THE RELATIONSHIP OF MUTATION RATE PER ROENTGEN TO
DNA CONTENT PER CHROMOSOME AND TO
INTERPHASE CHROMOSOME VOLUME

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LOCALIZED phenotypic changes in petal color following X-irradiation and
acute or chronic gamma irradiation have been reported for several species of
higher plants (IBA, MATSUBARA, INOKOSHI, OKA and MESHIKU 1964; MATSU-
bara, IBA, OKA and MESHIKU 1964, MOES 1966; GUPTA and SAMATA 1963,
1964; RICHTER and SINGLETON 1955; SAGAWA and MEHLQUIST 1957; NEZU
1963b; MESHIKU, OKA, MATSUBARA and IBA 1963; MESHIKU, OKA, IBA,
MATSUBARA and INOKOSHI 1963). Mutation rates for individual loci controlling
flower color have been published for Antirrhinum majus (CUANY, SPARROW and
POND 1958), Impatiens balsamina (ALSTON and SPARROW 1962), Petunia hy-
brida, Tradescantia (clone 02), Lilium testaceum (SPARROW, CUANY, MIKSCHE
and SCHAIRER 1961), and Tulipa (NEZU 1963a). The possibility that mutation
rate per roentgen (CUANY, SPARROW and JAHN 1958; CUANY, SPARROW and POND
1958; SPARROW, CUANY, MIKSCHE and SCHAIRER 1961) or frequency of chro-
mosome deletion per nucleus per roentgen (SPARROW and EVANS 1961) might be
related to certain nuclear parameters was recognized several years ago, and some
of the present data were reported in preliminary form in 1962 (SHAVER and
SPARROW 1962). Further experiments confirming the relationship between chro-
mosome size and induced somatic mutation rate are reported here (see also
BAETCKE, SPARROW, SHAVER and POND 1967).

It has been shown previously that plant radiosensitivity as measured by leth-
ality, growth inhibition, etc. also depends partially on DNA content per chromo-
some (SPARROW and MIKSCHE 1961; SPARROW, SPARROW, THOMPSON and
SCHAIRER 1965; BAETCKE, SPARROW, NAUMAN and SCHWEMMER 1967). It there-
fore seemed appropriate to test whether mutation rate also might be at least partly
dependent on DNA content per cell or per chromosome. The data presented below
show that such a relationship does exist.

MATERIALS AND METHODS

Five species of plants were selected to represent a wide range in chromosome volume. In de-
creasing order of chromosome size they were Tradescantia (clone 02), Tulipa HV golden harvest,
Clematis jackmanii, Gladiolus HV mansoer, and Tropaeolum majus. Each of these species was of
clonal origin including Tropaeolum majus which was hybridized to achieve heterozygosity and

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Figure 1.—Somatic mutations in the petal epidermal cells of (A) Tradescantia (clone 02), (B) Tulipa HV golden harvest, (C) Clematis jackmanii, (D) Tropaeolum majus, and (E) Gladiolus HV mansoer. All magnifications X225.
MUTATION RATE AND CHROMOSOMAL DNA CONTENT

thereafter propagated by cuttings. Average nuclear diameter was measured at interphase in the epidermis of flower petal primordia from at least two plants per species. The slides used for these measurements were prepared in the manner described previously (Sparrow and Mickisch 1961). Nuclear volumes were determined for each species from an average of two diameters per cell and at least 20 cells per tissue. Division of this value by the chromosome number gave the average volume occupied by a chromosome at interphase (ICV).

Strains heterozygous for genes controlling flower color were found or produced for four of the five species used. It was considered that mutation, or the loss by deletion of a chromosome segment containing the dominant allele, would result in the production by further cell division of a lineage of cells showing the recessive color phenotype. Since the petal epidermis is a highly pigmented, single-cell layer overlying a relatively thick, differently colored mesophyll region, mutant areas are well defined and amenable to scoring in the forms studied (see Figure 1). Several other species, however, had to be excluded from the study because of poor definition of the borders of mutant areas. Mutations in the species studied were marked by a change in color from blue to pink (Tradescantia), dark purple to pale purple (Clematis), yellow to red (Tulipa), reddish orange to yellow (Tropaeolum), and red to colorless (Gladiolus).

The pertinent genetic situation in the Clematis variety used could not be well established. However, this species is actually of hybrid origin. Since mutant sectors appeared to be of intermediate pale purple color, as though due to incomplete dominance of a remaining purple allele, it was assumed that the variety was homozygous for the dark purple color of the petals, and that mutant sectors resulted from the deletion of either of the two dominant alleles. According to Prof. G. A. L. Mehlquist (personal communication) Clematis jackmanii breeds true for the dark purple color. Therefore, for comparison with the other four species, which were all heterozygous, mutation rates per locus given for this form are one-half of those actually observed.

For the induction of mutations, overnight exposures were 16 hours in duration. Irradiations were from a 3800-Ci 60Co outdoor source or from a 15-Ci 60Co greenhouse source. Since the different exposures for any one experiment were all done simultaneously, exposure rates varied. Actual rates per hour can be obtained by dividing the total exposure by 16.

Mutation rates were calculated in the following manner: for each species, the total number of antecedent petal cells present at the time of irradiation was estimated by dividing the total number of cells per unit area scored (1 cm²) in the mature flower petal by the average number of cells per mutant spot. This method is based on the assumption that mutant cells divide at the same rate as nonmutant cells. This assumption has been shown to be valid in the case of Antirrhinum (Sparrow, Cuany, Mickisch and Schairer 1961) but may not be the situation in other species, as indicated by studies of Tradescantia (clone 02) (Mericke and Mericke 1967). However, the error, if any, introduced by the change in rate of cell division would probably be a minor one. The number of epidermal cells present per cm² at the time of scoring was 7,653 for Tradescantia; 28,570 for Tulipa; 72,268 for Clematis; 199,135 for Tropaeolum; and 52,706 for Gladiolus. Presuming that each spot is the consequence of a single mutation in a single cell at the time of irradiation, the mutation rate can be calculated, i.e. the number of mutant cells induced per total number of cells present at the time of irradiation.

In order to compare the mutation rates among the five species, it was desirable to irradiate all species at similar stages of flower organogenesis. This was accomplished empirically by selecting an appropriate interval between irradiation and scoring such that approximately three cell divisions occurred between irradiation and scoring the mature flower petals (that is, when the induced mutant sectors contained an average of eight cells per sector). Scoring was done with the aid of a high-power stereoscope.

For DNA determinations, 40 root tips were collected from each species studied and ground up in a tissue grinder in cold methanol. Root tips were used because the presence of contaminating substances in flower petals interferes with the diphenylamine reaction (Burton 1956) employed for the estimation of DNA content. The DNA was extracted according to a modified Schmidt-Tannhauser procedure as reported by Mickisch (1965). The standard used was salmon sperm DNA (Nutritional Biochemical Corp.). Cell counts were made by the chromic acid maceration technique of Brown and Rickless (1949).
TABLE 1

Chromosome numbers (2n), nuclear volumes (NV), interphase chromosome volumes (ICV), DNA per cell, DNA per chromosome, and mutation rates per roentgen (MR/R) for 5 species of higher plants

<table>
<thead>
<tr>
<th>Plant</th>
<th>2n*</th>
<th>NV (petal) ($\mu^3$)</th>
<th>ICV (petal) ($\mu^3$)</th>
<th>DNA/Cell (root) (pg)</th>
<th>DNA/Chrom. (root) (pg)</th>
<th>MR; R</th>
<th>(x10^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tradescantia</td>
<td>12</td>
<td>527 ± 23.56</td>
<td>43.9 ± 1.96</td>
<td>59 ± 5</td>
<td>4.9</td>
<td>149.2</td>
<td>(106.8-178.6)</td>
</tr>
<tr>
<td>(clone 02)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tulipa HV</td>
<td>24</td>
<td>627 ± 30.25</td>
<td>26.1 ± 1.26</td>
<td>72 ± 8</td>
<td>3.0</td>
<td>11.4</td>
<td>(4.8-19.9)</td>
</tr>
<tr>
<td>golden harvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clematis jackmanii</td>
<td>16</td>
<td>353 ± 14.66</td>
<td>22.0 ± 0.92</td>
<td>22 ± 1</td>
<td>1.4</td>
<td>9.1‡</td>
<td>(6.4-12.7)</td>
</tr>
<tr>
<td>Tropaeolum majus</td>
<td>28</td>
<td>102 ± 3.11</td>
<td>3.6 ± 0.11</td>
<td>11 ± 1</td>
<td>0.4</td>
<td>3.9</td>
<td>(3.0-6.1)</td>
</tr>
<tr>
<td>Gladiolus HV</td>
<td>60</td>
<td>217 ± 20.26</td>
<td>3.6 ± 0.34</td>
<td>6 ± 1</td>
<td>0.1</td>
<td>1.8</td>
<td>(1.3-2.7)</td>
</tr>
<tr>
<td>mansoer (4x)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Somatic chromosome number.
‡ MR = mutation rate per cell per locus. The ranges in mutation rates are given in parentheses.
† One-half the observed rate (see MATERIALS AND METHODS).

RESULTS

The nuclear volumes in the young petals at the time of irradiation ranged from 627 $\mu^3$ in Tulipa to only 102 $\mu^3$ in Tropaeolum, and the range in interphase chromosome volumes (ICV) was from 43.9 $\mu^3$ to 3.6 $\mu^3$ (Table 1). Differences in the calculated ICVs appear to be roughly correlated with gross size differences of condensed metaphase chromosomes prepared from root tips (Figure 2). Since other plant species are known which have chromosomes smaller or larger than those shown in Figure 2, it would appear feasible to extend the study to an even greater range of size and presumably of induced mutation rate.

The number of spontaneously occurring mutant cells per 10⁶ cells and the total number following irradiation of the five species are given in Table 2. When the spontaneous rate is subtracted from the latter values, the number of radiation-induced mutant cells per 10⁶ cells ranged from a low of 200 at 25 R for Tulipa HV golden harvest (1962) to a high of 42,477 at 300 R for Tradescantia (clone 02). It is believed that the relatively large error term associated with the mutation rates at some of the exposures for a number of the species is far outweighed by the overall differences in mutation rates among the five species studied.

Figure 3 is a log-log plot of the number of mutant cells per 10⁶ cells against various exposures for the five species included in the study. All species except Clematis jackmanii (dashed line) appear to exhibit a linear response to an increase in exposure. The reason for the different response of Clematis in comparison with the other four species is not known although its homozygous nature makes it different from other species, and perhaps the scoring of the intermediate color
change was less efficient (see MATERIALS AND METHODS).

In Figure 3 the slopes of the regression lines are 0.8591 (Tradescantia), 1.4216 and 1.3232 (Tulipa, 1962 and 1965, respectively), 1.2927 (Tropaeolum), and 1.2504 (Gladiolus). A straight-line relationship plotted for Clematis, although possibly less meaningful than the others, would give a slope of 0.9218. The finding of only slight differences among the slopes shows that the response of the various species to increasing exposure is approximately the same. An arithmetic average mutation rate per roentgen was determined for each species by dividing the number of mutant cells produced at each exposure by the exposure and averaging the resulting values. The average mutation rate for Tulipa used in comparisons with the various nuclear parameters is an overall average from the 1962 and 1965 experiments.

Table 1 lists the five species studied and the nuclear volume (NV), interphase
### TABLE 2

The number of mutant cells (per 10⁶ cells) produced at various exposures following acute gamma irradiation*

<table>
<thead>
<tr>
<th>Exposure (r)</th>
<th>Tradescantia</th>
<th>Clematis</th>
<th>Tulipa (1962)</th>
<th>Tulipa (1965)</th>
<th>Tropaeolum</th>
<th>Gladiolus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2700 ± 350(28)</td>
<td>188 ± 20(24)</td>
<td>110 ± 10(3)</td>
<td>78 ± 40(4)</td>
<td>15 ± 3(7)</td>
<td>58 ± 5(22)</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>10646 ± 600(32)</td>
<td>825 ± 120(14)</td>
<td>520 ± 30(4)</td>
<td>380 ± 30(4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>20558 ± 910(21)</td>
<td>890 ± 90(12)</td>
<td>1270 ± 130(7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>28192 ± 1350(25)</td>
<td>2430 ± 140(9)</td>
<td></td>
<td>470 ± 140(8)</td>
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<tr>
<td>200</td>
<td>24062 ± 470(17)</td>
<td>1460 ± 140(6)</td>
<td>3700 ± 250(11)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>37567 ± 1540(18)</td>
<td>4570 ± 270(13)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>45177 ± 1970(8)</td>
<td>2640 ± 580(6)</td>
<td>6090 ± 390(19)</td>
<td></td>
<td>1160 ± 110(9)</td>
<td></td>
</tr>
<tr>
<td>375</td>
<td></td>
<td></td>
<td></td>
<td>3099 ± 540(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>400</td>
<td></td>
<td>4660 ± 760(4)</td>
<td></td>
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<tr>
<td>450</td>
<td></td>
<td></td>
<td></td>
<td>1830 ± 200(10)</td>
<td></td>
<td>735 ± 67(16)</td>
</tr>
<tr>
<td>500</td>
<td></td>
<td></td>
<td></td>
<td>5295 (1)‡</td>
<td></td>
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<tr>
<td>600</td>
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<td></td>
<td>3670 ± 50(9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>750</td>
<td></td>
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<td></td>
<td>7881 ± 620(3)</td>
<td></td>
<td></td>
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<tr>
<td>1000</td>
<td></td>
<td></td>
<td></td>
<td>1390 ± 110(13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td>3391 ± 160(8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td></td>
<td></td>
<td></td>
<td>7033 ± 420(10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6000</td>
<td></td>
<td></td>
<td></td>
<td>16393 ± 600(6)</td>
<td></td>
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</tr>
</tbody>
</table>

* The number of flowers scored at a given exposure is given in parentheses.
‡ One-half the observed number (see MATERIALS AND METHODS).
‡‡ No standard error is given since only one flower scored at this exposure.
chromosome volume (ICV), and average mutation rate per roentgen for each species. The ranges in mutation rates per roentgen are shown in parentheses. Figure 4, a semi-log plot of mutation rate per roentgen against ICV, shows that there is a linear relationship between the two variables: as interphase chromosome volume increases, mutation rate increases. From a plot of mutation rate against nuclear volume (Figure 5) it can only be concluded that mutation rate is not dependent on nuclear volume.

It has been demonstrated that nuclear volumes and chromosome volumes are directly related to DNA content per cell and DNA content per chromosome, respectively (Sparrow, Sparrow, Thompson and Schairer 1965; Sparrow and Miikshe 1961; Baetcke, Sparrow, Nauman and Schwemmer 1967). However, since the present study shows that mutation rate is directly related to ICV (Figure 4) and not to nuclear volume (Figure 5), it was expected that mutation rate would be dependent upon the DNA content per chromosome and not on DNA content per cell (i.e., per nucleus).

Figures 6 and 7 are semi-log plots based on the data from Table 1. Figure 6
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**Figure 4.**—Semi-log plot of mutation rate per roentgen versus interphase chromosome volume (ICV).

**Figure 5.**—Semi-log plot of mutation rate per roentgen versus nuclear volume.
Figure 6.—Semi-log plot of mutation rate per roentgen versus DNA content per chromosome.

Figure 7.—Semi-log plot of mutation rate per roentgen versus DNA content per cell.
shows that mutation rate increases linearly with an increase in DNA content per chromosome. A plot of mutation rate against DNA content per cell (Figure 7) shows that the correlation between the two variables is less than that shown in Figure 6.

DISCUSSION

\(D_{37}\) and \(LD_{50}\) values have been shown previously to be related in an inverse manner to interphase chromosome volume (Sparrow, Sparrow, Thompson and Schairer 1965; Baetcke, Sparrow, Shaver and Pond 1967; Ichikawa and Sparrow 1967; Sparrow, Underbrink and Sparrow 1967). In addition, Smith and Rossi (1966) have shown that the frequency of mutation or loss of the \(Y_{g2}\) gene in maize is higher in leaf 4 than in leaf 5 and that the difference in mutation rates can be related to the larger nuclear and chromosome volumes of leaf 4.

The results reported in the current study indicate that mutation rate per roentgen is also related to ICV. As ICV increases, mutation rate per roentgen also increases in almost a direct manner. It therefore appears that ICV can be utilized as an index of the mutation rate to be expected for a given species. However, it will be noted from Table 1 that Tradescantia (clone 02) has a mutation rate eleven times greater than Tulipa and yet there is less than a two-fold difference in the ICVs of these two plants. The interpretation of these data leads to the conclusion that with the same amount of radiation, the locus controlling the blue flower color in Tradescantia is lost or mutates much more frequently than the Tulipa flower color locus or, for that matter, the loci controlling pigment production in the other species included in the study.

Chromosome breakage (locus loss) is suggested as the likely basis of the relationship observed in this study, since it has been shown that deletions per roentgen increase with increasing chromosome size (Sparrow and Evans 1961) and that an increase in the frequency of chromosome breaks is accompanied by a corresponding increase in somatic mutation rate in higher plants (Sparrow, Cuany, Miksche and Schairer 1961).

Comparable results have been reported elsewhere. Fabergé (1957) reported a four-fold difference in the rate of loss of loci located at different points on the same chromosome in \textit{Zea mays}. The same principle is presumed to hold in our experiments where the flower color loci can be considered to be located further from the centromere in species with larger chromosomes. Thus, the greater is the distance between the centromere and the flower color locus the greater the probability of a break or breaks (leading to deletion). However, there is no \textit{a priori} reason why the flower color loci in distantly related plants should occupy the same relative position with respect to the centromere and hence chromosome size or length would not always be correlated with specific locus mutation rate. On the other hand, total mutation rate per chromosome for all loci would be expected in all cases to be related to chromosome size or to DNA per chromosome.

The possible presence of the modifying factors seems less significant when all the data of this paper are considered. The slope of the regression line for the log-log plot of mutation rate against ICV is 1.2 (\(\log Y = -0.3358 + 1.2178 \log X;\))
correlation coefficient 0.8580) and is not significantly different from -1. It can be concluded from these results that there is nearly a direct, positive correlation between ICV and mutation rate per roentgen for the five species studied despite the possible presence of other factors which would indirectly influence the response of the chromosomes to ionizing radiation.

Chromosome volumes were calculated from petal epidermal cells whereas the DNA determinations were made from root tips. Recent studies (BAETCKE, SPARROW, NAUMAN and SCHWEMMER 1967; BAETCKE, unpublished data) show that there is very little variation in nuclear size from tissue to tissue. Also SWIFT (1950) found similar DNA values in petal and root-tip nuclei based on cytophotometric measurement of *Tradescantia paludosa* tissues. Hence, it seems valid to make comparisons of mutation rate in petal cells with the chromosomal DNA content of root-tip cells. Our results and those of RUDKIN (1965) showing a close correlation between mutation rate per roentgen and DNA content per chromosome (or per locus) support the generally accepted concept that the actual target for biological effect of ionizing radiation is DNA. EPSTEIN (1953), using inactivation data for 10 viruses, first implicated the nucleic acids as being the determinants of radiosensitivity, and his proposal was strengthened later by the work of TERZI (1961) and KAPLAN and Moses (1964). Recently, HUTCHINSON (1966) has reviewed the evidence which points toward DNA as the most probable sensitive cellular target for lethality or loss of reproductive ability. He points out that although DNA has been related to radiation injury, it is not clear in what manner DNA is initially affected, but it appears that chromosome breakage leading to deletions and/or alterations in base pairs resulting in point mutations are likely explanations. However, STADLER (1954) has proposed that in higher plants point mutations may not be involved in the genetic effects observed following exposure to ionizing radiation.

The results showing that a correlation of mutation rate with DNA content is better on a per chromosome basis than on a per cell basis are consistent with previous findings obtained in our laboratory involving a study of the relationship between DNA content and LD_{50} values (BAETCKE, SPARROW, NAUMAN and SCHWEMMER 1967). For 10 species of higher plants DNA content per chromosome was found to be inversely related to LD_{50}, but a similar correlation was not found between DNA content per cell and LD_{50}. In the present study, the difference in the relationship of DNA content per chromosome and DNA content per cell to mutation rate is not as readily apparent. Nevertheless, a consideration of the combined data leads to the conclusion that DNA content per chromosome is a better index of mutation rate per roentgen. These results can be explained if the mutations observed were loss events or deletions. For a somatic mutation to occur, breakage and loss would occur in the chromosome region carrying the dominant allele. In contrast, if one were to determine the total number of mutations at all loci in a nucleus, then it would be expected that total mutation rate per cell would be related to DNA per cell or to nuclear volume.

Since DNA content per chromosome and interphase chromosome volume have each been shown to be related to mutation rate per roentgen and to LD_{50} or severe
growth inhibition (SPARROW, SPARROW, THOMPSON and SCHAIRER 1965; SPARROW and MIKSCHE 1961; BAETCKE, SPARROW, NAUMAN and SCHWEMMER 1967), it is reasonable to suppose that mutation rate per roentgen and LD$_{50}$ can be related to each other. Preliminary data indicate a linear relationship between mutation rate per roentgen and LD$_{50}$, but additional results are needed to determine the general validity of the correlation over a wider range of values. Such a correlation would be expected if radiation-induced deaths are the ultimate consequence of injury to the genetic system, which seems a logical proposition.

It should be pointed out that the relationship found between mutation rate per roentgen and the two nuclear parameters, ICV and DNA content per chromosome, was based on a study of higher plants. SPARROW, UNDERBRINK and SPARROW (1967) and UNDERBRINK, SPARROW and POND (1968) have shown that the relationship found between ICV or DNA content and D$_x$ in one group of organisms (radiotaxon) cannot be utilized to predict the response of other groups of organisms to ionizing radiation. For this reason, it is unlikely that the relationship found between mutation rate and ICV and between mutation rate and DNA content per chromosome for higher plants can serve as a basis for estimating mutation rates among organisms belonging to other radiotaxa. However, it seems not unlikely that the radiotaxon concept can be extended to mutation rate studies when sufficient data have been accumulated.

It is a pleasure to extend thanks to: MRS. ANNE F. ROGERS who obtained the nuclear volume data; MISS ALEXANDRA H. JAHN and MR. E. ERIC KLUG for their valuable assistance in scoring; MR. KEITH H. THOMPSON for his statistical advice; MR. ROBERT F. SMITH who is responsible for the excellent photomicrographs; and DR. ROBERT W. BRIGGS for his helpful suggestions regarding the manuscript.

SUMMARY

Mutation rates per roentgen based on the number of mutant cells which appeared on flower petals following acute irradiation with a $^{60}$Co source have been determined for five species of higher plants. The species studied were Tradescantia (clone 02), Tulipa HV golden harvest, Clematis juckmanii, Tropaeolum majus, and Gladiolus HV mansoer. The stocks used, except Clematis juckmanii, were heterozygous for flower color. Average mutation rates per roentgen were found to range from a low of 1.8 to a high of 149.2 mutant cells per $10^6$ irradiated cells (Gladiolus and Tradescantia, respectively). Interphase chromosome volumes (ICVs), determined by dividing the nuclear volume of a species by its chromosome number, extended from a low of 3.6 $\mu^3$ (Tropaeolum and Gladiolus) to 43.9 $\mu^3$ (Tradescantia). DNA content per chromosome was estimated for each species by chemical extraction procedures. The amount of DNA per chromosome was found to be the highest in Tradescantia (4.9 pg) and the lowest in Gladiolus (0.1 pg). When ICVs and DNA content per chromosome were compared with mutation rates per roentgen, it was found that an increase in mutation rate per roentgen was highly correlated with an increase in both ICV and DNA per chromosome. A similar relationship was not found when mutation rate per roentgen was compared with nuclear volume or DNA content per cell.
LITERATURE CITED


FABERGÉ, A. C., 1957 The possibility of forecasting the relative rate of induced loss for endosperm markers in maize. Genetics 42: 464–472.


