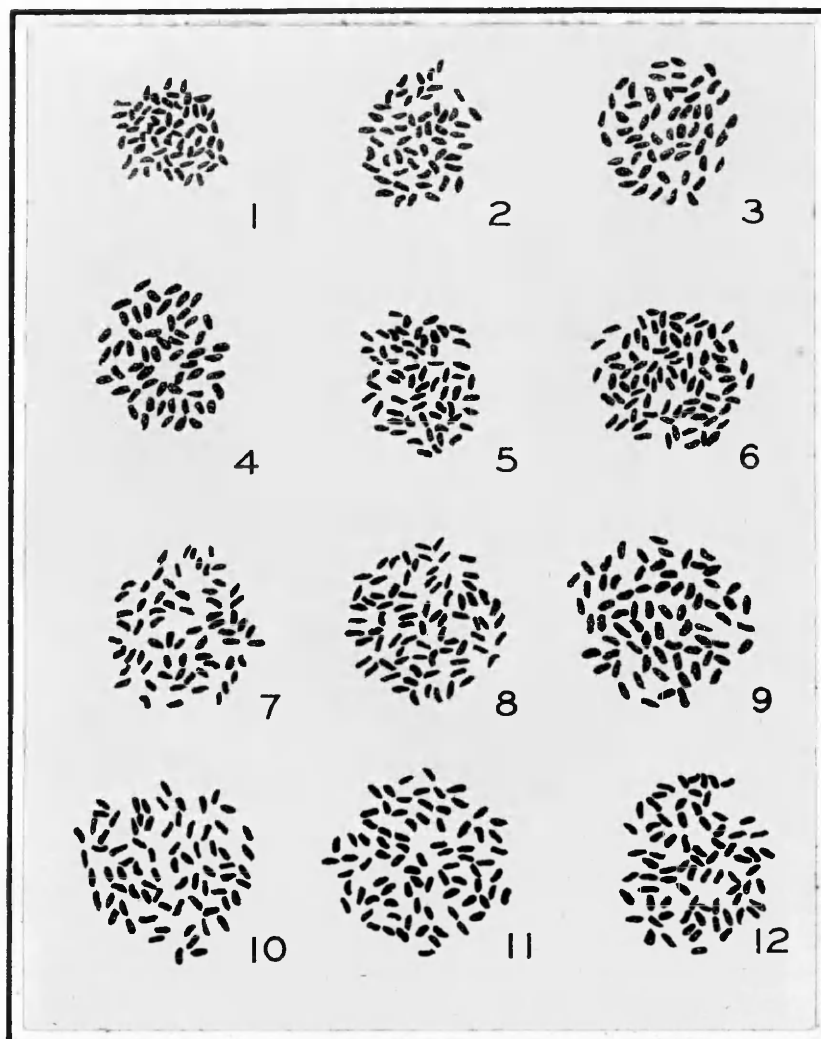
Fig. 6. A persistent nucleus found in a root tip cell of a triploid-diploid hybrid.

Magnification approximately 2500x



Chromosomes of the triploid-diploid progeny

1. [G. tristis var. concolor (30) x Prof. Donders (60)] x [G. tristis var. concolor (30) x G. hirsutus (30)], 34 chromosomes.
2. [Goost Vondel (60) x (G. tristis var. concolor (30) x G. hirsutus (30))] x [G. tristis var. concolor (30) x G. hirsutus (30)], 42 chromosomes.
3. [Prof. Donders (60) x (G. tristis var. concolor (30) x G. callistus (30))] x [G. tristis var. concolor (30) x self (30)], 48 chromosomes.
4. [(G. angustus (30) x G. undulatus (30)) x (Prof. Donders (60) x [G. blandus (30) x G. angustus (30)]), 45 chromosomes.
5. [Dillenberg (60) x G. undulatus (30)] x [G. tristis var. concolor (30)], 43 chromosomes.
6. [G. tristis var. concolor (30) x Prof. Donders (60)] x [G. tristis var. concolor (30)], 45 chromosomes.
7. [Prof. Donders (60) x G. hirsutus (30)] x [G. tristis var. concolor (30)], 57 chromosomes.
8. [Prof. Donders (60) x G. undulatus (30)] x [G. tristis var. concolor (30) x G. watsonius (30)], 65 chromosomes.
9. [G. tristis var. concolor (30) x Prof. Donders (60)] x [G. blandus (30) x G. angustus (30)], 60 chromosomes.
10. [Prof. Donders (60) x G. tristis var. concolor (30)] x [G. tristis var. concolor (30) x self (30)], 60 chromosomes.
11. [Prof. Donders (60) x G. undulatus (30)] x [G. tristis var. concolor (30) x G. watsonius (30)], 60 chromosomes.
12. [G. tristis var. concolor (30) x Prof. Donders (60)] x [G. tristis var. concolor (30) x G. watsonius (30)], 75 chromosomes.



Chromosomes of the triploid-tetraploid progeny.

1. {Prof. Donders (60) x (G. tristis var. concolor (30) x G. callistus (30))} x {Dr. Moody (60)}, 60 chromosomes.
2. {Prof. Donders (60) x G. tristis var. concolor (30)} x {Dr. Moody (60)}, 54 chromosomes.
3. {Prof. Donders (60) x G. undulatus (30)} x {Dr. Moody (60)}, 54 chromosomes.
4. {G. tristis var. concolor (30) x Prof. Donders (60)} x {P. C. Hooft. (60)}, 56 chromosomes.
5. {Prof. Donders (60) x (G. tristis var. concolor (30) x G. callistus (30))} x {Edith Mason (60)}, 63 chromosomes.
6. {Prof. Donders (60) x G. undulatus (30)} x {Mrs. Francis King (60) x self (60)}, 80 chromosomes.
7. {Prof. Donders (60) x G. tristis var. concolor (30)} x {Prof. Donders (60)}, 66 chromosomes.
8. {Prof. Donders (60) x G. angustus (30)} x {Joost Vondel (60)}, 77 chromosomes.
9. {Prof. Donders (60) x G. angustus (30)} x {unnamed seedling (60) x G. primulinus (60)}, 71 chromosomes.
10. {Prof. Donders (60) x G. undulatus (30)} x {Prof. Donders (60)}, 75 chromosomes.
11. {Prof. Donders (60) x G. angustus (30)} x {Prof. Donders (60)}, 80 chromosomes.
12. {Prof. Donders (60) x G. angustus (30)} x {Joost Vondel (60)}, 75 chromosomes.