NUCLEOLAR AND CELL VOLUMES IN A POLYPLOID SERIES OF THE MUSAE

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(With Two Text-figures)

I. Introduction

The relationship between chromosome number and size of an organism does not appear to be subject to any inviolable law, but in general there is some indication that increase in chromosome number is accompanied by increase in size. This relationship is usual in new polyploid series, but in old-established ones such correlation is much less marked except for certain tissues such as sex cells. Darlington (1937) discusses this point and quotes a number of figures from a variety of materials including *Funaria hygrometrica*, *Crepis capillaris*, *Raphanus-Brassica* hybrids and *Drosophila* eye facets. In all these cases the correlation between chromosome number and cell volume is roughly 1 : 1, but in the vast majority of established polyploids there is little or no indication of any relationship. Thrombetta (1942) lists a number of cases where cell size is a function of its nuclear mass, but also points out that established polyploids are little different from diploids in cell or tissue size.

According to Gates (1942) the relationship between chromosome number aud nucleolar volume is similarly variable. For instance, the nucleolar volume in tetraploid wheat is roughly two-thirds of that in hexaploids, but between a diploid and autotriploid rice there was no significant difference.

The present investigation has been carried out primarily to determine whether or not there is any relationship between the degree of polyploidy and cell and nucleolar size in the Musae. At the same time counts of chromocentres have also been made.

II. Materials and methods

The materials used were diploid, triploid and tetraploid families of Musae. While the series is not an autopolyploid one, the tetraploids used were offspring of the triploid × diploid. Cell volumes and nucleolar volumes as well as chromocentre numbers were obtained from pollen mother cells at zygotene. In addition, pollen-grain volumes were calculated from figures already in the press (Wilson, 1946 *a*, *b* and *c*).

All measurements were made with a micrometer scale mounted in a 20× ocular on material fixed in 3 : 1 alcohol-acetic acid and stained in aceto-carmine.

III. Observations

1. *Cell volumes.* The pollen mother cells of the Musae are more or less ovoid in shape. Relative volumes have therefore been obtained by cubing the sum of the length and the greatest width divided by two. The relevant figures are given in Table 1 and have been plotted in Fig. 1. It is clear from these data that the cell volume increases with increase in chromosome number, that the relationship is nearly a straight line one and that the ratio of $2x : 3x : 4x$ is very nearly 1 : 2 : 3. That is, doubling the chromosome number about triples the cell volume.

Table 2 gives an abstract of pollen-grain measurements for diploid, triploid and tetraploid families taken from figures already published (Wilson, 1946 *a*, *b* and *c*). Again the relationship between size and chromosome content is a direct one approaching a straight line. The ratio of $2x : 3x : 4x$ is, however, more nearly 2 : 3 : 4; i.e. a 1 : 1 correlation.

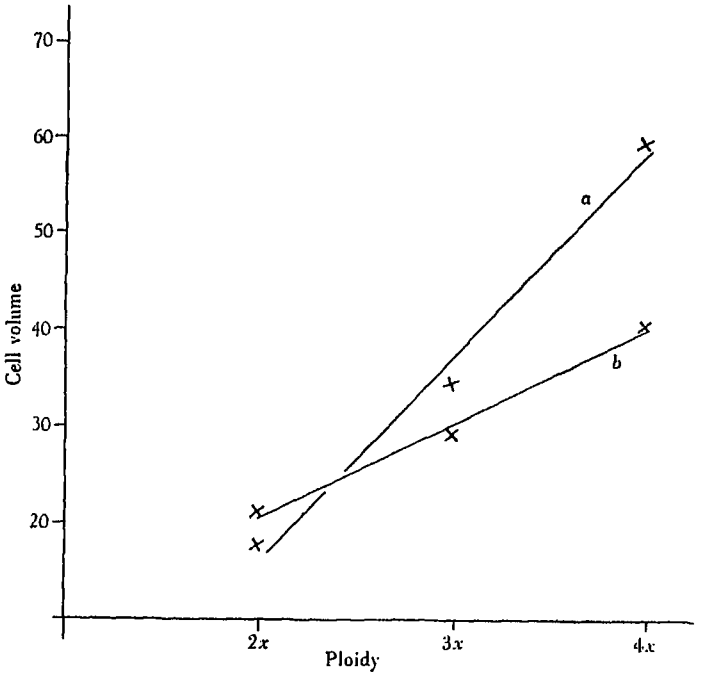

Fig. 1. Showing change in cell volume with increase in ploidy: (*a*) pollen mother cells, (*b*) pollen grains.

Table 1. *Relative volumes of prophase cells in diploid, triploid and tetraploid Musae*

Variety	No. measured	Chromosome no.	Mean (Length + Width)/2	Standard error	(L. + W.)³/2
Pisang Lilan	100	$2n = 22$	58·0	0·39	$19·5 \times 10^4$
B 7	100	$2n = 22$	54·2	0·31	$15·9 \times 10^4$
Total	200		112·2		
Mean			56·1		$17·6 \times 10^4$
Gros Michel	100	$2n = 33$	70·3	0·35	$34·7 \times 10^4$
Gros Michel × Pisang Lilan	100	$2n = 44$	84·4	0·58	$64·1 \times 10^4$
Gros Michel × B 7	100	$2n = 44$	83·7	0·54	$58·6 \times 10^4$
Total	200		168·1		
Mean			84·1		$59·5 \times 10^4$

Table 2. *Relative volumes of pollen grains*

Ploidy	No. varieties	Mean diam.	(Mean diam.)³
$2x$	18	59·0	$20·9 \times 10^4$
$3x$	6	66·3	$29·1 \times 10^4$
$4x$	20	73·9	$40·4 \times 10^4$

2. *Nucleolar volume.* The nucleolus in the Musae is a relatively large (about one-fifth to one-fourth the diameter of the resting nucleus), deeply staining body in both somatic and meiotic resting stage and prophase. A single nucleolus is characteristic of all degrees of ploidy studied; i.e. diploid to heptaploid somatic tissues and diploid to tetraploid meiotic prophases. It is, therefore, clear that there is no correlation between nucleolar

and chromosome numbers. There is, however, a definite increase in nucleolar size with increase in degree of ploidy (Table 3 and Fig. 2). The relationship appears to be almost identical with that between meiotic prophase cell volume and chromosome number; i.e. a three-fold increase in volume associated with a doubling of the chromosome number.

Table 3. *Relative nucleolar volumes in diploid, triploid and tetraploid Musae*

Variety	Chromosome no.	Mean diam. of nucleolus	Standard error	(Mean diam.)^3
Musa rubra (?)	$2n=22$	14·6	0·14	$31{\cdot}1\times10^2$
Zebrina 'A'	$2n=22$	14·7	0·15	$31{\cdot}8\times10^2$
Pisang Lilan	$2n=22$	14·0	0·14	$27{\cdot}4\times10^2$
B 7	$2n=22$	16·0	0·08	$41{\cdot}0\times10^2$
Total		59·3		$131{\cdot}3\times10^2$
Mean		14·8		$32{\cdot}8\times10^2$
Gros Michel	$2n=33$	18·0	0·11	$58{\cdot}3\times10^2$
Gros Michel × Pisang Lilan	$2n=44$	20·2	0·13	$82{\cdot}4\times10^2$
Gros Michel × B 7	$2n=44$	21·3	0·14	$96{\cdot}6\times10^2$
Total		41·5		$179{\cdot}0\times10^2$
Mean		20·8		$89{\cdot}5\times10^2$

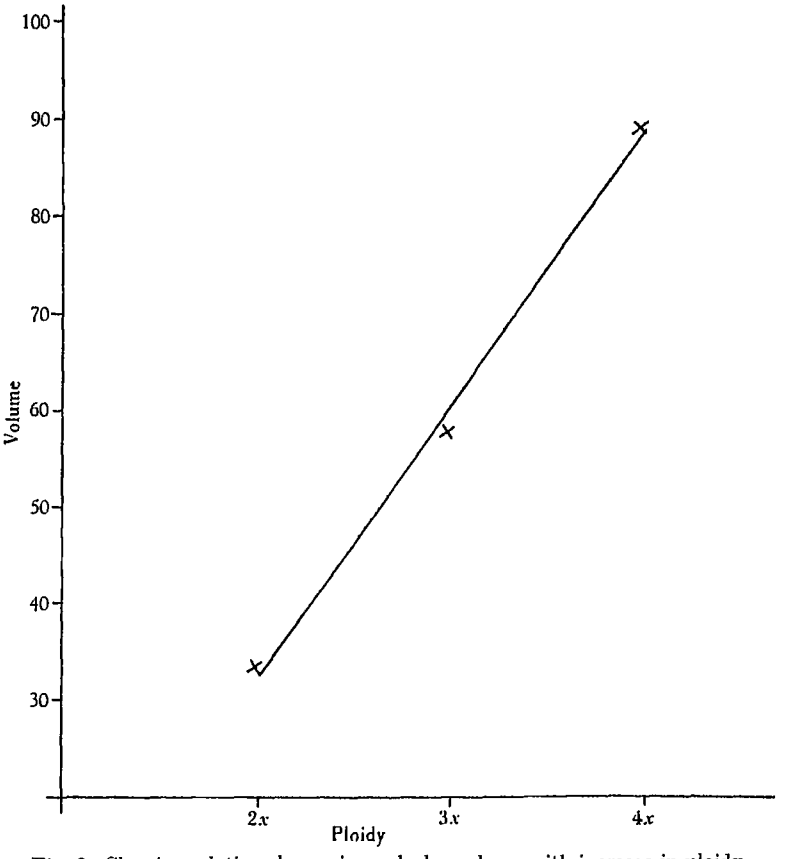

Fig. 2. Showing relative change in nucleolar volume with increase in ploidy.

3. *Chromocentres.* Resting stage and early prophase cells of many plants exhibit a number of nucleolar-like extra chromosomal bodies which have variously been considered to be 'prochromosomes', heteropycnotic regions and simply extra-chromosomal material of undefined utility. Darlington & LaCour (1938) suggest that these bodies represent

those regions capable of showing differential reactivity to cold treatment, but Wilson & Boothroyd (1941) found no indication of correlation between the number of chromocentres and the number of differential regions in *Trillium*. At zygotene in diploid, triploid and tetraploid bananas variability was found to be exceedingly high, and no correlation between the degree of ploidy and chromocentre number was indicated (Table 4). Admittedly two of the diploids showed relatively low average numbers, but a third was fully as high as the triploids or tetraploids which were themselves not significantly different. If, therefore, any correlation exists it is completely masked by other factors.

Table 4. *Number of chromocentres in diploid, triploid and tetraploid Musae*

Variety	No. counted	Mean	Standard error
Musa rubra (?)	100	23·1	0·40
Zebrina 'A'	100	7·2	0·19
Pisang Lilan	200	7·3	0·12
B 7	100	33·8	0·51
Gros Michel	200	33·1	0·39
Gros Michel × Pisang Lilan	200	20·6	0·15
Gros Michel × B 7	100	38·0	0·59

IV. DISCUSSION

Although the diploid and triploid bananas used in the present investigation are old-established varieties, they appear to have retained what Darlington (1937) considers to be the almost inevitable initial size difference. The tetraploids, though of recent origin, actually consist of the triploid complex plus a set of chromosomes from the diploid. It is, therefore, difficult to prophesy what would be expected of the cell and nucleolar volumes. It would not be unreasonable to expect that the tetraploid would be the sum of the triploid and roughly half the diploid volumes. This is more or less true of the pollen grains, but pollen mother cells and nucleoli are more nearly equal to triploid plus diploid figures. The fact that cell and nucleolar volumes increase faster than chromosome number suggests that factors other than ploidy are involved. It may be relevant that in both tetraploid and hexaploid wheats it was found that the total nucleolar volume decreased with increase in the number of nucleoli (Gates, 1942).

In general, then, cell and nucleolar size in the banana appears to be a function of chromosome number plus in some cases an unknown additional factor or factors. Whether or not this relationship is continued by the higher polyploids has not yet been investigated, although there is little doubt that the somatic cells of hexaploids are somewhat larger than the tetraploids.

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