CHROMOSOME NUMBERS OF Orchids in Hawaii

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HAWAII AGRICULTURAL EXPERIMENT STATION
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COVER PHOTO: Triploid *Vanda* Nellie Morley.
(Photo courtesy Awards Committee, Honolulu Orchid Society.)

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CONTENTS

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INTRODUCTION

Chromosome studies during the past 15 years have resulted in the accumulation of knowledge which can be of considerable practical value to the orchid breeder. Because an increase in chromosome number is usually accompanied by improved horticultural characteristics, orchid breeders have come to accept chromosome number determinations as an important tool in breeding. Such terms as diploids, triploids, tetraploids, and even aneuploids have become common usage among orchidists.

Since the initiation of the research project on orchid cytogenetics at the University of Hawaii in 1950, several articles on this subject appeared in various orchid society bulletins. These articles gave chromosome numbers of orchid plants which were pertinent to the subject under discussion. In 1958–59, Ryuso Tanaka of Hiroshima University was invited as an Orchid Research Fellow to conduct orchid cytogenetics research. In the course of his study, he was able to establish chromosome numbers of many exceptional orchid plants, and therefore, it was deemed desirable at this time to tabulate and record all chromosome counts of orchids of horticultural interest made in Hawaii during the past decade. Such a list should be of interest and value to the orchid breeder.

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VARIATIONS IN CHROMOSOME NUMBER

An orchid plant is composed of hundreds upon hundreds of cells and within the nuclei of those cells are tiny discrete bodies known as *chromosomes*. These chromosomes carry *genes* which are the determiners of heredity.

The chromosome number of a given species is generally constant—40 for Cattleyas, 38 for Vandas, 38 for Dendrobiums, 38 for Phalaenopsis, etc. These numbers represent two sets of chromosomes, one set derived from the pollen parent and the other from the seed-bearing parent. They are called *diploids* (*di*—two; *ploid*—fold). Reduction division or meiosis results in the production of eggs and pollen, each possessing only one set of chromosomes. Upon successful pollination and fertilization, the united sperm and egg form the first cell of a new plant having two sets of chromosomes. This is the usual pattern—the production of eggs and pollen with reduced chromosome number and their fusion in fertilization to restore the diploid number and thereby maintain the constancy of chromosome number for the species. Occasionally, however, changes in chromosome numbers occur, some of which are increases in multiple sets of chromosomes. Plants with three sets of chromosomes are *triploids* (*tri*—three; *ploid*—fold); those with four sets are *tetraploids* (*tetra*—four); those with five sets are *pentaploids* (*penta*—five); those with six sets are *hexaploids* (*hexa*—six). Triploids, tetraploids, pentaploids, hexaploids, and higher ploids are collectively referred to as *polyploids* (*poly*—many; *ploid*—fold). These polyploids, along with *haploids* (*monoploids*) and diploids, are also termed *euploids* (*eu*—good or advantageous) because they possess chromosome numbers which are exact multiples of a given set.

An individual with chromosome number other than an exact multiple of a chromosome set is an *aneuploid* (*an*—not). In Cattleyas the euploid numbers are 20 (haploid), 40 (diploid), 60 (triploid), 80 (tetraploid), 100 (pentaploid), etc. Plants with numbers deviating from the above euploids such as 41, 42, 58, 59, 61, 62, 81, 82, etc., are correctly termed *aneuploids*.

Characteristics of polyploids and aneuploids

An increase in ploidy in orchids is often accompanied by an increase in size of plant parts. Plants are stockier; leaves are darker green, wider, and thicker; and flowers are of improved form. Due to the increase in width and substance of sepals and petals, the flowers are often erect, sturdy, and compact, characteristics that are desired for exhibition purposes.

Because increase in ploidy results in improvement of individual flowers, it stands to reason that more award winners are found among tetraploids than among triploids. However, for cut flower purposes, an important consideration is floriferousness, and it appears that this characteristic is generally inversely related to increased ploidy. Triploidy appears to be the most desirable level for cut flower production in Cattleyas as well as in Cymbidiums. At this level, improved flower quality is obtained without sacrificing flower production.

Not all polyploids have superior characteristics. Since genes are the ultimate determiners of heredity, a duplication of a poor set of genes in a tetraploid will accentuate inferior qualities. Conversely, a diploid with a collection of good genes can produce flowers of better quality than a triploid or tetraploid with poor genes. A combination of good genes and polyploidy should be the aim in breeding for award-winning plants.

In some instances when diploids already have genes for heavy substance, an increase in ploidy may possibly result in "too-heavy" substance which might cause crippling. Many tetraploid yellows are notorious for this character. It has been noted in some crosses that triploidy substantially reduces the malformation of flowers among yellows.

For cut flower production among Vandas and Dendrobiums, the diploids have maintained their importance. A superior commercial cut flower variety which will probably remain in commercial production is the diploid *Vanda* Miss Joaquim. *D.* Jacquelyn Thomas and *D.* Neo Hawaii, which are also diploids, have demonstrated their value as cut flowers among Dendrobiums.

Occasionally, plants with one or two additional chromosomes arise. Morphological differences are not always clearly evident among Cattleyas with 41, 42, or 43 chromosomes. Also, aneuploids on the polyploid level, such as those with 61, 62, 79, 81, 82, 83, 101 and 102, often do not exhibit detectable morphological variations from their corresponding euploids (60, 80, and 100). On the other hand, aneuploids with chromosome numbers deviating considerably from the euploid numbers may exhibit differences in plant vigor and morphological characteristics. Their breeding behavior may also be adversely affected.

Breeding behavior of polyploids and aneuploids

The best orchid stud plants are tetraploids because they are fertile and produce offspring that are relatively uniform. Variations in degree of fertility occur among tetraploids depending upon the constitution of the chromosome complements. If all four sets are uniform, such as tetraploid strap-leaved Vanda (*autotetraploid,* SSSS), fertility may be reduced due to irregularity in meiosis which results in the formation of univalents, bivalents, trivalents, and tetravalents. On the other hand, tetraploid semiterete Vanda (*allotetraploid,* SSTT) exhibits less irregularity at meiosis because normal chromosome pairing can occur within similar sets of strap and terete Vanda chromosomes.

Tetraploids can be selfed or crossed with other tetraploids to produce further tetraploids. When crossed with diploids, triploids will result; while crossed with triploids, variable offspring might be predicted.

Triploids are generally of low fertility and often represent a dead-end in breeding. The reason for this poor fertility is the high irregularity in reduction division. Because there are three sets of chromosomes, distribution of chromosomes to the poles is unequal, resulting in pollen and eggs with varying chromosome numbers, many of which are nonfunctional. Occasionally, restitution of nuclei will give rise to functional unreduced eggs and pollen.

Some triploids produce offspring. The chances of success with triploids are improved if they are used as the seed-bearing parent instead of the pollen parent, and if tetraploids instead of diploids are used as the pollen parent. The resulting progenies can be expected to be highly variable owing to the wide range of products of reduction division. For example, triploid *V.* Nellie Morley × diploid strap-leaved Vanda has resulted in individuals with 38, 39, 52, 57, 70, 71, 73, 75, 76, and 95 chromosomes. Triploid *Dendrobium* Lady Constance × diploid *D. phalaenopsis* has produced seedlings with 38, 42, 46, 51, 52, 57, and 75 chromosomes. This type of cross can therefore be expected to yield diploid, triploid, tetraploid, and pentaploid offspring in addition to aneuploids. Some pentaploids might be anticipated from triploid × tetraploid crosses as has been the case with triploid *C.* Rembrandt × tetraploid *Lc.* Pasadena which produced pentaploid *Lc.* Rosa Kirsch. However, variability can also be expected as shown in the cross, triploid *C. bowringiana* 'Splendens' × tetraploid *Blc.* Wendell Hoshino, which produced individuals with chromosome numbers of 100, 79, 70, and 71.

Pentaploids generally appear to be more fertile than triploids. Studies on meiosis in pentaploid strap-terete Vandas have revealed that usually two sets of chromosomes reach either pole and the chromosomes of the extra set assort at random. Thus, in crosses involving the pentaploids, *V.* Nora Potter, *V.* Colorful, and *V.* Roberta Chun, with diploid strap-leaved Vanda, chromosome numbers of offspring ranged from 59 to 68, with the majority having from 65 to 68 chromosomes. These are aneuploids between the triploid and tetraploid levels.

Aneuploids with deviations of one or two chromosomes from the euploid level apparently do not exhibit adverse morphological characteristics or breeding behavior, and therefore, from the practical standpoint, they might be included with the euploids. Aneuploid Cattleyas with 61 or 62 chromosomes will show poor fertility similar to triploids with 60 chromosomes, while aneuploids with 81 or 82 chromosomes can be expected to be fertile similar to tetraploids with 80 chromosomes.

Those aneuploids with chromosome numbers more or less intermediate between the triploid and tetraploid levels can be expected to be low in fertility because of chromosome unbalance.

Sterility among diploids

Although orchidists generally attribute sterility in orchids to triploidy and aneuploidy, many diploids also exhibit sterility. Sterility can result from incompatibility of genes, male sterile genes, or genes that cause irregularities in meiosis such as asynapsis, stickiness, and supernumerary cell divisions. Translocations, inversions, and deletions of chromosomes may also result in sterility. The most common cause of sterility encountered among diploid orchids is probably lack of homology of parental chromosomes in primary hybrids. Normal chromosome pairing at meiosis is often a prerequisite to fertility. In interspecific hybrids, partial pairing or complete lack of pairing results in poor fertility. Generally, hybrids of distantly related species are lower in fertility than those of closely related species. Since, in Hawaii, efforts are being directed toward producing increased numbers of intergeneric hybrids, sterility problems will undoubtedly be encountered. On the other hand, improvements in germination technique involving ovule culture may successfully surmount some sterility barriers encountered with the usual seed germination methods.

TECHNIQUE OF COUNTING CHROMOSOMES

A few commercial orchid establishments on the mainland United States are now equipped with cytology laboratories for routine chromosome counts of exceptional orchids. Such chromosome determinations will aid in the selection of desirable plants to be used for hybridization.

Recently, inquiries regarding the counting of orchid chromosomes have been received from orchid enthusiasts in the Islands, and, therefore, the equipment, supplies, and technique used in this laboratory are recorded here. The technique for making routine counts is not difficult to master if approximate counts suffice. Although accurate counts are necessary in scientific research, counts of plus or minus one or two chromosomes are usually satisfactory for practical purposes, particularly when chromosome numbers are at the triploid and higher polyploid levels.

The microscope

Excepting Paphiopedilums which possess large chromosomes that can be counted with a high dry objective (44X), orchids require a microscope equipped with an oil immersion lens (90 to 100X) and 10 to 15X oculars. The optical system should be clean and perfectly aligned to give a clear image. Either monocular or binocular microscopes can be used, although a binocular microscope will decrease eye strain, especially if one uses the microscope for prolonged periods.

Other equipment and supplies needed

- Microscope illuminating lamp
- Green filter
- Slides and cover slips
- Vials with stoppers
- Alcohol lamp
- Tweezers and dissecting needles
- Sharp knife or razor blades
- Wax pencil
- Orcein stain

Glacial acetic acid
Ethyl alcohol (95%)
Chloroform
Concentrated hydrochloric acid
8-oxyquinoline
Paraffin
Gum mastic
Immersion oil
Blotting paper

Preparation of aceto-orcein stain

Prepare 100 cc. of 45% acetic acid by pouring 45 cc. of glacial acetic acid in 55 cc. of distilled water. Place 1 gram of orcein in the acetic acid and heat to dissolve orcein. Cool the solution, filter, and transfer the stain into a medicine dropper bottle. The stain is now ready for use.

Preparation of 8-oxyquinoline solution

Pre-treatment of root tips with 8-oxyquinoline will cause contraction and improve spreading of chromosomes and thereby facilitate counting. Prepare 0.002M solution of 8-oxyquinoline (M.W. = 145.15) by dissolving 0.029 gram of 8-oxyquinoline in 100 cc. of distilled water.

Preparation of fixing fluids

The fixing fluid should kill the cells rapidly with a minimum of shrinkage, swelling, distortions, and production of artifacts. Any of the following fixing fluids is satisfactory:

1. Modified Carnoy's
   1 part chloroform
   1 part ethyl alcohol
   1 part glacial acetic acid
2. Carnoy's
   3 parts ethyl alcohol
   1 part glacial acetic acid
3. 45% acetic acid

Preparation of hydrochloric acid-alcohol mixture

Hydrochloric acid is used to soften tissues so that they may be spread easily. One can use 1N hydrochloric acid at 140° F. (60° C.) or a 1:1 mixture of concentrated hydrochloric acid (12N) and 95% ethyl alcohol at room temperature.

Preparation of paraffin-gum mastic mixture

Heat 1 part of gum mastic with 9 parts of paraffin until they melt and form a mixture. Cool to solidify. This mixture is used to seal cover slips.

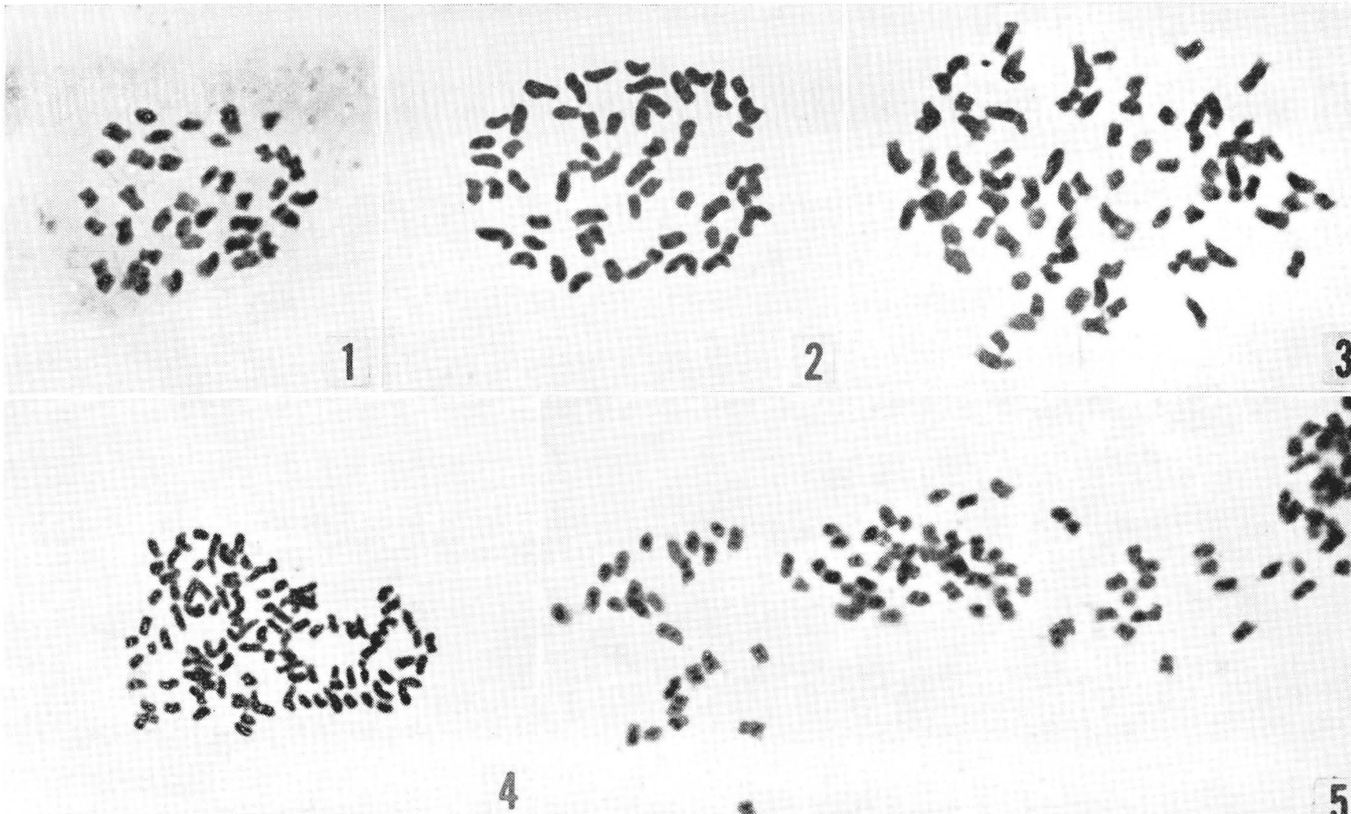
Staining technique

1. Remove the tips (⅛ inch) of rapidly growing roots with a sharp knife and place in a small vial containing 0.002M 8-oxyquinoline solution for 3 to 4 hours at about 65° F.
2. Wash in water and place roots in 45% acetic acid at about 60° F. for 10 minutes to an hour. For overnight fixation, transfer roots to Carnoy's solution and place in 45° F. refrigerator.
3. Treat roots with 1N hydrochloric acid at 140° F. (60° C.) for 30 seconds, and proceed with staining, or treat with 1:1 mixture of concentrated hydrochloric acid and ethyl alcohol at room temperature for 3 to 5 minutes, wash with water, and proceed with staining.
4. Place a root tip on blotting paper, separate the root cap, and transfer root onto a clean slide. Add a drop of aceto-orcein on the root tip and gently macerate it with dissecting needles. Place a cover glass and heat the slide over the flame of an alcohol lamp for 10 to 30 seconds. Do not allow the stain to boil over. Heating will darken the stain on chromosomes and clear the cytoplasm. Cover the slide with a blotting paper or paper towel and press down on the cover slip with the thumb. This will flatten the cells and drive off the excess stain. Care should be exercised to avoid sideways movement when pressing the cover slip.
5. Seal the edges of the cover slip with paraffin-gum mastic mixture.
6. Slides can be examined immediately, but often, they will improve upon standing for a day. They can be stored in good condition for several weeks in a glass chamber saturated with 45% acetic acid.

EXPLANATION AND DISCUSSION OF TABLES

Tables 1 to 4 present chromosome numbers of Cattleyas, Phalaenopsis, Vandas, and Dendrobiums determined in Hawaii during the past 10 years. The plants are listed in alphabetical order within each group. Varietal names are indicated in quotation marks. Abbreviations following names refer to awards by various organizations. The awards are F.C.C. (First Class Certificate), A.M. (Award of Merit), and H.C.C. (Highly Commendable Certificate). Some of the organizations offering orchid awards are R.H.S. (Royal Horticultural Society of England), A.O.S. (American Orchid Society), and H.O.S. (Honolulu Orchid Society).

As explained in the tables, an asterisk following a chromosome number denotes accuracy in counts of plus or minus one chromosome, and two asterisks denote an accuracy of plus or minus two chromosomes. Actually, as mentioned previously, a deviation of one or two chromosomes from the euploid level does not seem to seriously affect morphological characteristics or breeding behavior of orchids, and therefore, for all practical pur-



FIGS. 1–5. Chromosomes of diploid and polyploid *Vanda*. 1. Diploid *V*. Emma van Deventer, 2n = 38. 2. Triploid *V*. Nellie Morley, 2n = 57. 3. Tetraploid *V*. Emma van Deventer, 2n = 76. 4. Pentaploid *V*. Nellie Morley, 2n = 95. 5. Hexaploid *V*. *spathulata*, 2n = 114. × 1728.

poses, a plant with 61 chromosomes can be classified as a triploid, and a plant with 81 or 82 chromosomes as a tetraploid. Exact counts are desirable for critical scientific investigations, but for routine counts, an accuracy within 1 or 2 chromosomes usually suffices.

Cattleya

The frequency of chromosome distribution among plants sampled is summarized in table 5. In Cattleyas, 63 out of 144 plants examined were tetraploids (78–82 chromosomes), and 39 were triploids (59–62 chromosomes). Since the plants sampled were presumably horticulturally superior plants, and since the majority were found to be triploids or tetraploids, it may be concluded that polyploids are superior to their diploid counterparts. The numerous awards received by these polyploids are further evidence of the horticultural excellence of polyploids.

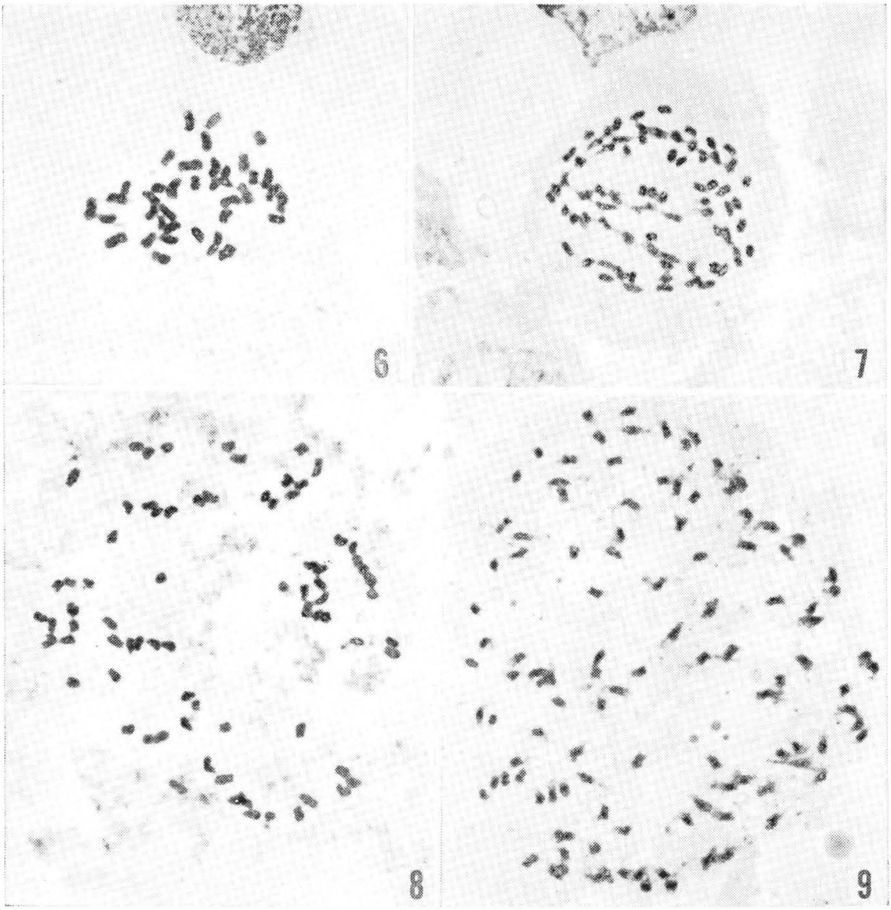
Eighteen plants were recorded as diploids. Some of these, however, were examined not on the basis of their plant characteristics, but rather on their breeding behavior. Eleven were aneuploids with 63 to 77 chromosomes, eight had 93 to 98 chromosomes, and five were pentaploids with 100 chromosomes.

Many superior Cattleyas have not yet been cytologically examined, but their ploidy can be predicted with some degree of accuracy if their fertility and the chromosome numbers of their parents are known. If both parents are tetraploids, the offspring are invariably tetraploids, while if one parent is a tetraploid and the other a diploid, the offspring can be expected to be uniformly triploid. The chromosome number of offspring of triploids and pentaploids, however, cannot be accurately predicted.

Phalaenopsis

As with Cattleyas, the majority of Phalaenopsis plants examined had chromosome numbers above the diploid level (table 5). This supports the hypothesis that there is a positive correlation between polyploidy and improved horticultural characteristics in orchids. Twelve out of 39 plants examined were tetraploids (74–78 chromosomes). It is interesting to note that most of the aneuploids had between 60 to 73 chromosomes. It might be assumed that several crosses involving triploids and tetraploids gave rise to the individuals with numbers between the triploid and tetraploid level. Two hexaploids with 114 chromosomes were found to have heavy substance. The horticultural merits of these plants have not been established.

Phalaenopsis Alice Bowen probably resulted from a cross between a triploid and a tetraploid, since four seedlings showed counts of 81, 71, 64, and 62 chromosomes. The plant with 81 chromosomes is an aneuploid falling between the tetraploid and pentaploid levels, while the other three are aneuploids between the triploid and tetraploid levels. These aneuploids are very poor seeders.



FIGS. 6–9. Somatic chromosomes of diploid, polyploid, and aneuploid *Phalaenopsis* hybrids. 6. Diploid *P.* John Seden, 2n = 38. 7. Aneuploid *P.* Sunrise 'Radiant, 2n = 72. 8. Tetraploid *P.* Grace Palm, 2n = 76. 9. Hexaploid *P.* Lee Wilder 'Ruffles,' 2n = 114. × 1512.

Vanda

The majority of strap-leaved Vandas examined (39 out of 77) were diploids, 14 were triploids, 21 were tetraploids, 2 were pentaploids, and 1 was hexaploid (table 5). These figures point to the following conclusions: (1) Many diploids with the proper genetic constitution are excellent horticultural specimens; (2) unlike Cattleyas and Phalaenopsis, polyploidy has not come to assume an all-important role in Vandas, probably because intensive hybridization in this group dates back only a few years and sufficient time has not elapsed for the origin and multiplication of polyploids; (3) aneuploids are not prevalent, indicating that the evolution of polyploids has been a relatively recent occurrence. Breeders have, however, utilized available polyploids in hybridization, and consequently, the number of polyploids and aneuploids should increase considerably in the next few years.

In the terete and semi-terete groups of Vanda, most of the plants listed are tetraploids, since only exceptional plants in this group were sampled.

The strap-terete Vandas are invariably polyploids or aneuploids of one type or another, for even diploid semi-teretes will give rise to either triploids or pentaploids if they are successful in producing offspring. Of course, a tetraploid semi-terete will produce triploids when crossed with a diploid strap-leaved Vanda.

Dendrobium

Intensive hybridization in the Phalaenopsis type of Dendrobium has resulted in a number of polyploid and aneuploid forms. The rapid improvement in quality within the past few years can be directly attributed to the increase in polyploid forms such as *D.* Diamond Head Beauty, *D.* Anouk, and *D.* Lady Hamilton. The utilization of triploids in crosses has given rise to aneuploids such as *D.* Lady Fay and *D.* Helen Fukumura. As with Cattleya, practically all of the present-day award winners among the Phalaenopsis type are polyploids.

REFERENCES

1. KAMEMOTO, H. 1951. POLYPLOIDY AND ORCHID BREEDING. Na Pua Okika o Hawaii Nei 1: 5–11.

2. STOREY, W. B. 1951. CHROMOSOMES AND ORCHIDS. Hawaii Orchid Soc. Bul. 3: 48–54.

3. ———. 1952. CHROMOSOME NUMBER OF SOME *Vanda* SPECIES AND HYBRIDS. American Orchid Soc. Bul. 21: 801–806.

4. KAMEMOTO, H. 1952. FURTHER STUDIES ON POLYPLOID CATTLEYAS. Pacific Orchid Soc. Bul. 10: 141–148.

5. STOREY, W. B. 1953. THE PENTAPLOIDAL ORIGIN OF *Vanda Nora Potter*. Pacific Orchid Soc. Bul. 11: 17–25.

6. KAMEMOTO, H. 1955. Cytology of V. *Nellie Morley* and V. *Emma van Deventer*. Na Pua Okika o Hawaii Nei 5: 146–158.

7. STOREY, W. B. 1955. FERTILITY AND STERILITY IN *Vanda*. Na Pua Okika o Hawaii Nei 5: 160–168.

8. ———. 1956. DIPLOID AND POLYPLOID GAMETE FORMATION IN ORCHIDS. Proc. Amer. Soc. Hort. Sci. 68: 491–502.

9. KAMEMOTO, H. 1957. CYTOGENETICS RESEARCH—A VALUABLE AID IN ORCHID BREEDING. Hawaii Farm Sci. 6(2): 6–7.

10. ———. 1958. POLYPLOIDY IN *Vanda*. Proc. Second World Orchid Conf. Pp. 51–55.

11. KOSAKI, K. 1958. PRELIMINARY INVESTIGATIONS ON THE CYTOGENETICS OF *Dendrobium*. Proc. Second World Orchid Conf. Pp. 25–29.

12. KAMEMOTO, H. 1959. THE ORIGIN AND SIGNIFICANCE OF POLYPLOIDY IN VANDA. Pacific Orchid Soc. Bul. 16: 77–95.

13. KAMEMOTO, H. 1960. RECENT RESEARCH ON THE CYTOGENETICS OF ORCHIDS. Na Pua Okika o Hawaii Nei 10: 17–21.

14. ———, and R. TANAKA. 1960. CHROMOSOME TRANSMISSION OF TRIPLOID AND PENTAPLOID *Vanda* HYBRIDS. American Orchid Soc. Bul. 29: 667–675.

15. TANAKA, R., and H. KAMEMOTO. 1960. MEIOTIC CHROMOSOME BEHAVIOR IN DIPLOID AND POLYPLOID *Vanda* ORCHID HYBRIDS. Cytologia 25: 405–418.

16. NAKASONE, H. Y., and H. KAMEMOTO. 1961. ARTIFICIAL INDUCTION OF POLYPLOIDY IN ORCHIDS BY THE USE OF COLCHICINE. Hawaii Agr. Exp. Sta. Tech. Bul. No. 42. 28 pp.

17. TANAKA, R., and H. KAMEMOTO. 1961. MEIOTIC CHROMOSOME BEHAVIOR IN SOME INTERGENERIC HYBRIDS OF THE *Vanda* ALLIANCE. Amer. Jour. Bot. 48: 573–582.

18. KAMEMOTO, H., and R. TANAKA. 1961. REVERSAL OF PLOIDY IN *Vanda Emma van Deventer*. Proc. Amer. Soc. Hort. Sci. 77: 594–599.

19. KOSAKI, K., and H. KAMEMOTO. 1961. CHROMOSOMES OF SOME *Dendrobium* SPECIES AND HYBRIDS. Na Pua Okika o Hawaii Nei 11: 75–86.

TABLE 1. Chromosome Numbers in the Cattleya Group
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
BRASSAVOLA		
B. nodosa 'Gigas'	W. W. G. Moir	40
BRASSOCATTLEYA		
Bc. Akebono 'No.1'	M. Miyamoto	60*
Bc. Cliftonii 'Magnifica' F.C.C.R.H.S.	M. Warne	60
Bc. Hartland F.C.C.R.H.S.	M. Miyamoto	80
Bc. Hula Girl 'Sunshine'	M. Warne	40
Bc. Hula Girl 'Sweet Sixteen' A.M.H.O.S.	M. Warne	60
Bc. Massangeana	O. M. Kirsch	100*
Bc. Princess Patricia F.C.C.R.H.S.	M. Miyamoto	80**
BRASSOLAELIOCATTLEYA		
Blc. Ben Kodama 'No. 1'	M. Warne	60
Blc. Charles H. Tanaka	M. Giovannettone	63*
Blc. Daffora	K. Ishii	80*
Blc. Eudora	M. Yamada	67*
Blc. Frank Tatsumura 'Tomiyasu'	M. Yamada	80**
Blc. Golden Crown 'Excelsior'	B. Kodama	60
Blc. Golden Dome F.C.C.R.H.S.	J. Lowson	60
Blc. Golden Queen 'Regina' A.M.H.O.S.	M. Miyamoto	81*
Blc. Iliad	M. Warne	60*
Blc. Malvern 'Grace'	M. Yamada	80
Blc. Marjorie Frey	B. Kodama	92
Blc. Matriarch 'Luscious' H.C.C.A.O.S.	M. Warne	80*
Blc. Myophia 'Hardesty' A.M.H.O.S.	T. Tomiyasu	60**
Blc. Nanette	M. Miyamoto	80**
Blc. Norman's Bay 'Splendor'	B. Kodama	80
Blc. Norman's Bay 'Stuart Low' F.C.C.R.H.S.	M. Miyamoto	81*
Blc. Nugget 'Puritan'	B. Kodama	80
Blc. Ojai 'Tomiyasu'	M. Miyamoto	60*
Blc. Paul Nomura	B. Kodama	60**
Blc. Wake Island 'No. 7'	M. Warne	80
Blc. Wake Island 'Queen'	M. Warne	80
Blc. Wake Island 'Victory'	C. Wong	80

(Continued)

TABLE 1. Chromosome Numbers in the Cattleya Group *(Continued)*
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
Blc. Wake Island × *Lc.* Emma Matsuguma	R. Okamoto	80
Blc. Walter Abe	M. Miyamoto	80
Blc. Wendell Hoshino	M. Miyamoto	83**
Blc. Wendell Hoshino × *Lc.* Supervia	M. Omoto	86**
CATTLEYA		
C. Ashland 'Lion'	M. Miyamoto	60*
C. Barbara Dane	H. Otake	61*
C. Barbara Dane 'Perfection'	H. Otake	61*
C. Barbara Dane × *Bc.* Everest	C. Wong	60*
C. Bengrave 'No. 2'	M. Miyamoto	60**
C. Bengrave 'No. 3'	M. Miyamoto	40
C. Bertii	W. W. G. Moir	40
C. Bob Betts 'Betty' H.C.C.A.O.S.	C. Wong	83
C. Bob Betts 'No. 1' A.M.H.O.S.	T. Tomiyasu	82**
C. Bob Betts 'No. 2' A.M.H.O.S.	T. Tomiyasu	80**
C. Bob Betts 'No. 3' A.M.H.O.S.	T. Tomiyasu	80**
C. Bob Betts 'No. 10'	R. Shirai	80*
C. Bob Betts 'No. 29'	C. Wong	82*
C. Bob Betts 'No. 43'	T. Tomiyasu	80**
C. bowringiana 'Splendens'	W. W. G. Moir	61*
C. bowringiana 'Splendens'	M. Yamada	61*
C. bowringiana 'Splendens' × *Blc.* Wendell Hoshino (seedling 1)	M. Yamada	100*
C. bowringiana 'Splendens' × *Blc.* Wendell Hoshino (seedling 2)	M. Yamada	79*
C. bowringiana 'Splendens' × *Blc.* Wendell Hoshino (seedling 3)	M. Yamada	70
C. bowringiana 'Splendens' × *Blc.* Wendell Hoshino (seedling 4)	M. Yamada	71*
C. Bow Bells 'Elzada' A.M.A.O.S.	H. Otake	60
C. Bow Bells 'Athena' × *C.* Empress Bells 'Eugenia'	M. Giovannettone	79*
C. Brussels	O. M. Kirsch	80*
C. Celia	H. Nishimura	80
C. Claire Ayau 'Mae'	M. Omoto	60*

(Continued)

TABLE 1. Chromosome Numbers in the Cattleya Group *(Continued)*
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
C. Dinah A.M.R.H.S.	M. Miyamoto	80*
C. Edithiae 'White Empress' F.C.C.R.H.S.	M. Miyamoto	40
C. elongata 'No. 1'	M. Miyamoto	80
C. Empress Bells	H. Otake	81*
C. Empress Bells	H. Tanaka	80**
C. Enid 'Orchidhaven'	M. Yamada	84*
C. Enid Alba 'United Nations'	M. Yamada	60
C. Enid Alba 'Warne'	M. Warne	60
C. Estelle Alba 'Cynosure'	W. Kirsch	80*
C. Francis T. C. Au	H. Otake	60**
C. General Patton	H. Otake	71**
C. General Patton 'Victory' A.M.H.O.S.	M. Warne	80*
C. gigas 'Firmin Lambeau'	M. Miyamoto	40
C. Jean Barrow 'Kodama'	B. Kodama	80*
C. Joyce Hannington	M. Warne	60
C. Kiwi 'Festival'	M. Warne	67*
C. labiata 'Westonbirt'	H. Otake	40
C. Madeleine Knowlton 'G–1'	T. Ogawa	80**
C. Madeleine Knowlton 'No. 1'	T. Ogawa	85*
C. Mem. T. Yamada 'Marijo' A.M.H.O.S.	C. Wong	78**
C. Pearl Harbor	H. Otake	80**
C. Portia	W. W. G. Moir	42
C. Portia 'Shinjuku'	Y. Hirose	60
C. R. Prowe	M. Miyamoto	40
C. Rembrandt	O. M. Kirsch	60
C. Rembrandt × *Lc.* Cuesta	M. Miyamoto	100*
C. Rodomont	O. M. Kirsch	86**
C. Thebes 'Bronze King'	M. Miyamoto	80*
C. Thebes × *C.* Aureata	M. Yamada	60*
C. Tityus 'Westonbirt'	M. Miyamoto	80**
C. trianae 'A. C. Burrage' A.M.R.H.S.	M. Miyamoto	60*
C. trianae × *Lc.* Marie Dobrott	H. Nishimura	69*
C. Varuna	M. Miyamoto	40
LAELIA		
L. purpurata 'Semi-alba'	W. W. G. Moir	40*

(Continued)

TABLE 1. Chromosome Numbers in the Cattleya Group *(Continued)*
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
LAELIOCATTLEYA		
Lc. Bikan	K. Ito	80*
Lc. Bonanza 'Kahu'	M. Yamada	80
Lc. Braceyana 'Hercules'	M. Miyamoto	60
Lc. Canberra 'Stonehurst'	M. Miyamoto	80**
Lc. Cantabile Alba 'Doris Bush'	S. Bush	80
Lc. Cantabile Alba 'No. 1'	S. Bush	40
Lc. Clara Hoshino	H. Otake	60*
Lc. Clara Hoshino 'Exotica'	M. Giovannettone	60*
Lc. Copper Charm	M. Warne	40
Lc. Dinard × *Blc.* Galatea	M. Miyamoto	82**
Lc. Dorothy Fried 'Compacta' × *Lc.* Mysedo 'Miya'	M. Miyamoto	80**
Lc. Eva Robinson	M. Miyamoto	62**
Lc. Fedora var. Everest	M. Warne	40
Lc. General Maude	B. Kodama	60*
Lc. General Maude 'Victory'	M. Miyamoto	60**
Lc. Gitche Manito 'Splendor'	M. Miyamoto	80**
Lc. Gorse × *Lc.* Mysedo	T. Tomiyasu	61**
Lc. Governor Gore	N. Nakamura	68**
Lc. Grandee 'Jules Furthman'	M. Miyamoto	80
Lc. H. G. Alexander	M. Yamada	100**
Lc. Harriet Yin	M. Yamada	60**
Lc. Hecuva	T. Ogawa	80**
Lc. Hyperion F.C.C.R.H.S.	H. Otake	80**
Lc. Indra 'Kahu'	M. Yamada	80**
Lc. Invicta F.C.C.R.H.S.	M. Miyamoto	82**
Lc. Ishtar × *Lc.* Valencia	M. Giovannettone	80
Lc. Jane Warne 'Alii'	M. Warne	40**
Lc. Jocelyn	K. Shimamoto	64**
Lc. Liliha	K. Ito	82**
Lc. Mark Hoshino	M. Yamada	80*
Lc. Mem. J. K. Butler 'Wooley'	M. Miyamoto	61*
Lc. Mercia	M. Warne	40
Lc. Mysedo	M. Miyamoto	80**
Lc. Mysedo × *Blc.* Wendell Hoshino	R. Okamoto	80*

(Continued)

TABLE 1. Chromosome Numbers in the Cattleya Group *(Continued)*
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
Lc. Ormesby	B. Kodama	60
Lc. Pasadena	O. M. Kirsch	81**
Lc. Princess Margaret F.C.C.R.H.S.	M. Miyamoto	80*
Lc. Princess Margaret × *Lc.* Profusion	T. Tomiyasu	82**
Lc. Princess Margaret × *Lc.* S. J. Bracey	M. Yamada	80*
Lc. Roberta Off	B. Kodama	65
Lc. Roberta Off 'Ginza'	B. Kodama	64*
Lc. Rosa Kirsch	O. M. Kirsch	100**
Lc. Sargon 'Holford'	M. Yamada	60
Lc. Sargon 'Magnifica'	M. Miyamoto	82**
Lc. Snowdrift 'Doris' A.M.A.O.S.	C. Wong	59*
Lc. Supervia	C. Wong	85**
Lc. Ted Trimble 'Walder'	M. Yamada	81*
Lc. Twinkle 'No. 6'	M. Warne	40
Lc. Twinkle Star 'Midnight'	M. Miyamoto	40
Lc. Windermere 'Clovelly' A.M.R.H.S.	M. Miyamoto	80**

TABLE 2. Chromosome Numbers in Phalaenopsis
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
Phalaenopsis Adm. Stump	L. McCoy	74**
P. Alice Bowen 'Deana'	L. McCoy	81**
P. Alice Bowen 'Diamond Head'	L. McCoy	64**
P. Alice Bowen 'Kaalawai'	L. McCoy	62**
P. Alice Bowen 'No. 1407'	L. McCoy	71*
P. amabilis 'Grandiflora No. 224A'	L. McCoy	38
P. Blanche Overman	O. M. Kirsch	87*
P. Chief Awaho 'No. 1377A'	L. McCoy	57
P. Chieftain 'No. 1518A'	L. McCoy	76*
P. Doris 'No. 935C'	L. McCoy	72*
P. Doris 'No. 1110J'	L. McCoy	76*
P. Doris × *P.* Harold Fisher	M. Yamada	88**
P. equestris	O. M. Kirsch	38
P. equestris 'Three Lips'	O. M. Kirsch	38
P. Gilles Gratiot 'No. 206H'	L. McCoy	76
P. Grace Palm 'No. 115A'	L. McCoy	78
P. Grace Palm 'No. KS57'	L. McCoy	73*
P. Grace Palm 'No. 644'	L. McCoy	76
P. Harold Fisher	H. Yamayoshi	114*
P. Helen Richards 'No. 1423'	L. McCoy	78
P. John Seden	O. M. Kirsch	38
P. Lee Wilder 'Ruffles'	M. Warne	114
P. Lokelani	O. M. Kirsch	38
P. Louise Dillingham 'No. 1493F'	L. McCoy	76*
P. Misty Cloud 'No. 1369E'	L. McCoy	76*
P. Monique 'No. 934F'	L. McCoy	57
P. Pink Cloud 'No. 192A'	L. McCoy	60
P. Pink Cloud 'No. 192C'	L. McCoy	70
P. Pink Vision 'No. 1622C'	L. McCoy	73
P. Ramona 'Jewel Box's Viola'	H. Tanaka	76
P. Regnier 'No. 3–F'	L. McCoy	38
P. schilleriana	K. Yee	76
P. *schilleriana* 'No. 1280A'	L. McCoy	38
P. Shocking Pink 'No. 1506G'	L. McCoy	63*
P. Snow Bird 'No. 1370H'	L. McCoy	76**
P. Sunrise 'I'	L. McCoy	72*
P. Sunrise 'No. 1480A'	L. McCoy	72*
P. Sunrise 'Radiant K' A.M.A.O.S.	L. McCoy	72
P. Susie Darlin 'No. 1587B'	L. McCoy	72*

TABLE 3. Chromosome Numbers in Vanda
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
STRAP-LEAVED VANDA		
V. Alice Fukunaga	E. Iwanaga	38
V. *amoena*	O. M. Kirsch	38
V. Betsy Sumner	F. Sorayama	38*
V. Bill Sutton	K. Miyamoto	38
V. Bill Sutton	F. Sorayama	38
V. Bill Sutton A.M.H.O.S.	R. Shirai	76
V. Bill Sutton 'No. 1'	M. Miyamoto	76*
V. Bill Sutton 'No. 2'	M. Miyamoto	76
V. Chimey Walker	A. Bowman	76*
V. Clara Shipman Fisher A.M.A.O.S.	T. Ota	38
V. Clara Shipman Fisher 'Karen'	R. Ogawa	38**
V. Clara Shipman Fisher 'No. 1' A.M.A.O.S.	T. Ota	57
V. Clara Shipman Fisher 'No. 2'	T. Ota	57*
V. Clara Shipman Fisher 'No. 4'	T. Ota	57*
V. Clara Shipman Fisher 'No. 7'	T. Ota	57*
V. *coerulea*	M. Miyao	38
V. *dearei*	Y. Hirose	38
V. Eisenhower	K. Shimamoto	38
V. Eisenhower	F. Sorayama	38
V. Elizabeth McNeil	A. Bowman	38
V. Ellen Noa	E. Iwanaga	76*
V. Ellen Noa A.M.H.O.S.	A. Bowman	38
V. Ellen Noa 'Saito'	R. Ogawa	38*
V. Faye	T. Kono	38
V. Helen Paoa	M. Miyamoto	76*
V. Jennie Hashimoto	M. Miyamoto	38
V. Kinau	O. M. Kirsch	76**
V. Mabelmae Kamahele	W. Y. Chong	38
V. Mabelmae Kamahele	K. Miyamoto	38
V. Mabelmae Kamahele 'No. 1'	T. Ota	38
V. Mabelmae Kamahele 'No. 2'	T. Ota	38
V. Manila	M. Miyao	38
V. Manila	H. Yamada	76*
V. Manila 'No. 1'	A. Bowman	95
V. Manila 'No. 2'	A. Bowman	95*

(Continued)

TABLE 3. Chromosome Numbers in Vanda *(Continued)*
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
STRAP-LEAVED VANDA (Continued)		
V. Manila 'No. 3'	A. Bowman	57*
V. Manila 'No. 4'	A. Bowman	57**
V. Manila 'No. 6'	A. Bowman	76**
V. Manila 'No. 29'	H. Nishimura	57*
V. Manila 'No. 46'	H. Nishimura	57*
V. Manila 'No. 50'	K. Miyamoto	38
V. Manila 'No. 51'	K. Miyamoto	76
V. Manila 'No. 94'	H. Nishimura	76**
V. Mary Foster × *V.* Clara Shipman Fisher	M. Miyamoto	57
V. Moana	E. Ayau	57
V. Monacensis	O. M. Kirsch	76
V. Ohuohu	A. Bowman	38
V. Ohuohu	T. Ota	38*
V. Ohuohu '010–7'	T. Ogawa	38
V. Onomea 'Hilo'	T. Ogawa	38
V. Onomea 'Ogawa'	T. Ogawa	38*
V. Oscar Kirsch	O. M. Kirsch	57
V. Piihonua	S. Sugihara	76*
V. Rothschildiana	O. M. Kirsch	76*
V. Rothschildiana	K. Miyamoto	76
V. Rothschildiana	T. Mukaida	76
V. Rothschildiana	H. Nishimura	76*
V. Rothschildiana 'No. 300–1'	S. Sugihara	76**
V. sanderiana	H. Fujimoto	38
V. sanderiana	B. Kodama	38
V. sanderiana	W. W. G. Moir	38
V. sanderiana	T. Ogawa	38
V. sanderiana '0'	T. Ota	38
V. sanderiana 'No. 1'	F. Takakura	38
V. sanderiana 'No. 2'	F. Takakura	38
V. sanderiana 'No. 3'	T. Ota	38
V. sanderiana 'No. 38'	K. Miyamoto	38
V. spathulata	K. Kamemoto	114
V. Sunset	O. M. Kirsch	76
V. Sunset	F. Takakura	76
V. Tan Lok Tek 'No. 610–1'	A. Bowman	38

(Continued)

TABLE 3. Chromosome Numbers in Vanda *(Continued)*
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
V. Tan Lok Tek 'No. 610–2'	A. Bowman	38
V. Tatzeri	T. Ota	76*
V. Waimea 'No. 1'	W. Y. Chong	57*
V. Waimea 'No. 2'	W. Y. Chong	57*
V. Waimea 'No. 3'	W. Y. Chong	57
V. Waipuna A.M.H.O.S.	B. Kodama	38
TERETE-LEAVED VANDA		
V. Miss Joaquim 'Douglas'	E. Iwanaga	76
V. Miss Joaquim 'Douglas'	M. Yamada	76
V. Miss Joaquim 'Juliet'	E. Iwanaga	76
V. Miss Joaquim 'Snowdrift'	R. Warne	76
V. Poepoe 'No. 3'	H. C. Shipman	76
V. Poepoe 'No. 9'	H. C. Shipman	76
V. Rose Marie	University of Hawaii	76
V. teres alba	M. Yamada	38
V. teres alba 'Candida'	H. Tanaka	38
SEMI-TERETE VANDA		
V. Emma van Deventer	E. Ayau	76
V. Emma van Deventer	H. Iwanaga	76
V. Emma van Deventer	Koga	76
V. Emma van Deventer	J. Noa	76
V. Emma van Deventer 'Kondo'	E. Iwanaga	76
V. Emma van Deventer 'No. 310–1'	H. Tanaka	76
V. Emma van Deventer 'No. 310–2'	H. Tanaka	76
V. Josephine Van Brero	E. Iwanaga	76
V. Maurice Restrepo	Shimonishi	76
V. Mevr. L. Velthuis	H. Tanoue	76
STRAP-TERETE VANDA		
V. Betty Goto		57
V. Brenden D. Loui		57
V. Colorsan	E. Iwanaga	57, 95
V. Colorsan	S. Noda	57
V. Colorsan	H. Tanaka	95

(Continued)

TABLE 3. Chromosome Numbers in Vanda *(Continued)*
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
STRAP-TERETE VANDA (Continued)		
V. Gam Ho	H. Tanoue	57
V. Herbert Beaumont	T. Ota	95
V. Irma C. Bryan	T. Kazumura	57
V. Janet Kanealii		Variable
V. Kona	E. Ayau	57
V. Kona	T. Ota	57
V. Leilani		Variable
V. Nellie Morley		57
V. Nellie Morley	H. Tanaka	97
V. Noel	O. M. Kirsch	57
V. Nora Potter	O. M. Kirsch	97
V. Prince Kan	H. Tanoue	57
V. Roberta Chun	M. Miyao	57, 95
V. Tan Chay Yan	E. Iwanaga	57
V. Walter Oumae	H. Tanoue	57
V. Walter Oumae	W. Oumae	95
V. Yuet Yeng Lim	Shimonishi	57

TABLE 4. Chromosome Numbers in Dendrobium
(*Denotes ±1 chromosome; **denote ±2 chromosomes)

NAME OF PLANT	OWNER	CHROMOSOME NUMBER (2N)
D. Agnes Cheok	M. Yoshimura	57*
D. Anouk	T. Fukumura	57
D. Cleopatra	Y. Inouye	57
D. Concert	K. Kamemoto	74**
D. Diamond Head Beauty F.C.C.H.O.S.	Y. Inouye	76*
D. Esther Moriguchi	M. Miyamoto	55**
D. Hawaii	E. Iwanaga	57*
D. Hawaiian Beauty		75**
D. Helen Fukumura	T. Kazumura	Variable
D. Hula Girl	M. Miyamoto	38
D. Lady Constance	T. Kazumura	57*
D. Lady Fay	T. Kazumura	Variable
D. Lady Hamilton	K. Kamemoto	76
D. Lady Hamilton × *D.* phalaenopsis	T. Kazumura	76*
D. Louis Bleriot	K. Kamemoto	57
D. Maui Beauty	T. Fukumura	75**
D. Momi Cummins		56**
D. Orchidwood	L. McCoy	57**
D. phalaenopsis 'Extra'	K. Kamemoto	76
D. phalaenopsis 'Giganteum'	H. Otake	76*
D. phalaenopsis 'Lyons Light'	M. Miyamoto	38
D. phalaenopsis 'Lyons Light'	H. Otake	38
D. phalaenopsis 'Ruby'	E. Iwanaga	76
D. phalaenopsis 'Shibata'	T. Fukumura	38
D. Ruby King	E. Iwanaga	75*
D. Waikiki Beauty	L. McCoy	66**

TABLE 5. Distribution of Chromosome Numbers

	CHROMOSOME NUMBERS							
GROUP	40–42	59–62	63–77	78–82	83–98	98–102	120	TOTAL
Cattleya	18	39	11	63	8		5	144

	CHROMOSOME NUMBERS							
	38	55–59	60–73	74–78	79–92	93–97	114	TOTAL
Phalaenopsis	7	2	13	12	3		2	39
Strap-leaved Vanda	39	14		21		2		76
Dendrobium	4	9	1	10				24

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