

TRANSMISSION AND SIGNIFICANCE OF B CHROMOSOMES
IN ANTHURIUM WAROCQUEANUM J. MOORE

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By

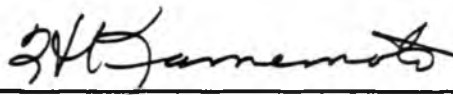
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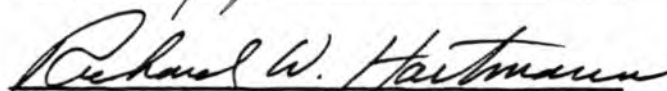
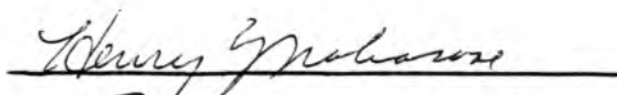
Haruyuki Kamemoto, Chairman
Richard W. Hartmann
Henry Y. Nakasone

We certify that we have read this thesis and that in our opinion it is satisfactory in scope and quality as a thesis for the degree of Master of Science in Horticulture.

THESIS COMMITTEE



Chairman



ABSTRACT

Somatic and meiotic chromosomes of Anthurium warocqueanum J. Moore and its selfed offspring were analyzed. The parent showed $2n=30 + 3B$ in both somatic cells and pollen mother cells. In somatic cell division B chromosomes behaved regularly, whereas their meiotic activities were found to be variable. Three configurations of 3 B chromosomes were observed at metaphase I of parent meiosis: one trivalent, one bivalent and one univalent, and three univalents. At anaphase I univalent B chromosomes tended to lag and eventually form micronuclei.

The number of B chromosomes in offspring ranged from 0 to 6, indicating their transmission from both male and female gametes. The offspring with 2 B chromosomes appeared in greatest frequency. It was hypothesized that both male and female gametes frequently contained one B chromosome through the normal distribution of the bivalent B at meiosis and the elimination of the univalent B due to lagging.

Investigation on pollen mother cells of offspring also revealed irregular behavior of B chromosomes. When two or more B chromosomes were present, 2 Bs were often associated together at early meiotic stages and had normal disjunction at anaphase I. In contrast, univalent B chromosomes showed variable movements during anaphase I; moving toward either poles, lagging, or two sister chromatids separating to opposite poles. With the higher

number of B chromosomes, normal A chromosome bivalent formation seemed to be reduced.

No distinct phenotypic effects of B chromosomes in Anthurium warocqueanum were observed.

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I. INTRODUCTION

Anthurium warocqueanum J. Moore, a native of Colombia, belongs to the largest genus in Araceae. This species, cultivated for its velvety foliage, is taxonomically placed in Sect. Cardiolonchium Schott (Engler, 1905) in which B chromosomes are very common (Sheffer and Kamemoto, 1976a).

The chromosome number of A. warocqueanum has been determined to be $2n = \text{ca. } 30$ by Gaiser (1927), $n=15$ by Pfitzer (1957) and $2n=30+3B$ by Sheffer and Kamemoto (1976a). Kaneko and Kamemoto (1979) analyzed the karyotype of A. warocqueanum with $2n=30+3B$ and reported that the three B chromosomes were submetacentrics of about half the size of the smallest A chromosomes or autosomal chromosomes.

The inheritance of B chromosomes is non-Mendelian (Jones, 1975). In many plants and animals the distribution of B chromosomes through meiosis has been found to be very irregular (Jones, 1975; Müntzing, 1974; Battaglia, 1964). Nine offspring of A. warocqueanum ($2n=30+3B$) selfed fell into three classes of somatic chromosomes: $2n=30+2B$, $2n=30+3B$ and $2n=30+4B$ (Kaneko and Kamemoto, 1979).

In the present study A. warocqueanum with $2n=30+3B$ and its 104 selfed offspring were investigated to elucidate the transmission and inheritance of B chromosomes, to determine the effect of B chromosomes on meiotic behavior, and to examine the effects of B chromosomes on plant morphology and plant development.

II. REVIEW OF LITERATURE

B chromosomes, which are also commonly called supernumerary or accessory chromosomes, are additional chromosomes to the main chromosome complement in an organism. They are found in both animals and plants and exhibit great variation in terms of the number and structure within a species, or in some cases within an individual organism. In general, B chromosomes are smaller than normal (A) chromosomes, possess no distinct phenotypic effect, and often show irregular transmission during meiosis and/or mitosis. No homologous pairings between B chromosomes and A chromosomes at meiosis have been seen, and yet it is assumed that B chromosomes are derived from A chromosomes (Jones, 1975).

Occurrence of B chromosomes in plants

Although B chromosomes are found in both plants and animals, their occurrence is more frequent in plants. Findings of variable chromosome numbers (Kuwada, 1915; Reeves, 1925) and the recognition of the presence of small extra bodies in meiosis (Fisk, 1925) led to the first studies of B chromosomes in plants done in maize (Longley, 1927). Longley (1927) examined the behavior of an extra chromosome in the microspore mother cell and studied the size and shape of the chromosome. Information on the distribution of the B chromosomes among plants has been

given by Darlington and Wylie (1955), Battaglia (1964), Federov (1969), Jones (1975, 1976), and Rees and Jones (1977). In the most recent survey, Rees and Jones (1977) reported that 644 species of flowering plants contained B chromosomes. Seven species belong to the class gymnosperm. Among 637 B chromosome-containing angiosperm species, 318 were dicotyledons and 319 monocotyledons (Rees and Jones, 1977). Having insufficient cytological information on a large number of plant species, Darlington (1956) estimated that B chromosomes occur in as many as 10 % of flowering plants, and also pointed out that in many cases chromosome counts were based on examination of a single individual of a species.

According to Jones (1975), B chromosomes are much more common in certain angiosperm families such as the Compositae in the dicotyledons, and Gramineae, Liliaceae, and Amaryllidaceae in the monocotyledons. Admitting the lack of cytological observations on many plant species, he suggested the possibility of more frequent B chromosome occurrence in highly evolved herbaceous families of angiosperms. In 1968, B chromosomes were reported for the first time for six woody angiosperms in the Himalayas (Mehra and Bawa, 1968) and later in the tree Ficus krishnae (Joshi and Raghuvanshi, 1970).

Inbreeding species have rarely shown the appearance of B chromosomes. The positive correlation between outbreeding and the presence of B chromosomes was

demonstrated by Moss (1969) in experiments with rye where B chromosomes caused a greater reduction in fertility when the plant was selfed than when crossed.

Proportionally, B chromosomes were found as frequently in polyploid plants as in diploids (Jones, 1975; Rees and Jones, 1977). However, there was the interesting case of Ranunculus ficaria from Britain where B chromosomes occurred only in diploid plants but not in tetraploids (Gill et al., 1972).

In natural populations, the geographic distribution of B chromosomes within a single species may vary. Several studies have attempted to show the adaptive advantage of B-chromosome plants in natural habitats. Fröst (1958a), for example, studied 222 populations of Centaurea scabiosa in northern Europe and showed that populations with a higher number of B chromosomes were frequently found at lower, humid areas. Bosemark (1956) found differences in the occurrence of B chromosomes in Festuca pratensis in different areas in Sweden and suggested a positive correlation between clay content of the soil and the frequency of B chromosomes. Similar population studies have been done in Clarkia williamsonii (Wedberg et al., 1968), Allium cernuum (Grun, 1959), Clarkia elegans (Mooring, 1960), Caltha palustris (Kootin-Sanwu and Woodell, 1969), Crepis conyzaefolia (Fröst, 1962), Dactylis glomerata (Zohary and Ashkenazi, 1958), Phleum phleoides (Bosemark, 1967), Ranunculus ficaria

(Gill et al., 1972), Secale cereale (Müntzing, 1950, 1957), Tainia laxiflora (Tanaka and Matsuda, 1972), Zea mays (Longley, 1938), and Alopecurus pratensis (Rapp, 1979).

The highest number of B chromosomes in a natural population, 16, was found in Centaurea scabiosa (Fröst, 1958b). Experimentally, 34 B chromosomes were obtained in maize (Randolph, 1941).

Major characteristics of B chromosomes

1. Structure of B chromosomes

B chromosomes are characteristically smaller than A chromosomes. They are first recognized in species by their small size at meiosis and mitosis. For example, the typical B chromosome of corn was found to be about half the length of the shortest A chromosome (Carlson, 1978) and appeared to have a subterminal constriction (Randolph, 1941).

A second characteristic of B chromosomes is their heterochromatic nature. B chromosomes tend to be darkly stained at interphase and early prophase, especially in animal cells. In plants, Jones (1975) listed an equal number of plants with heterochromatic B chromosomes and those with euchromatic ones.

Active genes are absent in B chromosomes. The search for possible gene loci in B chromosomes of maize was unsuccessful (Randolph, 1941). The biochemical studies of B chromosome DNA in maize (Chilton and McCarthy, 1973) and

in rye (Rimpan and Flavell, 1976) showed that A and B chromosome DNAs were very similar in their composition. Yet, the detailed genetic organization of B chromosome is still undetermined. Although nucleolar organizers are generally lacking in B chromosomes, Rimpan and Flavell (1976) found the presence of ribosomal RNA genes on B chromosomes from a certain rye.

2. The behavior of B chromosomes at somatic cell division

In many plant species B chromosomes are generally transmitted very regularly at somatic cell divisions. Jones (1975) listed mitotically stable and unstable plants and surveyed patterns of instability in B chromosome systems. An example of noticeable B chromosome instability was reported in Crepis capillaris (Rutishauser and Röthlisberger, 1966) in which, although the rosette plants had constant B chromosome numbers, stems, bracts, young inflorescences, receptacles, and florets varied in their number. Röthlisberger (1970) suggested that the instability of B chromosomes was coincident with flower initiation.

3. Meiotic behavior of B chromosomes

At metaphase I, B chromosomes do not pair with A chromosomes, but tend to appear as univalents. When more than one B chromosome is present, they are capable of forming bivalents, the most frequent configuration, and in some cases multivalents such as trivalents and quadrivalents in addition to univalents (Jones, 1975). Very interesting interarm pairing of univalent B chromosomes was reported in

Poa trivialis and Holcus lanatus (Bosemark, 1957).

The movements of B chromosomes at anaphase I and anaphase II varies. In some species such as Festuca pratensis (Bosemark, 1954), F. arundinacea (Bosemark, 1957), and Poa trivialis (Bosemark, 1957), B chromosomes divide at anaphase I, whereas they separate at anaphase II in some other species like Plantago serraria (Fröst, 1959) and Ranunculus acris (Fröst, 1969). The accumulation mechanism of B chromosomes has been explained by their unusual behavior at AI and AII (Battaglia, 1964; Müntzing, 1974; Jones, 1975).

Nondisjunction occurring at a post-meiotic division may also contribute to the accumulation of B chromosomes. Directed nondisjunction in pollen mitosis was reported for the first time in rye by Hasegawa (1934). Håkansson (1948) found a similar situation in the first mitosis of the egg cell in the same plant. In Hypochoeris maculata, however, the inheritance of B chromosomes was reported to be different between male and female meiosis such that Bs accumulated on the female side while random transmission of Bs occurred on the male side (Parker, 1976).

Effects of B chromosomes

1. Effect on general plant development

Normally the phenotypes of plants are not distinguishably affected by the presence of B chromosomes aside from two exceptions reported in Haplopappus gracilis and

Plantago coronopus. Jackson and Newmark (1960) reported a color change in the achenes from brownish-red to dark purple when Haplopappus gracilis contained a B chromosome, while in Plantago coronopus, Paliwal and Hyde (1959) found complete male sterility due to the presence of B chromosomes. The general B-chromosome effects in plants were reviewed by Battaglia (1964) and Jones (1975) and they concluded that low numbers of Bs had neutral effects whereas with high numbers plants might have reduced fertility and vigor. Müntzing (1963) demonstrated the influence of B chromosomes on vegetative characters in rye; the straw weight and tiller number were reduced with higher numbers of B chromosomes and odd-numbered Bs had a more severe effect on reduction of plant growth than did even-numbered Bs. In Lolium perenne, on the other hand, Teoh et al. (1976) showed a selective advantage of plants with B chromosomes under high sowing density conditions.

2. Effects on A chromosomes

The effect of B chromosomes on chiasma frequency and distribution of A chromosomes has been investigated by many researchers. Increased recombination in A chromosomes in the presence of Bs has been reported in some species such as Zea mays (Ayonoadu and Rees, 1968; Hanson, 1969; Chang and Kikudome, 1971; Ward, 1973), while a reduction of A chromosome chiasma frequency was observed in some other plants like Lolium perenne (Cameron and Rees, 1967). The B-chromosome control over A-chromosome pairings in

some hybrid plants is interesting. Evans and Macefield (1973) reported that in the diploid hybrid (Lolium perenne X L. temulentum), B chromosomes suppressed the homoeologous pairings between two genomes. In contrast, the tetraploid hybrid synthesized from the diploid hybrids showed multivalent formations when B chromosomes were absent, and with Bs there were only the homologous pairings that is typical in an allotetraploid.

Origin of B chromosomes

The origin of B chromosomes is uncertain. Some schemes for the origin of B chromosomes in plants have been proposed by several cytologists. Chromosome breakage at the weak secondary constriction and dissociation of the satellite from the main chromosome body had been suggested as one of the mechanisms of production of B chromosomes (Battaglia, 1964). In Tradescantia paludosa, Swanson (1943) hypothesized chromosomal fragmentation by a translocation event. B chromosomes in Lolium were assumed to be results of longitudinal misdivision of A chromosome univalents or misdivision of the centromere during prometaphase (Hovin and Hill, 1966). B-chromosome polymorphism due to centromere misdivision and deletion of standard fragment is very common in rye (Jones, 1977). Rapp (1979) studied Alopecurus pratensis and hypothesized the origin of B chromosomes starting with a paracentric inversion, crossing over within the inversion loop, and formation of anaphase

bridge. He also showed the transmission mechanism of B chromosome through further generations. It was suggested that the evolution of B chromosomes from A chromosomes in Solanum viarum was a long process and that increasing breakability and heterochromatization of fragments had led to the status of neutral and dispensable B chromosome (Dnyansagar and Pingle, 1979).

B chromosome studies in Anthurium

B chromosomes in the genus Anthurium were observed for the first time in A. crystallinum ($n=15+0-2B$), A. forgetti ($n=15+0-2B$), and A. magnificum ($n=15+0-2B$) by Pfitzer (1957). Sheffer and Kamemoto (1976a) determined chromosome numbers of 63 Anthurium species and found frequent occurrences of B chromosomes in the Sect. Cardiolonchium with numbers varying from one to three. Seven species were listed to have B chromosomes; A. trianae ($2n=28, 29+1B$), A. crystallinum ($2n=30+1B$), A. regale ($2n=30+1B$), A. splendidum ($2n=30+2B$), A. wallisii ($2n=30+2B$), A. walujewii ($2n=30+2B$), and A. warocqueanum ($2n=30+3B$) (Sheffer and Kamemoto, 1976a, 1976b).

Sharma and Bhattacharyya (1961) analyzed the karyotypes of A. glaziovii and three varieties of A. andraeanum, and discovered that different populations of the same species had different numbers of B chromosomes.

Tsuchiya and Takada (1962) reported the chromosome number of $2n=32$ for A. andraeanum, an important cut flower.

However, Kaneko and Kamemoto (1978) suggested that the smallest pair might be accessory chromosomes, based on the presence of 2B chromosomes in a white cultivar 'Uniwai'.

The meiotic behavior and transmission of B chromosomes in Anthurium were reported in A. andraeanum 'Uniwai' (Kaneko and Kamemoto, 1978) and A. warocqueanum (Kaneko and Kamemoto, 1979). At metaphase I of meiosis in pollen mother cells, 2 B chromosomes in 'Uniwai' were either paired or remained unpaired (Kaneko and Kamemoto, 1978). The selfed A. warocqueanum ($2n=30+3B$) produced offspring with 2, 3 and 4 B chromosomes, indicating that B chromosomes were transmitted through both male and female gametes (Kaneko and Kamemoto, 1979).

III. MATERIALS AND METHODS

The clone of Anthurium warocqueanum (Fig. 1) was available in the collection of the University of Hawaii. The chromosome number of the clone was determined earlier by Sheffer and Kamemoto (1976a) and Kaneko and Kamemoto (1979) as $2n=30+3B$.

Seeds of self-pollinated A. warocqueanum were germinated on finely chopped tree fern fiber on February 19, 1976. Seedlings were transplanted into flats filled with chopped tree fern fiber on December 28, 1976, individually into 6-inch pots, and finally into deeper 6-inch pots with wood shavings as the medium on August 4, 1978. The selfed progeny of 104 offspring was grown under 80 % saranshade.

Chromosome numbers were determined by examining both somatic cells from actively growing root tips and pollen mother cells from anthers. For the study of mitotic chromosomes, root tips were sampled between 8:00 a.m. and 10:00 a.m. and placed in a pretreatment solution of 0.002 M 8-hydroxyquinoline or 15-20 ppm o-isopropyl-N-phenyl-carbamate (IPC) for 3-5 hours at about 18°C. After fixing in 2:1:1 Carnoy's solution (95 % ethyl alcohol, chloroform, and glacial acetic acid) for 20 minutes at 18°C. and hydrolyzing in 1 N hydrochloric acid for 10 minutes at 50°C., root tips were washed in tap water and placed in 45 % acetic acid for 10 minutes. On a microscope slide root caps were removed under a dissecting microscope and the remaining root tissues were squashed in 1 % aceto-orcein

after applying a cover slip. Air bubbles were removed by gentle tapping of the cover slip with the point of a dissecting needle. The slide was placed in a saturated 45 % acetic acid chamber for about 30 minutes. The excess stain was removed, the slide was heated gently, and the cover slip was pressed firmly. The edges of the cover slip were then sealed with dental wax. The preparation was examined under a light microscope.

For meiotic analysis, spadices were fixed in Carnoy's mixture of 6:3:1 (chloroform, 95 % ethyl alcohol, and glacial acetic acid) for at least 24 hours at room temperature (ca. 24°C.) and stored in a freezer at minus 10°C. Anthers dissected out from a spadix were squashed in 45 % acetic acid. After blotting out the excess acetic acid and removing the anther walls, a drop of 1 % acetoorcein was added to the pollen mother cells. A cover slip was placed over the cells, and air bubbles were removed. The slide was heated for a few seconds and then pressed in bibulous paper to remove excess stain and to flatten the cells. Dental wax was applied to seal the edges of the cover slip. Meiotic behavior of chromosomes was studied under 40X and 100X oil objectives of a light microscope. Diakinesis and metaphase I were investigated to determine the chromosome number of a plant.

The pollen grains were stained with acetocarmine for 1-2 hours and examined under a light microscope to determine pollen stainability as a possible indication of

the pollen fertility of the plant.

Photomicrographs of selected mitotic and meiotic chromosomes were taken with a Zeiss photomicroscope at a magnification of 550X on Kodak High Contrast Copy film.

Karyotypes were made by cutting each chromosome from a print that was enlarged from a photomicrograph negative and arranging the chromosomes in descending order of length.

To determine the effects of B chromosomes in the offspring of selfed Anthurium warocqueanum, leaf length, leaf width, increase in stem length, and date of first flowering were investigated. Both length and width of the largest leaf of each plant were measured on August 4, 1978, February 6, 1979, and August 9, 1979. Increase in stem length was determined after the final transplanting to 6-inch pots. A piece of thin wire was stretched across the top of the pot to give a base line (reference line). The distance from this base line to the base of the petiole of the youngest leaf was measured; a positive measurement being above the base line and a negative measurement being below. Three measurements were done in 6-month intervals; August 15, 1978, February 6, 1979 and August 9, 1979. Absolute differences between measurements were calculated in order to determine the increase in the rate of growth of the stem length of each offspring. The date of first flowering was recorded when the young inflorescence emerged and became visible. Means of observations and standard

errors were calculated in each B-class. Effects of B chromosomes on plant phenotype were examined by carrying out a regression analysis.

Plate I

Figure:

1. Photo of the parent Anthurium warocqueanum



IV. RESULTS AND DISCUSSION

Cytology of the parent

The somatic chromosome number of Anthurium warocqueanum was determined to be $2n=30+3B$ (Fig. 2). This determination confirms the earlier report of Sheffer and Kamemoto (1976a). The karyotype (Fig. 3) consists of 2 pairs of large chromosomes, 12 pairs of medium to small chromosomes, 1 pair of satellite chromosomes, and 3 B chromosomes which are about half the size of the smallest A (autosomal) chromosomes. This result does not differ from the analysis of Kaneko and Kamemoto (1979).

Observation of PMCs in the parent (Figs. 4 - 16) showed the presence of three B chromosomes. At diakinesis and metaphase I there were three different configurations of the 3 Bs; 1 trivalent (Figs. 7 and 8), 1 bivalent and 1 univalent (Figs. 9 and 11), and 3 univalents (Fig. 10). About 70 % of the cells observed showed 1 bivalent and 1 univalent (Table 1). In cells without a bivalent two B chromosomes tended to be close to each other. The occurrence of trivalents despite their relatively small size indicates that the 3 B chromosomes are homologous or partially homologous and have a common or similar origin.

The A chromosomes formed predominantly 15 bivalents, however, some irregularities were noted; about 6 % of PMCs showed 14 bivalents + 2 univalents and 1 % showed 13 bivalents + 4 univalents (Table 1). The degree of pollen stainability of about 86 % possibly reflected the slight

TABLE 1. -- B and A chromosome configuration in PMCs of the Anthurium warocqueanum parent

| Spadix sample | B chromosomes | | | | A chromosomes | | | | |
|---------------|---------------|---------|------|-------|---------------|---------|---------|---------|-------|
| | 1 III | 1III+1I | 3I | Total | 15II | 14II+2I | 13II+4I | 12II+6I | Total |
| 1 | 1 | 68 | 31 | 100 | 93 | 6 | 1 | 0 | 100 |
| 2 | 2 | 69 | 29 | 100 | 88 | 9 | 3 | 0 | 100 |
| 3 | 0 | 76 | 24 | 100 | 96 | 4 | 0 | 0 | 100 |
| Mean | 1.0 | 71.0 | 28.0 | | 92.3 | 6.3 | 1.3 | 0 | |

TABLE 2. -- Stainability of pollen grains of the
Anthurium warocqueanum parent

| Spadix sample | Stained | Unstained | Total |
|---------------|----------------|---------------|-------|
| 1 | 440 (88 %) | 60 (12 %) | 500 |
| 2 | 442 (88.4 %) | 58 (11.6 %) | 500 |
| 3 | 410 (82 %) | 90 (18 %) | 500 |
| Mean | 430.7 (86.1 %) | 69.3 (13.9 %) | |

Plate II. Somatic chromosomes and karyotype of
the parent Anthurium warocqueanum.

Figure:

2. Somatic chromosomes of the parent
Anthurium warocqueanum ($2n=30+3B$)
(1650X)
3. Karyotype of the parent Anthurium
warocqueanum ($2n=30+3B$) (2200X).

2



3

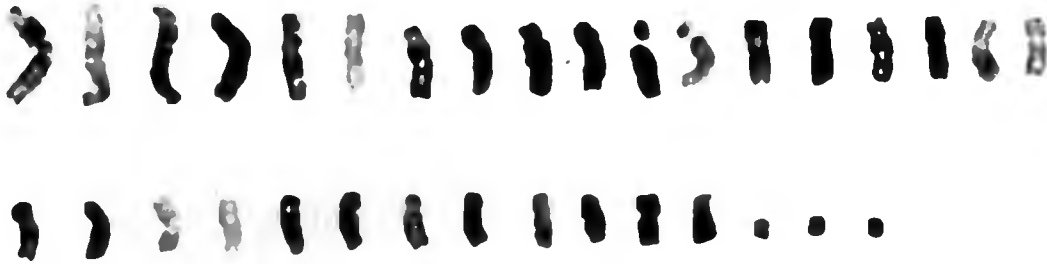


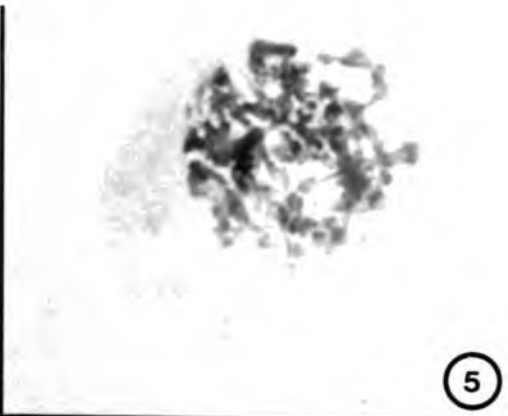
Plate III. Early meiosis (PMC) of the parent
Anthurium warocqueanum (1650X).

Figure:

4. Interphase
5. Early prophase I
6. Diplotene (prophase I)
7. Diakinesis (prophase I), showing three
B chromosomes as a trivalent.



4



5



6



7

Plate IV. Metaphase I (PMC) of the parent Anthurium warocqueanum (1650X).

Figure:

8. A chromosomes form 15 bivalents and B chromosomes form a trivalent (A-- 15 II and B-- 1 III) (polar view).
9. A chromosomes form 15 bivalents and B chromosomes form one bivalent and one univalent (A-- 15 II and B-- 1 II + 1 I) (polar view).
10. A chromosomes form 15 bivalents and B chromosomes form three univalents (A-- 15 II and B-- 3 I) (polar view).
11. B-- 1 II + 1 I (equatorial view).

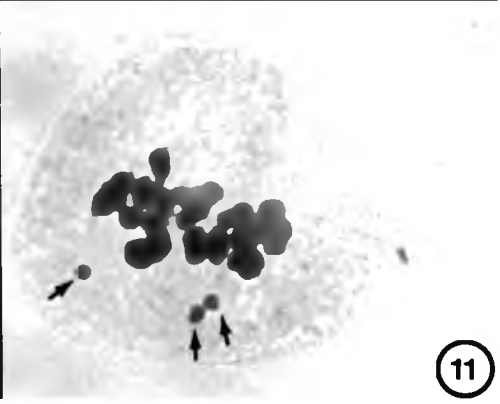
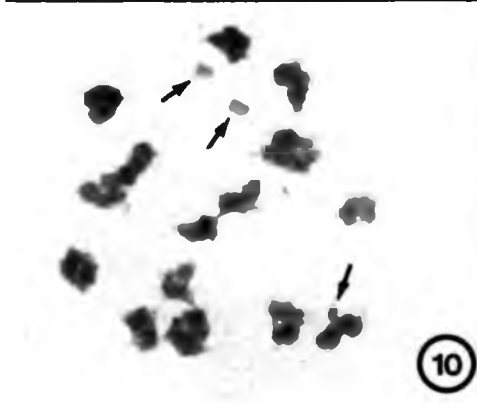
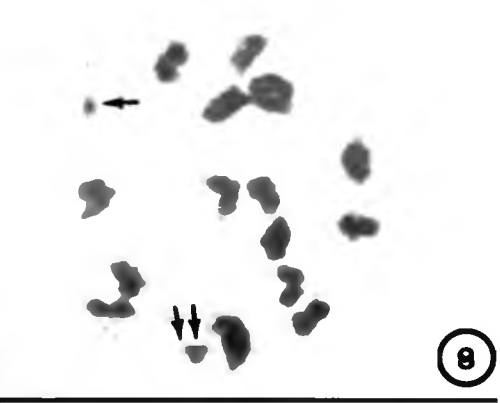
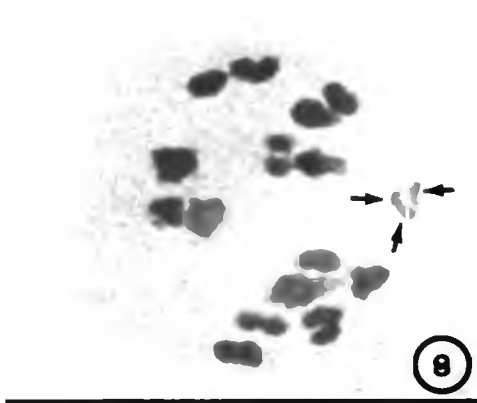
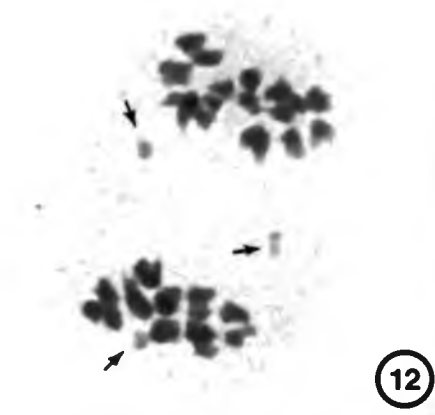


Plate V. Meiosis (PMC) of the parent Anthurium
warocqueanum (1650X).

Figure:

12. Anaphase I, 2 Bs move toward opposite poles while univalent B chromosome lags at about metaphase plate.
13. Anaphase I, 2 Bs at the same pole and a lagging B showing its chromatids starting to divide from each other.
14. Anaphase I, showing separation of chromatids of B chromosome.
15. Telophase I, formation of micronucleus.
16. Tetrad formation at the end of meiosis.
17. Pollen mitosis, showing the presence of B chromosome.



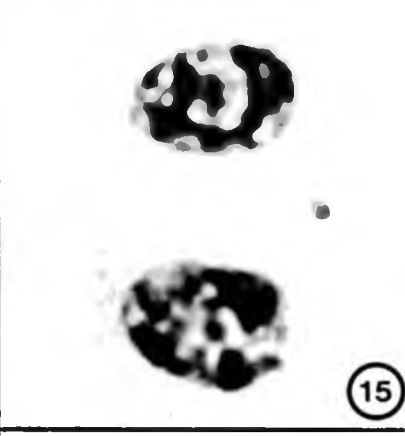
12



13



14



15



16

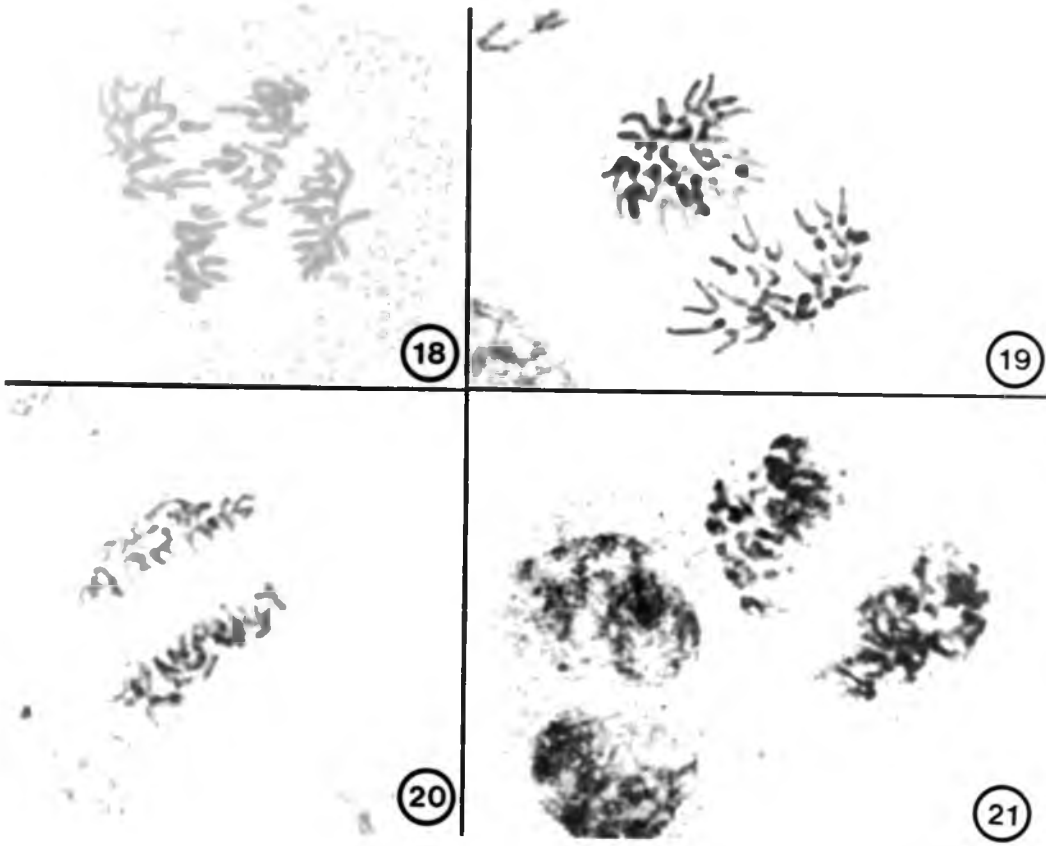


17

Plate VI. Somatic cell division of the parent
Anthurium warocqueanum (1650X).

Figure:

18. Early anaphase.
19. Anaphase.
20. Late anaphase.
21. Telophase.



irregularity in meiosis of the A chromosomes (Table 2).

A clue to the transmission mechanism of B chromosomes can be observed in anaphase I of meiosis where univalent B chromosomes showed a tendency to lag (Fig. 12), or sometimes chromatids started to divide from each other (Figs. 13 and 14). The irregular distribution and lagging of B chromosomes at anaphase I may have led to the formation of micronuclei at telophase I (Fig. 15). An example of normal tetrad formation at the end of meiosis of the parent is shown in Figure 16. Observation of pollen mitosis showed the presence of B chromosomes in some pollen grains, confirming the transmission of Bs through the male parent (Fig. 17).

Unlike their irregular movements at meiosis, B chromosomes were found to be stable in somatic cell divisions (Figs. 18 - 21).

Distribution of B chromosomes in the offspring

Chromosome number determination from pollen mother cells of 94 selfed offspring of Anthurium warocqueanum with $2n=30+3B$ showed seven categories of B chromosome ranging from 0 to 6 B (Table 3). The distribution was calculated to be normal (Table 4), although 2B plants exhibited the highest frequency. The results indicate that B chromosomes were transmitted from both male and female gametes, which confirms the report by Kaneko and Kamemoto (1979). The higher number of 2B offspring over 3B

TABLE 3. -- Frequency of offspring with various numbers of B chromosomes determined from pollen mother cells

| | Number of B chromosomes | | | | | | | Total |
|-------------------|-------------------------|-----|------|------|------|-----|-----|-------|
| | 0B | 1B | 2B | 3B | 4B | 5B | 6B | |
| Number of plants | 1 | 7 | 36 | 26 | 18 | 5 | 1 | 94 |
| Percent of plants | 1.1 | 7.4 | 38.3 | 27.7 | 19.1 | 5.3 | 1.1 | 100 |

TABLE 4. -- Calculation of the Goodness of Fit χ^2 for the distribution of selfed offspring of Anthurium warocqueanum for each B-chromosome class

| Number of B chromosomes | Frequencies | | $\frac{(f - \hat{f})^2}{\hat{f}}$ |
|----------------------------|---------------|-----------------------|-----------------------------------|
| | Observed f | Expected \hat{f} | |
| 0 | 1 | 2.7 | 1.070 |
| 1 | 7 | 11.2 | 1.575 |
| 2 | 36 | 24.6 | 5.283 |
| 3 | 26 | 29.0 | 0.310 |
| 4 | 18 | 18.5 | 0.014 |
| 5 | 5 | 6.3 | 0.078 |
| 6 | 1 | 1.2 | 0.033 |
| Total | 94 | 93.5 | 8.363 |

$$\chi^2 = 8.363, \text{ d.f.} = 7 - 3 = 4. \text{ } p > 0.05^z$$

z The hypothesis of normality is not rejected at 5 % significance level.

offspring might be explained from observation of B chromosome behavior in meiosis of the parent. At metaphase I 2 B chromosomes tend to pair, distributing each B chromosome equally to opposite poles during anaphase I, while a lagging univalent seems to form a micronucleus or microcyte and ultimately be eliminated. As a result, a pollen grain would frequently contain only one B chromosome at the end of meiosis. Assuming that the same phenomenon occurs in female gametogenesis to often produce an embryo with one B chromosome, it can be predicted that 2B offspring will appear with highest frequency.

In some plants, especially those with a higher number of B chromosomes, there was found to be some discrepant counts of B chromosomes between somatic cells and pollen mother cells (Table 5). These differences are assumed to be errors in counts of B chromosomes from somatic cells due to the presence of loose satellites from satellite chromosomes. The satellites are about the same size as B chromosomes.

Figures 22 - 28 show somatic chromosomes of seven different types of offspring where 0B, 1B, 2B, 3B, 4B, 5B, and 6B are observed. In figures 29 - 35, the karyotypes of each category of offspring are shown.

Comparing somatic cells with pollen mother cells, the B chromosomes in Anthurium warocqueanum seem to be stable in number.

TABLE 5. -- Counts of B chromosomes in pollen mother cells (PMC) and somatic cells of offspring

| Plant no. | PMC | Somatic cells | Plant no. | PMC | Somatic cells |
|-----------|-----|---------------|-----------|-----|---------------|
| 1 (#57) | 0 | 0 | 46 (# 4) | 3 | 3 |
| 2 (# 6) | 1 | 1 | 47 (#23) | 3 | 3 |
| 3 (#55) | 1 | 1 | 48 (#24) | 3 | 3 |
| 4 (#68) | 1 | 1 | 49 (#25) | 3 | 3 |
| 5 (#88) | 1 | 1 | 50 (#26) | 3 | 3 |
| 6 (#27) | 1 | 2 | 51 (#28) | 3 | 3 |
| 7 (#32) | 1 | 2 | 52 (#37) | 3 | 3 |
| 8 (#43) | 1 | 2 | 53 (#38) | 3 | 3 |
| 9 (#13) | 2 | 2 | 54 (#54) | 3 | 3 |
| 10 (#15) | 2 | 2 | 55 (#62) | 3 | 3 |
| 11 (#19) | 2 | 2 | 56 (#64) | 3 | 3 |
| 12 (#29) | 2 | 2 | 57 (#70) | 3 | 3 |
| 13 (#33) | 2 | 2 | 58 (#76) | 3 | 3 |
| 14 (#41) | 2 | 2 | 59 (#94) | 3 | 3 |
| 15 (#46) | 2 | ca. 2 | 60 (#102) | 3 | 3 |
| 16 (#47) | 2 | 2 | 61 (#104) | 3 | 3 |
| 17 (#51) | 2 | 2 | 62 (# 1) | 3 | 4 |
| 18 (#63) | 2 | 2 | 63 (# 3) | 3 | 4 |
| 19 (#72) | 2 | 2 | 64 (# 9) | 3 | 4 |
| 20 (#80) | 2 | 2 | 65 (#10) | 3 | 4 |
| 21 (#92) | 2 | 2 | 66 (#31) | 3 | 4 |
| 22 (#96) | 2 | 2 | 67 (#65) | 3 | 4 |
| 23 (#97) | 2 | 2 | 68 (#75) | 3 | 4 |
| 24 (#99) | 2 | 2 | 69 (#90) | 3 | 4 |
| 25 (#101) | 2 | 2 | 70 (#103) | 3 | 4 |
| 26 (# 2) | 2 | 3 | 71 (#52) | 3 | 5 |
| 27 (# 5) | 2 | 3 | 72 (#21) | - | 3 |
| 28 (#12) | 2 | 3 | 73 (#60) | - | 3 |
| 29 (#18) | 2 | 3 | 74 (#71) | - | 3 |
| 30 (#20) | 2 | 3 | 75 (#74) | - | 3 |
| 31 (#30) | 2 | 3 | 76 (#93) | - | 3 |
| 32 (#39) | 2 | 3 | 77 (#82) | 4 | 2 |
| 33 (#45) | 2 | 3 | 78 (#36) | 4 | 3 |
| 34 (#48) | 2 | 3 | 79 (#69) | 4 | 3 |
| 35 (#67) | 2 | 3 | 80 (#35) | 4 | 4 |
| 36 (#73) | 2 | 3 | 81 (#40) | 4 | 4 |
| 37 (#86) | 2 | 3 | 82 (#44) | 4 | 4 |
| 38 (#89) | 2 | 3 | 83 (#50) | 4 | 4 |
| 39 (#49) | 2 | 4 | 84 (#66) | 4 | 4 |
| 40 (#56) | 2 | 4 | 85 (#79) | 4 | 4 |
| 41 (#58) | 2 | 4 | 86 (#95) | 4 | 4 |
| 42 (#81) | 2 | 4 | 87 (#100) | 4 | 4 |
| 43 (#87) | 2 | 4 | 88 (# 7) | 4 | 5 |
| 44 (#27) | 2 | - | 89 (#11) | 4 | 5 |
| 45 (#98) | - | 2 | 90 (#14) | 4 | 5 |

TABLE 5. -- (Continued) Counts of B chromosomes in pollen mother cells (PMC) and somatic cells of offspring

| Plant no. | PMC | Somatic cells |
|-----------|-----|---------------|
| 91 (#17) | 4 | 5 |
| 92 (#34) | 4 | 5 |
| 93 (#78) | 4 | 5 |
| 94 (#84) | 4 | 5 |
| 95 (#22) | - | 4 |
| 96 (#77) | - | 4 |
| 97 (#91) | - | 4 |
| 98 (#61) | 5 | 3 |
| 99 (#42) | 5 | 5 |
| 100 (#59) | 5 | 5 |
| 101 (# 8) | 5 | <u>Ca</u> .6 |
| 102 (#16) | 5 | <u>Ca</u> .6 |
| 103 (#85) | - | 5 |
| 104 (#83) | 6 | 5 |

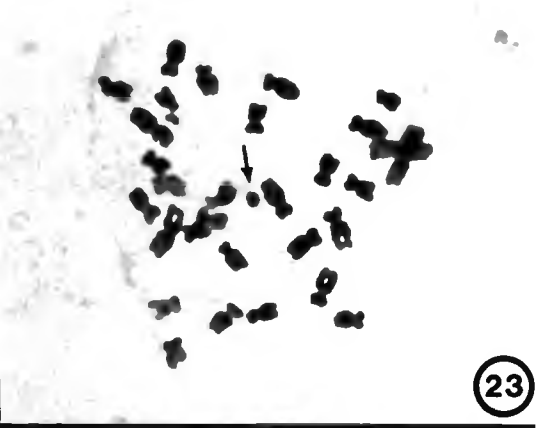
Plate VII. Somatic chromosomes of offspring (1650X).

Figure:

- 22. 0B offspring.
- 23. 1B offspring.
- 24. 2B offspring.
- 25. 3B offspring.
- 26. 4B offspring.
- 27. 5B offspring.
- 28. 6B offspring.



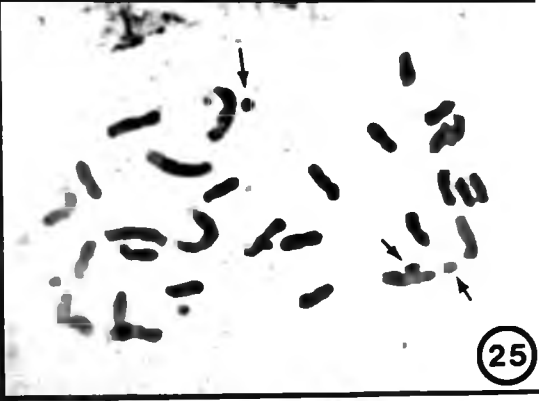
22



23



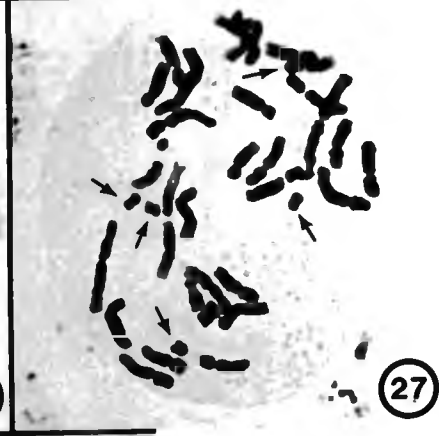
24



25



26



27



28

Plate VIII. Karyotypes of offspring (2200X).

Figure:

29. 0B offspring.

30. 1B offspring.

31. 2B offspring.

32. 3B offspring.

5 9 11 13 15 17 19 21 23 25 27 29 31 33 35

29

37 39 41 43 45 47 49 51 53 55 57 59 61 63 65

67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99

30

101 103 105 107 109 111 113 115 117 119 121 123 125 127 129 131 133 135 137 139 141 143 145 147 149 151 153 155 157 159 161 163 165 167 169 171 173 175 177 179 181 183 185 187 189 191 193 195 197 199 201 203 205 207 209 211 213 215 217 219 221 223 225 227 229 231 233 235 237 239 241 243 245 247 249 251 253 255 257 259 261 263 265 267 269 271 273 275 277 279 281 283 285 287 289 291 293 295 297 299 301 303 305 307 309 311 313 315 317 319 321 323 325 327 329 331 333 335 337 339 341 343 345 347 349 351 353 355 357 359 361 363 365 367 369 371 373 375 377 379 381 383 385 387 389 391 393 395 397 399 401 403 405 407 409 411 413 415 417 419 421 423 425 427 429 431 433 435 437 439 441 443 445 447 449 451 453 455 457 459 461 463 465 467 469 471 473 475 477 479 481 483 485 487 489 491 493 495 497 499 501 503 505 507 509 511 513 515 517 519 521 523 525 527 529 531 533 535 537 539 541 543 545 547 549 551 553 555 557 559 561 563 565 567 569 571 573 575 577 579 581 583 585 587 589 591 593 595 597 599 601 603 605 607 609 611 613 615 617 619 621 623 625 627 629 631 633 635 637 639 641 643 645 647 649 651 653 655 657 659 661 663 665 667 669 671 673 675 677 679 681 683 685 687 689 691 693 695 697 699 701 703 705 707 709 711 713 715 717 719 721 723 725 727 729 731 733 735 737 739 741 743 745 747 749 751 753 755 757 759 761 763 765 767 769 771 773 775 777 779 781 783 785 787 789 791 793 795 797 799 801 803 805 807 809 811 813 815 817 819 821 823 825 827 829 831 833 835 837 839 841 843 845 847 849 851 853 855 857 859 861 863 865 867 869 871 873 875 877 879 881 883 885 887 889 891 893 895 897 899 901 903 905 907 909 911 913 915 917 919 921 923 925 927 929 931 933 935 937 939 941 943 945 947 949 951 953 955 957 959 961 963 965 967 969 971 973 975 977 979 981 983 985 987 989 991 993 995 997 999

31

1001 1003 1005 1007 1009 1011 1013 1015 1017 1019 1021 1023 1025 1027 1029 1031 1033 1035 1037 1039 1041 1043 1045 1047 1049 1051 1053 1055 1057 1059 1061 1063 1065 1067 1069 1071 1073 1075 1077 1079 1081 1083 1085 1087 1089 1091 1093 1095 1097 1099 1101 1103 1105 1107 1109 1111 1113 1115 1117 1119 1121 1123 1125 1127 1129 1131 1133 1135 1137 1139 1141 1143 1145 1147 1149 1151 1153 1155 1157 1159 1161 1163 1165 1167 1169 1171 1173 1175 1177 1179 1181 1183 1185 1187 1189 1191 1193 1195 1197 1199 1201 1203 1205 1207 1209 1211 1213 1215 1217 1219 1221 1223 1225 1227 1229 1231 1233 1235 1237 1239 1241 1243 1245 1247 1249 1251 1253 1255 1257 1259 1261 1263 1265 1267 1269 1271 1273 1275 1277 1279 1281 1283 1285 1287 1289 1291 1293 1295 1297 1299 1301 1303 1305 1307 1309 1311 1313 1315 1317 1319 1321 1323 1325 1327 1329 1331 1333 1335 1337 1339 1341 1343 1345 1347 1349 1351 1353 1355 1357 1359 1361 1363 1365 1367 1369 1371 1373 1375 1377 1379 1381 1383 1385 1387 1389 1391 1393 1395 1397 1399 1401 1403 1405 1407 1409 1411 1413 1415 1417 1419 1421 1423 1425 1427 1429 1431 1433 1435 1437 1439 1441 1443 1445 1447 1449 1451 1453 1455 1457 1459 1461 1463 1465 1467 1469 1471 1473 1475 1477 1479 1481 1483 1485 1487 1489 1491 1493 1495 1497 1499 1501 1503 1505 1507 1509 1511 1513 1515 1517 1519 1521 1523 1525 1527 1529 1531 1533 1535 1537 1539 1541 1543 1545 1547 1549 1551 1553 1555 1557 1559 1561 1563 1565 1567 1569 1571 1573 1575 1577 1579 1581 1583 1585 1587 1589 1591 1593 1595 1597 1599 1601 1603 1605 1607 1609 1611 1613 1615 1617 1619 1621 1623 1625 1627 1629 1631 1633 1635 1637 1639 1641 1643 1645 1647 1649 1651 1653 1655 1657 1659 1661 1663 1665 1667 1669 1671 1673 1675 1677 1679 1681 1683 1685 1687 1689 1691 1693 1695 1697 1699 1701 1703 1705 1707 1709 1711 1713 1715 1717 1719 1721 1723 1725 1727 1729 1731 1733 1735 1737 1739 1741 1743 1745 1747 1749 1751 1753 1755 1757 1759 1761 1763 1765 1767 1769 1771 1773 1775 1777 1779 1781 1783 1785 1787 1789 1791 1793 1795 1797 1799 1801 1803 1805 1807 1809 1811 1813 1815 1817 1819 1821 1823 1825 1827 1829 1831 1833 1835 1837 1839 1841 1843 1845 1847 1849 1851 1853 1855 1857 1859 1861 1863 1865 1867 1869 1871 1873 1875 1877 1879 1881 1883 1885 1887 1889 1891 1893 1895 1897 1899 1901 1903 1905 1907 1909 1911 1913 1915 1917 1919 1921 1923 1925 1927 1929 1931 1933 1935 1937 1939 1941 1943 1945 1947 1949 1951 1953 1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021 2023 2025 2027 2029 2031 2033 2035 2037 2039 2041 2043 2045 2047 2049 2051 2053 2055 2057 2059 2061 2063 2065 2067 2069 2071 2073 2075 2077 2079 2081 2083 2085 2087 2089 2091 2093 2095 2097 2099 2101 2103 2105 2107 2109 2111 2113 2115 2117 2119 2121 2123 2125 2127 2129 2131 2133 2135 2137 2139 2141 2143 2145 2147 2149 2151 2153 2155 2157 2159 2161 2163 2165 2167 2169 2171 2173 2175 2177 2179 2181 2183 2185 2187 2189 2191 2193 2195 2197 2199 2201 2203 2205 2207 2209 2211 2213 2215 2217 2219 2221 2223 2225 2227 2229 2231 2233 2235 2237 2239 2241 2243 2245 2247 2249 2251 2253 2255 2257 2259 2261 2263 2265 2267 2269 2271 2273 2275 2277 2279 2281 2283 2285 2287 2289 2291 2293 2295 2297 2299 2301 2303 2305 2307 2309 2311 2313 2315 2317 2319 2321 2323 2325 2327 2329 2331 2333 2335 2337 2339 2341 2343 2345 2347 2349 2351 2353 2355 2357 2359 2361 2363 2365 2367 2369 2371 2373 2375 2377 2379 2381 2383 2385 2387 2389 2391 2393 2395 2397 2399 2401 2403 2405 2407 2409 2411 2413 2415 2417 2419 2421 2423 2425 2427 2429 2431 2433 2435 2437 2439 2441 2443 2445 2447 2449 2451 2453 2455 2457 2459 2461 2463 2465 2467 2469 2471 2473 2475 2477 2479 2481 2483 2485 2487 2489 2491 2493 2495 2497 2499 2501 2503 2505 2507 2509 2511 2513 2515 2517 2519 2521 2523 2525 2527 2529 2531 2533 2535 2537 2539 2541 2543 2545 2547 2549 2551 2553 2555 2557 2559 2561 2563 2565 2567 2569 2571 2573 2575 2577 2579 2581 2583 2585 2587 2589 2591 2593 2595 2597 2599 2601 2603 2605 2607 2609 2611 2613 2615 2617 2619 2621 2623 2625 2627 2629 2631 2633 2635 2637 2639 2641 2643 2645 2647 2649 2651 2653 2655 2657 2659 2661 2663 2665 2667 2669 2671 2673 2675 2677 2679 2681 2683 2685 2687 2689 2691 2693 2695 2697 2699 2701 2703 2705 2707 2709 2711 2713 2715 2717 2719 2721 2723 2725 2727 2729 2731 2733 2735 2737 2739 2741 2743 2745 2747 2749 2751 2753 2755 2757 2759 2761 2763 2765 2767 2769 2771 2773 2775 2777 2779 2781 2783 2785 2787 2789 2791 2793 2795 2797 2799 2801 2803 2805 2807 2809 2811 2813 2815 2817 2819 2821 2823 2825 2827 2829 2831 2833 2835 2837 2839 2841 2843 2845 2847 2849 2851 2853 2855 2857 2859 2861 2863 2865 2867 2869 2871 2873 2875 2877 2879 2881 2883 2885 2887 2889 2891 2893 2895 2897 2899 2901 2903 2905 2907 2909 2911 2913 2915 2917 2919 2921 2923 2925 2927 2929 2931 2933 2935 2937 2939 2941 2943 2945 2947 2949 2951 2953 2955 2957 2959 2961 2963 2965 2967 2969 2971 2973 2975 2977 2979 2981 2983 2985 2987 2989 2991 2993 2995 2997 2999 3001 3003 3005 3007 3009 3011 3013 3015 3017 3019 3021 3023 3025 3027 3029 3031 3033 3035 3037 3039 3041 3043 3045 3047 3049 3051 3053 3055 3057 3059 3061 3063 3065 3067 3069 3071 3073 3075 3077 3079 3081 3083 3085 3087 3089 3091 3093 3095 3097 3099 3101 3103 3105 3107 3109 3111 3113 3115 3117 3119 3121 3123 3125 3127 3129 3131 3133 3135 3137 3139 3141 3143 3145 3147 3149 3151 3153 3155 3157 3159 3161 3163 3165 3167 3169 3171 3173 3175 3177 3179 3181 3183 3185 3187 3189 3191 3193 3195 3197 3199 3201 3203 3205 3207 3209 3211 3213 3215 3217 3219 3221 3223 3225 3227 3229 3231 3233 3235 3237 3239 3241 3243 3245 3247 3249 3251 3253 3255 3257 3259 3261 3263 3265 3267 3269 3271 3273 3275 3277 3279 3281 3283 3285 3287 3289 3291 3293 3295 3297 3299 3301 3303 3305 3307 3309 3311 3313 3315 3317 3319 3321 3323 3325 3327 3329 3331 3333 3335 3337 3339 3341 3343 3345 3347 3349 3351 3353 3355 3357 3359 3361 3363 3365 3367 3369 3371 3373 3375 3377 3379 3381 3383 3385 3387 3389 3391 3393 3395 3397 3399 3401 3403 3405 3407 3409 3411 3413 3415 3417 3419 3421 3423 3425 3427 3429 3431 3433 3435 3437 3439 3441 3443 3445 3447 3449 3451 3453 3455 3457 3459 3461 3463 3465 3467 3469 3471 3473 3475 3477 3479 3481 3483 3485 3487 3489 3491 3493 3495 3497 3499 3501 3503 3505 3507 3509 3511 3513 3515 3517 3519 3521 3523 3525 3527 3529 3531 3533 3535 3537 3539 3541 3543 3545 3547 3549 3551 3553 3555 3557 3559 3561 3563 3565 3567 3569 3571 3573 3575 3577 3579 3581 3583 3585 3587 3589 3591 3593 3595 3597 3599 3601 3603 3605 3607 3609 3611 3613 3615 3617 3619 3621 3623 3625 3627 3629 3631 3633 3635 3637 3639 3641 3643 3645 3647 3649 3651 3653 3655 3657 3659 3661 3663 3665 3667 3669 3671 3673 3675 3677 3679 3681 3683 3685 3687 3689 3691 3693 3695 3697 3699 3701 3703 3705 3707 3709 3711 3713 3715 3717 3719 3721 3723 3725 3727 3729 3731 3733 3735 3737 3739 3741 3743 3745 3747 3749 3751 3753 3755 3757 3759 3761 3763 3765 3767 3769 3771 3773 3775 3777 3779 3781 3783 3785 3787 3789 3791 3793 3795 3797 3799 3801 3803 3805 3807 3809 3811 3813 3815 3817 3819 3821 3823 3825 3827 3829 3831 3833 3835 3837 3839 3841 3843 3845 3847 3849 3851 3853 3855 3857 3859 3861 3863 3865 3867 3869 3871 3873 3875 3877 3879 3881 3883 3885 3887 3889 3891 3893 3895 3897 3899 3901 3903 3905 3907 3909 3911 3913 3915 3917 3919 3921 3923 3925 3927 3929 3931 3933 3935 3937 3939 3941 3943 3945 3947 3949 3951 3953 3955 3957 3959 3961 3963 3965 3967 3969 3971 3973 3975 3977 3979 3981 3983 3985 3987 3989 3991 3993 3995 3997 3999 4001 4003 4005 4007 4009 4011 4013 4015 4017 4019 4021 4023 4025 4027 4029 4031 4033 4035 4037 4039 4041 4043 4045 4047 4049 4051 4053 4055 4057 4059 4061 4063 4065 4067 4069 4071 4073 4075 4077 4079 4081 4083 4085 4087 4089 4091 4093 4095 4097 4099 4101 4103 4105 4107 4109 4111 4113 4115 4117 4119 4121 4123 4125 4127 4129 4131 4133 4135 4137 4139 4141 4143 4145 4147 4149 4151 4153 4155 4157 4159 4161 4163 4165 4167 4169 4171 4173 4175 4177 4179 4181 4183 4185 4187 4189 4191 4193 4195 4197 4199 4201 4203 4205 4207 4209 4211 4213 4215 4217 4219 4221 4223 4225 4227 4229 4231 4233 4235 4237 4239 4241 4243 4245 4247 4249 4251 4253 4255 4257 4259 4261 4263 4265 4267 4269 4271 4273 4275 4277 4279 4281 4283 4285 4287 4289 4291 4293 4295 4297 4299 4301 4303 4305 4307 4309 4311 4313 4315 4317 4319 4321 4323 4325 4327 4329 4331 4333 4335 4337 4339 4341 4343 4345 4347 4349 4351 4353 4355 4357 4359 4361 4363 4365 4367 4369 4371 4373 4375 4377 4379 4381 4383 4385 4387 4389 4391 4393 4395 4397 4399 4401 4403 4405 4407 4409 4411 4413 4415 4417 4419 4421 4423 4425 4427 4429 4431 4433 4435 4437 4439 4441 4443 4445 4447 4449 4451 4453 4455 4457 4459 4461 4463 4465 4467 4469 4471 4473 4475 4477 4479 4481 4483 4485 4487 4489 4491 4493 4495 4497 4499 4501 4503 4505 4507 4509 4511 4513 4515 4517 4519 4521 4523 4525 4527 4529 4531 4533 4535 4537 4539 4541 4543 4545 4547 4549 4551 4553 4555 4557 4559 4561 4563 4565 4567 4569 4571 4573 4575 4577 4579 4581 4583 4585 4587 4589 4591 4593 4595 4597 4599 4601 4603 4605 4607 4609 4611 4613 4615 4617 4619 4621 4623 4625 4627 4629 4631 4633 4635 4637 4639 4641 4643 4645 4647 4649 4651 4653 4655 4657 4659 4661 4663 4665 4667 4669 4671 4673 4675 4677 4679 4681 4683 4685 4687 4689 4691 4693 4695 4697 4699 4701 4703 4705 4707 4709 4711 4713 4715 4717 4719 4721 4723 4725 4727 4729 4731 4733 4735 4737 4739 4741 4743 4745 4747 4749 4751 4753 4755 4757 4759 4761 4763 4765 4767 4769 4771 4773 4775 4777 4779 4781 4783 4785 4787 4789 4791 4793 4795 4797 4799 4801 4803 4805 4807 4809 4811 4813 4815 4817 4819 4821 4823 4825 4827 4829 4831 4833 4835 4837 4839 4841 4843 4845 4847 4849 4851 4853 4855 4857 4859 4861 4863 4865 4867 4869 4871 4873 4875 4877 4879 4881 4883 4885 4887 4889 4891 4893 4895 4897 4899 4901 4903 4905 4907 4909 4911 4913 4915 4917 4919 4921 4923 4925 4927 4929 4931 4933 4935 4937 4939 4941 4943 4945 4947 4949 4951 4953 4955 4957 4959 4961 4963 4965 4967 4969 4971 4973 4975 4977 4979 4981 4983 4985 4987 4989 4991 4993 4995 4997 4999 5001 5003 5005 5007 5009 5011 5013 5015 5017 5019 5021 5023 5025 5027 5029 5031 5033 5035 5037 5039 5041 5043 5045 5047 5049 5051 5053 5055 5057 5059 5061 5063 5065 5067 5069 5071

Plate IX. Karyotypes of offspring (2200X).

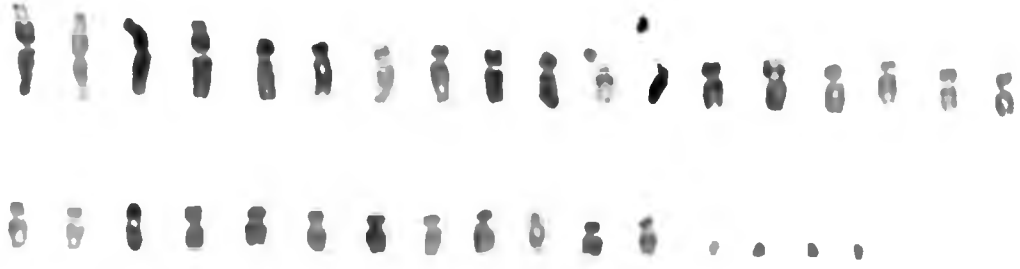
Figure:

33. 4B offspring.

34. 5B offspring.

35. 6B offspring.

33



34



35



Meiotic behavior of B chromosomes of offspring

Different behaviors of B chromosomes, as well as their effect on A chromosomes, were observed in PMCs of selfed offspring of Anthurium warocqueanum (Figs. 36 - 68). Figure 36 shows metaphase I of the plant lacking B chromosomes where 30 A chromosomes form 15 bivalents. The mean A chromosome configuration at diakinesis and metaphase I of the 0B plant was found to be $14.92\text{II} + 0.16\text{I}$ from examination of 25 pollen mother cells (Table 6a).

The single B chromosome present in the 1B offspring can be seen at diakinesis (Fig. 37) and at metaphase I (Fig. 38). The B chromosome tended to lag at anaphase I (Fig. 39). Studies on late anaphase I of the same 1B plant revealed variable behavior of the B chromosome. In Figure 40 the presence of the B chromosome is not discernible, indicating that it had moved toward one of the two poles and was included within a set of basic chromosomes. Frequently, the B chromosome lagged at or near the metaphase plate (Fig. 41); however, the separation of chromatids toward the two opposite poles was also observed (Fig. 42). Stickiness of B chromosomes can be seen in Figure 43 where the association of the B chromosome with a part of the A chromosome at the center of the cell causes an uneven distribution of the A chromosomes, possibly leading to the formation of a micronucleus at the end of meiosis. Although it cannot be concluded that the production of sterile pollen is due to

TABLE 6a. -- Chromosome configurations at diakinesis and metaphase I of 0B and 1B offspring (25 PMCs per spadix were examined)

| Configuration of A chromosomes | | | |
|--------------------------------|----------------|------------------------|-----------------|
| Offspring | Range | Mode (No. of cells) | Mean |
| 0B | 15II - 14II+2I | 15II(23) | 14.92II+0.16I |
| 1B #1 | 15II - 14II+2I | 15II(23) | 14.92II+0.16I |
| #2 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I |
| #3 | 15II | 15II(25) | 15II |
| #4 | 15II | 15II(25) | 15II |
| #5 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I |
| #6 | 15II | 15II(25) | 15II |
| #7 | 15II | 15II(25) | 15II |
| | | mean | 14.977II+0.046I |

Plate X. Meiosis (PMC) in OB and 1B offspring of
Anthurium warocqueanum (1650X).

Figure:

36. Metaphase I of OB offspring.
37. Diakinesis of 1B offspring.
38. Metaphase I of 1B offspring.
39. Anaphase I of 1B offspring, showing
a B chromosome lagging.

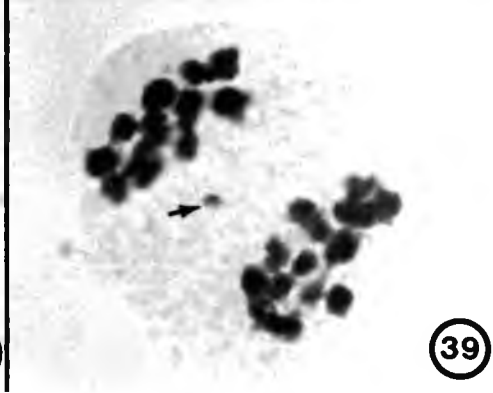
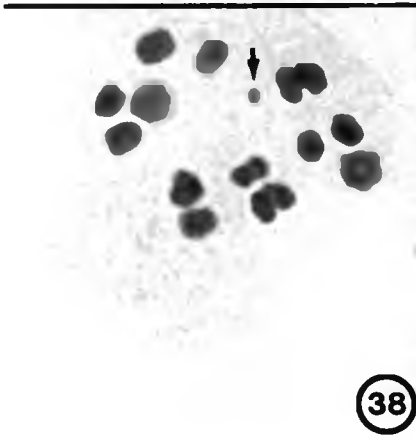
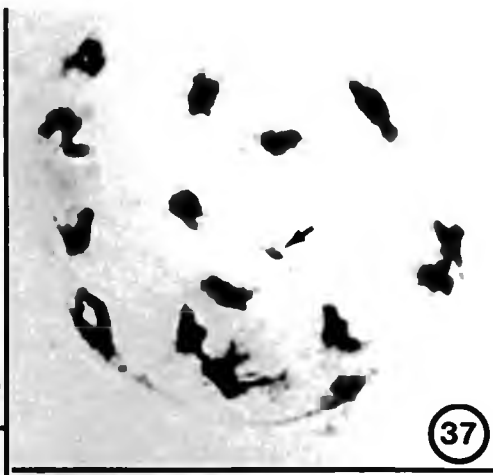


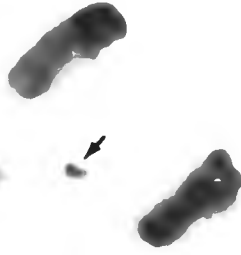
Plate XI. Late anaphase I in 1B offspring of
Anthurium warocqueanum (1650X).

Figure:

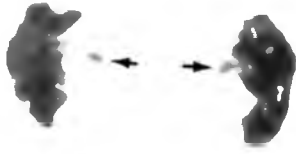
40. No lagging B chromosomes.
41. Lagging B chromosome at the metaphase plate.
42. Separation of a B chromosome.
43. Association of A and B chromosomes.



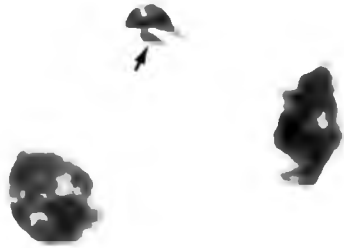
40



41



42



43

the effect of a B chromosome on the A chromosomes, it is assumed that a B chromosome participates in inducing this phenomenon. The mean meiotic configuration of the 1B plant shows almost perfect pairing of the two sets of homologous A chromosomes (Table 6a).

The largest number of the offspring (38.3 %) had two B chromosomes (Table 3). A close association of the two B chromosomes was found in some cells at diakinesis (Fig. 44) and at metaphase I (Fig. 45). Within a single plant the 2Bs may or may not be paired (Figs. 46 and 47; Table 6b). The later stages of meiosis have again displayed some irregular types of behavior of B chromosomes, such as lagging at anaphase I (Fig. 48), formation of micronuclei after the reduction division (Fig. 49) and the production of unfunctional microspores at the end of meiosis (Fig. 50). The configurations of the A chromosomes in 2B offspring were similar to those of 0B and 1B plants (Table 6b).

The three B chromosomes of 3B offspring exhibited meiotic behavior similar to that of the parent (Figs. 51 - 55; Table 6c). At diakinesis and metaphase I they form three univalents (Fig. 51), one bivalent and one univalent (Fig. 52), or one trivalent, as observed in two cases (Table 6c). Figures 53 - 55 show irregular meiotic behavior of the 3B plant: lagging of one B chromosome (Figs. 53 and 54), and the formation of micronuclei (Fig. 55). The lagging B chromosome at anaphase I in

TABLE 6b. -- Chromosome configurations at diakinesis and metaphase I of meiosis of
2B offspring

| Offspring | No. of cells according to configurations of 2 B chromosomes | | | Configuration of A chromosomes | | |
|-----------|---|-----|-------|--------------------------------|-------------------------|---------------|
| | 1 II | 2 I | Total | Range | Mode (No. of cells) | Mean |
| #1 | 6 | 19 | 25 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I |
| #2 | 4 | 21 | 25 | 15II - 14II+2I | 15II(19) | 14.76II+0.48I |
| #3 | 5 | 20 | 25 | 15II - 14II+2I | 15II(22) | 14.88II+0.24I |
| #4 | 8 | 17 | 25 | 15II - 13II+4I | 15II(23) | 14.88II+0.24I |
| #5 | 8 | 17 | 25 | 15II - 14II+2I | 15II(21) | 14.84II+0.32I |
| #6 | 11 | 14 | 25 | 15II - 14II+2I | 15II(22) | 14.88II+0.24I |
| #7 | 4 | 21 | 25 | 15II - 14II+2I | 15II(18) | 14.72II+0.56I |
| #8 | 8 | 17 | 25 | 15II - 14II+2I | 15II(23) | 14.92II+0.16I |
| #9 | 9 | 16 | 25 | 15II - 14II+2I | 15II(17) | 14.68II+0.64I |
| #10 | 4 | 21 | 25 | 15II - 12II+6I | 14II+2I(12) | 14.16II+1.68I |
| #11 | 4 | 21 | 25 | 15II - 13II+4I | 15II(15) | 14.48II+1.04I |
| #12 | 11 | 14 | 25 | 15II - 13II+4I | 15II(23) | 14.88II+0.24I |
| #13 | 14 | 11 | 25 | 15II - 14II+2I | 15II(22) | 14.88II+0.24I |
| #14 | 5 | 20 | 25 | 15II - 14II+2I | 15II(22) | 14.88II+0.24I |
| #15 | 13 | 12 | 25 | 15II | 15II(25) | 15II |
| #16 | 10 | 15 | 25 | 15II - 12II+6I | 15II(21) | 14.76II+0.48I |
| #17 | 14 | 11 | 25 | 15II - 13II+4I | 15II(21) | 14.80II+0.40I |
| #18 | 11 | 14 | 25 | 15II - 14II+2I | 15II(17) | 14.68II+0.64I |
| #19 | 10 | 15 | 25 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I |
| #20 | 9 | 16 | 25 | 15II - 14II+2I | 15II(16) | 14.64II+0.72I |
| #21 | 6 | 19 | 25 | 15II - 12II+6I | 15II(11) 14II+2I(11) | 14.24II+1.52I |
| #22 | 13 | 12 | 25 | 15II - 14II+2I | 15II(21) | 14.84II+0.32I |

TABLE 6b. -- (Continued) Chromosome configurations at diakinesis and metaphase I of meiosis of 2B offspring

| Offspring | No. of cells according to configurations of 2 B chromosomes | | | Configuration of A chromosomes | | |
|-----------|---|-----|-------|--------------------------------|------------------------|----------------------|
| | 1 II | 2 I | Total | Range | Mode (No. of cells) | Mean |
| #23 | 19 | 6 | 25 | 15II | 15II (25) | 15II |
| #24 | 15 | 10 | 25 | 15II - 14II+2I | 15II (22) | 14.88II+0.24I |
| #25 | 17 | 8 | 25 | 15II - 13II+4I | 15II (19) | 14.72II+0.56I |
| #26 | 13 | 12 | 25 | 15II - 14II+2I | 15II (22) | 14.88II+0.24I |
| #27 | 20 | 5 | 25 | 15II - 14II+2I | 15II (22) | 14.88II+0.24I |
| #28 | 21 | 4 | 25 | 15II - 14II+2I | 15II (23) | 14.92II+0.16I |
| #29 | 9 | 16 | 25 | 15II - 13II+4I | 15II (19) | 14.64II+0.72I |
| #30 | 14 | 11 | 25 | 15II | 15II (25) | 15II |
| #31 | 13 | 12 | 25 | 15II - 14II+2I | 15II (24) | 14.96II+0.08I |
| #32 | 18 | 7 | 25 | 15II - 14II+2I | 15II (23) | 14.92II+0.16I |
| #33 | 23 | 2 | 25 | 15II | 15II (25) | 15II |
| #34 | 18 | 7 | 25 | 15II - 14II+2I | 15II (22) | 14.88II+0.24I |
| #35 | 13 | 12 | 25 | 15II - 14II+2I | 15II (24) | 14.96II+0.08I |
| #36 | 18 | 7 | 25 | 15II | 15II (25) | 15II |
| | | | | | | mean 14.816II+0.369I |

TABLE 6c -- Chromosome configurations at diakinesis and metaphase I of meiosis of
3B offspring

| Offspring | No. of cells according to configurations of 3 B chromosomes | | | | Configuration of A chromosomes | | | |
|-----------|---|------------|-----|-------|--------------------------------|---------------------|---------------|--|
| | 1 III | 1 II + 1 I | 3 I | Total | Range | Mode (No. of cells) | Mean | |
| #1 | - | 12 | 13 | 25 | 15II - 13II+4I | 15II(22) | 14.84II+0.32I | |
| #2 | - | 14 | 11 | 25 | 15II - 12II+6I | 15II(9) | 13.92II+2.16I | |
| #3 | - | 15 | 10 | 25 | 15II - 14II+2I | 15II(21) | 14.84II+0.32I | |
| #4 | - | 22 | 3 | 25 | 15II - 13II+4I | 15II(21) | 14.80II+0.40I | |
| #5 | - | 12 | 13 | 25 | 15II - 13II+4I | 15II(22) | 14.84II+0.32I | |
| #6 | - | 16 | 9 | 25 | 15II - 14II+2I | 15II(21) | 14.84II+0.32I | |
| #7 | - | 19 | 6 | 25 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I | |
| #8 | - | 21 | 4 | 25 | 15II | 15II(25) | 15II | |
| #9 | - | 10 | 15 | 25 | 15II - 12II+6I | 15II(12) | 14.20II+1.60I | |
| #10 | - | 20 | 5 | 25 | 15II - 14II+2I | 15II(23) | 14.92II+0.16I | |
| #11 | - | 22 | 3 | 25 | 15II - 14II+2I | 15II(22) | 14.88II+0.24I | |
| #12 | - | 14 | 11 | 25 | 15II - 14II+2I | 15II(23) | 14.92II+0.16I | |
| #13 | 0 | 16 | 9 | 25 | 15II - 11II+8I | 15II(22) | 14.76II+0.48I | |
| #14 | 0 | 16 | 9 | 25 | 15II - 14II+2I | 15II(23) | 14.92II+0.16I | |
| #15 | 0 | 18 | 7 | 25 | 15II - 13II+4I | 15II(23) | 14.88II+0.24I | |
| #16 | 0 | 17 | 8 | 25 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I | |
| #17 | 0 | 25 | 0 | 25 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I | |
| #18 | 1 | 21 | 3 | 25 | 15II - 14II+2I | 15II(22) | 14.88II+0.24I | |
| #19 | 0 | 13 | 12 | 25 | 15II | 15II(25) | 15II | |
| #20 | 0 | 17 | 8 | 25 | 15II | 15II(25) | 15II | |
| #21 | 0 | 23 | 2 | 25 | 15II | 15II(25) | 15II | |
| #22 | 0 | 18 | 7 | 25 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I | |

TABLE 6c -- (Continued) Chromosome configurations at diakinesis and metaphase I of meiosis of 3B offspring

| Offspring | No. of cells according to configurations of 3 B chromosomes | | | | Configuration of A chromosomes | | |
|-----------|---|---------------|-----|-------|--------------------------------|------------------------|----------------------|
| | 1 III | 1 II + 1 I | 3 I | Total | Range | Mode (No. of cells) | Mean |
| #23 | 1 | 19 | 5 | 25 | 15II | 15II(25) | 15II |
| #24 | 0 | 16 | 9 | 25 | 15II | 15II(25) | 15II |
| #25 | 0 | 16 | 9 | 25 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I |
| | | | | | | | mean 14.850II+0.301I |

Plate XII. Meiosis (PMC) in 2B offspring of
Anthurium warocqueanum (1650X).

Figure:

44. Diakinesis
45. Metaphase I, 2 Bs paired (polar view).
46. Metaphase I, 2 Bs paired (equatorial
view).
47. Metaphase I, 2 Bs unpaired (equatorial
view).

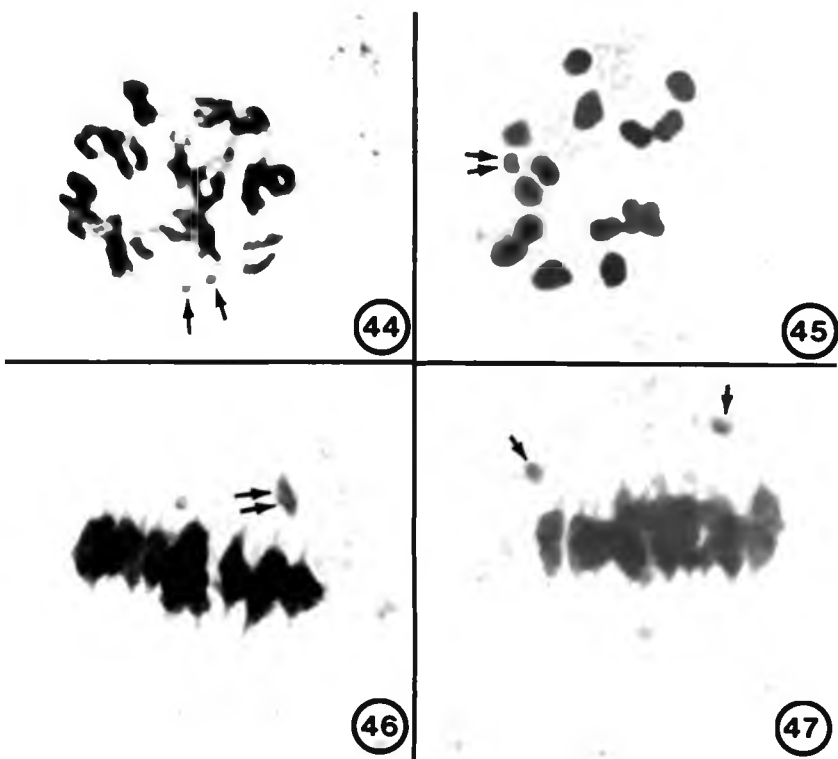


Plate XIII. Meiosis (PMC) in 2B offspring of
Anthurium warocqueanum (1650X).

Figure:

48. Anaphase I, 2 Bs are lagging.
49. Metaphase II, formation of two micronuclei.
50. The end of meiosis, tetrad plus extra small microspore.

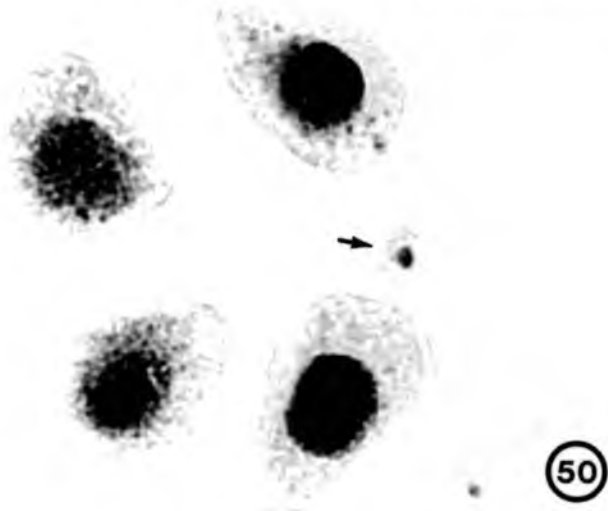
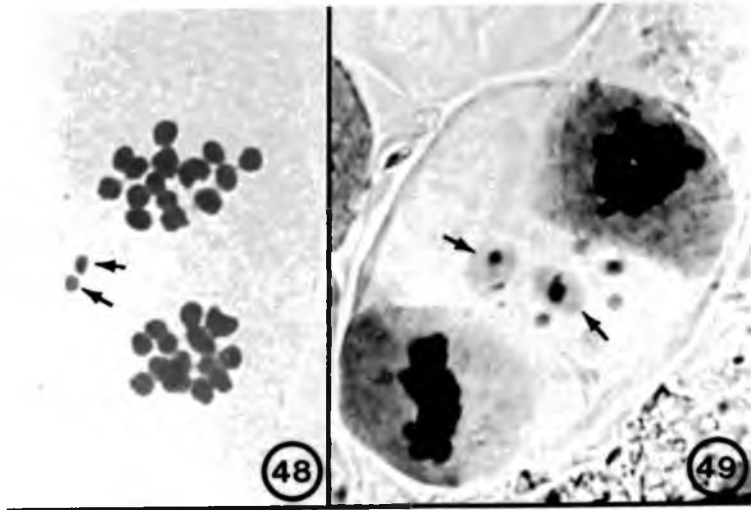


Plate XIV. Meiosis (PMC) in 3B offspring of
Anthurium warocqueanum (1650X).

Figure:

51. Diakinesis, A--15 bivalents (15 II) and B--3 univalents (3 I).
52. Metaphase I, A--15 bivalents (15 II) and B--1 bivalent and 1 univalent (1 II + 1 I).
53. Anaphase I, an univalent B is lagging.
54. Anaphase I, association of A and B chromosomes.
55. Late anaphase II, formation of micronuclei.

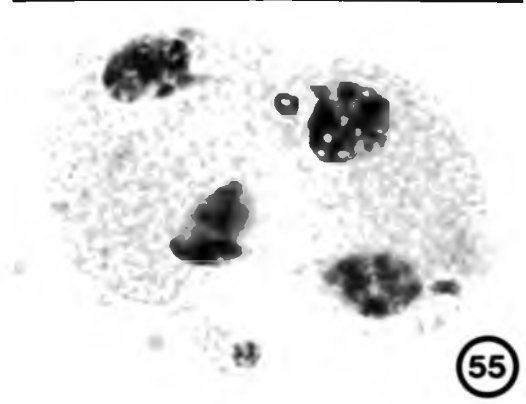
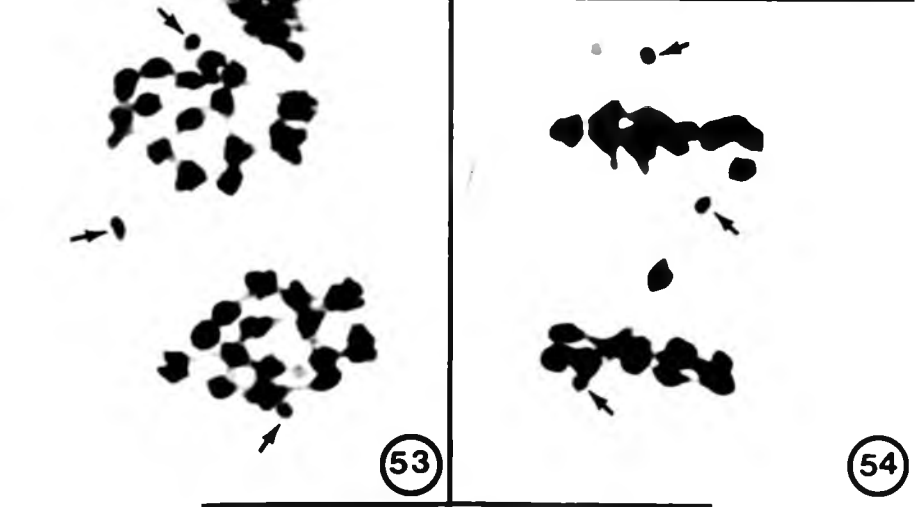
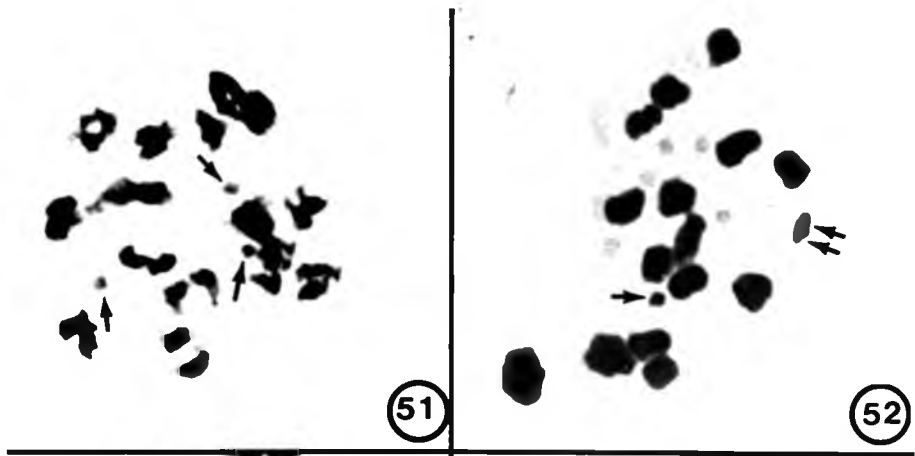


Figure 54 seems to be affecting the movement of A chromosomes by its physical affinity with the As through a slender threadlike formation, thus delaying the distribution of A chromosomes to the opposite poles.

At diakinesis and metaphase I of the 4B offspring, four classes of B-chromosomal configuration were found (Table 6d): one trivalent and one univalent (Fig. 56), two bivalents (Fig. 57), one bivalent and two univalents (Figs. 58 and 59), and four univalents. Association of higher numbers of B chromosomes by themselves such as formation of trivalents or quadrivalents, were hardly seen, whereas 2 B pairings were predominant. In Figures 58 and 59, a pair of A chromosomes appear as two univalents, possibly indicating that a higher number of B chromosomes can prevent homologous pairings of A chromosomes in the meiotic process.

The meiotic configurations of 5 and 6 B chromosomes were also examined and tabulated in Table 6d. In 5B plants, the formations of two bivalents and one univalent (Fig. 61), one bivalent and three univalents (Fig. 62) and five univalents (Fig. 63) were commonly observed while one trivalent and one bivalent was found in only one case. The 6B plant exhibited four types of B-chromosomal configuration: three bivalents (Fig. 65), two bivalents and two univalents, one bivalent and four univalents, and six univalents (Figs. 66 and 67). Later meiotic stages of higher-numbered B plants again showed variable behavior of

TABLE 6d. -- Chromosome configurations at diakinesis and metaphase I of meiosis of 4B, 5B, and 6B offspring

| Offspring | No. of cells according to configurations of B chromosomes | | | | | Configuration of A chromosomes | | |
|-----------|---|------|---------------|-----|-------|--------------------------------|------------------------|----------------------|
| | 1 III + 1 I | 2 II | 1 II + 2 I | 4 I | Total | Range | Mode (No. of cells) | Mean |
| #1 | - | 2 | 10 | 13 | 25 | 15II - 12II+6I | 15II(11) | 14.12II+1.76I |
| #2 | - | 1 | 7 | 4 | 12 | 15II - 13II+4I | 15II(7) | 14.50II+1.00I |
| #3 | - | 2 | 15 | 8 | 25 | 15II - 12II+6I | 15II(17) | 14.40II+1.20I |
| #4 | - | 1 | 10 | 14 | 25 | 15II - 12II+6I | 15II(10) | 13.96II+2.08I |
| #5 | - | 4 | 19 | 2 | 25 | 15II - 12II+6I | 15II(21) | 14.72II+0.56I |
| #6 | - | 4 | 16 | 5 | 25 | 15II - 13II+4I | 15II(17) | 14.60II+0.80I |
| #7 | - | 7 | 10 | 8 | 25 | 15II - 13II+4I | 15II(22) | 14.84II+0.32I |
| #8 | - | 6 | 18 | 1 | 25 | 15II - 13II+4I | 15II(17) | 14.64II+0.72I |
| #9 | 1 | 4 | 9 | 11 | 25 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I |
| #10 | 1 | 13 | 8 | 3 | 25 | 15II - 13II+4I | 15II(22) | 14.84II+0.32I |
| #11 | 0 | 17 | 7 | 1 | 25 | 15II - 13II+4I | 15II(24) | 14.92II+0.16I |
| #12 | 0 | 4 | 12 | 9 | 25 | 15II - 14II+2I | 15II(23) | 14.92II+0.16I |
| #13 | 0 | 12 | 10 | 3 | 25 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I |
| #14 | 0 | 6 | 15 | 4 | 25 | 15II - 14II+2I | 15II(24) | 14.96II+0.08I |
| #15 | 0 | 7 | 14 | 4 | 25 | 15II - 14II+2I | 15II(23) | 14.92II+0.16I |
| | | | | | | | | mean 14.684II+0.632I |

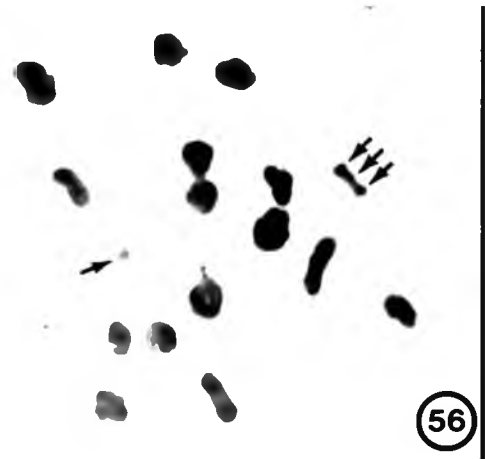
TABLE 6d. -- (Continued) Chromosome configurations at diakinesis and metaphase I of meiosis of 4B, 5B, and 6B offspring

| Offspring | No. of cells according to configurations of B chromosomes | | | | | Configuration of A chromosomes | | | |
|-----------|---|---------------|---------------|-----|-------|--------------------------------|------------------------|----------------------|--|
| | 1 III + 1 II | 2 II + 1 I | 1 II + 3 I | 5 I | Total | Range | Mode (No. of cells) | Mean | |
| 5B | | | | | | | | | |
| #1 | - | 4 | 17 | 4 | 25 | 15II - 11III+8I | 14II+2I(10) | 12.56II+2.48I | |
| #2 | - | 7 | 12 | 6 | 25 | 15II - 12II+6I | 14II+2I(14) | 13.88II+2.24I | |
| #3 | - | 5 | 9 | 11 | 25 | 15II - 9II+12I | 13II+4I(7) | 12.20II+5.60I | |
| #4 | 1 | 14 | 9 | 1 | 25 | 15II - 14II+2I | 15II (21) | 14.84II+0.32I | |
| | | | | | | | | mean 13.370II+2.660I | |
| 6B | | | | | | | | | |
| | 3 II + 2 I | 2 II + 2 I | 1 II + 4 I | 6 I | Total | | | | |
| | 3 | 11 | 7 | 4 | 25 | 15II - 10II+10I | 13II+4I(9) | 13.32II+3.36I | |

Plate XV. Meiosis (PMC) in 4B offspring of
Anthurium warocqueanum (1650X).

Figure:

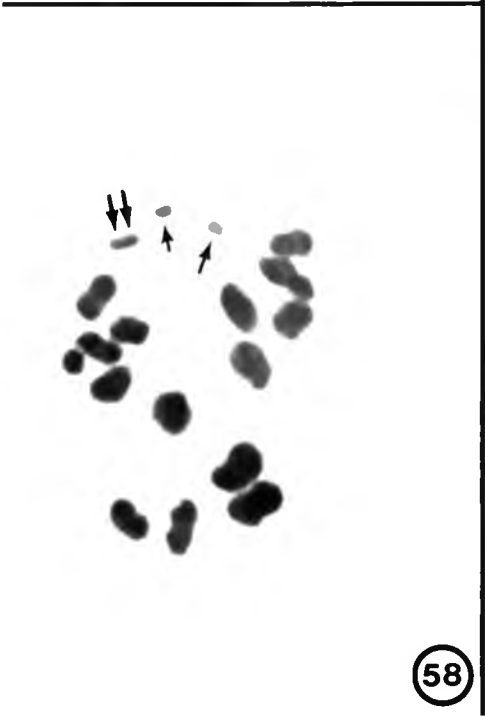
56. Metaphase I, A-- 15 bivalents (15 II)
and B-- 1 trivalent and 1 univalent
(1 III + 1 I).
57. Metaphase I, A-- 15 bivalents (15 II)
and B-- 2 bivalents (2 II).
58. Metaphase I, A-- 14 bivalents and 2
univalents (14 II + 2 I) and B-- 1
bivalent and 2 univalents (1 II + 2 I).
59. Metaphase I, A-- 14 bivalents and 2
univalents (14 II + 2 I) and B-- 1
bivalent and 2 univalents (1 II + 2 I)
(equatorial view).
60. Anaphase I, showing irregular movements
of B chromosomes.



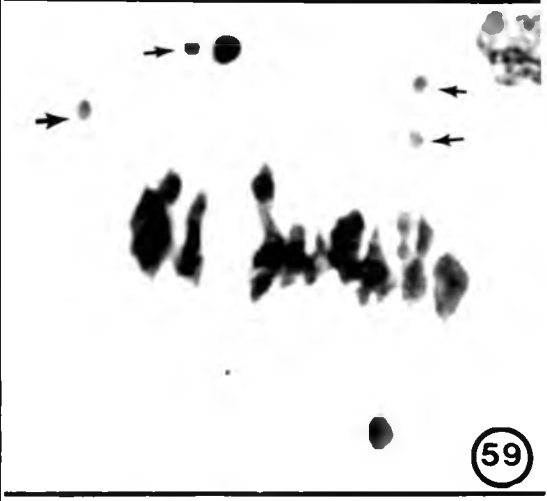
56



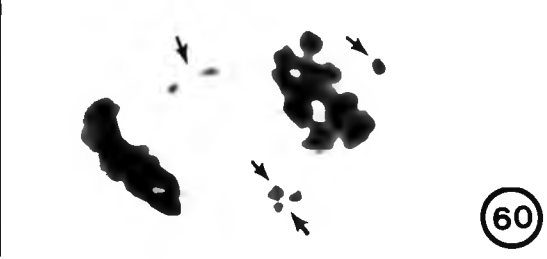
57



58



59



60

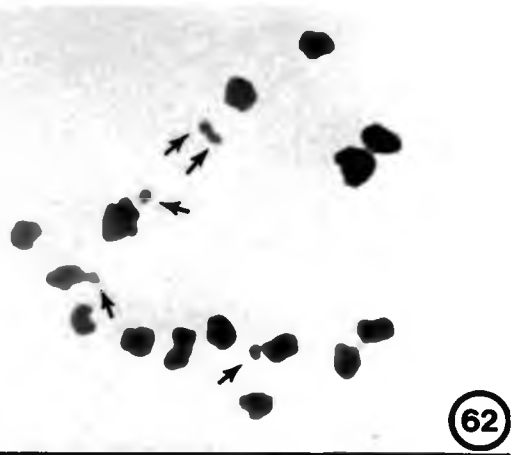
Plate XVI. Meiosis (PMC) in 5B offspring of
Anthurium warocqueanum (1650X).

Figure:

61. Metaphase I, A-- 15 bivalents (15 II)
and B-- 2 bivalents and 1 univalent
(2 II + 1 I).
62. Metaphase I, A-- 15 bivalents (15 II)
and B-- 1 bivalent and 3 univalents
(1 II + 3 I).
63. Metaphase I, A-- 15 bivalents (15 II)
and B-- 5 univalents (5 I).
64. Anaphase I.



61



62



63



64

Plate XVII. Meiosis (PMC) in 6B offspring of
Anthurium warocqueanum (1650X).

Figure:

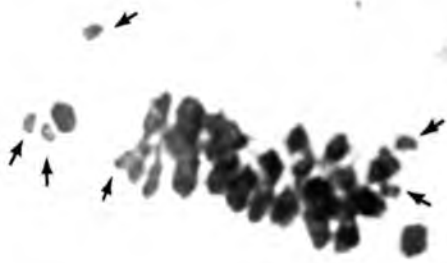
65. Metaphase I, A-- 15 bivalents (15 II)
and B-- 3 bivalents (3 II).
66. Metaphase I, A--12 bivalents and 6
univalents (6 I) and B-- 6 univalents
(6 I) (polar view).
67. Metaphase I, B-- 6 univalents (6 I)
(equatorial view).
68. Metaphase II, formation of micronuclei.



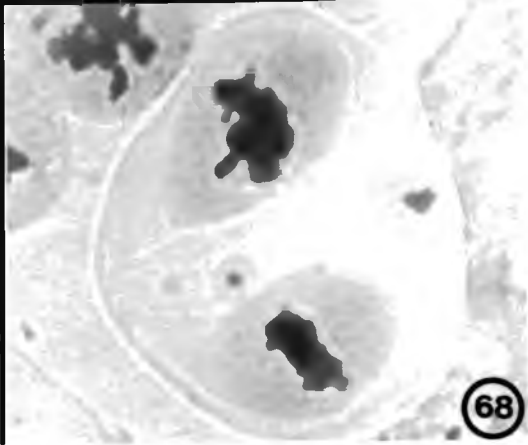
65



66



67



68

Bs, which could lead to the formation of micronuclei and microcytes. For example, anaphase I of 4B and 5B offspring are shown in Figures 60 and 64, respectively, exhibiting B-laggards in both cases. The unequal size of two micronuclei are observable in the 6B plant at metaphase II (Fig. 68). Table 6(a-d) shows that PMCs of 5 and 6B offspring exhibit a wider range of A-chromosomal configuration and a lower degree of bivalent formations.

Observations of pollen mother cells in the offspring have revealed several interesting features of B chromosomes in Anthurium warocqueanum. When two or more B chromosomes are present, 2 Bs are frequently associated together during the early meiotic stages, forming bivalents or positioning themselves close to each other. B bivalents generally undergo normal disjunction at anaphase I; however, in some cases, the paired Bs lag at or near the metaphase plate or both move toward the same pole. Behavior of unpaired Bs at anaphase I is more unpredictable than that of paired ones. They may move toward either pole, lag, or two sister chromatids may separate to opposite poles. Lagging B chromosomes possibly result in the formation of micronuclei at the end of reduction division.

An interaction between A and B chromosomes was found to exist to some extent. Although no pairing between the two classes of chromosomes was observed during meiotic activities earlier than metaphase I, some physical

TABLE 7. -- Comparison of A chromosome configurations at meiosis of offspring

| Offspring | Overall mean configuration of A chromosomes |
|-----------|--|
| 0B(1)* | 14.92II+0.16I |
| 1B(7) | 14.977II+0.046I |
| 2B(36) | 14.816II+0.369I |
| 3B(25) | 14.850II+0.301I |
| 4B(15) | 14.684II+0.632I |
| 5B(4) | 13.370II+2.660I |
| 6B(1) | 13.32II+3.36I |

* Number of offspring observed are shown in parenthesis.

affinities were seen in anaphase I where Bs were delaying the movements of A chromosomes. With the higher number of Bs, normal A-bivalent formations seemed to be reduced (Table 7), enhancing production of abnormal pollen grains.

Phenotypic effects of B chromosomes

Means of observations and standard errors for four characters (leaf length, leaf width, increase in stem length, and first flowering date) were calculated in each B-class and tabulated in Table 8. The similar mean values for each class indicate that there are no odd and even effects of B chromosomes in Anthurium warocqueanum, as reported for straw weight and tiller number of rye (Muntzing, 1963). Regression analysis showed that the number of Bs had not affected any plant characteristic (Table 9).

Plant species possessing B chromosomes, in general, show no effects of the B chromosomes on their phenotypes (Jones, 1975). In this experiment it is concluded that B chromosomes in Anthurium warocqueanum had no distinguishable influence on leaf length, leaf width, increase in stem length, or the first flowering date.

TABLE 8. -- Phenotypic effects of B chromosomes in Anthurium warocqueanum

| Character | Date of measurement Time interval or Days to first flower | Number of B chromosomes | | | | | | | | |
|--------------|---|-------------------------|-------------|-------|-------|-------|-------|-------|-------|-------|
| | | 0(1)* | 1(7) | 2(36) | 3(26) | 4(18) | 5(5) | 6(1) | | |
| Leaf length | Date of measurement Aug. 4, 1978 | \bar{x} | 34.00 | 28.04 | 29.24 | 30.42 | 27.48 | 29.74 | 28.20 | |
| | | S \bar{x} | | 1.596 | 0.757 | 0.793 | 1.099 | 2.249 | | |
| | Feb. 6, 1979 | \bar{x} | 37.60 | 34.17 | 36.37 | 36.92 | 35.33 | 37.92 | 37.50 | |
| | | S \bar{x} | | 1.076 | 0.834 | 0.801 | 0.853 | 2.499 | | |
| | Aug. 9, 1979 | \bar{x} | 36.70 | 39.51 | 38.56 | 39.65 | 38.72 | 40.54 | 37.20 | |
| | | S \bar{x} | | 1.714 | 0.797 | 0.705 | 0.892 | 2.056 | | |
| | Leaf width | Aug. 4, 1978 | \bar{x} | 11.40 | 8.49 | 9.04 | 9.33 | 8.41 | 8.60 | 8.00 |
| | | | S \bar{x} | | 0.537 | 0.244 | 0.280 | 0.331 | 0.636 | |
| | | Feb. 6, 1979 | \bar{x} | 12.30 | 10.86 | 11.46 | 11.70 | 10.91 | 11.54 | 10.50 |
| S \bar{x} | | | | 0.530 | 0.277 | 0.298 | 0.312 | 0.788 | | |
| Aug. 9, 1979 | | \bar{x} | 12.80 | 13.40 | 13.28 | 13.36 | 13.39 | 12.90 | 11.70 | |
| | | S \bar{x} | | 0.587 | 0.289 | 0.313 | 0.453 | 0.995 | | |

* Number of offspring observed are shown in parenthesis.

TABLE 8. -- (Continued) Phenotypic effects of B chromosomes in Anthurium warocqueanum

| Character | Date of measurement, Time interval or Days to first flower | | Number of B chromosomes | | | | | | |
|-------------------------|--|-------------|-------------------------|-------|-------|--------|--------|-------|--------|
| | | | 0(1)* | 1(7) | 2(36) | 3(26) | 4(18) | 5(5) | 6(1) |
| Increase in stem length | Time interval | | | | | | | | |
| | Aug. 15, 1978 | \bar{x} | 9.30 | 10.27 | 8.84 | 8.70 | 7.06 | 8.48 | 12.00 |
| | - Feb. 6, 1979 | S \bar{x} | | 1.038 | 0.409 | 0.485 | 0.823 | 1.206 | |
| | Feb. 6, 1979 | \bar{x} | 4.70 | 9.33 | 7.21 | 7.28 | 7.89 | 10.24 | 9.40 |
| | - Aug. 9, 1979 | S \bar{x} | | 1.220 | 0.694 | 0.626 | 0.579 | 2.022 | |
| | Aug. 15, 1978 | \bar{x} | 14.00 | 19.60 | 16.04 | 15.98 | 14.95 | 18.72 | 21.40 |
| | - Aug. 9 1979 | S \bar{x} | | 2.122 | 0.859 | 1.024 | 1.148 | 2.795 | |
| Days to flower | Days from germination to first flower | \bar{x} | 897.0 | 990.4 | 978.6 | 1003.8 | 1002.2 | 952.0 | 1069.0 |
| | | S \bar{x} | | 21.60 | 12.92 | 23.24 | 21.05 | 21.68 | |

* Number of offspring observed are shown in parenthesis.

TABLE 9. -- Regression analysis of the relationship between B chromosomes and plant characters of Anthurium warocqueanum

| Character | Date of measurement, Time interval or Days to first flower | Statistical values | | | | |
|-------------------------|--|--------------------|--------|-------|--------|---------|
| | | r | b | Sb | t | p |
| Leaf length | Date of measurement | | | | | |
| | Aug. 4, 1978 | 0.081 | 0.373 | 0.478 | 0.780 | 0.437ns |
| | Feb. 6, 1979 | 0.173 | 0.847 | 0.500 | 1.694 | 0.094ns |
| | Aug. 9, 1979 | 0.140 | 0.699 | 0.515 | 1.357 | 0.178ns |
| Leaf width | Date of measurement | | | | | |
| | Aug. 4, 1978 | -0.008 | -0.012 | 0.155 | -0.080 | 0.936ns |
| | Feb. 6, 1979 | 0.084 | 0.138 | 0.171 | 0.806 | 0.422ns |
| | Aug. 9, 1979 | 0.093 | 0.173 | 0.193 | 0.895 | 0.373ns |
| Increase in stem length | Time interval | | | | | |
| | Aug. 15, 1978 - Feb. 6, 1979 | -0.127 | -0.323 | 0.264 | -1.223 | 0.224ns |
| | Feb. 6, 1979 - Aug. 9, 1979 | 0.143 | 0.460 | 0.332 | 1.382 | 0.170ns |
| | Aug. 15, 1978 - Aug. 9, 1979 | 0.004 | 0.017 | 0.498 | 0.033 | 0.974ns |
| Days to flower | Days from germination to first flower | 0.200 | 22.61 | 11.55 | 1.958 | 0.053ns |

ns indicates that values are not significant at the p=0.05 level.

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