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NUCLEAR DNA AMOUNTS IN ANGIOSPERMS

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The number of angiosperm species for which nuclear DNA amount estimates have been made has nearly trebled since the last collected lists of such values were published, and therefore, publication of a more comprehensive list is overdue. This paper lists absolute nuclear DNA amounts for 753 angiosperm species. The data were assembled primarily for reference purposes, and so the species are listed in alphabetical order, as this was felt to be more helpful to cyto- and biochemists whom, it is anticipated, will be among its major users.

The paper also reviews aspects of the history, nomenclature, methods, accuracy and problems of nuclear DNA estimation in angiosperms. No attempt is made to reconsider those aspects of nuclear DNA estimation which have been fully revised previously, although the bibliography of such aspects is given. Instead, the paper is intended as a source of basic information regarding the terminology, practice and limitations of nuclear DNA estimation, especially by Feulgen microdensitometry, as currently practiced.

1. Introduction

Numerous studies have shown that the DNA content per genome is usually constant and therefore is characteristic for each species. However, considerable interspecific variation in DNA content per genome has been noted. Knowledge of such variation is useful for cyto-taxonomical and evolutionary studies (Rees & Walters 1965; Southern 1967; Price & Bachmann 1975). DNA content per genome has been shown to be closely correlated with the rates of somatic (Van't Hof & Sparrow 1963; Evans, Rees, Snell & Sun 1972) and meiotic (Bennett 1971, 1973) cell development, and with radiosensitivity (Sparrow & Miksche 1961; Underbrink, Sparrow & Pond 1968) and radiation-induced mutation rates (Sparrow, Baetcke, Shaver & Pond 1968; Abrahamson, Bender, Conger & Wolff 1973) in plants. Thus, given the nuclear DNA content, the duration of the mitotic cycle in root-tip cells, and of meiosis in pollen mother cells, the radiosensitivity and the forward mutation rate per locus per rad can often be predicted to a close approximation.

Nuclear DNA amounts of a small number of related or unrelated angiosperm species have been published in numerous papers so that locating an estimate for a given species, or finding out whether an estimate has been made, can be very time consuming. Several collected lists of DNA amounts in higher plants have already been published (Rees & Jones 1972; Sparrow, Price & Underbrink 1972; Bennett 1973). However, the number of angiosperm species for which nuclear DNA content has been estimated has more than doubled in the last three years, and therefore, it seemed worthwhile to assemble a more comprehensive list of species DNA amounts than was available hitherto. Previous lists were usually composed to test or illustrate various hypotheses concerning the consequences of variation in nuclear DNA content. However, the present list is assembled primarily for reference purposes. For this reason the species are presented not in the order in which they would occur in a flora, but in alphabetical order. This arrangement was felt to be more helpful to cyto- and biochemists, whom it is anticipated, will be the major users of this list.

2. Nomenclature of DNA amounts

(a) C-values

DNA amounts are often expressed as 'C' values. This term was first used by Swift (1950) in an attempt to avoid confusion with chromosome number. Thus, a diploid nucleus ($2n = 2x$) entering prophase, and a tetraploid nucleus ($2n = 4x$) in early interphase both contain the $4C$ DNA amount, although they contain different numbers of chromosomes. The letter C stands for 'constant', i.e. the amount of DNA that is characteristic of a particular genotype (H. Swift, private communication). The C-value (or $1C$ value) for any genotype is the DNA content of the unreplicated haploid chromosome complement.

Nuclear DNA content usually doubles at DNA synthesis phase (S-phase) of the cell cycle. Consequently the minimum and maximum C-values for nuclei at a single ploidy level normally differ in the ratio $1:2$, while the range of C-values increases in direct proportion to the ploidy level of the nucleus. Thus the normal ranges of C-values in haploid, diploid and triploid nuclei are $1-2C$, $2-4C$ and $3-6C$, respectively. C-values are estimated by using nuclei of known ploidy level which are known to have *either* not initiated S-phase, *or* to have completed it. For instance, $2C$ and $4C$ amounts have been frequently estimated in measurements of single mitotic nuclei in

meristems (usually root-tips) of diploid plants because, the DNA content of such nuclei is characteristically $4C$ at prophase and metaphase, and $2C$ at telophase. Similarly, the $1C$ value has often been estimated in measurements of individual nuclei in meiocytes at second telophase or young tetrads which characteristically contain unreplicated haploid chromosome complements.

(b) 'Per cell' values

DNA estimates are also frequently expressed as the mean content per cell. Sometimes a 'per cell' value corresponds to a known C-value. For instance, the mean DNA content per cell for a pure sample of meiocytes at first prophase of meiosis usually corresponds to the $4C$ value which these cells characteristically contain (Swift 1950; Bennett, Rao, Smith & Bayliss 1973). Clearly, however, the mean DNA content per cell does not bear a fixed relationship to any C-value, and may vary considerably depending upon many factors including the proportion of nuclei at different stages of the cell cycle, the ploidy levels of the nuclei sampled, and even the number of nuclei per cell. Thus, increasing the proportion of nuclei at G2 or of polyploid or multinucleate cells in a sample all increases the mean DNA content, and hence the mean C-value, per cell. In a meristem containing only diploid cells the mean DNA content per cell must lie between $2C$ and $4C$. In practice many tissues contain a proportion of polyploid cells. For instance, root-tips (the tissue most frequently used to estimate DNA per cell in plants) contain polyploid root-cap cells (Barlow 1975 b), and developing metaxylem (List 1963) with up to the $16C$ and $64C$, respectively, in individual nuclei of some species. Thus, the mean DNA content per cell may approach, and even exceed, the $4C$ value.

(c) Arbitrary units

The relative DNA contents of nuclei are often given in arbitrary units alone (see, for example Jones & Rees 1968). In intraspecific studies, relative nuclear DNA contents may be given in C-values. Here a biological yardstick, namely the DNA content of the unreplicated haploid chromosome number, arbitrarily defined as unity, is used. DNA contents of nuclei with a constant C-value in several species are often expressed either as a percentage of the DNA amount in one of the species measured (which is therefore given the arbitrary value of 100 units (see, for example, Chooi 1971), or relative to one species measured which is arbitrarily given the value unity (see, for example, Rothfels & Heimburger 1968). Here too, in either case, a biological yardstick is used, namely the $2C$ or $4C$ DNA content of a standard species. Alternatively in interspecific comparisons a non-biological arbitrary unit derived from the technique or the machine used to estimate DNA amounts has often been adopted. For instance, when DNA amount is estimated by densitometry, the results have often been given in arbitrary units such as, 'relative Feulgen absorption units' (see, for example, Miksche 1971).

Most data given in arbitrary units alone are not readily convertible into absolute units of DNA amount without further calibration experiments and this limits their usefulness.

(d) Absolute DNA amounts

Absolute DNA amounts may be expressed in several ways. *First,* they may be given in units of mass; usually either in picograms (pg) as in table 1 of the present work (n.b. 1 picogram = 10^{-12} g), or, in daltons as in McCarthy (1969) (n.b. 1 dalton = the mass of one hydrogen atom = 1.66×10^{-24} g). *Second,* DNA amounts may be given in molecular terms as a number of

nucleotide pairs, as in Sparrow *et al.* (1972). DNA amounts given in daltons or in nucleotide pairs are readily converted to picograms by means of the following formulae:

(i) 1 nucleotide pair = 660 daltons

(ii) 1 picogram = 0.965×10^9 nucleotide pairs (Straus 1971). (N.B. The relative molecular masses of the four nucleotides, adenine-, thymidine-, cytosine- and guanosine-5'-monophosphates are 347.25, 322.23, 322.22 and 363.25, respectively. Hence the mean molecular mass per nucleotide is about 339. The formation of a nucleotide pair involves the loss of a water molecule and so the mean molecular mass per nucleotide pair is about: $(339 \times 2) - 18 = 660$. Use of this conversion factor assumes that the DNA contains in a 1:1:1:1 ratio only the four nucleotides listed above. As both of these assumptions are known to be incorrect, use of the above formulae gives only a good approximation to the real DNA amount.)

3. METHODS FOR ESTIMATING DNA

(a) Chemical extraction

DNA amounts are usually estimated either chemically after extraction, or *in situ* by micro-photodensitometry. For chemical estimates the total DNA is extracted from a sample of cells and dissolved in a known volume of solvent. The concentration of DNA is estimated colori-metrically using various modifications of the diphenylamine reaction (Burton 1956, 1968), which produces a colour reaction whose intensity is proportional to the concentration of deoxyribose, and hence of DNA. Chemical analysis uses very large numbers of cells, the number present being estimated by sample counts with a haemocytometer (Brown & Rickless 1949), and the results are usually given as mean DNA content per cell. The results are calibrated in absolute units using a plot of colour intensity against known concentrations of DNA or deoxyribose. Alternatively, the concentration of extracted DNA has also been estimated by ultraviolet spectrophotometry with known concentrations of DNA as a standard (Sunderland & McLeish 1961). For further details of the chemical methods used for estimating DNA see Schmidt & Thannhauser (1945); Sunderland & McLeish (1961); Lyndon (1963) and Rothfels *et al.* (1966).

(b) Microdensitometry

Measurements of DNA amounts by microdensitometry usually use nuclei stained by the Feulgen method. This method, first described by Feulgen & Rössenbeck (1924) utilizes Schiff's reagent containing leuco-basic fuchsin which gives a purple coloration when it complexes with the aldehyde groups of DNA and RNA. As the result of usage in the literature it has become normal practice to describe organelles stained with Schiff's reagent as 'Feulgen-stained', and the whole technique as 'Feulgen microdensitometry'. Consequently, these terms will be used in the present work. Plant material is usually prepared for Feulgen microdensitometry using various modifications of the method for higher plants described by McLeish & Sunderland (1961), itself a modification of the method first described by Leuchtenberger (1958) for animal tissues. It is generally accepted that Feulgen-staining is specific for DNA (after removal of RNA by acid hydrolysis), and, subject to certain checks, that proportionality between stain density and DNA amount can be assumed. Consequently the light absorption of a nucleus so stained is a quantitative measure of the DNA present in it (McLeish & Sunderland 1961). Thus, the Feulgen-DNA complex is measured either using monochromatic light at the wavelength of the

maximum absorption for the complex (about 565 nm) and comparing each nucleus with an adjacent area of background cytoplasm, or using the two wavelength method (Patau 1952; Pollister, Swift & Rasch 1969). Early Feulgen-staining estimates were obtained by using a microscope with an attached spectrophotometer as a source of monochromatic light and a non-integrating densitometer for measuring the absorption. Later this was measured on integrating microdensitometers designed specifically for this purpose, first with prototype instruments (e.g. the 'Deeley box' named after its designer (Deeley 1955)), but later with production instruments such as the Barr & Stroud integrating microdensitometer type GN2, and, the Vickers M85/86 scanning microdensitometer.

For further details concerning the use of Feulgen microdensitometry see Ris & Mirsky (1949), Swift (1950, 1955), Vendreley & Vendreley (1956), Leuchtenberger (1958), and McLeish & Sunderland (1961).

Other DNA specific reactions have also occasionally been used to estimate nuclear DNA content in plants. For instance, the BAO (2,5-bis[4'aminiphenyl-(1')]1,3,4-oxidizole) fluorescence reaction of Ruch (Ruch & Rosslet 1970). By this method, DNA amount is estimated by micro-fluorometry.

Feulgen microdensitometry has been justified in terms of yielding appropriate readings in comparisons of diploid and polyploid series for chromatin of a particular species, consistent results between either plant or animal species, and from comparisons of identical preparations such as isolated nuclei (Ris & Mirsky 1949; McLeish & Sunderland 1961). On the basis of such evidence it has been concluded that Feulgen microdensitometry can give quantitative data of considerable accuracy (Swift 1950). However, various technical problems encountered in Feulgen microdensitometry have long been recognized and, therefore, the method should not be accepted indiscriminately as being quantitative. Swift (1955) stated that misuse of the method and the instruments has resulted in the appearance of a certain amount of conflicting data in the literature, and some natural scepticism as to the validity of microdensitometry as a quantitative method. Unfortunately this situation has not changed (Wallace, Sparkes & Maden 1972) and, consequently, it seemed worthwhile to outline in the following sections common sources of inaccurate or variable results. These sources are variable staining or measurement of stain, or intraspecific variation in nuclear DNA content.

(c) *Problems and errors in Feulgen densitometry*

As most of the data given in table 8 were obtained by Feulgen microdensitometry it seemed worth while listing some of the main errors and problems associated with the technique.

(i) *Misuse of the Feulgen method*

The most common errors affecting estimates of nuclear DNA content by Feulgen micro-densitometry are associated with misuse of the method itself. It is important that use of the method be standardized in every aspect. It is essential that the optimum hydrolysis time giving maximum staining of nuclear DNA be determined. Insufficient hydrolysis gives reduced staining and results in under-estimation of nuclear DNA. On the other hand it is essential that hydrolysis should not be prolonged until extraction of nuclear DNA is begun. These and other elementary considerations are amply considered in the literature (Swift 1955; McLeish & Sunderland 1961; Fox 1968; and Dietch, Wagner & Richart 1968) to which reference should be made.

(ii) *Staining failure*

Use of Feulgen microdensitometry assumes that Feulgen staining is proportional to nuclear DNA amount. While this assumption has been justified in numerous tests, nevertheless, apparent failure of the Feulgen reaction to stain highly polymerized DNA has been noted in a variety of organisms (Heslop-Harrison 1972) including, the egg cell nucleus and primary endosperm nucleus of *Stellaria media, Pteridium aquilinum, Hordeum vulgare* (Pritchard 1964; M. D. Bennett, unpublished); and in öocytes of sea urchin and frog (Hotchkiss 1955). The cause of this staining failure is unknown, but may be associated with the extremely large volume of the nuclei and the very high dilution of DNA in the nuclei concerned (Pritchard 1964).

(iii) *Non-staining DNA*

McLeish (1964) reported that about 17 % of the nuclear DNA in *Vicia faba* root-tip nuclei was nucleolar, and virtually Feulgen-negative, even though 50–75 % of it was not extracted by the acid hydrolysis of the Feulgen procedure. McLeish claimed that this DNA fraction was non-chromosomal. Its exact nature is unknown but it may have been metabolic DNA (Stroun, Charles, Anker & Pelc 1968).

At certain stages of development some nuclei amplify the number of copies of specific DNA sequences. For example, the $4C$ DNA amount in *Xenopus laevis* is about 12.6 pg, but female meiocytes at pachytene produce up to 20 pg of additional rDNA (Bird & Birnstiel 1971). The additional nuclear DNA is not incorporated in the linear continuity of the chromosomal DNA (Hourcade, Dressler & Wolfson 1973). The existence of Feulgen-negative DNA means that estimates of nuclear DNA content made by Feulgen microdensitometry and chemical extraction may differ considerably as such DNA is detected only by the second technique. However, if Feulgen-negative DNA fractions are often not located in the chromosomes, then the Feulgen estimate may usually give a more reliable estimate of the DNA content per genome.

(iv) *Variation in DNA density*

Apparent intraspecific variation in nuclear DNA content can be caused by variation in the nature of the nuclei being measured. For example, several workers have noted that the accuracy of DNA measurements by microdensitometry is markedly influenced by nuclear DNA density. To be specific, DNA amount tends to be underestimated as the DNA density increases (Mittwoch 1969; Verma & Rees 1974; Bennett & Jellings 1975). This error is of particular importance in species containing a large proportion of heterochromatin in their genome (Narayan & Rees 1974). Error due to variation in nuclear density or the presence of heterochromatin can be corrected for as described by Bedi & Goldstein (1974); Verma & Rees (1974) and Narayan & Rees (1974).

(v) *Optical errors*

Apparent intraspecific variation in nuclear DNA content may have a physical basis associated with the technique used to measure absorption. Errors have been recognised which are inherent to the optical system used for microdensitometry, for example, that caused by glare. Goldstein (1970) stated that, 'apparent differences in the amount of dye taken up by nuclei of different sizes, stained by the Feulgen method, which have been reported by various workers and attributed to differences in DNA content, are of an order of magnitude which could be due to

the presence of glare'. The amount of glare (and hence the size of the error involved) is closely related to the size of the specimen-free field illuminated. This error increases sharply with increasing absorbance of chromatin, and hence with chromosome contraction (Goldstein 1970). Clearly, therefore, the errors involved in reading well-spread metaphase plates or telophase nuclei are much greater than those involved in measuring prophase nuclei, since both the illuminated specimen-free area and the absorbance is high at metaphase and telophase compared with prophase.

(vi) *The type of tissue*

The nature of the material being examined can have a large effect on the error attached to estimates of nuclear DNA content made by Feulgen densitometry. The size of the error is greatly increased in tissue containing numerous refractile organelles, such as chloroplasts, starch granules and oil droplets. The errors are particularly large for nuclei in tissues containing coloured oil droplets, resins or tannins which interfere with the measurement of absorption due to Feulgen staining. Apart from selecting a tissue with minimal interference of these types, little else can be done about this problem in some species, such as *Linum usitatissimum*. In other species varying the fixative has given improved Feulgen staining. For instance, fixing in formalinpyridine, and after urea pre-treatment, gave improved Feulgen staining in *Bryophyllum crenatum* (Warden 1974).

4. Intraspecific variation in DNA amount per genome

Although it is generally assumed that the DNA content per genome is usually constant for each species, numerous exceptions to this rule are known, or are claimed, to exist. Chromosome variation such as aneuploidy, the presence of supernumerary chromosomes, and the loss or duplication of chromosome segments, all of which can have large effects on nuclear DNA content, cannot be regarded as true examples of intraspecific variation in DNA amount per genome. However, several other types of chromosomal variation are known which are undoubtedly a source of true intraspecific variation in DNA content per genome.

Intraspecific variation in the number of ribosomal DNA (rDNA) genes per genome has been demonstrated in several plant species (including *Zea mays* (Phillips, Kleese & Wang 1973), wheat and rye (Flavell & Smith 1974) and peas (Cullis 1975)). For example, in rye rDNA constituted 0.174 and 0.071 % of the genome in the varieties Petkus and King II, respectively (Flavell & Smith 1974). Such variation, although large in terms of a percentage of the total nuclear DNA, would produce only a minute change in the DNA content per genome, and indeed, would be undetectable by either Feulgen microdensitometry or chemical methods.

Another variable which could give rise to very large intraspecific variation in DNA content per genome is the occurrence of megachromosomes. In F1 hybrids of *Nicotiana tabacum × N. otophora* one chromosome in a few cells was enlarged by up to twenty times its normal size (Gerstel & Burns 1967). Megachromosomes, whose size varied from cell to cell, contained additional DNA in proportion to their size (Collins, Andersen & Legg 1970). A megachromosome was also noted in cultured cells of *Triticum aestivum* L. cv. Thatcher (Kao, Miller, Gamborg & Harvey 1970). How megachromosomes are produced is unknown. However, in *Nicotiana* hybrids they appeared to result from the differential additional replication of a prominent block of heterochromatin. The importance of megachromosomes lies in their showing that a mechanism exists

whereby sudden large changes in the DNA content of a single chromosome can occur in somatic cells.

A similar mechanism may be responsible for the intraspecific variation in DNA content per genome reported in flax. Heritable changes in plant weight can be induced in the flax variety Stormont Cirrus by growing the plants from germination in specific fertilizer environments (Durrant 1971). Two extreme forms, large (L) and small (S) stable genotrophs, result. During the first 5 weeks of induction the specific treatments induce divergence of nuclear DNA content with (L) ultimately having 16 % more than (S), the original parent having an intermediate DNA content (Evans, Durrant & Rees 1966; Evans 1968). Biochemical analysis has shown that rRNA genes are preferentially affected during induction. Plants with an extra 16 % DNA (L) have 70 % more sequences coding for rRNA than (S) genotrophs (Timmis & Ingle 1973). As this difference only accounts for 0.23 % of the difference in DNA content between (L) and (S) genotrophs, other sequences must also be involved. This conclusion is supported by additional biochemical studies (Cullis 1973; Timmis & Ingle 1974). Attempts to induce intraspecific varia- tion in nuclear DNA content in a few other species similar to those obtained in flax have been unsuccessful. This may indicate that the mechanism responsible for variation in flax is not widely distributed in higher plant species, or, that the right conditions for activating changes in DNA amount have not been found. The extent and distribution of naturally occurring intra- specific variation in nuclear DNA content in angiosperms is unknown. There is an indication that such variation may exist in some *Nicotiana* species (Perkins, Eglington & Jinks 1971) and it might explain the intraspecific variation noted in *Capsicum annuum* and *C. baccatum* (S. Owens, private communication). Both these species contain 25–30 % higher DNA amounts in cultivated forms than in their wild forms (table 8). Japanese workers have reported intraspecific variation in $2C$ DNA amount of up to about 20 % in various diploid and tetraploid wheat species in- cluding, *Aegilops squarrosa*, *Triticum monococcum* and *T. timopheevi* (Nishikawa & Sawai 1969; Furuta *et al.* 1974, 1975).

Several examples of major intraspecific variation in DNA content per genome have not been confirmed by subsequent studies. For instance, Abbott (1971) claimed that the DNA content of cells of excised pea roots cultured *in vitro* was only 27 % of that in cells of attached control roots. Schweizer & Davies (1972) repeated Abbott's experiments and found no evidence to support his claim, although they did find significant differences in $4C$ DNA contents of up to 7 % between cultivated varieties of *Pisum sativum* and *P. sativum* ssp. *abyssinicum*. Miksche (1968, 1971) reported intraspecific variation in DNA per cell of up to 50 % in *Pinus banksiana*, 58 % in *Picea glauca* and up to 92 % in *Picea sitchensis*. Independently conducted reinvestigations of DNA amounts in *Picea glauca* (Teoh & Rees 1976) and *P. sitchensis* (R. B. Moir & D. P. Fox, private communication) collected from the same range of environments previously sampled by Miksche (1968, 1971) have both failed to repeat Miksche's observations. However, Teoh & Rees (1976) have found some differences in DNA content between provenances but these were largely due to the presence of a variable number of B-chromosomes. For further examples comparison should be made between the initial claims of Pai *et al.* (1961) and the subsequent papers by Upadhya & Swaminathan (1963), Rees & Walters (1965) and Nishikawa (1971); and between Deka & Sen (1973) and Bennett & Jellings (1975).

Recently, Zakirowa & Vakhtina (1974) reported considerable intraspecific variation in several *Allium* species, and intravarietal variation in $1C$ DNA amount of up to 77 % in *A. cepa* cv. Dungansky. Because of the importance of *A. cepa* as an assumed standard in Feulgen

densitometry (see § 7 (a)) these results demand further comment. The examples given above provide good reasons why these results for *Allium* should be treated with caution until an independent re-examination of the material is made. However, Zakirowa & Vakhtina's account (1974) of the methods they used provides good reasons for concluding that their reported intra-specific variation in DNA amount was apparent rather than real. Thus they state that after hydrolysing anthers at 60 °C in 1 M HCl for 10 min they then allowed the anthers to cool down in 1 M HCl before placing them in Schiff's reagent. This treatment could easily result in over-hydrolysis and the loss of a fraction of the DNA from some cells. Their use of whole anthers is also questionable and may have resulted in unequal penetration of 1 M HCl, Schiff's reagent and SO_2 water with consequential variation in Feulgen staining between nuclei.

5. INTRASPECIFIC STABILITY OF DNA AMOUNT PER GENOME

Although the distribution and extent of intraspecific variation in nuclear DNA content in angiosperms is unknown it is nevertheless, possible to put the examples cited above in perspective with respect to the numerous published studies of species DNA amounts. *First*, the consensus of published data for animal and plant species agrees in demonstrating the principle of species DNA constancy. *Second*, several experiments screening for intraspecific variation in crop species which have been subject to intense selection pressure have failed to detect significant variation. For instance, Bennett & Smith (1971) found no significant difference in $4C$ DNA amount between accessions of barley (*Hordeum vulgare*) from widely different geographical locations. Similarly, no differences were found among 25 Japanese and U.S. varieties of wheat (*Triticum aestivum*) by Nishikawa & Furuta (1967). *Third*, the incidence of intraspecific variation is probably over-represented in the literature as there has almost certainly been a tendency to publish examples where intraspecific variation was found more often than instances where it was not. For example, the present authors have not published the results of surveys which failed to detect significant intraspecific variation in DNA amount between cultivars of *Vicia faba* or between cultivars of winter and spring wheat (*T. aestivum*). Similarly, no intraspecific variation in DNA amount was found in *Festuca pratensis* comparing accessions from a range extending from Spain to Siberia (H. Rees, private communication). It seems reasonable to conclude, therefore, that although intraspecific variation in DNA amount may be common at levels below $\pm 1 \%$, it is rare at or above the level at which current methods can reliably detect it (i.e. ± 3–5%).

Taken together, the various factors known to produce variation in DNA content per genome (unequal crossing-over, differential amplification, megachromosomes, etc.) must generate a considerable amount of variation in this character. It is perhaps surprising, therefore, that species DNA amounts are so relatively constant. Indeed, the observed constancy suggests that there must be some mechanism whereby DNA amount per genome is monitored and controlled at or near to an adaptively determined norm for each species. Evidence which appears to support this notion comes from several experiments using widely different cell types. *First*, the $4C$ DNA content of (L) and (S) flax genotrophs return to a value close to that of the original parent within a few generations in the absence of selection, even though the (L) and (S) phenotypes continue to be displayed (Durrant & Jones 1971; Joarder, Al-Saheal, Beguar & Durrant 1975). *Second*, in the great majority of comparisons of DNA amounts in naturally occurring polyploids and their presumed diploid ancestors, the polyploids have DNA amounts not significantly different from those expected assuming DNA constancy per diploid genome (Rees & Walters

1965; Southern 1967; Grant 1969; Nishikawa 1971; Yang & Dodson 1970; Bennett & Smith 1971; Bullen & Rees 1972; Narayan & Rees 1974). For instance, Smith & Bennett (1975) have found that the 4C DNA amount of tetraploid *Ranunculus ficaria* which reproduces vegetatively by bulbils is almost exactly double that of the diploid species which reproduces sexually. Similarly, Furuta, Nishikawa & Tanino (1974) have demonstrated that the sum of the DNA contents of the AA and BB genomes in present-day allo-hexaploid wheat is not significantly different from that of present day Emmer wheat (a tetraploid species with the genomic constitution AABB). Thus, they have concluded that no appreciable quantitative change in the DNA contents of the A and B genomes of common wheat have taken place during at least the past seven thousand years, in spite of the considerable genetic changes which have occurred. Only two conclusions may be drawn from the examples cited above; either intraspecific variation in DNA content per genome has not occurred in diploid and derived polyploid species subsequent to formation of the latter, or, that such variation has usually been heavily selected against.

TABLE 1. A COMPARISON OF THE ABSOLUTE DNA AMOUNT/pg PER NUCLEUS OR PER CELL IN SEVERAL ANGIOSPERMS ESTIMATED INDEPENDENTLY BY SEVERAL LABORATORIES USING EITHER FEULGEN MICRODENSITOMETRY OR A CHEMICAL METHOD

				references					
	DNA amount estimated by Feulgen microdensitometry				DNA amount per cell estimated by chemical extraction and the diphenylamine reaction				
	this paper (table 8)		Ingle & Sinclair (1972)	Evans & Rees (1971)	McLeish & Sunderland (1961)	Sparrow & Miksche (1961)	Lyndon (1962)	Baetcke et al. (1967)	Martin (1966)
species	2C	3C	2C	2C					
Allium cepa	33.5	53.4	32.0	33.5	78.7	54.3†	—	54 ± 6	65.6
Beta vulgaris	2.5	3.7	2.5	—	—	—	—	—	—
Zea mays	4.7	7.1	7.5	11.0	15.5	14.1	—	—	30.2
Pisum sativum	9.7	14.7	10.0	—	21.4	—	16.0	—	—
Secale cereale	16.6	25.4	—	18.9	41.6	—	—	—	—
Vicia faba	26.7	40.0	—	23.9	60.5	38.4	—	44 ± 8	56.2
Triticum aestivum	34.6	51.9	—	—	—	—	—	—	—
Tradescantia paludosa	41.3	61.9	—	38.8	—	59.4	—	54 ± 6	—

† The standard 2C *Allium cepa* = 33.5 pg was calculated from this value by Van't Hof (1965).

6. HOW ACCURATE ARE ABSOLUTE DNA AMOUNTS?

Published estimates of DNA amounts for the same species obtained by using both chemical and Feulgen microdensitometric methods sometimes differ greatly. Wallace *et al.* (1972) recently noted that, '*Vicia faba* provides an outrageous example of imprecision, with a 2C DNA content calculated to be either 24 or 40 pg'. The chemically determined estimates of 0.73 and 8.0 pg for *Rumex obtusifolius* given by Bowen (1962) and Baetcke *et al.* (1967) provide evidence of even wilder imprecision, and prompts the question, 'How accurate are absolute DNA estimates?'

Published DNA amounts are clearly of widely different reliabilities. Only a fault in the extraction, staining or measurement could explain differences like those quoted above. Comparing estimates for individual species with the concensus of data available for those species in the literature usually allows wildly erroneous results to be identified and discarded (e.g., see § 7 (*c*)).

However, even after this has been done, considerable variation often remains between estimates for the same species. For example, table 1, which gives DNA per cell measured by chemical extraction and the diphenylamine reaction in several angiosperms in five separate papers, shows typical intraspecific variation. Some of the differences represent real variation in DNA content per cell caused by variation in the proportion of G2 and polyploid cells in the root-tips sampled (McLeish & Sunderland 1961; Lyndon 1963). However, some differences were doubtless the result of faulty technique. Two major errors affecting chemical determinations of DNA per cell in higher plants are recognized, namely, inefficient extraction of DNA (due to the presence of thick cell walls), and the presence of substances which interfere with the diphenylamine reaction. Unfortunately it is impossible to assess the relative contributions of these factors in producing the different DNA per cell estimates cited in table 1. However, it should be noted that the various authors were usually aware of the limitations of their technique (Baetcke *et al.* 1967) and did not claim as great an accuracy for their estimates as is implied by some subsequent criticism of their work. The standard errors given by Baetcke *et al.* (1967) range from about ± 5 to $\pm 29 \%$ of the estimated content per cell for individual species.

The accuracy of absolute DNA amounts calculated by Feulgen microdensitometry depend *first*, on the accuracy with which each species is measured relative to the standard species used for calibration, and *secondly*, on the accuracy of the assumed DNA amount of the standard species. The reliability of the former may be roughly gauged by comparing results for the same species obtained by different workers using the same Feulgen method. Table 1 gives the $2C$ DNA amounts for several species estimated in three independent laboratories by Feulgen densitometry using either *Allium cepa* ($2C = 33.5$ pg) or *Pisum sativum* ($2C = 10$ pg) as an assumed standard. With the exception of the results for *Zea mays* (which require further investigation) the three sets of results are in close agreement, indeed, much closer than the results obtained by the chemical method for the same species which are also given (table 1). Thus, individual estimates obtained by the Feulgen method by Ingle & Sinclair (1972) or by Evans & Rees (1971) differ from those given by the present authors for the same species by from zero to 14 %, while the mean percentage difference for the seven possible comparisons is about 7.3 %. Table 2 presents data for 13 *Ranunculus* species estimated by Feulgen densitometry by both Goepfert (1974) and ourselves, and expressed in arbitrary units relative to *Anemone virginiana*. Results for individual species differ by from 2.4 to 20.7 %, with a mean difference of 11.4 %. Table 3 compares the results for four *Tulipa* species given by Southern (1967) and ourselves. Assuming the ratio of estimates for *T. biflora* is one, then comparing the ratios for the three other species gives differences ranging from 7.8 to 12.3 %. McLeish & Sunderland (1961) compared the ratios of DNA estimates obtained by chemical and Feulgen methods. Taking the ratio for *V. faba* as a standard equal to unity they found that the ratios for eight other species agreed to within 10 %, while the ratios for two others differed by 12 and 24 %, respectively. Swift (1953) stated that, 'in general estimates of the nucleic acids in cells are at present accurate to 10 or 20 % '. The various comparisons listed above suggest that the accuracy of estimates of individual species DNA amounts relative to an assumed standard has in general not improved. While a few estimates are not accurate even to within 20 %, careful measurements of $4C$ DNA amounts in species with amounts of from 0.5 to 2.0 times that of the standard species are probably accurate to within 5–10 %.

For reasons more incidental than scientific, the vast majority of species DNA amounts measured by Feulgen densitometry have been calibrated directly or indirectly by using Van't Hof's $2C$ estimate for *Allium cepa* (33.55 pg) as an assumed standard. Thus, this value was

originally chosen as a standard by Professor H. Rees and his colleagues because, of the strictly limited number of plant species whose published chemically determined $2C$ DNA amounts appeared reliable, material of *A. cepa* was always readily available, and also, because they happened to be measuring DNA amounts of several species in the genus *Allium* (Jones & Rees 1968; and H. Rees, personal communication). Thereafter, the same standard was used in numerous studies by Rees and different co-workers (see, for example, Paroda & Rees 1971; Narayan & Rees 1974; Verma & Rees 1974), by ourselves (Bennett & Smith 1971; Bennett 1972) and others (Ayonoadu 1974; Nagl & Ehrendorfer 1974). As the accuracy of all absolute DNA amounts estimated by Feulgen microdensitometry is partly determined by the accuracy of the assumed standard used for calibration, it follows that the reliability of estimates for several hundred species given in table 8 depends upon the accuracy of Van't Hof's original estimate for the $2C$ value in *A. cepa*. It is, therefore, worth considering how this value was derived, and also, its reliability.

TABLE 2. THE $4C$ DNA AMOUNTS IN SEVERAL *RANUNCULUS* SPECIES (IN ARBITRARY UNITS RELATIVE TO *ANEMONE VIRGINIANA* = 1.0) REPORTED BY TWO LABORATORIES, MEASURED BY FEULGEN MICRODENSITOMETRY

(The percentage difference between the two estimates (d) is also given assuming Goepfert's estimates for each species are equal to 100%.)

species	Goepfert (1974)	this paper (table 8)	d (%)
Anemone virginiana	1.0	1.0	—
Ranunculus lingua	2.374	2.815	+15.64
R. ficaria (4x)	1.994	2.142	+7.12
R. cortusifolius	1.049	0.976	−8.47
R. muricatus	1.036	1.301	+20.37
R. arvensis	0.718	0.687	−4.50
R. flammula	0.689	0.712	+3.24
R. bulbosus	0.600	0.630	+4.77
R. falcatus	0.591	0.577	−2.42
R. acris	0.525	0.599	+12.36
R. sardous	0.429	0.362	−18.50
R. chius	0.400	0.493	+18.87
R. scleratus	0.397	0.449	+11.59
R. lateriflorus	0.257	0.213	−20.65
R. auricomus†	—	—	—

† The data for *R. auricomus* are omitted as there is obviously an error due to misidentification in one of the two papers.

TABLE 3. THE DNA AMOUNTS IN FOUR *TULIPA* SPECIES (IN ARBITRARY UNITS RELATIVE TO *T. BIFLORA* = 1.0) REPORTED BY TWO LABORATORIES, MEASURED BY FEULGEN MICRODENSITOMETRY

(The percentage difference between the two estimates (d) is also given assuming Southern's estimates for each species are equal to 100%)

	Southern (1967)	this paper (table 8)	d (%)
Tulipa biflora	1.0	1.0	—
T. saxatilis	1.443	1.599	+8.10
T. turkestanica	1.910	2.059	+7.80
T. urumiensis	1.059	0.929	−12.27

Using chemical methods and cell counts, Sparrow & Miksche (1961) estimated the DNA content per cell in *A. cepa* as 54.3 pg. Working in the same laboratory, Van't Hof (1965), used this value to derive an estimate of the 2C for *A. cepa* (namely, 33.55 pg) by assuming that the frequencies of 2C, intermediate, and 4C cells were proportionate to the relative durations of the corresponding phases of the cell cycle: G1, S, and G2 + M, respectively. This assumption is invalidated if the meristem contains a proportion of non-dividing cells (Van't Hof 1965). As root-tips meristems are well known to contain a proportion of non-dividing cells (Brown 1951; Webster & Davidson 1968), Van't Hof's estimate of the 2C DNA amount in *A. cepa* is almost certainly subject to this error. The extent of the error depends upon the proportions of non-dividing G1 and G2 cells, the former tending to produce an underestimate in Van't Hof's estimate of the 2C value, and the latter having the reverse effect. As these data are unknown for the *A. cepa* root-tips used by Sparrow & Miksche (1961) the resulting error in Van't Hof's estimate of the 2C amount in *A. cepa* cannot be accurately assessed. However, given that the histograms for DNA contents of *A. cepa* root-tip nuclei presented by McLeish & Sunderland (1961) are typical (and hence apply to the root-tips used by Sparrow & Miksche (1961)), Wallace *et al.* (1972) state that this error would only alter Van't Hof's estimated 2C value by about 1 pg. If they are correct then the error due to non-dividing cells in Van't Hof's estimate is only of the order of about 3 %.

TABLE 4. THE 2C DNA AMOUNT/pg IN TWO DICOTS ESTIMATED BY FEULGEN DENSITOMETRY USING EITHER AN ANIMAL OR A PLANT STANDARD SPECIES FOR CALIBRATION

species		Wallace *et al.* (1972)	Brown & Jones private communication	Bachmann private communication	Maher & Fox (1973)	Evans & Rees (1971)	Bennett & Smith (this paper)
standard (assumed)	*Xenopus laevis*	6.3	—	—	—	—	—
	Mus musculus	—	—	—	7.0	—	—
	Allium cepa	—	33.5	33.5	—	33.5	33.5
calibrated plant species	*Crepis capillaris*	5.2	4.7	4.8	—	4.2	—
	Vicia faba	—	—	—	28.8	23.3	26.7

An alternative test of the accuracy of Van't Hof's estimate for *A. cepa* is to compare estimated DNA contents for individual species obtained by using both *A. cepa* and an animal species for calibration. Thus, using *Xenopus laevis* erythrocytes as a standard Wallace *et al.* (1972) estimated the 2C amount for *Crepis capillaris* as 5.2 pg, while two other laboratories (table 4) using *A. cepa* 2C = 33.5 pg as standard estimated *C. capillaris* as 4.7 and 4.8 pg, respectively. Thus, estimates obtained by using either standard agree to within 10 %. Similarly, Maher & Fox (1973) using *Mus musculus* (2C = 7.0 pg) as a standard, estimated the 2C DNA content of *Vicia faba* as 28.8 pg, while two other laboratories using *A. cepa* as standard estimated *V. faba* to be 26.7 and 23.3 pg, respectively. Here the estimates obtained using *A. cepa* as standard are about 7 and 19 % lower, respectively, than the estimate obtained with *Mus* as standard. As all four estimates obtained with *A. cepa* as standard are low compared with those obtained from animal standards these comparisons suggest that Van't Hof may have slightly understimated the 2C DNA amount for *A. cepa*. However, the comparisons just related also agree in suggesting that Van't Hof's estimate for *A. cepa* is probably correct to within about 10 %.

7. Preparation of the list of DNA amounts in angiosperms

(a) DNA amount in Allium cepa cv. Ailsa Craig

Zakirowa & Vakhtina (1974) claim to have detected intravarietal variation in DNA amount in *A. cepa* cv. 'Dungansky' of up to 77 %. As we used *A. cepa* cv. Ailsa Craig as standard for calibration purposes we decided to screen this variety for variation in $4C$ DNA content. The preparation and measurement of root-tip squashes was as described below (§ 7 (*b*)). Table 5 presents the results (in arbitrary units) for the mean absorption per mid-prophase ($4C$) nucleus, in samples of 10 nuclei per root-tip, for sixty individual root-tips (each taken from a different seedling) stained in groups of three on twenty different days.

TABLE 5. THE MEAN ABSORPTION PER $4C$ PROPHASE NUCLEUS IN 60 INDIVIDUAL ROOT-TIPS EACH FROM A SEPARATE SEEDLING OF *ALLIUM CEPA* CV. AILSA CRAIG MEASURED IN 20 EXPERIMENTS, EACH PERFORMED ON A DIFFERENT DAY

	seedling			mean ± s.e.
day	1	2	3	(for each day)
1	25.52	25.68	25.58	25.59 ± 0.05
2	25.62	25.19	25.68	25.50 ± 0.15
3	26.21	26.73	26.84	26.59 ± 0.19
4	25.87	24.85	26.38	25.70 ± 0.45
5	25.90	26.02	25.57	25.83 ± 0.13
6	26.21	26.11	25.89	26.07 ± 0.09
7	25.67	24.53	24.65	24.95 ± 0.36
8	24.48	24.42	24.62	24.51 ± 0.06
9	25.35	25.34	24.63	25.11 ± 0.24
10	25.11	25.11	25.56	25.26 ± 0.15
11	25.34	25.51	25.66	25.50 ± 0.09
12	25.35	25.24	24.86	25.15 ± 0.15
13	25.64	25.20	25.84	25.56 ± 0.19
14	25.09	25.91	25.81	25.60 ± 0.26
15	24.86	24.38	24.71	24.65 ± 0.14
16	26.02	25.50	25.79	25.77 ± 0.15
17	25.17	25.33	24.98	25.16 ± 0.1
18	25.58	25.72	25.59	25.63 ± 0.05
19	25.04	24.68	24.69	24.80 ± 0.12
20	24.63	25.20	25.43	25.09 ± 0.24

The mean absorption per $4C$ nucleus on individual slides was from 24.42 to 26.84 arbitrary units (table 5), a difference of only about 10 %. The means for sets of three slides measured on different days ranged from 24.65 to 26.59 which almost equals the range for individual slides. Analysis of variance showed highly significant ($P < = 0.001$) differences between the means for different days. Thus, the differences were caused by differential staining or measurement of DNA on different days. The present results provide no evidence of detectable intravarietal variation in $4C$ DNA content in *A. cepa* cv. Ailsa Craig. Consequently root-tips of this variety were considered suitable for use as a standard for calibrating other species.

(b) Recalibration of DNA amounts in 'standard' species

In view of possible errors in previous estimates of $2C$ and $4C$ DNA amounts obtained by Feulgen microdensitometry (see § 3 (c)) it was decided to recalibrate carefully several species against *A. cepa* cv. Ailsa Craig, in order to justify their use as known standards for calibrating other species. The genotypes for recalibration were chosen by using the following criteria

1. They should be easy to culture under laboratory conditions, and root-tips should be readily available for use as standards throughout the year.

2. They should be either named cultivars, or seed of a defined population, in order to minimize possible error due to intraspecific variation in nuclear DNA content between standards.

3. The spread of DNA amounts should form a series covering the range of DNA amounts in angiosperms, thus allowing the DNA amount of each species to be estimated by using a standard species for calibration with a similar DNA amount. This procedure tends to minimize some technical errors inherent in Feulgen microdensitometry.

4. They should include species often measured in published investigations of DNA amounts in angiosperms, thus facilitating comparison of the present and past results, and calibration or recalibration of the latter where appropriate.

On these criteria the following seven species were recalibrated against *A. cepa* for use as standards:

(a) *Triticum aestivum* cv. Chinese Spring ($2n = 6x = 42$)

(b) *Vicia faba* (PBI inbred fertile line 6: $2n = 2x = 12$)

(c) *Anemone virginiana* (line AV 200 – kindly supplied by Dr G. E. Marks, John Innes Institute, Norwich: $2n = 2x = 16$).

(d) *Secale cereale* cv. Petkus Spring ($2n = 2x = 14$)

(e) *Hordeum vulgare* cv. Sultan ($2n = 2x = 14$)

(f) *Pisum sativum* cv. Minerva Maple ($2n = 2x = 14$)

(g) *Senecio vulgaris* (a wild population growing at the Plant Breeding Institute, Cambridge: $2n = 4x = 40$)

Seeds of *A. cepa* and the species listed above were germinated on Whatman No. 1 filter paper moistened with distilled water in plastic petri dishes. Tips of roots about 1–2 cm in length were fixed in freshly made 3:1 absolute ethyl alcohol:glacial acetic acid (by vol.) for about 20 h at room temperature. Thereafter they were hydrolysed in 1 M HCl at 60 °C for 10 min, stained in leuco-basic fuchsin (pH adjusted to 3.6) for 2 h, and then given three 10 min washes in SO_2 water (McLeish & Sunderland 1961). Root-tips from different species were kept in separate tubes during this procedure. The darkly stained root-tip was then excised with a clean scalpel and squashed in a drop of 45 % acetic acid on a microscope slide (Camlab (Glass) Ltd Cambridge – Belgian microscope slides 0.8–1.0 mm thick) under a cover slip (Chance No. 1). All microdensitometer readings were made on a Vickers M86 integrating microdensitometer usually within 3 h but always within 5 h of squashing. No significant variation in stain intensity in nuclei mounted in 45 % acetic acid occurred during this period. In each experiment (day) ten nuclei judged to be at mid-prophase ($4C$) were measured on each of three slides (replicates). Each slide was prepared using a single root-tip from a different plant. The absorption of each nucleus was calculated as the mean of three readings. Each standard species was compared with *A. cepa* in three or four experiments, each performed on a different day.

The present results (table 6) are in close general agreement with, but show some difference from, those published previously (Evans & Rees 1972; Bennett 1972). In view of the greater care

TABLE 6. THE MEAN ABSORPTION PER $4C$ PROPHASE NUCLEUS (IN ARBITRARY UNITS) IN 9 OR 12 INDIVIDUAL ROOT-TIPS MEASURED IN THREE OR FOUR EXPERIMENTS ON DIFFERENT DAYS, AND THE ESTIMATED $4C$ DNA AMOUNT/pg IN EACH EXPERIMENT CALCULATED FROM THE MEAN ABSORPTION PER PROPHASE NUCLEUS IN *ALLIUM CEPA* ON THE SAME DAY (SEE TABLE 5) AS AN ASSUMED STANDARD ($4C = 67$ pg), IN SEVEN ANGIOSPERM SPECIES

species	day	seedling 1	seedling 2	seedling 3	means for each day ± s.e. (arbitrary units)	means corrected for *A. cepa* on the same day ± s.e./pg	mean for the species ± s.e./pg
Triticum aestivum	2	25.71	26.69	25.77	26.06 ± 0.32	68.47 ± 0.84 ⎫	
cv. Chinese	4	26.25	27.08	26.25	26.53 ± 0.28	69.16 ± 0.73 ⎬	69.27 ± 0.50
Spring	5	26.59	27.16	27.42	27.06 ± 0.25	70.19 ± 0.65 ⎭	
Vicia faba (PBI,	1	19.16	20.77	20.61	20.18 ± 0.51	52.84 ± 1.34 ⎫	
inbred line 6)	2	19.57	20.01	21.37	20.32 ± 0.54	53.39 ± 1.42 ⎪	
	3	21.24	20.71	21.01	20.99 ± 0.51	52.89 ± 1.28 ⎬	53.31 ± 0.29
	4	21.13	20.64	20.48	20.75 ± 0.2	54.10 ± 0.52 ⎭	
Anemone virginiana	6	14.11	14.18	14.30	14.20 ± 0.06	36.49 ± 0.15 ⎫	
line AV 200	9	13.45	13.39	12.97	13.27 ± 0.15	35.41 ± 0.40 ⎬	35.67 ± 0.42
	10	13.56	13.11	13.05	13.25 ± 0.16	35.12 ± 0.42 ⎭	
Secale cereale cv.	2	12.29	12.19	11.99	12.16 ± 0.09	31.95 ± 0.24 ⎫	
Petkus Spring	5	12.05	12.90	12.39	12.45 ± 0.25	32.29 ± 0.64 ⎪	
	7	12.58	13.03	13.02	12.88 ± 0.15	34.59 ± 0.40 ⎬	33.14 ± 0.62
	8	12.28	12.38	12.36	12.34 ± 0.03	33.73 ± 0.08 ⎭	
Hordeum vulgare	1	8.09	8.44	8.41	8.31 ± 0.11	21.76 ± 0.29 ⎫	
cv. Sultan	2	8.90	8.75	8.83	8.83 ± 0.04	23.20 ± 0.11 ⎪	
	4	8.01	7.97	8.02	8.0 ± 0.02	20.86 ± 0.05 ⎬	22.24 ± 0.57
	5	9.04	8.84	8.89	8.92 ± 0.06	23.14 ± 0.15 ⎭	
Pisum sativum cv.	1	6.92	7.32	7.07	7.10 ± 0.12	18.59 ± 0.13 ⎫	
Minerva Maple	6	7.75	7.51	7.78	7.68 ± 0.09	19.74 ± 0.23 ⎪	
	7	7.51	7.28	7.49	7.43 ± 0.07	19.95 ± 0.18 ⎬	19.46 ± 0.30
	8	7.19	7.15	7.13	7.16 ± 0.02	19.57 ± 0.05 ⎭	
Senecio vulgaris	6	2.09	2.15	2.15	2.13 ± 0.02	5.47 ± 0.05 ⎫	
(PBI popula-	7	2.24	2.37	2.34	2.32 ± 0.04	6.23 ± 0.10 ⎬	5.88 ± 0.22
tion)	8	2.28	2.07	2.16	2.17 ± 0.06	5.93 ± 0.16 ⎭	

TABLE 7. THE $4C$ DNA CONTENTS IN 8 ANGIOSPERM SPECIES USED AS CALIBRATION STANDARDS

species	$4C$ DNA amount/pg
A. *Triticum aestivum* cv. Chinese Spring	69.27
B. *Allium cepa* cv. Ailsa Craig	67.00†
C. *Vicia faba* (PBI, inbred line 6)	53.31
D. *Anemone virginiana* line AV 200	35.67
E. *Secale cereale* cv. Petkus Spring	33.14
F. *Hordeum vulgare* cv. Sultan	21.89
G. *Pisum sativum* cv. Minerva Maple	19.46
H. *Senecio vulgaris* (PBI population)	5.88

† The $2C$ value for *A. cepa* originally calculated by Van't Hof (1965) was 33.55 pg, which gives a $4C$ value of 67.1 pg. While a few workers have taken the exact value, $2C$ *A. cepa* = 33.55 pg (e.g. Ayonoadu 1974), the majority have taken the value $2C$ *A. cepa* = 33.5 pg, which gives a $4C$ value of 67.0 pg (see, for example, Evans & Rees 1971; Nagl & Ehrendorfer 1974). Values for species calibrated using either value for *A. cepa* as standard are included in table 8. To avoid confusion, the present work has followed the majority and taken the slightly lower value (33.5 pg) as an assumed standard.

with which the new estimates were made, it was decided to use these (rather than those previously published) as standards for calibration purposes. Consequently, where the estimated value for a species given in table 8 differs from that published previously by the present authors (see, for example, Bennett & Smith 1971; Bennett 1972) the latter should be ignored in favour of those given in tables 7 and 8).

The species listed in table 7 are referred to hereafter as 'standard species'. The standard species differ by 12-fold in their $4C$ DNA amounts, which range from 5.88–69.27 pg. The values for individual species constitute a useful series covering much of the range of species DNA amounts known in the angiosperms.

(c) *The choice and handling of data for inclusion in table* 8

As published DNA amounts are of widely different reliability, some choice had to be exercised in deciding which estimates should be included in table 8, and which omitted. The following procedure was adopted

(1) All absolute DNA amounts for species originally calculated by using any species listed in table 7 as a standard are included in table 8. If the DNA amount assumed for a standard species is the same as that given in table 7, then the original estimates for the species listed are given (such data are termed 'original' (O) in table 8). However, when the DNA amount assumed for a standard species differed from that given in table 7, estimates for the other listed species were recalibrated using the DNA amount for the appropriate standard given in table 7 (such data are termed 'recalibrated' (R) in table 8. For example, the original estimates for Eu-*Sorghum* species given by Paroda & Rees (1971) are included because they were obtained using the $2C$ value for *A. cepa* given in table 7 as a calibration standard. However, values for species in the Ranunculaceae and Droseraceae given by Rothfels *et al.* (1966) and Rothfels & Heimberger (1968) have been included after recalibration because the original chemically-estimated DNA per cell standard for *Anemone virginiana* (21 pg) differed from the $2C$ estimate for this species given in table 7 (17.9 pg) (see also table 8, footnote q).

(2) Several lists of DNA amounts for species including a standard species, which were given in arbitrary units only, have been calibrated by us using the value for the appropriate standard species given in table 7 as an assumed standard, (such data are termed 'calibrated' (C) in table 8). For example, the relative $4C$ DNA amounts for 25 *Allium* species given in arbitrary units by Jones & Rees (1968) were calibrated using the standard, $2C$ *Allium cepa* = 33.5 pg, as this species was included in their study.

(3) Several lists giving estimates of relative $2C$ or $4C$ DNA amounts for groups of species originally given in arbitrary units only, which did not include any standard species, were calibrated by us (such data are termed 'calibrated' (C) in table 8). One or more species listed in each paper were obtained and calibrated by using a standard species, then the results for the other listed species were also converted into absolute units using the newly-calibrated species as assumed standards. For example, Borsos (1973) gave relative $2C$ DNA contents for 8 *Lotus* species (including *L. corniculatus*) in arbitrary units only. We estimated the $2C$ DNA content of *L. corniculatus* (2.1 pg) using *Pisum sativum* as a standard. Then, the results for the other 7 *Lotus* species were converted into picograms using the newly-determined value for *L. corniculatus* as a standard. For further details of results calibrated in this way see footnotes c–g of table 8.

(4) Lists of relative $2C$ or $4C$ DNA amounts for species given in arbitrary units alone, which do

not include a standard species listed in table 7, but do include one or more species whose DNA amounts have been calibrated by using a standard species, were calibrated using the values for species with known DNA amounts as assumed standards (such data are termed 'calibrated'(C) in table 8). For example, Furuta (1970) gave relative DNA amounts in arbitrary units for several wheat species including *Aegilops speltoides* but not including *Triticum aestivum* (which is listed in table 7). As the 2C DNA amount of *Ae. speltoides* has been calibrated against *T. aestivum* using the results of Rees & Walters (1965), Furuta's results (1970) were calibrated by using the value for *Ae. speltoides* (2C = 11.6) as an assumed standard.

(5) Several lists of chemically determined estimates of DNA content per cell are included because they give values for standard species which are in general agreement with the expected 2C–4C range of values for those species, i.e. similar to the 3C standard amount (see, for example, Rasch & Woodard 1959; McLeish & Sunderland 1961; Sunderland & McLeish 1961; Sparrow & Miksche 1961; Lyndon 1963; Van't Hof & Sparrow 1963; Martin 1966; Baetcke *et al.* 1967). The results of Baetcke *et al.* (1967) show particularly good agreement in this respect, thus, the DNA contents per cell for *V. faba* (44 pg) and *A. cepa* (54 pg) are both close to the expected 3C DNA amounts for those species (40 and 53.4 pg) respectively, see table 1). By comparison the estimates given by McLeish & Sunderland (1961) are consistently somewhat higher than expectation.

A few other chemically determined estimates of DNA amount per cell were also included in table 8, which were not originally given together with estimates for a standard species (see, for example, Ruch & Rosselet 1970; Price *et al.* 1972).

(6) When several estimates for the DNA amount of the same species are published, each has been included in table 8 together with its source. If estimates for a species have been made by ourselves and one or more other laboratories, then our estimate is listed first. Otherwise, the order of listing estimates for the same species is arbitrary.

(7) All estimates of DNA amount per cell or per nucleus based solely on cell size or nuclear volume have been omitted from table 8. While nuclear DNA content and nuclear volume often exhibit a highly significant positive correlation (Baetcke *et al.* 1967), estimates of DNA amounts in individual species obtained using such correlations are subject to larger errors than those estimated by careful chemical extraction or Feulgen densitometry experiments. For instance, using the relation of nuclear volume to nuclear DNA content, Sparrow & Nauman (1973) estimated the 2C DNA amount in two genotypes of *Hordeum distichum* as 6.55 and 9.79 pg, respectively, a difference of nearly 50 %. While estimates derived in this way are undoubtedly suitable for certain types of comparisons (see, for example, Bennett *et al.* 1972; Sparrow & Nauman 1973; Price, Sparrow & Nauman 1973), they are a poor substitute for direct measurements of nuclear DNA content.

(8) Lists of absolute DNA amounts for species which were obviously grossly inaccurate were omitted from table 8. For instance, Bowen (1962) estimated the DNA content per cell of *Pinus sylvestris* to be about 8 pg, and of *Rumex obtusifolius* to be about 0.73 pg, while Miksche (1967) estimated *P. sylvestris* to have about 93 pg per cell, and Baetcke *et al.* (1967) gave an estimate for *R. obtusifolius* of about 8 pg. As Bowen (1962) gave estimates of DNA amounts which are consistently about one-tenth of the values for the same species given by other workers, his results are excluded from table 8.

The majority of species in table 8 are included subject to items 1–4 listed above, and consequently are given values calibrated directly or indirectly against the assumed value for

Allium cepa $2C = 33.5$ pg. Such species may be identified in table 8 which gives the standard used for calibration for each species. If the $2C$ value for *A. cepa* is subsequently shown to differ from Van't Hof's (1965) estimate it will be simple to recalibrate all such estimates using the appropriate correction factor.

Relative DNA amounts for species given in arbitrary units only are of very limited use compared with estimates calibrated in absolute units. It is desirable, therefore, that future investigations of species DNA amounts should give results in absolute units. This need involve very little additional effort, and may be achieved by including in each experiment one or more species whose DNA amount is already known as a calibration standard. Seed of the 8 standard species listed in table 7 may be obtained on request from the present authors for this purpose.

8. LIST OF DNA AMOUNTS IN ANGIOSPERMS

This information is presented for 753 species in table 8 which appears on pages 246–269. Some explanatory notes relating to table 8 appear in §9 on pages 270 and 271.

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TABLE 8. CHROMOSOME NUMBER, PLOIDY LEVEL, LIFE CYCLE TYPE AND NUCLEAR DNA CONTENT IN 753 ANGIOSPERM SPECIES

| species | family | monocot (M) or dicot (D) | chromosome number, $2n$ | ploidy level, x | life cycle type (annual (A), biennial (B) or perennial (P)) | DNA amount/pg | | | | | original reference (for key see §9(a)) | present amount (original value (O), calibrated value (C) or recalibrated value (R)) | standard species used to calculate the present amount (for key see §9(b)) | method used for DNA estimate (Feulgen densitometry, Fe, chemical extraction, Ch.) |
						$1C$	$2C$	$3C$	$4C$	$4C$ per cell				
1a Aegilops bicornis (Forsk.) Jaub. et Sp.	Gramineae	M	14	2	A	7.1	14.2	21.4	28.5	—	4	R	A	Fe.
1b Ae. bicornis (Forsk.) Jaub. et Sp.	Gramineae	M	14	2	A	7.3	14.7	22.0	29.3	—	3	C	A-13	Fe.
2 Ae. biuncialis Vis.	Gramineae	M	28	4	A	11.3	22.6	33.9	45.2	—	3	C	A-13	Fe.
3 Ae. caudata L.	Gramineae	M	14	2	A	4.6	9.3	13.9	18.5	—	3	C	A-13	Fe.
4 Ae. columnaris Zhuk.	Gramineae	M	28	4	A	10.5	21.0	31.5	42.0	—	3	C	A-13	Fe.
5 Ae. comosa Sibth. et Sm.	Gramineae	M	14	2	A	6.2	12.4	18.5	24.7	—	3	C	A-13	Fe.
6 Ae. crassa Boiss.	Gramineae	M	28	4	A	10.5	20.9	31.4	41.9	—	3	C	A-13	Fe.
7 Ae. crassa Boiss.	Gramineae	M	42	6	A	15.7	31.4	47.1	62.8	—	3	C	A-13	Fe.
8 Ae. cylindrica Host.	Gramineae	M	28	4	A	4.7p	9.3p	14.0p	18.6p	—	3	C	A-13	Fe.
9 Ae. juvenalis (Thell.) Eig	Gramineae	M	42	6	A	18.8	37.6	56.4	75.2	—	3	C	A-13	Fe.
10 Ae. longissima Schw. et Musch.	Gramineae	M	14	2	A	6.4	12.9	19.3	25.8	—	3	C	A-13	Fe.
11 Ae. mutica Boiss.	Gramineae	M	14	2	A	6.3	12.6	18.9	25.2	—	3	C	A-13	Fe.
12 Ae. ovata L.	Gramineae	M	28	4	A	9.2	18.5	27.7	36.9	—	3	C	A-13	Fe.
13 Ae. speltoides Tausch	Gramineae	M	14	2	A	5.8	11.6	17.4	23.2	—	4	R	A	Fe.
14 Ae. squarrosa L.	Gramineae	M	14	2	A	5.1	10.2	15.3	20.4	—	4	R	A	Fe.
15 Ae. squarrosa L. var. meyeri Griseb.	Gramineae	M	14	2	A	4.9	9.8	14.7	19.7	—	3	C	A-13	Fe.
16 Ae. squarrosa L. var. typica L.	Gramineae	M	14	2	A	3.6	7.2	10.9	14.5	—	3	C	A-13	Fe.
17 Ae. triaristata Willd.	Gramineae	M	28	4	A	15.5	31.0	46.5	62.0	—	3	C	A-13	Fe.
18 Ae. triaristata Willd.	Gramineae	M	42	6	A	21.6	43.2	64.9	86.5	—	3	C	A-13	Fe.
19 Ae. truncialis L.	Gramineae	M	28	4	A	9.7	19.4	29.1	38.8	—	3	C	A-13	Fe.
20 Ae. truncialis L. var. persica (Boiss.) Eig	Gramineae	M	28	4	A	9.5	18.9	28.4	37.8	—	3	C	A-13	Fe.
21 Ae. truncialis L. var. typica L.	Gramineae	M	28	4	A	10.5	21.0	31.5	42.0	—	3	C	A-13	Fe.
22 Ae. umbellulata Zhuk.	Gramineae	M	14	2	A	5.1	10.1	15.2	20.2	—	3	C	A-13	Fe.
23 Ae. uniaristata Vis.	Gramineae	M	14	2	A	6.3	12.6	18.9	25.2	—	3	C	A-13	Fe.
24 Ae. variabilis Eig	Gramineae	M	28	4	A	13.8	27.5	41.3	55.1	—	3	C	A-13	Fe.
25 Ae. vavilovi (Zhuk.) Chenn.	Gramineae	M	42	6	A	18.3	36.9	55.0	73.4	—	3	C	A-13	Fe.
26 Ae. ventricosa Tausch	Gramineae	M	28	4	A	9.8	19.6	29.4	39.2	—	3	C	A-13	Fe.
27 Agave attenuata Salm-Dyck	Agavaceae	M	—	—	P	—	—	—	—	14.4	23	O	—	Ch.
28 Agapanthus sp. cv. Dwarf blue	Amaryllidaceae	M	30	2	P	13.3	26.6	39.9	53.1	—	1	R	C	Fe.

#	Species	Family													
29	*Agoseris glauca* (Pursh) Raf.	Compositae	D	18	2	—	3.5	7.0	10.5	14.0	—	47	C	B	Fe.
30	*A. grandiflora* (Nutt.) Greene	Compositae	D	18	2	P	2.0	4.0	6.0	8.0	—	47	C	B	Fe.
31	*A. heterophylla* (Nutt.) Greene	Compositae	D	18	2	A	1.1	2.3	3.4	4.6	—	47	C	B	Fe.
32	*A. retrorsa* (Benth.) Greene	Compositae	D	18	2	—	3.2	6.4	9.6	12.8	—	47	C	B	Fe.
33	*Agropyron elongatum* Host ex Beauv.	Gramineae	M	14	2	P	5.6	11.2	16.7	22.3	—	1	R	C	Fe.
34	*A. junceum* Auct.	Gramineae	M	42	6	P	16.4	32.7	49.1	65.4	—	1	R	C	Fe.
35	*A. pungens* (Pers.) Roem. & Schult	Gramineae	M	42	6	P	17.6	35.3	52.9	70.5	—	1	R	C	Fe.
36	*Alliaria petiolata* (Bieb.) Cavara & Grande	Cruciferae	D	36	4	P	1.9	3.9	5.8	7.8	—	1	R	F	Fe.
37	*Allium angulosum* L.	Amaryllidaceae	M	32	4	P	20.6	41.2	61.8	82.4	—	5	O	B	Fe.
38	*A. azureum* Ledebour	Amaryllidaceae	M	16	2	P	8.9	17.8	26.7	35.6	—	5	O	B	Fe.
39a	*A. cepa* L.	Amaryllidaceae	M	16	2	P	17.9	33.5	53.4	67.0	—	6	O	—	Ch.
39b	*A. cepa* L.	Amaryllidaceae	M	16	2	P	—	—	—	—	54.3	9	O	—	Ch.
39c	*A. cepa* L. cv. Excel	Amaryllidaceae	M	16	2	P	—	—	—	—	54.0	10	O	—	Ch.
39d	*A. cepa* L.	Amaryllidaceae	M	16	2	P	—	—	—	—	78.7	14	O	—	Ch.
39e	*A. cepa* L.	Amaryllidaceae	M	16	2	P	—	—	—	—	65.6	23	O	—	Ch.
40	*A. cepa* L. × *A. fistulosum* L.	Amaryllidaceae	M	16	2	P	14.9	29.9	44.9	59.8	—	7	O	B	Fe.
41	*A. cernuum* Roth.	Amaryllidaceae	M	14	2	P	17.1	34.2	51.3	68.4	—	5	O	B	Fe.
42	*A. darwasicum* Regel	Amaryllidaceae	M	16	2	P	8.8	17.7	26.5	35.4	—	5	O	B	Fe.
43	*A. dicipiens*[k]	Amaryllidaceae	M	16	2	P	10.7	21.5	32.2	43.0	—	5	O	B	Fe.
44a	*A. fistulosum* L.	Amaryllidaceae	M	16	2	P	13.1	26.3	39.4	52.6	—	5	O	B	Fe.
44b	*A. fistulosum* L.	Amaryllidaceae	M	16	2	P	12.5	25.1	37.6	50.1	41.0	6	O	B	Ch.
45	*A. fuscum*[k]	Amaryllidaceae	M	14	2	P	9.2	18.4	27.6	36.8	—	5	O	B	Fe.
46	*A. galanthum* Kar. & Kir.	Amaryllidaceae	M	16	2	P	12.2	24.4	36.6	48.8	—	5	O	B	Fe.
47	*A. globosum* Bieb.	Amaryllidaceae	M	32	4	P	37.9	75.8	113.7	151.6	—	5	O	B	Fe.
48	*A. hirsutum* Zucc.	Amaryllidaceae	M	14	2	P	17.9	35.9	53.8	71.8	—	5	O	B	Fe.
49	*A. jesolianum*[k]	Amaryllidaceae	M	16	2	P	12.0	24.1	36.1	48.2	—	5	O	B	Fe.
50	*A. karataviense* Regel	Amaryllidaceae	M	18	2	P	22.7	45.4	68.1	90.8	—	5	O	B	Fe.
51	*A. margaritaceum* Sibth. & Sm.	Amaryllidaceae	M	32	4	P	21.9	43.8	65.7	87.6	—	5	O	B	Fe.
52	*A. neapolitanum* Cyr.	Amaryllidaceae	M	14	2	P	15.6	31.2	46.8	62.4	—	5	O	B	Fe.
53	*A. odoratissimum* Desf.	Amaryllidaceae	M	16	2	P	7.8	15.6	23.4	31.2	—	5	O	B	Fe.
54	*A. roseum* L.	Amaryllidaceae	M	16	2	P	10.2	20.4	30.6	40.8	—	5	O	B	Fe.
55	*A. schoenoprasum* L.	Amaryllidaceae	M	16	2	P	8.4	16.9	25.3	33.8	—	5	O	B	Fe.
56	*A. senescens* L.	Amaryllidaceae	M	32	4	P	21.6	43.2	64.8	86.4	—	5	O	B	Fe.
57	*A. sibiricum* L.	Amaryllidaceae	M	16	2	P	7.6	15.2	22.8	30.4	—	5	O	B	Fe.
58	*A. stellatum* Fras. ex Ker-Gawl.	Amaryllidaceae	M	16	2	P	12.7	25.5	38.2	51.0	—	5	O	B	Fe.
59	*A. subhirsutum* L.	Amaryllidaceae	M	14	2	P	17.8	35.7	53.5	71.4	—	5	O	B	Fe.
60	*A. triquetrum* L.	Amaryllidaceae	M	18	2	P	18.1	36.3	54.4	72.6	—	5	O	B	Fe.
61	*A. tuberosum* Rottler	Amaryllidaceae	M	32	4	P	17.4	34.8	52.1	69.5	66.3	6	O	—	Ch.
62	*A. zebdanense* Boiss. & Noë	Amaryllidaceae	M	18	2	P	12.6	25.3	37.9	50.6	—	5	O	B	Fe.
63	*A. zebdanense* Boiss. & Noë	Amaryllidaceae	M	45	5	P	30.8	61.6	92.4	123.2	—	5	O	B	Fe.
64	*Anacyclus clavatus* (Desf.) Pers.	Compositae	D	18	2	A	5.2	10.5	15.7	21.0	—	32	O	B	Fe.

TABLE 8 (cont.)

species	family	monocot (M) or dicot (D)	chromosome number, 2n	ploidy level, x	life cycle type (annual (A), biennial (B), or perennial (P))	DNA amount/pg					original reference (for key see §9(a))	present amount (original value (O), calibrated value (C) or recalibrated value (R))	standard species used to calculate the present amount (for key see §9(b))	method used for DNA estimate (Feulgen densitometry, Fe., chemical extraction, Ch.)
						1C	2C	3C	4C	per cell				
65 A. depressus (Ball) Maire	Compositae	D	18	2	P	6.2	12.4	18.6	24.8	—	32	O	B	Fe.
66 A. radiatus Lois.	Compositae	D	18	2	A	8.5	16.9	25.4	33.8	—	32	O	B	Fe.
67 A. valentinus L.	Compositae	D	18	2	A	5.7	11.4	17.1	22.8	—	32	O	B	Fe.
68 Anemone blanda Schott & Ky.	Ranunculaceae	D	16	2	P	13.6	27.1	40.7	54.3	—	8	R	D	Fe.
69 A. caroliniana Walt.	Ranunculaceae	D	16	2	P	11.1	22.2	33.4	44.5	—	8	R	D	Fe.
70 A. coronaria L.	Ranunculaceae	D	16	2	P	8.5	16.9	25.4	33.8	—	8	R	D	Fe.
71 A. cylindrica Gray	Ranunculaceae	D	16	2	P	9.3	18.6	27.9	37.2	—	8	R	D	Fe.
72 A. decapetala Ard.	Ranunculaceae	D	16	2	P	8.8	17.7	26.6	35.4	—	8	R	D	Fe.
73 A. fasciculata L.	Ranunculaceae	D	14	2	P	21.2	42.3	63.5	84.7	—	8	R	D	Fe.
74 A. heterophylla Nutt. ex Torr. & Gray	Ranunculaceae	D	16	2	P	12.8	25.5	38.3	51.1	—	8	R	D	Fe.
75 A. parviflora Michx.	Ranunculaceae	D	16	2	P	5.9	11.9	17.8	23.8	—	8	R	D	Fe.
76 A. pavonina Lam.	Ranunculaceae	D	16	2	P	12.4	24.9	37.3	49.7	—	8	R	D	Fe.
77 A. riparia Fernald.	Ranunculaceae	D	16	2	P	9.0	17.9	26.9	35.8	—	8	R	D	Fe.
78 A. silvestris L.	Ranunculaceae	D	16	2	P	6.6	13.2	19.8	26.4	—	8	R	D	Fe.
79 A. tetrasepala Royle	Ranunculaceae	D	14	2	P	22.7	45.4	68.1	90.8	—	8	R	D	Fe.
80 A. virginiana L.	Ranunculaceae	D	16	2	P	8.9	17.9	26.9	35.7q	—	2	O	B	Fe.
81 Anthemis austriaca Jacq.	Compositae	D	18	2	A	4.8	9.6	14.4	19.3	—	32	O	B	Fe.
82 A. cota L.	Compositae	D	18	2	A	7.9	15.8	23.7	31.6	—	32	O	B	Fe.
83 A. tinctoria L.	Compositae	D	18	2	P	3.7	7.5	11.2	15.0	—	32	O	B	Fe.
84 Anthericum suffruticosum (Baker) Milne-Redhead	Liliaceae	M	16	2	P	6.9	13.7	20.6	27.4	—	1	R	C	Fe.
85 Anthericum suffruticosum (Baker) Milne-Redhead	Liliaceae	M	32	4	P	12.8	25.7	38.5	51.3	—	1	R	C	Fe.
86 Antirrhinum majus L.	Scrophulariaceae	D	16	2	P	1.6	3.2	4.8	6.4	—	1	R	C & E	Fe.
87 Aphanes arvensis L.	Rosaceae	D	48	6	A	0.6	1.1	1.7	2.3	—	1	R	F	Fe.
88 Aporocactus flagelliformis Lem.	Cactaceae	D	22	2	P	1.9	3.8	5.7	7.6	—	31	C	F	Fe.
89 Aquilegia caerulea James × chrysantha Gray	Ranunculaceae	D	14	2	P	0.5	1.1	1.6	2.1	—	8	R	D	Fe.
90 Arabidopsis thaliana L. (Heynh.)	Cruciferae	D	10	2	A	0.2	0.5	0.7	0.9	—	1	R	E-509	Fe.
91 Arachis hypogaea L.	Leguminosae	D	40	4	A	1.8	3.5	5.3	7.1	—	2	O	B	Fe.
92 Argemone platyceras Link & Otto.	Papaveraceae	D	28	2	A	0.6	1.2	1.8	2.4	—	2	O	G	Fe.
93 Arisarum proboscidium Savi	Araceae	M	—	—	P	9.0	17.9	26.8	35.8	—	1	R	C	Fe.

No.	Name	Family													
94	*Artemisia absinthium* L.	Compositae	D	18	2	P	**3.6**	7.3	10.9	14.6	—	32	O	B	Fe.
95	*A. annua* L.	Compositae	D	18	2	A	**2.0**	4.1	6.1	8.1	—	32	O	B	Fe.
96	*Arum maculatum* L.	Araceae	M	56	8	P	**10.9**	21.8	32.8	43.7	—	2	O	C	Fe.
97	*Astrodaucus littoralis* (Bieb.) Drude	Umbelliferae	D	20	2	B	**5.2**	10.3	15.5	20.7	—	25	O	B	Fe.
98	*A. orientalis* (L.) Drude	Umbelliferae	D	20	2	B	**4.9**	9.8	14.7	19.6	—	25	O	B	Fe.
99	*Avena abyssinica* Hochst.	Gramineae	M	14	2	A	**4.8**	9.6	14.4	19.2	—	2	O	F	Fe.
100a	*A. abyssinica* Hochst.	Gramineae	M	28	4	A	**8.9**	17.9	26.8	35.8	—	34	C	F^e	Fe.
100b	*A. abyssinica* Hochst.	Gramineae	M	28	4	A	**9.0**	18.0	27.0	36.0	—	35	C	F^d	Fe.
101a	*A. barbata* Pott.	Gramineae	M	28	4	A	**8.9**	17.8	26.7	35.7	—	2	C	F	Fe.
101b	*A. barbata* Pott.	Gramineae	M	28	4	A	**9.3**	18.5	27.8	37.1	—	34	C	F^e	Fe.
101c	*A. barbata* Pott.	Gramineae	M	28	4	A	**9.1**	18.1	27.2	36.2	—	35	C	F^d	Fe.
102a	*A. brevis* Roth.	Gramineae	M	14	2	A	**4.7**	9.5	14.2	18.9	—	2	O	F	Fe.
102b	*A. brevis* Roth.	Gramineae	M	14	2	A	**4.5**	8.9	13.4	17.9	—	34	C	F^e	Fe.
103a	*A. byzantina* C. Koch	Gramineae	M	42	6	A	**13.7**	27.4	41.1	54.8	—	2	C	F	Fe.
103b	*A. byzantina* C. Koch	Gramineae	M	42	6	A	**13.5**	27.1	40.6	54.1	—	35	C	F^d	Fe.
104	*A. clauda* Dur.	Gramineae	M	14	2	A	**5.3**	10.6	15.9	21.1	—	35	C	F^d	Fe.
105a	*A. fatua* L.	Gramineae	M	42	6	A	**14.2**	28.3	42.5	56.6	—	34	C	F^e	Fe.
105b	*A. fatua* L.	Gramineae	M	42	6	A	**12.9**	25.7	38.6	51.5	—	35	C	F^d	Fe.
106a	*A. hirtula* Lag.	Gramineae	M	14	2	A	**4.4**	8.8	13.2	17.6	—	2	O	F	Fe.
106b	*A. hirtula* Lag.	Gramineae	M	14	2	A	**4.7**	9.4	14.2	18.9	—	34	C	F^e	Fe.
106c	*A. hirtula* Lag.	Gramineae	M	14	2	A	**4.9**	9.8	14.7	19.6	—	35	C	F^d	Fe.
107a	*A. longiglumis* Dur.	Gramineae	M	14	2	A	**5.3**	10.6	16.0	21.3	—	2	C	F	Fe.
107b	*A. longiglumis* Dur.	Gramineae	M	14	2	A	**5.0**	9.9	14.9	19.9	—	34	C	F^e	Fe.
107c	*A. longiglumis* Dur.	Gramineae	M	14	2	A	**4.9**	9.8	14.8	19.7	—	35	C	F^d	Fe.
108a	*A. ludoviciana* Durieu	Gramineae	M	42	6	A	**13.8**	27.5	41.3	50.1	—	2	O	F	Fe.
108b	*A. ludoviciana* Durieu	Gramineae	M	42	6	A	**13.1**	26.2	39.3	52.3	—	34	C	F^e	Fe.
109a	*A. magna* Murphy et Terrell	Gramineae	M	28	4	A	**9.3**	18.6	27.9	37.2	—	2	O	F	Fe.
109b	*A. magna* Murphy et Terrell	Gramineae	M	28	4	A	**9.7**	19.4	29.0	38.8	—	35	C	F^d	Fe.
110	*A. nuda* L.	Gramineae	M	42	6	A	**12.9**	25.8	38.8	51.7	—	34	C	F^e	Fe.
111	*A. nudi-brevis* Vav.	Gramineae	M	14	2	A	**4.4**	8.8	13.2	17.6	—	34	C	F^e	Fe.
112a	*A. pilosa* M. Bieb.	Gramineae	M	14	2	A	**4.7**	9.5	14.2	18.9	—	2	O	F	Fe.
112b	*A. pilosa* M. Bieb.	Gramineae	M	14	2	A	**5.5**	11.0	16.5	21.9	—	35	C	F^d	Fe.
113a	*A. sativa* L.	Gramineae	M	42	6	A	**13.2**	26.5	39.7	52.9	—	2	O	F	Fe.
113b	*A. sativa* L.	Gramineae	M	42	6	A	**13.7**	27.5	41.2	55.0	—	34	C	F^e	Fe.
114a	*A. sterilis* L.	Gramineae	M	42	6	A	**13.7**	27.3	41.0	54.6	—	2	O	F	Fe.
114b	*A. sterilis* L.	Gramineae	M	42	6	A	**14.3**	28.6	42.9	57.1	—	34	C	F^e	Fe.
114c	*A. sterilis* L.	Gramineae	M	42	6	A	**14.1**	28.2	42.4	56.5	—	35	C	F	Fe.
115a	*A. strigosa* Schreb.	Gramineae	M	14	2	A	**4.0**	8.0	12.0	16.0	—	2	O	F	Fe.
115b	*A. strigosa* Schreb.	Gramineae	M	14	2	A	**4.8**	9.7	14.5	19.4	—	34	C	F^e	Fe.
115c	*A. strigosa* Schreb.	Gramineae	M	14	2	A	**5.0**	10.0	15.0	20.0	—	35	C	F^d	Fe.
116a	*A. vaviloviana* Malz.	Gramineae	M	28	4	A	**8.5**	17.0	25.5	34.0	—	34	C	F^e	Fe.
116b	*A. vaviloviana* Malz.	Gramineae	M	28	4	A	**9.2**	18.4	27.6	36.9	—	35	C	F^d	Fe.
117	*A. ventricosa* Bal.	Gramineae	M	14	2	A	**5.6**	10.9	16.4	21.9	—	35	C	F^d	Fe.
118a	*A. wiestii* Steud.	Gramineae	M	14	2	A	**5.1**	10.3	15.4	20.5	—	34	C	F^e	Fe.
118b	*A. wiestii* Steud.	Gramineae	M	14	2	A	**4.9**	9.8	14.6	19.5	—	35	C	F^d	Fe.
119	*Bellevalia romana* (L.) Rchb.	Liliaceae	M	8	2	P	**8.5**	16.9	25.4	33.9	—	2	O	G	Fe.
120	*Beta maritima* L.	Chenopodiaceae	D	18	2	P	**1.3**	2.6	3.8	5.1	—	1	R	C	Fe.
121a	*B. vulgaris* L.	Chenopodiaceae	D	18	2	P	**1.2**	2.5	3.7	5.0	—	1	R	C	Fe.
121b	*B. vulgaris* L. var. *Cicla*	Chenopodiaceae	D	18	2	P	**1.3**	2.6	3.9	5.2	—	22	R	B	Fe.
122	*Borzicactus aurivillus* Schumann	Cactaceae	D	22	2	P	**1.7**	3.4	5.1	6.7	—	31	C	F	Fe.

TABLE 8 (cont.)

| | species | family | monocot (M) or dicot (D) | chromosome number, 2n | ploidy level, x | life cycle type (annual (A), biennial (B) or perennial (P)) | DNA amount/pg | | | | | original reference (for key see § 9(a)) | present amount (original value (O), calibrated value (C) or recalibrated value (R)) | standard species used to calculate the present amount (for key see § 9(b)) | method used for DNA estimate (Feulgen densitometry, Fe, chemical extraction, Ch.) |
							1C	2C	3C	4C	per cell				
123	Bowiea volubilis Harvey	Liliaceae	M	20	2	P	4.6	9.3	13.9	18.5	—	2	O	E	Fe.
124	Brassica campestris L.	Cruciferae	D	20	2	A–B	0.8	1.6	2.5	3.3	—	27	O	B	Fe.
125	B. carinata A.Br.	Cruciferae	D	34	2	A	1.6	3.1	4.7	6.3	—	27	O	B	Fe.
126	B. juncea (L.) Czrm.	Cruciferae	D	36	2	A	1.5	3.1	4.6	6.1	—	27	O	B	Fe.
127	B. napus L.	Cruciferae	D	38	2	A–B	1.6	3.2	4.8	6.4	—	27	O	B	Fe.
128	B. nigra (L.) Koch	Cruciferae	D	16	2	A	0.8	1.6	2.3	3.1	—	27	O	B	Fe.
129	B. oleracea L.	Cruciferae	D	18	2	B–P	0.9	1.8	2.7	3.6	—	27	O	B	Fe.
130	Briza maxima L.	Gramineae	M	14	2	A	10.8	21.6	32.4	43.2	—	41	O	B	Fe.
131	B. media L.	Gramineae	M	14	2	P	8.5	16.9	25.4	33.8	—	41	O	B	Fe.
132	B. media L.	Gramineae	M	28	4	P	16.0	32.0	47.9	63.9	—	41	O	B	Fe.
133	B. minor L.	Gramineae	M	10	2	A	7.3	14.6	21.9	29.2	—	41	O	B	Fe.
134	B. poaemorpha (Presl.) Henrard	Gramineae	M	28	4	P	10.4	20.8	31.2	41.6	—	41	O	B	Fe.
135	B. stricta (Hook. & & Arn.) Steudel	Gramineae	M	28	4	P	11.7	23.3	35.0	46.7	—	41	O	B	Fe.
136	B. subaristata Lam.	Gramineae	M	28	4	P	11.4	22.9	34.3	47.8	—	41	O	B	Fe.
137	Bromus adoensis Hochst.	Gramineae	M	28	4	A	8.0	16.1	24.1	32.2	—	2	O	E	Fe.
138	Br. aegyptiacus Tausch ssp. palaestinus	Gramineae	M	14	2	A	5.7	11.3	17.0	22.6	—	2	O	E	Fe.
139	Br. aleutensis Trin.	Gramineae	M	56	8	P	9.6	19.3	28.9	38.5	—	2	O	E	Fe.
140	Br. alopecuros Poir.	Gramineae	M	14	2	A	5.9	11.7	17.6	23.5	—	2	O	E	Fe.
141	Br. arvensis L.	Gramineae	M	14	2	A	6.3	12.5	18.8	25.0	—	2	O	E	Fe.
142	Br. brachystachys Horn.	Gramineae	M	14	2	A	5.7	11.5	17.2	22.9	—	2	O	E	Fe.
143	Br. breviaristatus Buckl.	Gramineae	M	56	8	P	10.4	20.9	31.3	41.7	—	2	O	E	Fe.
144	Br. brevis Nees ex Steud.	Gramineae	M	42	6	P?	6.3	12.6	18.9	25.1	—	2	O	E	Fe.
145	Br. brizaeformis F. et M.	Gramineae	M	14	2	A	5.9	11.8	17.7	23.7	—	2	O	E	Fe.
146	Br. carinatus Hook. et Arn.	Gramineae	M	56	8	P	10.5	20.9	31.4	41.8	—	2	O	E	Fe.
147	Br. coloratus Steud.	Gramineae	M	42	6	P	6.8	13.6	20.4	27.2	—	2	O	E	Fe.
148	Br. commutatus Schrad.	Gramineae	M	28	4	A	10.9	21.7	32.6	43.5	—	2	O	E	Fe.
149	Br. diandrus Roth.	Gramineae	M	56	8	A	11.9	23.9	35.8	47.8	—	2	O	E	Fe.
150	Br. erectus Huds.	Gramineae	M	56	8	P	11.6	23.3	34.9	46.6	—	2	O	E	Fe.
151	Br. grossus Desf. ex DC.	Gramineae	M	28	4	A	13.9	27.8	41.8	55.7	—	2	O	E	Fe.
152	Br. haenkeanus Kunth.	Gramineae	M	42	6	P	6.7	13.3	20.0	26.7	—	2	O	E	Fe.
153	Br. hordeaceus L. ssp. hordeaceus	Gramineae	M	28	4	A	9.2	18.4	27.5	36.7	—	2	O	E	Fe.
154	Br. inermis Leyss.	Gramineae	M	56	8	P	11.8	23.6	35.4	47.2	—	2	O	E	Fe.
155	Br. intermedius Guss.	Gramineae	M	28	4	A	12.9	25.9	38.8	51.8	—	2	O	E	Fe.
156	Br. interruptus (Hack.) Druce	Gramineae	M	28	4	A	8.4	16.8	25.3	33.7	—	2	O	E	Fe.

No.	Species	Family		2n			DNA values				O/R	Code	
157	Br. japonicus Thunb.	Gramineae	M	14	2	A	5.5	11.0	16.5	22.0	—	2	O	E	Fe.
158	Br. lepidus Holmberg	Gramineae	M	28	4	A	7.9	15.7	23.6	31.4	—	2	O	E	Fe.
159	Br. macranthus E. Desv.	Gramineae	M	70	10	P	16.3	32.6	48.9	65.3	—	2	O	E	Fe.
160	Br. madritensis L.	Gramineae	M	28	4	A	4.9	9.7	14.6	19.5	—	2	O	E	Fe.
161	Br. marginatus Nees	Gramineae	M	42	6	P	5.4	10.8	16.1	21.5	—	2	O	E	Fe.
162	Br. oxyodon Schrenk.	Gramineae	M	28	4	A	7.7	15.5	23.2	31.0	—	2	O	E	Fe.
163	Br. × pseudothominii P. Smith	Gramineae	M	28	4	A	9.9	19.7	29.6	39.4	—	2	O	E	Fe.
164	Br. pumilio (Trin.) P. Smith	Gramineae	M	14	2	A	1.9	3.7	5.6	7.5	—	2	O	E	Fe.
165	Br. racemosus L.	Gramineae	M	28	4	A	13.5	27.0	40.4	53.9	—	2	O	E	Fe.
166	Br. rigidus Roth	Gramineae	M	42	6	A	8.6	17.2	25.8	34.4	—	2	O	E	Fe.
167	Br. rubens L.	Gramineae	M	28	4	A	4.9	9.7	14.6	19.4	—	2	O	E	Fe.
168	Br. scoparius L.	Gramineae	M	14	2	A	4.8	9.7	14.5	19.4	—	2	O	E	Fe.
169	Br. secalinus L.	Gramineae	M	28	4	A	14.0	27.9	41.9	55.8	—	2	O	E	Fe.
170	Br. sitchensis Trin.	Gramineae	M	56	8	P	9.4	18.8	28.3	37.7	—	2	O	E	Fe.
171	Br. squarrosus L.	Gramineae	M	14	2	A	5.7	11.5	17.2	23.0	—	2	O	E	Fe.
172	Br. stamineus E. Desv.	Gramineae	M	42	6	P	7.8	15.6	23.3	31.1	—	2	O	E	Fe.
173	Br. sterilis L.	Gramineae	M	14	2	A	3.3	6.7	10.0	13.4	—	2	O	E	Fe.
174	Br. tectorum L.	Gramineae	M	14	2	A	3.3	6.5	9.8	13.0	—	2	O	E	Fe.
175	Br. unioloides H.B.K.	Gramineae	M	42	6	P	7.4	14.9	22.3	29.7	—	2	O	E	Fe.
176	Br. ?valdivianus Phil.[1]	Gramineae	M	42	6	P	7.0	13.9	20.9	27.8	—	2	O	E	Fe.
177	Bryonia dioica Jacq.[1]	Cucurbitaceae	D	20	2	P	1.6	3.3	4.9	6.6	—	37	R	F	Fe.
178	Bulbine caulescens L.	Liliaceae	M	14	2	P	22.4	44.8	67.3	89.7	—	1	R	C	Fe.
179	B. semibarbata Haw.	Liliaceae	M	26	2	A	8.9	17.8	26.6	35.5	—	2	O	G	Fe.
180	Cajanus cajan (L.) Millsp.	Leguminosae	D	22	2	P	0.9	1.7	2.6	3.5	—	2	O	B	Fe.
181a	Callisia elegans Alex.	Commelinaceae	M	12	2	P	9.3	18.5	27.8	37.0	—	2	O	B	Fe.
181b	C. elegans Alex.	Commelinaceae	M	12	2	P	9.3	18.5	27.8	37.0	—	52	C	Be	Fe.
182	C. insignis C. B. Clarke	Commelinaceae	M	48	6	P	11.2	22.3	33.5	44.7	—	52	C	Be	Fe.
183	C. multiflora Stanl.	Commelinaceae	M	24	4	P	7.4	14.8	22.3	29.7	—	52	C	Be	Fe.
184a	C. repens L.	Commelinaceae	M	12	2	P	7.0	14.0	21.0	28.0	—	2	O	B	Fe.
184b	C. repens L.	Commelinaceae	M	12	2	P	7.0	14.0	21.0	28.0	—	52	C	Be	Fe.
185	Caltha palustris L.	Ranunculaceae	D	56	7	P	16.5	33.0	49.5	66.0	—	1	R	C	Fe.
186	Calycadenia pauciflora A. Gray (race Tehama)	Compositae	D	12	2	A	1.4	2.8	4.1	5.5	—	2	O	H	Fe.
187	Capsella bursa-pastoris (L.) Medic.	Cruciferae	D	32	4	A	0.7	1.4	2.1	2.8	—	1	R	F-325	Fe.
188a	Capsicum annuum L. (wild form)	Solanaceae	D	24	2	A–B	4.0	8.0	12.0	16.0	—	46	O	B	Fe.
188b	C. annuum L. (cultivated form)	Solanaceae	D	24	2	A–B	5.4	10.8	16.2	21.7	—	46	O	B	Fe.
189a	C. baccatum L. (wild form)	Solanaceae	D	24	2	P	4.9	9.8	14.7	19.5	—	46	O	B	Fe.
189b	C. baccatum L. (cultivated form)	Solanaceae	D	24	2	P	6.4	12.7	19.1	25.5	—	46	O	B	Fe.
190	C. chinense Jacq.	Solanaceae	D	24	2	P	5.9	11.8	17.6	23.5	—	46	O	B	Fe.
191	C. eximium Hunziker	Solanaceae	D	24	2	P	6.1	12.3	18.5	24.6	—	46	O	B	Fe.
192	C. frutescens L.	Solanaceae	D	24	2	P	6.0	12.0	18.0	24.0	—	46	O	B	Fe.
193	C. pubescens Ruiz et Pav.	Solanaceae	D	24	2	P	6.4	12.9	19.3	25.7	—	46	O	B	Fe.
194	Cenchrus ciliaris L.	Gramineae	M	—	—	P	1.3	2.6	3.9	5.3	—	2	O	B	Fe.
195	Chamaemelum fuscatum L.	Compositae	D	18	2	A	5.2	10.3	15.5	20.6	—	32	O	B	Fe.
196	C. mixtum L.	Compositae	D	18	2	A	3.8	7.6	11.4	15.2	—	32	O	B	Fe.
197	C. nobile L.	Compositae	D	18	2	P	5.3	10.7	16.0	21.3	—	32	O	B	Fe.

Table 8 (cont.)

	species	family	monocot (M) or dicot (D)	chromosome number, 2n	ploidy level, x	life cycle type (annual (A), biennial (B) or perennial (P))	DNA amount/pg 1C	2C	3C	4C	4C per cell	original reference (for key see § 9(a))	present amount (original value (O), calibrated value (C) or recalibrated value (R))	standard species used to calculate the present amount (for key see § 9(b))	method used for DNA estimate (Feulgen densitometry, Fe., chemical extraction, Ch.)
198	Chloris gayana Kunth.	Gramineae	M	20	2	P	0.3	0.7	1.0	1.4	—	2	O	B	Fe.
199	Chrysanthemum lacustre Brot.	Compositae	D	198	22	P	—	—	—	—	142.0	10	O	—	Ch.
200	C. nipponicum Matsum.	Compositae	D	18	2	P	—	—	—	—	44.0	10	O	—	Ch.
201	C. yezoense Mackawa	Compositae	D	56	6	P	—	—	—	—	29.0	10	O	—	Ch.
202	Chrysanthemum sp.	Compositae	D	36	—	—	—	—	—	—	37.0	10	O	—	Ch.
203	Chrysanthemum sp. Diener's hybrid	Compositae	D	138	—	—	—	—	—	—	79.0	10	O	—	Ch.
204	Cicer arietinum L.	Leguminosae	D	16	2	A	1.0	1.9	2.9	3.8	—	2	O	B	Fe.
205	Cleistocactus smaragdifolius (Weber) Speg.	Cactaceae	D	22	2	P	1.7	3.4	5.1	6.7	—	31	C	F	Fe.
206	Clematis jackmannii Moore	Ranunculaceae	D	16	2	P	—	—	—	—	22.0	10	O	—	Ch.
207	Clivia miniata Regel	Amaryllidaceae	M	22	2	P	17.6	35.3	52.9	70.5	—	2	O	C	Fe.
208	Coix lachryma-jobi L.	Gramineae	M	20	4	A	1.6	3.2	4.8	6.5	—	2	O	E	Fe.
209	Commelina coelestis Willd.	Commelinaceae	M	90	6	P	9.8	19.5	29.3	39.0	—	2	O	G	Fe.
210	Convallaria majalis L.	Liliaceae	M	38	2	P	24.7	49.3	74.0	98.6	—	1	R	C	Fe.
211	Crepis alpina L.	Compositae	D	10	2	A	3.0	6.0	9.0	12.0	—	42	O	B	Fe.
212	C. aurea (L.) Cass.	Compositae	D	10	2	P	2.5	5.0	7.5	10.1	—	42	O	B	Fe.
213a	C. biennis L.	Compositae	D	40	8	B	8.5	16.9	25.3	33.8	—	42	O	B	Fe.
213b	C. biennis L.	Compositae	D	40°	8°	B	8.6	17.2	25.9	34.5	—	48	C	B	Fe.
214	C. biennis L.	Compositae	D	—°	—°	B	15.7	31.3	47.0	62.7	—	48	C	B	Fe.
215	C. blattarioides Vill.	Compositae	D	8	2	P	4.6	9.3	13.9	18.5	—	42	O	B	Fe.
216	C. bulbosa^k	Compositae	D	—	—	—	0.9	1.8	2.6	3.5	—	42	O	B	Fe.
217	C. canariensis (Sch. Bip.) Babc.	Compositae	D	8	2	P	2.7	5.4	8.0	10.7	—	42	O	B	Fe.
218a	C. capillaris (L.) Wallr.	Compositae	D	6	2	A	2.4	4.7	7.0	9.4	—	42	O	B	Fe.
218b	C. capillaris (L.) Wallr.	Compositae	D	6	2	A	2.4	4.8	7.3	9.7	—	48	C	B	Fe.
218c	C. capillaris (L.) Wallr.	Compositae	D	6	2	A	2.7	5.2	7.8	10.4	—	29	O	Xenopus	Fe.
218d	C. capillaris (L.) Wallr.	Compositae	D	6	2	A	2.1	4.2	6.3	8.4	—	7	O	B	Fe.
218e	C. capillaris (L.) Wallr.	Compositae	D	6	2	A	1.3	2.5	3.7	4.9	3.8	6	O	—	Ch.
219	C. conyzifolia Gouan.	Compositae	D	8	2	P	4.3	8.7	13.0	17.4	—	48	C	B	Fe.
220	C. dioscoridis L.	Compositae	D	8	2	A	6.2	12.3	18.4	24.5	—	42	O	B	Fe.
221	C. foetida L.	Compositae	D	10	2	A	2.0	3.9	5.9	7.8	—	42	O	B	Fe.
222	C. fuliginosa Webb et Berth.	Compositae	D	6	2	A	0.9	1.8	2.7	3.6	—	29	O	Xenopus	Fe.
223	C. grandiflora Tausch	Compositae	D	8	2	—	6.5	13.0	19.5	26.0	—	42	O	B	Fe.
224	C. laciniata^k	Compositae	D	—	—	—	3.6	7.1	10.7	14.2	—	42	O	B	Fe.
225	C. lapsanoides^k	Compositae	D	12	2	P	5.6	11.2	16.2	22.3	—	42	O	B	Fe.
226a	C. neglecta L.	Compositae	D	8	2	A	1.8	3.6	5.4	7.2	—	29	O	Xenopus	Fe.

No.	Species	Family														
226 b	*C. neglecta* L.	Compositae	D	8	2	A	2.9	5.8	8.7	11.6	—	42	O	B	Fe.
227	*C. palaestina* Bornmüller	Compositae	D	8	2	A	6.3	12.6	18.8	25.1	—	42	O	B	Fe.
228	*C. pannonica* C. Koch	Compositae	D	8	2	P	2.1	4.1	6.1	8.2	—	42	O	B	Fe.
229	*C. pontana* L.	Compositae	D	10	2	P	6.9	13.8	20.6	27.5	—	42	O	B	Fe.
230	*C. pulchra* L.	Compositae	D	8	2	A	5.4	10.8	16.2	21.6	—	42	O	B	Fe.
231	*C. rubra* L.	Compositae	D	10	2	A	2.9	5.7	8.6	11.4	—	42	O	B	Fe.
232	*C. setosa* Haller. f.	Compositae	D	8	2	A	2.3	4.6	7.0	9.3	—	42	O	B	Fe.
233	*C. sibirica* L.	Compositae	D	10	2	P	7.3	14.5	21.7	29.0	—	42	O	B	Fe.
234	*C. taraxacifolia* Thuill [*C. versicaria* L. spp. *taraxacifolia* (Thuill.) Thell.]	Compositae	D	8	2	B	3.0	5.9	8.8	11.7	—	42	O	B	Fe.
235	*C. tectorum* L.	Compositae	D	8	2	A	3.4	6.8	10.1	13.5	—	42	O	B	Fe.
236	*C. zacintha* L.	Compositae	D	6	2	A	1.1	2.1	3.2	4.3	—	42	O	B	Fe.
237	*Cucumis sativus* L.	Cucurbitaceae	D	14	2	A	1.0	2.1	3.1	4.2	—	22	R	B	Fe.
238	*Cucurbita pepo* L.	Cucurbitaceae	D	40	4?	A	—	—	—	—	6.2	24	O	B	Ch.
239	*Cymbidium* sp. (hybrid 'in memoriam Cyrill Strauss')	Orchidaceae	M	—	—	P	5.4	10.7	16.3	21.4	—	43	O	B	Fe.
240	*Dactylis glomerata* L.	Gramineae	M	14	2	P	4.9	9.8	14.7	19.7	—	1	R	C	Fe.
241	*Datura discolor* Bernh.	Solanaceae	D	24	2	A	2.3	4.5	6.8	9.1	—	2	O	B	Fe.
242	*D. innoxia* Miller	Solanaceae	D	24	2	A	2.3	4.6	6.9	9.1	—	2	O	B	Fe.
243	*D. meteloides* Dunal.	Solanaceae	D	24	2	A	2.1	4.3	6.4	8.6	—	2	O	B	Fe.
244	*D. quercifolia* H.B.K.	Solanaceae	D	24	2	A	1.7	3.4	5.2	6.9	—	2	O	B	Fe.
245	*Daucus aureus* Desf.	Umbelliferae	D	22	2	A	1.1	2.3	3.5	4.6	—	25	O	B	Fe.
246	*D. blanchei* Reut.	Umbelliferae	D	20	2	A	4.7	9.3	14.0	18.7	—	25	O	B	Fe.
247	*D. carota* L. ssp. *carota*	Umbelliferae	D	18	2	A–B	1.0	2.0	3.0	4.0	—	25	O	B	Fe.
248	*D. carota* L. ssp. *gadecaei* (Rouy & Cam.) Heywood	Umbelliferae	D	18	2	A–B	1.3	2.5	3.8	5.0	—	25	O	B	Fe.
249	*D. carota* L. ssp. *gummifer* Hooker fil.	Umbelliferae	D	18	2	A–B	1.6	3.3	4.9	6.6	—	25	O	B	Fe.
250	*D. carota* L. ssp. *halophilus* (*D. halophilus* Brot.)	Umbelliferae	D	18	2	A–B	2.0	4.0	6.0	8.0	—	25	O	B	Fe.
251	*D. carota* L. ssp. *sativus* (Hoffm.) Arcangeli cv. 'Amsterdam Forcing'	Umbelliferae	D	18	2	A–B	1.2	2.4	3.6	4.9	—	25	O	B	Fe.
252	*D. crinitus* Desf.	Umbelliferae	D	22	2	P	3.9	7.8	11.6	15.5	—	25	O	B	Fe.
253	*D. littoralis* Sibth. & Sm.	Umbelliferae	D	20	2	A	3.0	5.9	8.9	11.9	—	25	O	B	Fe.
254	*D. montanus* Humb. et Bon. pl.	Umbelliferae	D	66	6	A	5.5	11.0	16.4	21.9	—	25	O	B	Fe.
255	*D. muricatus* L.	Umbelliferae	D	22	2	A	2.5	5.1	7.6	10.1	—	25	O	B	Fe.
256	*D. subsessilis* Boiss.	Umbelliferae	D	22	2	A	1.9	3.8	5.7	7.6	—	25	O	B	Fe.
257	*D. syrticus* Murb.	Umbelliferae	D	18	2	A	1.2	2.5	3.8	5.0	—	25	O	B	Fe.
258	*Delphinium consolida* L.	Ranunculaceae	D	16	2	A	4.3	8.6	12.8	17.1	—	2	O	C	Fe.
259	*Dicranostigma franchetiana* (Prain) Fedde	Papaveraceae	D	12	2	A	0.7	1.5	2.2	3.0	—	2	O	H	Fe.
260	*Dracunculus vulgaris* Schott.	Araceae	M	32	2	P	6.8	13.7	20.5	27.3	—	1	R	C	Fe.
261	*Drosera binata* Labill.	Droseraceae	D	32	3	P	0.6	1.2	1.9	2.5	—	39	C	D	Fe.
262	*D. capensis* L.	Droseraceae	D	40	4	P	0.3	0.6	0.9	1.2	—	39	C	D	Fe.

TABLE 8 (cont.)

	species	family	monocot (M) or dicot (D)	chromosome number, 2n	ploidy level, x	life cycle type (annual (A), biennial (B) or perennial (P))	1C	2C	3C	4C	4C per cell	original reference (for key see § 9 (a))	present amount (original value (O), calibrated value (C) or recalibrated value (R))	standard species used to calculate the present amount (for key see § 9 (b))	method used for DNA estimate (Feulgen densitometry, Fe, chemical extraction, Ch.)
263	D. intermedia Hayne	Droseraceae	D	20	2	P	0.9	2.0	2.8	3.8	—	39	C	D	Fe.
264	D. linearis Goldie	Droseraceae	D	20	2	P	0.9	1.8	2.8	3.7	—	39	C	D	Fe.
265	D. rotundifolia L.	Droseraceae	D	20	2	P	0.9	1.8	2.6	3.5	—	39	C	D	Fe.
266	D. spathulata Labill.	Droseraceae	D	80	8	P	0.7	1.5	2.3	3.0	—	39	C	D	Fe.
267	Drosophyllum lusitanicum.	Droseraceae	D	12	2	P	15.0	30.0	45.0	60.0	—	39	C	D	Fe.
268	Echinochloa frumentacea Link	Gramineae	M	—	—	A	1.3	2.7	4.0	5.3	—	2	O	E	Fe.
269	Eleusine coracana Gaertn.	Gramineae	M	40	4	A	1.6	3.2	4.9	6.5	—	2	O	G	Fe.
270	E. indica Gaertn.	Gramineae	M	20	2	A	0.7	1.4	2.2	2.9	—	2	O	G	Fe.
271a	Endymion hispanicus (Mill.) Chouard	Liliaceae	M	16	2	P	—	—	—	—	94.6	14	O	—	Ch.
271b	E. hispanicus (Mill.) Chouard	Liliaceae	M	16	2	P	—	—	—	—	89.9	23	O	—	Ch.
272	E. non-scriptus (L.) Garke	Liliaceae	M	16	2	P	21.2	42.4	63.6	84.8	—	1	R	C	Fe.
273	Eragrostis tef. (Zucc.) Trott.	Gramineae	M	40	4	A	0.7	1.3	2.0	2.7	—	2	O	E	Fe.
274	Eranthis hyemalis Salisb.	Ranunculaceae	D	16	2	A	9.3	18.6	27.9	37.2	—	2	O	C	Fe.
275	Eremopyron triticeum (Gaertn.) Nevski	Gramineae	M	14	2	A	5.5	11.0	16.5	22.0	—	1	R	C	Fe.
276	Escobaria bella Br. & R.	Cactaceae	D	22	2	P	1.5	3.1	4.6	6.1	—	31	C	F	Fe.
277	Fritillaria acmopetala Boiss.	Liliaceae	M	24	2	P	75.5	151.1	226.6	302.1	—	13	R	C-293	Fe.
278	F. assyriaca Baker	Liliaceae	M	48	4	P	127.4	254.8	382.2	509.6	—	13	R	C-293	Fe.
279	F. aurea Schott	Liliaceae	M	24	2	P	81.9	163.8	245.7	327.6	—	1	R	C	Fe.
280	F. crassifolia Boiss. & Huet	Liliaceae	M	24	2	P	80.4	160.8	241.1	321.5	—	13	R	C-293	Fe.
281	F. davisii Turrill	Liliaceae	M	24	2	P	89.5	179.0	268.4	357.9	—	13	R	C-293	Fe.
282	F. fleischeri Kunth	Liliaceae	M	24	2	P	77.1	154.2	231.2	308.3	—	1	R	C	Fe.
283	F. glauca Greene	Liliaceae	M	24	2	P	77.7	155.3	233.0	310.6	—	13	R	C-293	Fe.
284	F. glaucoviridis Turrill	Liliaceae	M	24	2	P	84.0	168.1	252.1	336.1	—	1	R	C	Fe.
285	F. graeca Boiss. & Sprun.	Liliaceae	M	24	2	P	67.3	134.7	202.0	269.4	—	13	R	C-293	Fe.
286	F. graeca Boiss. & Sprun. var. gussichae	Liliaceae	M	24	2	P	66.1	132.3	198.4	264.5	—	13	R	C-293	Fe.
287	F. imperialis L.	Liliaceae	M	24	2	P	72.5	145.0	217.5	290.0	—	13	R	C-293	Fe.
288	F. karadaghensis Turrill	Liliaceae	M	24	2	P	81.6	163.2	244.8	326.4	—	13	R	C-293	Fe.
289	F. liliacea Lindl.	Liliaceae	M	24	2	P	60.7	121.3	182.0	242.7	—	13	R	C-293	Fe.
290	F. meleagris L.	Liliaceae	M	24	2	P	70.7	141.4	212.0	282.7	—	13	R	C-293	Fe.
291	F. olivieri Baker	Liliaceae	M	24	2	P	72.8	145.6	218.4	291.2	—	13	R	C-293	Fe.

No.	Species	Family	M/D	2n	ploidy	P/A			DNA values		—	n	R/O/C	Code	Ch./Fe.
292	*F. oranensis* Pomel	Liliaceae	M	24	2	P	74.3	148.6	222.9	297.3	—	13	R	C-293	Fe.
293	*F. paludiflora* Schrenk	Liliaceae	M	24	2	P	58.3	116.7	175.0	233.3	—	1	R	C	Fe.
294	*F. pinardi* Boiss.	Liliaceae	M	24	2	P	82.2	164.4	246.6	328.8	—	13	R	C-293	Fe.
295	*F. platyptera* G. Samuelsson apud K. H. Reichinger	Liliaceae	M	24	2	P	86.1	172.1	258.2	344.2	—	1	R	C	Fe.
296	*F. pyrenaica* L.	Liliaceae	M	24	2	P	63.7	127.4	191.1	254.8	—	13	R	C-293	Fe.
297	*F. raddeana* Regel	Liliaceae	M	24	2	P	59.8	119.5	179.3	239.0	—	13	R	C-293	Fe.
298	*F. rhodocanakis* Orph.	Liliaceae	M	24	2	P	86.1	172.3	258.4	344.6	—	13	R	C-293	Fe.
299	*F. tuntasia* Heldr. ex Halacsy	Liliaceae	M	24	2	P	81.6	163.2	244.8	326.4	—	13	R	C-293	Fe.
300	*F. verticillata* Willd.	Liliaceae	M	24	2	P	48.2	96.5	144.7	192.9	—	13	R	C-293	Fe.
301	*Fumaria muralis* Sonder ex Koch	Fumariaceae	D	28	4	A	0.6	1.1	1.7	2.2	—	2	O	G	Fe.
302	*Galtonia candicans* Decne.	Liliaceae	M	16	2	P	—	—	—	—	40.0	23	O	—	Ch.
303	*Gladiolus* L. sp. H. V. mansoer	Iridaceae	M	61	4+1	P	—	—	—	—	6.0	10	O	—	Ch.
304	*Glaucium corniculatum* (L.) J. H. Rudolph	Papaveraceae	D	12	2	A	0.6	1.2	1.8	2.4	—	2	O	G	Fe.
305	*Glycine max* Merr.	Leguminosae	D	40	4	A	—	—	—	—	6.5	9	O	—	Ch.
306	*Haplopappus gracilis* A. Gray	Compositae	D	4	2	A	2.0	4.1	6.1	8.2	—	1	R	C & E	Fe.
307	*Hagnaldia villosa* Schur	Gramineae	M	14	2	A	5.4	10.7	16.1	21.4	—	1	R	F	Fe.
308a	*Helianthus annuus* L. H. V. Mammoth Russian	Compositae	D	34	2	A	—	—	—	—	16.0	10	O	—	Ch.
308b	*H. annuus* L.	Compositae	D	34	2	A	—	—	—	—	9.9	12	O	—	Ch.
309	*H. tuberosus* L.	Compositae	D	102	6	P	12.6	25.1	37.7	50.2	—	22	R	B	Fe.
310	*Helleborus niger* L.	Ranunculaceae	D	16	2	P	11.4	22.8	34.1	45.5	—	2	O	C	Fe.
311	*Hepatica acutiloba* DC.	Ranunculaceae	D	14	2	P	16.6	33.1	49.7	66.3	—	8	R	D	Fe.
312	*H. americana* (DC.) Ker.	Ranunculaceae	D	14	2	P	16.6	33.2	49.8	66.3	—	8	R	D	Fe.
313	*Hieracium piloselloides* Vill.	Compositae	D	—		P	1.1	2.1	3.2	4.3	—	48	C	B	Fe.
314	*H. piloselloides* Vill.	Compositae	D	—		P	2.8	5.5	8.3	11.1	—	48	C	B	Fe.
315	*H. piloselloides* Vill.	Compositae	D	—		P	4.7	9.4	14.1	18.8	—	48	C	C	Fe.
316	*Hippeastrum* sp.	Amaryllidaceae	M	44	4	P	37.5	75.0	112.5	150.0	—	1	R	C	Fe.
317	*Hordeum bulbosum* Nevski	Gramineae	M	14	2	P	5.5	11.0	16.5	22.0	—	50	R	F	Fe.
318	*H. bulbosum* Nevski	Gramineae	M	28	4	P	11.0	22.1	33.1	44.2	—	50	R	F	Fe.
319	*H. chilense* R & S	Gramineae	M	14	2	P	5.4	10.9	16.3	21.8	—	50	R	F	Fe.
320	*H. geniculatum* All.	Gramineae	M	14	2	A	5.4	10.8	16.2	21.6	—	50	R	F	Fe.
321	*H. geniculatum* All.	Gramineae	M	28	4	A	10.8	21.5	32.3	43.1	—	50	R	F	Fe.
322	*H. glaucum* Steud.	Gramineae	M	14	2	A	5.5	11.0	16.5	22.0	—	50	R	F	Fe.
323	*H. jubatum* var. *breviaristata* L. emend. Bowden	Gramineae	M	28	4	P	10.9	21.7	32.6	43.4	—	50	R	F	Fe.
324	*H. leporinum* var. *leporinum* Link. emend. Bowden	Gramineae	M	28	4	A	10.9	21.8	32.6	43.5	—	50	R	F	Fe.
325	*H. leporinum* var. *simulans* Link. emend. Bowden	Gramineae	M	42	6	A	16.4	32.8	49.2	65.6	—	50	R	F	Fe.
326	*H. marinum* L.	Gramineae	M	14	2	A	5.5	11.0	16.5	22.0	—	50	R	F	Fe.

TABLE 8 (cont.)

	species	family	monocot (M) or dicot (D)	chromosome number, 2n	ploidy level, x	life cycle type (annual (A), biennial (B) or perennial (P))	DNA amount/pg 1C	2C	3C	4C	per cell	original reference (for key see §9 (a))	present amount (original value (O), calibrated value (C) or recalibrated value (R))	standard species used to calculate the present amount (for key see §9 (b))	method used for DNA estimate (Feulgen densitometry, Fe, chemical extraction, Ch.)
327	H. murinum L.	Gramineae	M	14	2	A	5.5	11.1	16.6	22.2	—	50	R	F	Fe.
328	H. murinum L.	Gramineae	M	28	4	A	11.1	22.2	33.3	44.4	—	50	R	F	Fe.
329	H. pusillum Nutt.	Gramineae	M	14	2	A	5.5	11.0	16.6	22.1	—	50	R	F	Fe.
330	H. roshevitsii Bowden	Gramineae	M	14	2	P	5.5	11.0	16.6	22.1	—	50	R	F	Fe.
331	H. secalinum Schreb.	Gramineae	M	28	4	P	11.2	22.4	33.6	44.8	—	50	R	F	Fe.
332	H. spontaneum Koch	Gramineae	M	14	2	A	5.5	11.0	16.5	22.0	—	50	R	F	Fe.
333	H. violaceum Boiss. & Huet	Gramineae	M	14	2	P	5.5	11.0	16.5	22.0	—	50	R	F	Fe.
334a	H. vulgare L. cv. Algerie 48	Gramineae	M	14	2	A	5.4	10.7	16.1	21.4	—	50	R	F	Fe.
334b	H. vulgare L. cv. Gilgit 7	Gramineae	M	14	2	A	5.5	10.9	16.4	21.9	—	50	R	F	Fe.
334c	H. vulgare L. cv. Proctor	Gramineae	M	14	2	A	5.5	10.9	16.4	21.9	—	50	R	F	Fe.
334d	H. vulgare L. cv. Sultan Swanneck	Gramineae	M	14	2	A	5.5	11.1	16.6	22.2	—	2	O	B	Fe.
334e	H. vulgare L. cv.	Gramineae	M	14	2	A	5.5	10.9	16.4	21.9	—	50	R	F	Fe.
335	Hosta rectifolia Nakai	Liliaceae	M	60	2	P	9.9	19.8	27.8	39.7	—	1	R	C	Fe.
336	Hyacinthus orientalis L.	Liliaceae	M	27	4−1	P	24.8	49.7	74.5	99.4	—	7	O	B	Fe.
337	Impatiens balsamina L.	Balsaminaceae	D	14	2	P	1.4	2.7	4.0	5.3	5.1	6	O	—	Ch.
338	Kalanchoe daigremontiana Hamet & Perrier	Crassulaceae	M	34	2	P	—	—	—	—	11.0	10	O	—	Ch.
339	Kniphofia ensifolia Bak. ssp. ensifolia	Liliaceae	M	12	2	P	11.3	22.5	33.8	45.0	—	2	O	E	Fe.
340	Krigia virginica Willd.	Compositae	D	10	2	A	1.5	3.0	4.5	6.0	—	48	C	B	Fe.
341	Lablab niger Medik.	Leguminosae	D	22	2	P	0.4	0.7	1.1	1.5	—	2	O	B	Fe.
342	Lactuca sativa L.	Compositae	D	18°	2	A	—	—	—	—	14.5	14	O	—	Ch.
343	L. serriola Torner	Compositae	D	18°	2°	B	1.8	3.7	5.5	7.4	—	48	C	B	Fe.
344	L. serriola Torner	Compositae	D	—°	—°	B	3.1	6.2	9.4	12.5	—	48	C	B	Fe.
345	L. serriola Torner	Compositae	D	—°	—°	B	6.3	12.5	18.5	25.0	—	48	C	B	Fe.
346	Lamium album L.	Labiatae	D	18	2	B	1.1	2.2	3.3	4.4	—	1	R	F	Fe.
347	L. purpureum L.	Labiatae	D	18	2	A	1.1	2.2	3.3	4.4	—	1	R	F	Fe.
348	Lathyrus amphicarpos L.	Leguminosae	D	14	2	A	4.8	9.5	14.3	19.0	—	2	O	C	Fe.
349	L. angulatus L.	Leguminosae	D	14	2	A	4.5	8.9	13.5	17.9	—	7	O	B	Fe.
350	L. annuus L.	Leguminosae	D	14	2	A	7.3	14.5	21.7	28.9	—	15	C	B-349	Fe.
351	L. aphaca L.	Leguminosae	D	14	2	A	6.9	13.8	20.7	27.6	—	15	C	B-349	Fe.
352	L. articulatus L.	Leguminosae	D	14	2	A	6.2	12.4	18.6	24.8	—	7	O	B	Fe.
353	L. cicera L.	Leguminosae	D	14	2	A	7.0	14.0	21.0	28.0	—	15	C	B-349	Fe.
354	L. clymenum L.	Leguminosae	D	14	2	A	6.0	12.0	18.0	24.0	—	2	O	C	Fe.
355	L. hirsutus L.	Leguminosae	D	14	2	A	10.1	20.1	30.1	40.2	—	7	O	B	Fe.

No.	Species	Family		2n	x										
356	L. inconspicuus L.	Leguminosae	D	14	2	A	5.2	10.4	15.6	20.8	—	2	O	G	Fe.
357	L. latifolius L.	Leguminosae	D	14	2	P	10.8	21.7	32.6	43.5	—	15	C	B-349	Fe.
358	L. maritimus (L.) Bigel.	Leguminosae	D	14	2	P	7.8	15.6	23.4	31.1	—	15	C	B-349	Fe.
359	L. montanus Berhn.	Leguminosae	D	14	2	P	8.3	16.5	24.8	33.1	—	15	C	B-349	Fe.
360	L. niger Berhn.	Leguminosae	D	14	2	P	8.4	16.6	24.8	33.1	—	15	C	B-349	Fe.
361	L. nissolia L.	Leguminosae	D	14	2	A	6.5	13.0	19.6	26.1	—	15	C	B-349	Fe.
362	L. ochrus DC.	Leguminosae	D	14	2	A	6.9	13.7	20.6	27.5	—	15	C	B-349	Fe.
363	L. odoratus L.	Leguminosae	D	14	2	A	8.3	16.6	24.9	33.2	—	15	C	B-349	Fe.
364	L. sativus L.	Leguminosae	D	14	2	A	8.5	16.9	25.4	33.9	—	15	C	B-349	Fe.
365	L. setifolius L.	Leguminosae	D	14	2	A	5.2	10.4	15.5	20.7	—	2	O	G	Fe.
366	L. sphaericus Retz.	Leguminosae	D	14	2	A	6.9	13.7	20.6	27.4	—	15	C	B-349	Fe.
367	L. sylvestris L.	Leguminosae	D	14	2	P	11.5	23.0	34.5	45.9	—	15	O	B-349	Fe.
368	L. tingitanus L.	Leguminosae	D	14	2	A	9.1	18.1	27.1	36.2	—	7	O	B	Fe.
369	L. tuberosus L.	Leguminosae	D	14	2	P	9.3	18.6	27.9	37.2	—	15	O	B-349	Fe.
370	Lens esculenta Moench	Leguminosae	D	14	2	A	4.6	9.2	13.8	18.4	—	2	O	B	Fe.
371	Leontodon autumnalis L.	Compositae	D	12°	2°	P	1.3	2.7	4.0	5.4	—	48	C	B	Fe.
372	L. autumnalis L.	Compositae	D	24°	4°	P	3.0	6.0	9.0	12.0	—	48	C	B	Fe.
373	L. pyrenaicus Gouan	Compositae	D	—°	—°	P	1.4	2.8	4.3	5.7	—	48	C	B	Fe.
374	L. pyrenaicus Gouan	Compositae	D	—°	—°	P	2.7	5.4	8.1	10.8	—	48	C	B	Fe.
375	Leucanthemum multicaule (L.) Pers.	Compositae	D	18	2	A	7.8	15.5	23.3	31.1	—	32	O	B	Fe.
376	L. myconis (L.) Gir.	Compositae	D	18	2	A	7.2	14.4	21.7	28.9	—	32	O	B	Fe.
377	L. vulgare agg.	Compositae	D	36	4	P	5.8	11.5	17.3	23.1	—	32	O	B	Fe.
378	Lilium carniolicum Berhn. ex Mert. & Koch var. jankae	Liliaceae	M	24	2	P	33.5	66.9	100.4	133.8	—	1	R	C	Fe.
379	L. ciliatum P. H. Davies	Liliaceae	M	24	2	P	36.3	72.6	108.8	145.1	—	1	R	C	Fe.
380	L. davidii Duchatre	Liliaceae	M	24	2	P	43.2	86.4	129.6	172.8	—	1	R	C	Fe.
381	L. formosanum Wallace	Liliaceae	M	24	2	P	36.6	73.2	109.8	146.3	—	1	R	C	Fe.
382a	L. henryi Baker	Liliaceae	M	24	2	P	—	—	—	—	100.0	9	O	—	Ch.
382b	L. henryi Baker	Liliaceae	M	24	2	P	—	—	—	—	105.4	11	C	B	Fe.
383	L. longiflorum Thunb. H. V. Croft	Liliaceae	M	24	2	P	—	—	—	—	106	10	O	—	Ch.
384	L. longiflorum Thunb.	Liliaceae	M	24	2	P	—	—	—	—	141.1	23	O	—	Ch.
385a	L. longiflorum Thunb.	Liliaceae	M	48	4	P	—	—	—	—	313.4	14	O	—	Ch.
385b	L. longiflorum Thunb.	Liliaceae	M	48	4	P	—	—	—	—	177	10	O	—	Ch.
386	L. pyrenaiceum Gouan	Liliaceae	M	24	2	P	32.8	65.5	98.3	131.0	—	1	R	C	Fe.
387	Linum usitatissimum L.[h]	Linaceae	D	30	2	A	0.7	1.4	2.1	2.8	—	7	O	B	Fe.
388	Liriope muscari Bailey	Liliaceae	M	108	6	P	10.6	21.1	31.7	42.2	—	1	R	C	Fe.
389	Lolium italicum A.Br. (L. multiflorum)	Gramineae	M	14	2	A	4.9	9.8	14.7	19.6	—	17	C	B-391	Fe.
390	L. loliaceum (Borg. & Chaub.) Hand-Mazz	Gramineae	M	14	2	A	6.3	12.5	18.7	25.0	—	17	C	B-391	Fe.
391	L. perenne L.	Gramineae	M	14	2	P	4.9	9.9	14.9	19.8	—	7	O	B	Fe.
392	L. remotum Schrank.	Gramineae	M	14	2	A	6.8	13.7	20.6	27.4	—	17	C	B-391	Fe.
393	L. rigidum Gaudin	Gramineae	M	14	2	A	4.8	9.6	14.4	19.2	—	17	C	B-391	Fe.
394	L. temulentum L.	Gramineae	M	14	2	A	6.8	13.6	20.4	27.2	—	17	C	B-391	Fe.
395a	Lotus alpinus Schleich	Leguminosae	D	12	2	P	0.5	1.0	1.5	2.0	—	38	C	G-400	Fe.
395b	L. alpinus Schleich	Leguminosae	D	12	2	P	0.5	1.0	1.4	1.9	—	51	C	406	Fe.
396	L. arenarius Brot.	Leguminosae	D	14	2	A	1.1	2.2	3.4	4.5	—	51	C	406	Fe.
397	L. borbasii Ujhelyi	Leguminosae	D	12	2	P	0.5	1.0	1.5	2.0	—	38	C	G-400	Fe.
398	L. burttii Sz. Borzos	Leguminosae	D	12	2	P	0.5	1.1	1.6	2.1	—	51	C	406	Fe.
399	L. coimbrensis Willd.	Leguminosae	D	12	2	A	0.5	0.9	1.4	1.8	—	38	C	G-400	Fe.
400	L. corniculatus L.	Leguminosae	D	24	4	P	1.0	2.1	3.1	4.2	—	2	O	G	Fe.

TABLE 8 (cont.)

	species	family	monocot (M) or dicot (D)	chromosome number, $2n$	ploidy level, x	life cycle type (annual (A), biennial (B) or perennial (P))	DNA amount/pg 1C	2C	3C	4C	4C per cell	original reference (for key see §9(a))	present amount (original value (O), calibrated value (C) or recalibrated value (R))	standard species used to calculate the present amount (for key see §9(b))	method used for DNA estimate (Feulgen densitometry, Fe, chemical extraction, Ch.)
401	L. corniculatus L. var. brachyodon Boiss.	Leguminosae	D	12	2	P	0.5	0.9	1.4	1.9	—	38	C	G-400	Fe.
402	L. cytisoides L.	Leguminosae	D	14	2	P	1.4	2.8	4.2	5.6	—	51	C	406	Fe.
403	L. edulis L.	Leguminosae	D	14	2	A	1.1	2.2	3.3	4.4	—	51	C	406	Fe.
404	L. filicaulis Dur.	Leguminosae	D	12	2	P	0.5	1.0	1.5	2.0	—	38	C	G-400	Fe.
405a	L. japonicus (Regel) Larson	Leguminosae	D	12	2	P	0.5	1.0	1.5	1.9	—	38	C	G-400	Fe.
405b	L. japonicus (Regel) Larson	Leguminosae	D	12	2	P	0.5	1.1	1.6	2.1	—	51	C	406	Fe.
406	L. krylovii Schischk & Serg.	Leguminosae	D	12	2	P	0.5	1.0	1.5	2.1	—	38	C	G-400	Fe.
407	L. ornithopoides L.	Leguminosae	D	14	2	A	1.3	2.6	3.9	5.2	—	51	C	406	Fe.
408	L. palustris Willd.	Leguminosae	D	12	2	P	0.8	1.5	2.3	3.0	—	51	C	406	Fe.
409a	L. pedunculatus Cav.	Leguminosae	D	12	2	P	0.6	1.1	1.7	2.2	—	38	C	G-400	Fe.
409b	L. pedunculatus Cav.	Leguminosae	D	12	2	P	0.6	1.3	1.9	2.5	—	51	C	406	Fe.
410	L. requienii Mauri	Leguminosae	D	14	2	—	1.3	2.7	4.0	5.3	—	51	C	406	Fe.
411a	L. schoelleri Schweinf.	Leguminosae	D	12	2	P	0.5	1.0	1.5	2.0	—	38	C	G-400	Fe.
411b	L. schoelleri Schweinf.	Leguminosae	D	12	2	P	0.7	1.4	2.1	2.7	—	51	C	406	Fe.
412a	L. tenuis Waldst. et Kit.	Leguminosae	D	12	2	P	0.5	1.0	1.5	1.9	—	38	C	G-400	Fe.
412b	L. tenuis Waldst. et Kit.	Leguminosae	D	12	2	P	0.6	1.2	1.8	2.5	—	51	C	406	Fe.
413a	Lupinus albus L.	Leguminosae	D	40	2	A	—	—	—	—	5.5	14	O	—	Ch.
413b	L. albus L.	Leguminosae	D	—	—	A	0.6	1.2	1.8	2.4	—	2	O	B	Fe.
414	L. arboreus Sims	Leguminosae	D	—	—	P	0.8	1.6	2.4	3.3	—	2	O	H	Fe.
415	L. luteus L.	Leguminosae	D	—	—	A	0.9	1.9	2.8	3.7	—	2	O	H	Fe.
416	Luzula forsteri (Sm.) DC.	Juncaceae	M	24	m	P	0.7	1.4	2.1	2.8	—	31	C	F	Fe.
417	L. lutea DC.	Juncaceae	M	12	m	A	1.1	2.1	3.2	4.3	—	31	C	F	Fe.
418	L. luzuloides (Lam.) Dandy & Wilmott	Juncaceae	M	12	m	P	1.1	2.3	3.4	4.6	—	31	C	F	Fe.
419	L. multiflora (Retz.) Lej.ʳ	Juncaceae	M	—	m	P	0.9	1.9	2.8	3.8	—	31	C	F	Fe.
420	L. nivea (L.) DC.	Juncaceae	M	12	m	P	0.9	1.9	2.8	3.8	—	31	C	F	Fe.
421	L. pilosa (L.) Willd.	Juncaceae	M	c. 66	m	P	0.3	0.6	0.9	1.1	—	31	C	F	Fe.
422	L. purpurea Link.	Juncaceae	M	6	2	P	4.3	8.5	12.8	17.1	—	31	C	F	Fe.
423	L. sylvatica (Huds.) Gaud.	Juncaceae	M	12	m	P	0.8	1.6	2.3	3.1	—	31	C	F	Fe.
424a	Lycopersicon esculentum Mill. cv. Alicante	Solanaceae	D	24	2	A	1.0	2.0	3.1	4.1	—	2	O	B	Fe.
424b	L. esculentum Mill.	Solanaceae	D	24	2	A	1.9	3.9	5.9	7.8	—	7	O	B	Fe.
424c	L. esculentum Mill.	Solanaceae	D	24	2	A	2.6	5.1	7.6	10.2	8.4	6	O	—	Ch.
425	L. hirsutum H.B.K.	Solanaceae	D	24	2	A	0.9	1.9	2.8	3.7	—	2	O	B	Fe.

No.	Name	Family		2n	n										
426	L. humboldtii Dun.	Solanaceae	D	24	2	A	0.9	1.9	2.8	3.7	—	2	O	B	Fe.
427	L. pimpinellifolium (Jusl.) Mill.	Solanaceae	D	24	2	A	0.9	1.7	2.6	3.4	—	2	O	B	Fe.
428	L. racemiflorum Vilm.	Solanaceae	D	24	2	A	1.0	2.0	3.0	4.0	—	2	O	B	Fe.
429	L. racemigerum Lange.	Solanaceae	D	24	2	A	1.0	2.0	3.1	4.1	—	2	O	B	Fe.
430	Lycoris squamigera Maxim	Liliaceae	M	27	3	P	—	—	—	—	128.0	10	O	—	Ch.
431	Mammillaria bocasana Poselger.	Cactaceae	D	22	2	P	2.0	4.1	6.1	8.2	—	31	C	F	Fe.
432	M. woodsii[k]	Cactaceae	D	—	—	P	1.6	3.1	4.7	6.2	—	31	C	F	Fe.
433	Matricaria chamomilla L.	Compositae	D	18	2	A	3.9	7.8	11.7	15.5	—	32	O	B	Fe.
434	M. discoidea DC.	Compositae	D	18	2	A	2.5	4.9	7.4	9.8	—	32	O	B	Fe.
435	M. matricarioides (Less.) Porter	Compositae	D	18	2	A	2.3	4.6	7.0	9.3	—	1	R	F	Fe.
436	Medicago arborea L.	Leguminosae	D	32	4	P	1.8	3.6	5.4	7.2	—	1	R	F	Fe.
437	M. glutinosa Bieb.	Leguminosae	D	32	4	P	1.9	3.9	5.8	7.8	—	1	R	F	Fe.
438	M. sativa L. var. gaetula	Leguminosae	D	32	4	P	1.7	3.5	5.2	7.0	—	1	R	F	Fe.
439	Mercuralis perennis L.¹ (♂)	Euphorbiaceae	D	64	8	P	2.4	4.7	7.1	9.4	—	1	R	F-325	Fe.
440	Mibora minima (L.) Desv.	Gramineae	M	14	2	A	2.8	5.5	8.3	11.0	—	1	R	F	Fe.
441	Microseris bigelovii (Gray) Sch. Bip.	Compositae	D	18	2	—	1.5	3.0	4.5	6.0	—	47	C	B	Fe.
442	M. borealis (Bong.) Sch. Bip.	Compositae	D	18	2	—	4.0	8.0	12.0	16.0	—	47	C	B	Fe.
443	M. douglasii (DC.) Sch. Bip. var. douglasii	Compositae	D	18	2	A	1.4	2.8	4.3	5.7	—	47	C	B	Fe.
444	M. douglasii (DC.) Sch. Bip. var. tenella	Compositae	D	18	2	A	1.3	2.6	3.8	5.1	—	48	C	B	Fe.
445	M. elegans Greene ex. Gray	Compositae	D	18	2	—	1.4	2.8	4.3	5.7	—	47	C	B	Fe.
446	M. laciniata (Benth.) Gray var. laciniata	Compositae	D	18	2	P	3.3	6.7	10.0	13.4	—	47	C	B	Fe.
447	M. laciniata (Benth.) Gray var. leptosepala	Compositae	D	18	2	P	3.4	6.8	10.3	13.7	—	48	C	B	Fe.
448	M. lindleyi (DC.) Gray	Compositae	D	18	2	—	2.0	4.0	6.0	8.0	—	47	C	B	Fe.
449	M. nutans (Hook.) Sch. Bip.	Compositae	D	18	2	P	3.5	7.0	10.5	14.0	—	47	C	B	Fe.
450	M. pygmaea D. Don.	Compositae	D	—	—	—	1.4	2.8	4.3	5.7	—	48	C	B	Fe.
451	M. scapigera Sch. Bip.	Compositae	D	—	—	—	5.8	11.7	17.5	23.4	—	48	C	B	Fe.
452	M. sylvatica (Benth.) Gray	Compositae	D	18	2	—	3.4	6.8	10.3	13.7	—	47	C	B	Fe.
453	Montia perfoliata (Willd.) Howell	Portulacaceae	D	18	2	A	2.2	4.4	6.6	8.7	—	1	R	F	Fe.
454	Muscari moschatum Willd. var. flavum	Liliaceae	M	18	2	P	6.2	12.4	18.7	24.9	—	1	R	C	Fe.
455	Myosorus minimus L.	Ranunculaceae	D	16	2	A	1.1	2.2	3.3	4.4	—	2	O	G	Fe.
456	Narcissus pseudonarcissus L.	Amaryllidaceae	M	14	2	P	—	—	—	—	64.9	23	O	—	Ch.
457	N. tazetta L.	Amaryllidaceae	M	22	2	P	—	—	—	—	31.0	10	O	—	Ch.
458	Nicotiana otophora Grisebach var. cochobama	Solanaceae	D	24	2	P	2.7	5.4	8.0	10.7	—	33	O	B	Fe.
459	N. paniculata L.	Solanaceae	D	24	2	A	2.4	4.8	7.2	9.7	—	33	O	B	Fe.

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TABLE 8 (cont.)

	species	family	monocot (M) or dicot (D)	chromosome number, 2n	ploidy level, x	life cycle type (annual (A), biennial (B) or perennial (P))	DNA amount/pg 1C	2C	3C	4C	4C per cell	original reference (for key see § 9 (a))	present amount (original value (O), calibrated value (C) or recalibrated value (R))	standard species used to calculate the present amount (for key see § 9 (b))	method used for DNA estimate (Feulgen densitometry, Fe, chemical extraction, Ch.)
460	N. rustica L. var. brasilia Schrank	Solanaceae	D	48	4	A	4.1	8.2	12.3	16.4	—	33	O	B	Fe.
461	N. sylvestris Speg. et Comes	Solanaceae	D	24	2	P	2.1	4.2	6.4	8.5	—	33	O	B	Fe.
462	N. tabacum L. var. purpurea	Solanaceae	D	48	4	A	3.9	7.8	11.6	15.5	—	33	O	B	Fe.
463	N. tomentosiformis Goodspeed	Solanaceae	D	24	2	P	1.8	3.7	5.5	7.4	—	33	O	B	Fe.
464	N. undulata Ruiz et Pavon	Solanaceae	D	24	2	A	1.9	3.8	5.7	7.6	—	33	O	B	Fe.
465a	Nigella damascena L.	Ranunculaceae	D	12	2	A	—	—	—	—	28.0	10	O	—	Ch.
465b	N. damascena L.	Ranunculaceae	D	12	2	A	10.5	21.1	30.1	42.2	—	7	O	B	Fe.
466	N. sativa L.	Ranunculaceae	D	12	2	A	10.6	21.3	31.9	42.5	—	2	O	G	Fe.
467	Ornithogalum longi-bracteatum Jacq.	Liliaceae	M	c. 54	—	P	7.6	15.2	22.8	30.4	—	1	R	F	Fe.
468	O. virens Lindl.	Liliaceae	M	6	2	P	5.5	11.0	16.5	21.1	—	1	R	C & E	Fe.
469	Oryza sativa L.	Gramineae	M	24	2	A	0.6	1.2	1.8	2.4	—	2	O	F	Fe.
470	Panicum esculentum A.Br.	Gramineae	M	54	6	A	1.5	3.0	4.5	6.0	—	2	O	E	Fe.
471	Papaver dubium L.	Papaveraceae	D	28	4	A	4.5	9.0	13.5	18.0	—	2	O	G	Fe.
472	P. orientale L.	Papaveraceae	D	42	6	P	8.3	16.6	24.9	33.2	—	2	O	H	Fe.
473	P. rhoeas L.	Papaveraceae	D	14	2	A	2.6	5.2	7.9	10.5	—	2	O	G	Fe.
474	P. somniferum L.	Papaveraceae	D	22	2	A	3.8	7.6	11.4	15.2	—	1	R	F	Fe.
475	Paspalum dilatatum Poir.	Gramineae	M	20?	—	P	0.6	1.2	1.8	2.4	—	2	O	B	Fe.
476	P. notatum Flügge	Gramineae	M	40?	—	P	1.1	2.1	3.1	4.2	—	2	O	B	Fe.
477	Pennisetum clandestinum Hochst. ex Chiov.	Gramineae	M	36	4	P	1.1	2.3	3.4	4.6	—	2	O	B	Fe.
478	P. glaucum R.Br.	Gramineae	M	14	2	A	2.5	4.9	7.4	9.9	—	2	O	H	Fe.
479	Petunia hybrida Vilm. cv. Blue Dandy	Solanaceae	D	14	2	P	1.6	3.1	4.7	6.2	—	2	O	H	Fe.
480	Phalacroseris bolanderi Gray	Compositae	D	18	2	P	9.2	18.4	27.6	36.8	—	47	C	B	Fe.
481	Phalaris angusta Nees ex Trin.	Gramineae	M	14	2	A	2.0	4.0	6.0	8.1	—	26	C	F^t	Fe.
482	P. arundinacea L.	Gramineae	M	42	6	P	5.7	11.4	17.1	22.8	—	2	O	F	Fe.
483a	P. arundinacea L.	Gramineae	M	28	4	P	4.1	8.2	12.3	16.5	—	26	C	F^t	Fe.
483b	P. arundinacea L.	Gramineae	M	42	6	P	6.0	12.0	18.0	24.0	—	26	C	F^t	Fe.
484	P. brachystachys Link.	Gramineae	M	12	2	A	3.7	7.4	11.1	14.8	—	26	C	F^t	Fe.
485	P. californica Hook. et Arn.	Gramineae	M	28	4	P	4.3	8.6	12.9	17.1	—	26	C	F^t	Fe.
486	P. canariensis L.	Gramineae	M	12	2	A	3.8	7.7	11.5	15.3	—	26	C	F^t	Fe.

No.	Species	Family		2n		A/P						No.			
487	P. caroliniana Walt.	Gramineae	M	14	2	A	2.0	4.0	6.0	8.0	—	26	C	Fᶠ	Fe.
488a	P. coerulescens Desf.	Gramineae	M	14	2	P	1.4	2.8	4.1	5.5	—	26	C	Fᶠ	Fe.
488b	P. coerulescens Desf.	Gramineae	M	—	—	P	—	—	—	—	21.4	23	O	—	Ch.
489a	P. minor Retz.	Gramineae	M	28	4	A	4.5	9.0	13.4	18.0	—	26	C	Fᶠ	Fe.
489b	P. minor Retz.	Gramineae	M	28	4	A	—	—	—	—	33.4	23	O	—	Ch.
490a	P. paradoxa L.	Gramineae	M	14	2	A	1.8	3.5	5.3	7.0	—	2	O	F	Fe.
490b	P. paradoxa L.	Gramineae	M	14	2	A	1.7	3.3	5.0	6.7	—	26	C	Fᶠ	Fe.
491	P. truncata Guss.	Gramineae	M	12	2	P	3.1	6.2	9.4	12.5	—	26	C	Fᶠ	Fe.
492	P. tuberosa L.	Gramineae	M	28	4	P	4.0	8.0	12.0	16.0	—	26	C	Fᶠ	Fe.
493	Phaseolus angularis (Willd.) Wight.	Leguminosae	D	22	2	A	1.4	2.8	4.2	5.6	—	28	O	B	Fe.
494	P. coccineus L.	Leguminosae	D	22	2	P	1.7	3.5	5.2	7.0	—	28	O	B	Fe.
495	P. dumosus Macfad.	Leguminosae	D	22	2	—	1.9	3.8	5.7	7.6	—	28	O	B	Fe.
496	P. geophillus Burk.	Leguminosae	D	22	2	P	1.3	2.6	3.9	5.2	—	28	O	B	Fe.
497	P. lathyroides L.	Leguminosae	D	22	2	B	1.1	2.3	3.4	4.6	—	28	O	B	Fe.
498	P. leucanthus Piper	Leguminosae	D	22	2	A	1.6	3.3	4.9	6.6	—	28	O	B	Fe.
499	P. lunatus L.	Leguminosae	D	22	2	P	1.2	2.5	3.7	5.0	—	28	O	B	Fe.
500	P. vulgaris L.	Leguminosae	D	22	2	A	1.8	3.7	5.5	7.4	—	28	O	B	Fe.
501	Phleum bertolonii DC. cv. S 50	Gramineae	M	14	2	P	1.7	3.4	5.1	6.8	—	1	R	C	Fe.
502	Picris echioides L.	Compositae	D	10°	2°	A–B	1.2	2.4	3.6	4.8	—	48	C	B	Fe.
503	P. echioides L.	Compositae	D	20°	4°	A–B	2.1	4.1	6.2	8.3	—	48	C	B	Fe.
504	P. hieracioides L.	Compositae	D	10°	2°	B–P	1.6	3.1	4.7	6.3	—	48	C	B	Fe.
505	P. hieracioides L.	Compositae	D	20°	4°	B–P	2.8	5.7	8.5	11.4	—	48	C	B	Fe.
506a	Pisum sativum L. cv. Minerva Maple	Leguminosae	D	14	2	A	4.9ʰ	9.8ʰ	14.7ʰ	19.5ʰ	—	2	O	C	Fe.
506b	P. sativum L. cv. Meteor	Leguminosae	D	14	2	A	—	—	—	—	16.0ʰ	54	O	—	Ch.
506c	P. sativum L.	Leguminosae	D	14	2	A	—	—	—	—	11.7ʰ	12	O	—	Ch.
506d	P. sativum L.	Leguminosae	D	14	2	A	—	—	—	—	21.4ʰ	14	O	—	Ch.
506e	P. sativum L.	Leguminosae	D	14	2	A	5.2ʰ	10.5ʰ	15.7ʰ	20.9ʰ	—	22	R	B	Fe.
507	Poa annua L.	Gramineae	M	28	4	A	2.9	5.7	8.6	11.5	—	1	R	F	Fe.
508	P. infirma Kunth	Gramineae	M	14	2	A	1.2	2.4	3.5	4.7	—	1	R	F	Fe.
509	P. supina Chaix	Gramineae	M	14	2	P	1.4	2.8	4.1	5.5	—	1	R	E	Fe.
510	P. trivialis L.	Gramineae	M	14	2	P	2.8	5.6	8.4	11.3	—	1	R	F	Fe.
511	Pseudolobivia sp.	Cactaceae	D	—	—	P	1.6	3.2	4.8	6.5	—	31	C	F	Fe.
512	Psophocarpus tetragonolobus DC.	Leguminosae	D	18	2	P	0.8	1.6	2.4	3.2	—	2	O	B	Fe.
513	Pulsatilla occidentalis (Wats.) Freyn	Ranunculaceae	D	16	2	P	5.2	10.4	15.5	20.7	—	8	R	D	Fe.
514	P. nuttaliana (DC.) Bercht. Presl.	Ranunculaceae	D	16	2	P	4.3	8.7	13.0	17.4	—	8	R	D	Fe.
515	P. patens (L.) Mill.	Ranunculaceae	D	16	2	P	4.6	9.2	13.8	18.4	—	8	R	D	Fe.
516	Pyrrhopappus carolinianus (Walter) DC.	Compositae	D	12	2	B	6.3	12.5	18.8	25.1	—	48	C	B	Fe.
517	Ranunculus aconitifolius L. ssp. plantanifolius	Ranunculaceae	D	16	2	P	4.1	8.3	12.5	16.7	—	45	R	G	Fe.
518a	R. acris L.	Ranunculaceae	D	14	2	P	5.3	10.7	16.0	21.4	—	45	R	G	Fe.
518b	R. acris L. ssp. acris	Ranunculaceae	D	14	2	P	4.7	9.4	14.0	18.7	—	44	C	G	Fe.
519	R. acris L. ssp. borealis (Trautv.) Nyman	Ranunculaceae	D	14	2	P	4.5	8.9	13.4	17.8	—	44	C	D	Fe.
520	R. acris L. ssp. granatensis (Boiss.) Nym.	Ranunculaceae	D	28	4	P	7.8	15.6	23.4	31.2	—	44	C	D	Fe.
521	R. abortivus L.	Ranunculaceae	D	16	2	P	2.4	4.9	7.3	9.7	—	44	C	D	Fe.
522	R. affinis R.Br.	Ranunculaceae	D	32	4	P	3.8	7.5	11.3	15.1	—	44	C	D	Fe.

TABLE 8 (cont.)

	species	family	monocot (M) or dicot (D)	chromosome number, $2n$	ploidy level, x	life cycle type (annual (A), biennial (B) or perennial (P))	DNA amount/pg				$4C$ per cell	original reference (for key see § 9 (a))	present amount (original value (O), calibrated value (C) or recalibrated value (R))	standard species used to calculate the present amount (for key see § 9 (b))	method used for DNA estimate (Feulgen densitometry, Fe., chemical extraction, Ch.)
							$1C$	$2C$	$3C$	$4C$					
523	R. allenii Rob.	Ranunculaceae	D	32	4	P	4.1	8.2	12.3	16.4	—	44	C	D	Fe.
524	R. alpestris L.	Ranunculaceae	D	16	2	A	2.9	5.9	8.8	11.8	—	44	C	D	Fe.
525a	R. arvensis L.	Ranunculaceae	D	32	4	A	6.1	12.2	18.4	24.5	—	45	R	G	Fe.
525b	R. arvensis L.	Ranunculaceae	D	32	4	A	6.4	12.8	19.2	25.6	—	44	C	D	Fe.
526	R. asiaticus L.	Ranunculaceae	D	16	2	A	7.6	15.2	22.8	30.5	—	44	C	D	Fe.
527a	R. auricomus L.	Ranunculaceae	D	32	4	P	9.0	18.0	27.0	36.0	—	45	R	G	Fe.
527b	R. auricomus L.	Ranunculaceae	D	32	4	P	2.7	5.3	8.0	10.7	—	44	C	D	Fe.
528	R. baudotii Godr.	Ranunculaceae	D	32	4	A–P	4.2	8.4	12.5	16.7	—	44	C	D	Fe.
529a	R. bulbosus L. s.l.	Ranunculaceae	D	16	2	P	5.6	11.2	16.8	22.5	—	45	R	G	Fe.
529b	R. bulbosus L. s.l.	Ranunculaceae	D	16	2	P	5.3	10.7	16.0	21.4	—	44	C	D	Fe.
530	R. bupleuroides Brot.	Ranunculaceae	D	16	2	P	6.0	12.0	18.0	24.0	—	44	C	D	Fe.
531	R. calandrinioides Oliver	Ranunculaceae	D	16	2	—	6.2	12.3	18.5	24.7	—	44	C	D	Fe.
532	R. californicus Benth.	Ranunculaceae	D	28	4	—	7.1	14.2	21.2	28.3	—	44	C	D	Fe.
533	R. cappadocius Willd.	Ranunculaceae	D	16	2	P	6.8	13.5	20.3	27.0	—	44	C	D	Fe.
534	R. cardiophyllus Hook.	Ranunculaceae	D	64	8	P	5.9	11.8	17.6	23.5	—	44	C	D	Fe.
535	R. chinensis L.	Ranunculaceae	D	16	2	P	5.5	11.1	16.6	22.2	—	44	C	D	Fe.
536a	R. chius DC.	Ranunculaceae	D	14	2	A	4.4	8.8	13.2	17.6	—	45	R	G	Fe.
536b	R. chius DC.	Ranunculaceae	D	14	2	A	3.6	7.1	10.7	14.2	—	44	C	D	Fe.
537	R. constantinopolitanus (DC.) d'Urv.	Ranunculaceae	D	42	6	P	12.1	24.3	36.4	48.5	—	44	C	D	Fe.
538a	R. cortusifolius Willd.	Ranunculaceae	D	16	2	P	8.6	17.2	25.9	34.5	—	45	R	G	Fe.
538b	R. cortusifolius Willd.	Ranunculaceae	D	16	2	P	9.3	18.7	28.0	37.4	—	44	C	D	Fe.
539	R. crenatus Waldst. & Kit.	Ranunculaceae	D	16	2	P	3.3	6.6	9.9	13.2	—	44	C	D	Fe.
540	R. creticus L.	Ranunculaceae	D	16	2	P	6.6	13.2	19.7	26.3	—	44	C	D	Fe.
541	R. cymbalaria Pursh	Ranunculaceae	D	16	2	P	3.6	7.2	10.9	14.5	—	44	C	D	Fe.
542	R. eschscholtzii Schlecht.	Ranunculaceae	D	48	6	P	6.5	12.9	19.4	25.9	—	44	R	G	Fe.
543a	R. falcatus L.[n]	Ranunculaceae	D	40	5	A	5.1	10.3	15.4	20.6	—	45	R	D	Fe.
543b	R. falcatus L.[n]	Ranunculaceae	D	40–41[n]	5[n]	A	5.3	10.5	15.8	21.1	—	44	C	D	Fe.
544	R. fascicularis Muhl.[n]	Ranunculaceae	D	32	4	—	10.9	21.9	32.8	43.8	—	44	C	D	Fe.
545	R. ficaria L.	Ranunculaceae	D	16	2	P	9.3	18.6	28.0	37.3	—	45	R	G	Fe.
546	R. ficaria L.	Ranunculaceae	D	24	3	P	14.1	28.3	42.5	56.7	—	45	R	G	Fe.
547a	R. ficaria L.	Ranunculaceae	D	32	4	P	19.1	38.3	57.3	76.4	—	45	R	G	Fe.
547b	R. ficaria L.	Ranunculaceae	D	32	4	P	17.8	35.6	53.3	71.1	—	44	C	D	Fe.
548	R. flabellatus Desf.	Ranunculaceae	D	32	4	P	8.2	16.5	24.7	33.0	—	45	R	D	Fe.
549a	R. flammula L.	Ranunculaceae	D	32	4	P	6.4	12.7	19.1	25.4	—	45	R	G	Fe.
549b	R. flammula L.	Ranunculaceae	D	32	4	P	6.1	12.3	18.4	24.6	—	44	C	D	Fe.
550	R. flammula L. var. filiformis (Michx.) Hook.	Ranunculaceae	D	32	4	P	6.0	12.0	18.0	24.0	—	44	C	D	Fe.
551	R. flammula L. var. filiformis (Michx.) Hook.	Ranunculaceae	D	48	6	P	7.3	14.7	22.0	29.3	—	44	C	D	Fe.

No.	Species	Family		2n	x	Life						2n			
552	R. geoides H.B. & K.	Ranunculaceae	D	64	8	P	18.0	37.2	55.8	74.4	—	44	C	D	Fe.
553	R. glacialis L.	Ranunculaceae	D	16	2	P	3.3	6.6	9.9	13.3	—	44	C	D	Fe.
554	R. gmelinii DC.	Ranunculaceae	D	64	8	P	7.8	15.6	23.3	31.3	—	44	C	D	Fe.
555	R. gouanii Willd.	Ranunculaceae	D	16	2	P	6.3	12.5	18.8	25.1	—	44	C	D	Fe.
556	R. gramineus L.	Ranunculaceae	D	16	2	P	5.2	10.3	15.5	20.6	—	44	C	D	Fe.
557	R. gregarius Brot.	Ranunculaceae	D	16	2	P	4.9	9.9	14.8	19.8	—	44	C	D	Fe.
558	R. grenierianus Jord.	Ranunculaceae	D	16	2	P	5.7	11.4	17.1	22.8	—	44	C	D	Fe.
559	R. hederaceus L.	Ranunculaceae	D	16	2	A–B	2.1	4.2	6.3	8.4	—	45	R	G	Fe.
560	R. hirtus Bks. & Sol.	Ranunculaceae	D	16	2	—	4.6	9.2	13.7	18.3	—	44	C	D	Fe.
561	R. hispidus Michx.	Ranunculaceae	D	32	4	P	10.1	20.2	30.4	40.5	—	44	C	D	Fe.
562	R. illyricus L.	Ranunculaceae	D	32	4	P	7.3	14.6	21.9	29.2	—	44	C	D	Fe.
563	R. insignis Hook.	Ranunculaceae	D	48	6	—	7.9	15.9	23.8	31.8	—	44	C	D	Fe.
564	R. inundatus R. Br. ex DC.	Ranunculaceae	D	48	6	P	4.7	9.3	14.0	18.6	—	44	C	D	Fe.
565	R. lanuginosus L.	Ranunculaceae	D	28	4	P	9.4	18.8	28.2	37.6	—	44	C	D	Fe.
566	R. lapponicus L.	Ranunculaceae	D	16	2	P	8.5	17.0	25.5	34.1	—	44	C	D	Fe.
567a	R. lateriflorus DC.	Ranunculaceae	D	16	2	A	1.9	3.8	5.7	7.6	—	45	R	G	Fe.
567b	R. lateriflorus DC.	Ranunculaceae	D	16	2	A	2.3	4.6	6.9	9.2	—	44	C	D	Fe.
568a	R. lingua L.	Ranunculaceae	D	128	16	P	25.1	50.2	75.3	100.4	—	45	R	G	Fe.
568b	R. lingua L.	Ranunculaceae	D	128	16	P	21.2	42.4	63.5	84.7	—	44	C	D	Fe.
569	R. macounii Britt.	Ranunculaceae	D	48	6	P	13.0	26.0	39.0	52.0	—	44	C	D	Fe.
570	R. macrophyllus Desf.	Ranunculaceae	D	16	2	P	6.3	12.6	18.9	25.1	—	44	C	D	Fe.
571	R. marginatus d'Urv.	Ranunculaceae	D	32	4	P	6.7	13.5	20.2	27.0	—	44	C	D	Fe.
572	R. millefoliatus Vahl.	Ranunculaceae	D	16	2	A	7.5	15.0	22.4	30.0	—	44	C	D	Fe.
573	R. monspeliacus L.	Ranunculaceae	D	32	4	P	9.4	18.7	28.1	37.4	—	44	C	D	Fe.
574	R. montanus Willd.	Ranunculaceae	D	32	4	P	9.7	19.5	29.2	39.0	—	44	C	D	Fe.
575	R. multifidus Nutt.	Ranunculaceae	D	64	8	—	7.6	15.3	22.9	30.6	—	44	C	D	Fe.
576a	R. muricatus L.	Ranunculaceae	D	48	6	A	11.6	23.2	34.8	46.4	—	45	R	G	Fe.
576b	R. muricatus L.	Ranunculaceae	D	48	6	A	9.2	18.5	27.7	36.9	—	44	C	D	Fe.
577	R. nemorosus DC.	Ranunculaceae	D	16	2	A	6.1	12.2	18.3	24.4	—	44	C	D	Fe.
578	R. nigrescens Freyn	Ranunculaceae	D	16	2	P	5.4	10.9	16.3	21.8	—	44	C	D	Fe.
579	R. nivalis L.	Ranunculaceae	D	48	6	P	5.9	11.9	17.8	23.7	—	44	C	D	Fe.
580	R. ophioglossifolius Vill.	Ranunculaceae	D	16	2	A	5.6	11.3	16.9	22.6	—	44	C	D	Fe.
581	R. oreophilus Bieb.	Ranunculaceae	D	16	2	P	4.3	8.6	12.8	17.1	—	44	C	D	Fe.
582	R. oxyspermus Bieb.	Ranunculaceae	D	16	2	P	5.4	10.8	16.2	21.6	—	44	C	D	Fe.
583	R. parnassifolius L.	Ranunculaceae	D	32	4	P	7.2	14.5	21.7	29.0	—	44	C	D	Fe.
584	R. parviflorus L.	Ranunculaceae	D	28	4	A	6.2	12.5	18.7	25.0	—	44	C	D	Fe.
585	R. pedatus Waldst. & Kit.	Ranunculaceae	D	16	2	P	4.2	8.4	12.6	16.8	—	44	C	D	Fe.
586	R. pensylvanicus L. Fil.	Ranunculaceae	D	16	2	A	4.5	9.0	13.5	18.0	—	44	C	D	Fe.
587	R. pentandrus J. M. Black	Ranunculaceae	D	14	2	P	2.5	4.9	7.4	9.9	—	44	C	D	Fe.
588	R. plantaginifolius Murr.	Ranunculaceae	D	48	6	P	12.1	24.2	36.2	48.4	—	44	C	D	Fe.
589	R. polyanthemos L.	Ranunculaceae	D	16	2	P	6.2	12.4	18.7	24.9	—	44	C	D	Fe.
590	R. pratensis C. Presl.	Ranunculaceae	D	16	2	P	6.6	13.3	19.9	26.6	—	44	C	D	Fe.
591	R. psilostachys Gris.	Ranunculaceae	D	16	2	P	4.9	9.9	14.8	19.8	—	44	C	D	Fe.
592	R. recurvatus Poir.	Ranunculaceae	D	32	4	P	8.8	17.7	26.5	35.4	—	44	C	D	Fe.
593a	R. repens L.	Ranunculaceae	D	32	4	P	11.2	22.4	33.6	44.8	—	45	R	G	Fe.
593b	R. repens L.	Ranunculaceae	D	32	4	P	9.6	19.1	28.7	38.3	—	44	C	D	Fe.
594	R. rhomboideus Goldie	Ranunculaceae	D	16	2	P	2.4	4.9	7.3	9.8	—	44	C	D	Fe.
595a	R. sardous Crantz	Ranunculaceae	D	16	2	A	3.2	6.4	9.7	12.9	—	45	R	G	Fe.
595b	R. sardous Crantz	Ranunculaceae	D	16	2	A	3.8	7.6	11.5	15.3	—	44	C	D	Fe.
596a	R. sceleratus L.	Ranunculaceae	D	32	4	A	4.0	8.0	12.0	16.0	—	45	R	G	Fe.
596b	R. sceleratus L.	Ranunculaceae	D	32	4	A	3.5	7.1	10.6	14.2	—	44	C	D	Fe.

TABLE 8 (cont.)

	species	family	monocot (M) or dicot (D)	chromosome number, 2n	ploidy level, x	life cycle type (annual (A), biennial (B) or perennial (P))	DNA amount/pg 1C	2C	3C	4C	4C per cell	original reference (for key see §9(a))	present amount (original value (O), calibrated value (C) or recalibrated value (R))	standard species used to calculate the present amount (for key see §9(b))	method used for DNA estimate (Feulgen densitometry, Fe., chemical extraction, Ch.)
597	R. septentrionalis Poir.	Ranunculaceae	D	64	8	P	16.7	33.5	50.2	67.0	—	44	C	D	Fe.
598	R. sericus Vis.	Ranunculaceae	D	28	4	P	8.4	16.9	25.3	33.8	—	44	C	D	Fe.
599	R. sericeus Bks. & Sol.	Ranunculaceae	D	14	2	—	3.9	7.8	11.7	15.6	—	44	C	D	Fe.
600	R. sphaerospermus Boiss. & Blanche	Ranunculaceae	D	16	2	A–P	2.6	5.3	7.9	10.5	—	44	C	D	Fe.
601	R. thora L.	Ranunculaceae	D	16	2	P	3.5	7.1	10.6	14.2	—	44	C	D	Fe.
602	R. trichophyllus Chaix	Ranunculaceae	D	32	4	A–P	4.8	9.7	14.6	19.5	—	45	R	G	Fe.
603	R. trilobus Desf.	Ranunculaceae	D	48	6	A	8.7	17.4	26.0	34.8	—	44	C	D	Fe.
604	R. tripartitus DC.	Ranunculaceae	D	48	6	A–P	4.5	9.0	13.5	18.0	—	44	C	D	Fe.
605	R. uncinatus D. Don	Ranunculaceae	D	28	4	—	6.2	12.4	18.7	24.9	—	44	C	D	Fe.
606	R. velutinus Ten.	Ranunculaceae	D	14	2	P	5.8	11.6	17.3	23.1	—	44	C	D	Fe.
607	Raphanus sativus L. cv. Cherry Belle	Cruciferae	D	18	2	A–B	—	—	—	—	5.0	10	O	—	Ch.
608a	Rhoeo discolor Hance	Commelinaceae	M	12	2	P	7.2	14.4	21.7	28.9	—	1	R	C	Fe.
608b	R. discolor Hance	Commelinaceae	M	12	2	P	—	—	—	—	24.6	11	C	B	Fe.
608c	R. discolor Hance	Commelinaceae	M	12	2	P	5.1	10.1	15.2	20.2	34.1	16	O	Bos taurus	Ch.
609	Rumex longifolius DC.	Polygonaceae	D	60	6	P	—	—	—	—	13.0	10	O	—	Ch.
610	R. obtusifolius L.	Polygonaceae	D	40	4	P	—	—	—	—	8.0	10	O	—	Ch.
611	R. sanguineus L.	Polygonaceae	D	20	2	P	—	—	—	—	5.0	10	O	—	Ch.
612	R. stenophyllus Ledeb.	Polygonaceae	D	60	6	P	—	—	—	—	12.0	10	O	—	Ch.
613a	Saccharum (commercial variety L62-96)	Gramineae	M	c. 110	—	P	5.9	11.9	17.8	23.7	—	2	O	F	Fe.
613b	Saccharum (commercial variety CP31-588)	Gramineae	M	c. 112	—	P	6.1	12.2	18.3	24.4	—	2	O	F	Fe.
613c	Saccharum (commercial variety CP52-68)	Gramineae	M	c. 116–117	—	P	6.4	12.8	19.2	25.6	—	2	O	F	Fe.
614a	S. officinarum L. (HA orig. 35)	Gramineae	M	c. 76–78	—	P	4.0	8.1	12.2	16.2	—	2	O	F	Fe.
614b	S. officinarum L. (Criolla Morada)	Gramineae	M	80	8	P	4.3	8.7	13.0	17.4	—	2	O	F	Fe.
615	S. robustum (NG 57-55)	Gramineae	M	80	8	P	4.3	8.6	12.9	17.2	—	2	O	F	Fe.
616	S. robustum (NG 57-12)	Gramineae	M	60	6	P	3.8	7.7	11.5	15.3	—	2	O	F	Fe.
617	S. spontaneum L. (SUK)	Gramineae	M	—	—	P	6.3	12.6	18.9	25.1	—	2	O	F	Fe.
	Scilla campanulata Ait. (listed under Endymion hispanicus 271)														
618	S. socialis Baker	Liliaceae	M	28	2	P	11.5	22.9	34.4	45.9	—	1	R	C	Fe.
619	S. peruviana L.	Liliaceae	M	16	2	P	18.1	36.1	54.1	72.2	—	1	R	C	Fe.
620	S. sibirica Haw. cv. Alba	Liliaceae	M	12	2	P	—	—	—	—	73.0	10	O	—	Ch.

NUCLEAR DNA AMOUNTS IN ANGIOSPERMS

No.	Species	Family													
621	*S. violacea* Hutchinson	Liliaceae	M	26	2	P	7.5	14.9	22.4	29.9	—	1	R	C	Fe.
622	*Secale africanum* Stapf	Gramineae	M	14	2	P	7.4	14.8	22.2	29.7	—	2	O	E	Fe.
623a	*S. cereale* L. cv. Petkus Spring	Gramineae	M	14	2	A	8.8	16.6	25.4	33.1	—	2	O	B	Fe.
623b	*S. cereale* L.	Gramineae	M	14	2	A	9.5	18.9	28.4	37.8	—	7	O	B	Fe.
623c	*S. cereale* L.	Gramineae	M	14	2	A	—	—	—	—	41.6	14	O	—	Ch.
624	*S. cereale* ssp. *afghanicum* (Vav.) Roshev. PBI 8	Gramineae	M	14	2	A	8.3	16.6	24.9	33.2	—	2	O	E	Fe.
625a	*S. cereale* ssp. *ancestrale* Zhuk. PBI 27	Gramineae	M	14	2	A	7.9	15.9	23.8	31.8	—	2	O	E	Fe.
625b	*S. cereale* ssp. *ancestrale* UM 2D38	Gramineae	M	14	2	A	7.9	15.9	23.8	31.7	—	2	O	E	Fe.
626	*S. cereale* ssp. *dighoricum* (Vav.) Roshev. PBI 40	Gramineae	M	14	2	A	7.9	15.7	23.6	31.5	—	2	O	E	Fe.
627a	*S. cereale* ssp. *segetale* (Zhuk.) Roshev. PBI 41	Gramineae	M	14	2	A	8.2	16.4	24.6	32.8	—	2	O	E	Fe.
627b	*S. cereale* ssp. *segetale* UM 2D56	Gramineae	M	14	2	A	8.3	16.6	24.9	33.2	—	2	O	E	Fe.
628a	*S. fragile* (*S. silvestre* Host.) PBI 52	Gramineae	M	14	2	A	7.2	14.4	21.6	28.9	—	2	O	E	Fe.
628b	*S. fragile* (*S. silvestre* UM 2D20)	Gramineae	M	14	2	A	8.4	16.8	25.2	33.6	—	2	O	E	Fe.
629	*S. montanum* Guss. ssp. *kuprijanovii* Grossh. PBI 35	Gramineae	M	14	2	P	8.0	15.9	23.9	31.9	—	2	O	E	Fe.
630a	*S. montanum* Guss. ssp. *montanum* PBI 15	Gramineae	M	14	2	P	8.2	16.4	24.6	32.8	—	2	O	E	Fe.
630b	*S. montanum* Guss. ssp. *montanum* UM 2D35	Gramineae	M	14	2	P	8.4	16.7	25.1	33.5	—	2	O	E	Fe.
631a	*S. vavilovii* Grossh. PBI 11	Gramineae	M	14	2	A	8.2	16.5	24.7	32.9	—	2	O	E	Fe.
631b	*S. vavilovii* UM 2D49	Gramineae	M	14	2	A	8.6	17.3	25.9	34.6	—	2	O	E	Fe.
631c	*S. vavilovii* UM 2D116	Gramineae	M	14	2	A	8.5	17.0	25.5	34.1	—	2	O	E	Fe.
632	*Senecio aetnensis* Jan.	Compositae	D	20	2	P	0.9	1.9	2.9	3.9	—	2	O	G	Fe.
633	*S. aquaticus* Hill.	Compositae	D	40	4	B-P	1.8	3.6	5.4	7.2	—	2	O	G	Fe.
634	*S. battiscombei* R.E. & T.C.E. Fr.	Compositae	D	—	—	P	9.2	18.5	27.7	36.9	—	2	O	G	Fe.
635	*S. brassica* R.E. & T.C.E. Fr.	Compositae	D	—	—	P	5.5	11.0	16.5	22.0	—	2	O	G	Fe.
636	*S. cambrensis* Rosser	Compositae	D	60	6	A	2.6	5.1	7.7	10.3	—	2	O	G	Fe.
637	*S. chrysanthemifolius*[k]	Compositae	D	20	2	P	1.3	2.7	4.0	5.4	—	2	O	G	Fe.
638	*S. crassifolius* Willd.	Compositae	D	20	2	A	2.8	5.5	8.3	11.0	—	2	O	G	Fe.
639	*S. flavus*[k]	Compositae	D	—	—	A	1.4	2.8	4.2	5.5	—	2	O	G	Fe.
640	*S. leucanthemifolius* Poir.	Compositae	D	20	2	A	1.3	2.7	4.0	5.3	—	2	O	G	Fe.
641	*S. rupestris*[k]	Compositae	D	40	4	P	1.1	2.2	3.3	4.4	—	2	O	G	Fe.
642	*S. squalidus* L.	Compositae	D	20	2	P	0.9	1.8	2.7	3.6	—	2	O	G	Fe.
643	*S. vernalis* W. et K.	Compositae	D	40	4	A	1.2	2.5	3.7	4.9	—	2	O	G	Fe.
644	*S. vulgaris* L.	Compositae	D	40	4	A	1.5	3.0	4.5	5.9	—	2	O	B	Fe.
645	*Solanum tuberosum* L.	Solanaceae	D	48	4	P	2.1	4.2	6.3	8.4	—	2	O	B	Fe.
646	*Sonchus asper* (L.) Hill.	Compositae	D	18°	2°	A	1.8	3.7	5.5	7.4	—	48	C	B	Fe.
647	*S. asper* (L.) Hill.	Compositae	D	—°	—°	A	4.2	8.4	12.6	16.8	—	48	C	B	Fe.
648	*Sorghum caffrorum* Beauv.	Gramineae	M	20	4	A	5.1	10.1	15.2	20.3	—	18	O	B	Fe.
649	*S. caudatum* Stapf	Gramineae	M	20	4	A	4.9	9.8	14.8	19.2	—	18	O	B	Fe.
650	*S. conspicuum* Snowden	Gramineae	M	20	4	A	5.5	11.1	16.7	22.2	—	18	O	B	Fe.
651	*S. durra* Stapf	Gramineae	M	20	4	A	5.7	11.4	17.1	22.8	—	18	O	B	Fe.

TABLE 8 (cont.)

	species	family	monocot (M) or dicot (D)	chromosome number, 2n	ploidy level, x	life cycle type (annual (A), biennial (B) or perennial (P))	DNA amount/pg 1C	2C	3C	4C	4C per cell	original reference (for key see §9(a))	present amount (original (O), calibrated value (C) or recalibrated value (R))	standard species used to calculate the present amount (for key see §9(b))	method used for DNA estimate (Feulgen densitometry, Fe., chemical extraction, Ch.)
652	S. nervosum Bess. ex Schult	Gramineae	M	20	4	A	5.3	10.7	16.0	21.4	—	18	O	B	Fe.
653	S. roxburghii Stapf	Gramineae	M	20	4	A	3.4	6.8	10.2	13.7	—	18	O	B	Fe.
654	S. sudanense Stapf	Gramineae	M	20	4	A	4.5	9.0	13.6	18.1	—	18	O	B	Fe.
655	S. virgatum (Hack.) Stapf	Gramineae	M	20	4	A	4.4	8.8	13.2	17.6	—	18	O	B	Fe.
656	Sprekelia formosissima Herbert	Amaryllidaceae	M	—	—	P	—	—	—	—	180.0	30	O	—	Ch.
657	Stellaria media (L.) Vill.	Caryophyllaceae	D	42	7	A	1.0	2.1	3.1	4.2	—	1	R	F	Fe.
658	Taraxacum officinale Haller.	Compositae	D	—	—	P	1.3	2.6	3.8	5.1	—	48	C	B	Fe.
659	Tradescantia blossfeldiana Mildbr.	Commelinaceae	M	72	—	P	—	—	—	—	40.0	10	O	—	Ch.
660	T. ohioensis[k]	Commelinaceae	M	12	2	P	—	—	—	—	107.7	14	O	—	Ch.
661	T. ohioensis[k]	Commelinaceae	M	24	4	P	—	—	—	—	210.0	14	O	—	Ch.
662a	T. paludosa E. Anders & R. E. Woodson	Commelinaceae	M	12	2	P	20.6	41.3	61.9	82.5	—	2	O	C	Fe.
662b	T. paludosa	Commelinaceae	M	12	2	P	19.4	38.3	58.2	77.6	—	6	O	—	Ch.
662c	T. paludosa	Commelinaceae	M	12	2	P	19.4	38.8	58.2	77.6	—	7	O	B	Fe.
662d	T. paludosa	Commelinaceae	M	12	2	P	—	—	—	—	49.9	11	C	B	Fe.
662e	T. paludosa	Commelinaceae	M	12	2	P	—	—	—	—	59.4	9	O	—	Ch.
662f	T. paludosa (Clone B2-2)	Commelinaceae	M	12	2	P	—	—	—	—	54.0	10	O	—	Ch.
663	T. paludosa	Commelinaceae	M	24	4	P	—	—	—	—	118.0	10	O	—	Ch.
664	T. virginiana L. cv. Purple dome	Commelinaceae	M	24	4	P	—	—	—	—	116.0	10	O	—	Ch.
665	Trichocereus werdermanianus Backbg.	Cactaceae	D	—	—	P	2.0	3.9	5.9	7.8	—	31	C	F	Fe.
666	Trillium erectum L.	Trilliaceae	M	10	2	P	—	—	—	—	120.0	12	O	—	Ch.
667	Tripleurospermum maritimum (L.) Koch	Compositae	D	18	2	P	2.6	5.3	7.9	10.5	—	32	O	B	Fe.
668a	Triticale (Hexaploid 6A 190)	Gramineae	M	42	6	A	21.2	42.3	63.5	84.7	—	2	O	E	Fe.
668b	Triticale (Hexaploid 6A 190)	Gramineae	M	42	6	A	16.8	33.6	50.4	67.2	—	49	C	E	Fe.
669	Triticale (Octoploid)	Gramineae	M	56	8	A	26.0	52.0	78.0	103.9	—	1	R	C & E	Fe.
670	Triticum aegilopoides Bal. ex Koern.	Gramineae	M	14	2	A	6.9	13.8	20.7	27.6	—	4	R	A-674b	Fe.
671a	T. aestivum L. cv. Chinese Spring	Gramineae	M	42	6	A	17.3	34.6	51.9	69.3	—	2	O	B	Fe.

No.	Name	Family		2n	x										
671b	*T. aestivum* L.	Gramineae	M	42	6	A	15.7	31.4	47.1	62.8	—	22	R	B	Fe.
672	*T. dicoccoides* Koern.	Gramineae	M	28	4	A	12.3	24.5	36.8	49.1	—	4	R	A-676c	Fe.
673	*T. dicoccum* Schrank.	Gramineae	M	28	4	A	12.0	24.1	36.1	48.1	—	4	R	A-676c	Fe.
	T. durum Desf. (listed under *T. turgidum* L. var. *durum* 676)														
674a	*T. monococcum* L.	Gramineae	M	14	2	A	6.2	12.4	18.7	24.9	—	2	O	E	Fe.
674b	*T. monococcum* L.	Gramineae	M	14	2	A	6.7	13.4	20.1	26.8	—	4	R	A	Fe.
675	*T. timophaevi* (Zhukov.) Zhukov.	Gramineae	M	28	4	A	11.3	22.6	33.9	45.2	—	4	R	A-676c	Fe.
676a	*T. turgidum* L. var. *durum* cv. Stewart	Gramineae	M	28	4	A	12.3	24.6	36.8	49.1	—	2	O	E	Fe.
676b	*T. turgidum* L. var. *durum* cv. Stewart	Gramineae	M	28	4	A	11.0	21.9	32.9	43.8	—	49	C	E	Fe.
676c	*T. turgidum* L. var. *durum*	Gramineae	M	28	4	A	12.1	24.2	36.2	48.3	—	4	R	A	Fe.
677	*T. urartu* Thum.	Gramineae	M	14	2	A	4.9	9.8	14.8	19.7	—	2	O	E	Fe.
678	*Tropaeolum majus* L.	Tropaeolaceae	D	28	4	A	—	—	—	—	11.0	10	O	—	Ch.
679	*Tulbaghia violacea* Harv.	Amaryllidaceae	M	12	2	P	19.8	39.7	59.5	79.3	—	1	R	C	Fe.
680	*Tulipa aucheriana* Bak.	Liliaceae	M	24	2	P	22.0	44.2	66.3	88.4	—	40	C	Bg	Fe.
681	*T. australis* Link.	Liliaceae	M	24	2	P	25.7	51.4	77.0	102.7	—	40	C	Bg	Fe.
682a	*T. biflora* Pall.	Liliaceae	M	24	2	P	21.5	43.0	64.5	86.0	—	2	O	B	Fe.
682b	*T. biflora* Pall.	Liliaceae	M	24	2	P	22.8	45.7	68.5	91.3	—	40	C	Bg	Fe.
683	*T. cretica* Boiss. et Heldr.	Liliaceae	M	24	2	P	22.3	44.5	66.7	90.0	—	40	C	Bg	Fe.
684	*T. gesneriana* L.	Liliaceae	M	24	2	P	—	—	—	—	100.7	23	O	—	Ch.
685	*T. hageri* Heldr.	Liliaceae	M	24	2	P	24.6	49.3	73.9	98.5	—	40	C	Bg	Fe.
686a	*T. kaufmanniana* Regel.	Liliaceae	M	24	2	P	22.6	45.1	67.7	90.3	—	2	O	B	Fe.
686b	*T. kaufmanniana*	Liliaceae	M	24	2	P	—	—	—	—	93.7	12	O	—	Ch.
687	*T. orphanidea* Heldr.	Liliaceae	M	24	2	P	25.5	51.0	76.5	102.0	—	40	C	Bg	Fe.
688	*T. persica* Hort.	Liliaceae	M	24	2	P	26.2	52.3	78.5	104.6	—	40	C	Bg	Fe.
689	*T. polychroma* Stapf	Liliaceae	M	24	2	P	24.3	48.5	72.8	97.0	—	40	C	B	Fe.
690	*T. primulina* Bak.	Liliaceae	M	24	2	P	22.2	44.3	66.5	88.6	—	40	C	Bg	Fe.
691	*T. pulchella* Fenzl.	Liliaceae	M	24	2	P	25.6	51.2	76.9	102.5	—	40	C	Bg	Fe.
692a	*T. saxatilis* Spreng.	Liliaceae	M	36	3	P	34.4	68.8	103.1	137.5	—	2	O	B	Fe.
692b	*T. saxatilis* Spreng.	Liliaceae	M	36	3	P	32.9	65.9	98.8	131.7	—	40	C	Bg	Fe.
693	*T. tarda* Stapf	Liliaceae	M	24	2	P	23.7	47.5	71.2	95.0	—	40	C	B	Fe.
694a	*T. turkestanica* Regel.	Liliaceae	M	48	4	P	44.3	88.5	132.8	177.0	—	2	O	B	Fe.
694b	*T. turkestanica*	Liliaceae	M	48	4	P	43.5	87.0	130.5	174.0	—	40	C	Bg	Fe.
695a	*T. urumiensis* Stapf	Liliaceae	M	24	2	P	19.9	39.9	59.9	79.9	—	2	O	B	Fe.
695b	*T. urumiensis*	Liliaceae	M	24	2	P	24.2	48.3	72.5	96.7	—	40	C	Bg	Fe.
696	*T. violacea* Boiss. & Buhse	Liliaceae	M	24	2	P	23.9	47.8	71.7	95.6	—	40	C	Bg	Fe.
697	*T. whitlalli* (Dykes) Hall Harvest	Liliaceae	M	48	4	P	45.3	90.6	135.9	181.1	—	40	C	Bg	Fe.
698	*Tulipa* sp. Golden	Liliaceae	M	24	2	P	—	—	—	—	72.0	10	O	—	Ch.
699	*Urtica urens* L.	Urticaceae	D	—	—	A	0.3	0.6	0.9	1.2	—	2	O	H	Fe.
700	*Veronica persica* Poir.	Scrophulariaceae	D	28	4	A	0.8	1.5	2.3	3.1	—	1	R	F	Fe.
701	*Vicia amphicarpa* L.	Leguminosae	D	10	2	A	2.2	4.5	6.7	8.9	—	19	C	C	Fe.
702a	*V. angustifolia* L.	Leguminosae	D	12	2	A	2.3	4.5	6.8	9.0	—	20	Cl	C	Ch.
702b	*V. angustifolia* L.	Leguminosae	D	12	2	A	—	—	—	—	10.0	10	O	—	Fe.
703	*V. articulata* Hornem.	Leguminosae	D	14	2	A	6.0	12.1	18.1	24.1	—	21	C	C	Fe.
704	*V. atropurpurea* Desf.	Leguminosae	D	14	2	A–P	2.4	4.8	7.3	9.7	—	21	C	C	Fe.
705	*V. benghalensis* L.	Leguminosae	D	14	2	A–P	3.5	7.0	10.5	14.0	—	21	C	C	Fe.
706	*V. biennis* L.	Leguminosae	D	14	2	A	3.0	6.0	8.9	11.9	—	21	C	C	Fe.
707	*V. bithynica* (L.) L.	Leguminosae	D	14	2	A	4.6	9.1	13.7	18.3	—	21	C	C	Fe.

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TABLE 8 (*cont.*)

	species	family	monocot (M) or dicot (D)	chromosome number, 2n	ploidy level, x	life cycle type (annual (A), biennial (B) or perennial (P))	DNA amount/pg 1C	2C	3C	4C	DNA 4C per cell	original reference (for key see §9(a))	present amount (original value (O), calibrated value (C) or recalibrated value (R))	standard species used to calculate the present amount (for key see §9(b))	method used for DNA estimate (Feulgen densitometry, Fe., chemical extraction, Ch.)
708	*V. cassubica* L.	Leguminosae	D	12	2	P	4.1	8.3	12.4	16.5	—	21	C	C	Fe.
709	*V. cracca* L.	Leguminosae	D	28	4	P	5.3	10.6	15.9	21.2	—	21	C	C	Fe.
710	*V. disperma* DC.	Leguminosae	D	14	2	A	3.4	6.7	10.1	13.5	—	21	C	C	Fe.
711	*V. dumetorum* L.	Leguminosae	D	14	2	P	7.4	14.9	22.3	29.7	—	21	C	C	Fe.
712	*V. ervilea* (L.) Willd.	Leguminosae	D	14	2	A	5.1	10.3	15.5	20.6	—	21	C	C	Fe.
713a	*V. faba* L.	Leguminosae	D	12	2	A	13.3	26.7	40.0	53.3	—	2	O	B	Fe.
713b	*V. faba* L.	Leguminosae	D	12	2	A	11.9	23.9	35.8	47.8	—	7	O	B	Fe.
713c	*V. faba* L.	Leguminosae	D	12	2	A	—	—	—	—	60.5	14	O	—	Ch.
713d	*V. faba* L.	Leguminosae	D	12	2	A	—	—	—	—	38.4	9	O	—	Ch.
713e	*V. faba* L.	Leguminosae	D	12	2	A	—	—	—	—	22.4	11	O	B	Fe.
713f	*V. faba* L.	Leguminosae	D	12	2	A	—	—	—	—	56.2	23	O	—	Ch.
713g	*V. faba* L.	Leguminosae	D	12	2	A	14.4	28.8	43.2	57.6	—	53	O	Mouse	Fe.
713h	*V. faba* L. cv. Sutton's Prolific Longpod	Leguminosae	D	12	2	A	—	—	—	—	44.0	10	O	—	Ch.
714	*V. galeata* Boiss.	Leguminosae	D	14	2	A	4.3	8.6	12.9	17.2	—	21	C	C	Fe.
715	*V. graminea* Sm.	Leguminosae	D	14	2	A	5.2	10.3	15.5	20.7	—	21	C	C	Fe.
716	*V. grandiflora* Scop.	Leguminosae	D	14	2	A	3.3	6.6	9.9	13.4	—	21	C	C	Fe.
717	*V. hajastana* Grossh.	Leguminosae	D	10	2	A	7.5	15.0	22.5	30.0	—	21	C	C	Fe.
718a	*V. hirsuta* (L.) S. F. Gray	Leguminosae	D	14	2	A	4.0	8.0	12.0	16.0	—	21	C	C	Fe.
718b	*V. hirsuta*	Leguminosae	D	14	2	A	4.9	9.8	14.8	19.7	—	20	C¹	C	Fe.
719a	*V. hybrida* L.	Leguminosae	D	12	2	A	6.8	13.6	20.4	27.2	—	21	C	C	Fe.
719b	*V. hybrida* L.	Leguminosae	D	12	2	A	6.8	13.6	20.4	27.1	—	19	C	C	Fe.
720	*V. hyrcanica* Fisch. et Mey.	Leguminosae	D	12	2	A	6.7	13.5	20.2	27.0	—	21	C	C	Fe.
721	*V. incisaeformis* Stef.	Leguminosae	D	14	2	A	4.7	9.5	14.2	19.0	—	21	C	C	Fe.
722	*V. lathyroides* L.	Leguminosae	D	12	2	A	2.6	5.2	7.9	10.5	—	21	C	C	Fe.
723a	*V. lutea* L.	Leguminosae	D	14	2	A	7.4	14.8	22.2	29.6	—	21	C	C	Fe.
723b	*V. lutea* L.	Leguminosae	D	14	2	A	7.9	15.7	23.6	31.6	—	19	C	C	Fe.
723c	*V. lutea* L.	Leguminosae	D	14	2	A	6.2	12.3	18.5	24.6	—	20	C¹	C	Fe.
724	*V. melanops* Sibth. & Sm.	Leguminosae	D	10	2	A	11.5	22.9	34.4	45.9	—	21	C	C	Fe.
725	*V. mayeri* Boiss.	Leguminosae	D	14	2	A	6.3	12.5	18.8	25.0	—	21	C	C	Fe.
726	*V. michauxii* Spreng.	Leguminosae	D	14	2	A	8.3	16.6	24.9	33.2	—	21	C	C	Fe.
727a	*V. narbonensis* L.	Leguminosae	D	14	2	A	7.3	14.5	21.8	29.1	—	21	C	C	Fe.
727b	*V. narbonensis* L.	Leguminosae	D	14	2	A	7.6	15.1	22.7	30.2	—	19	C	C	Fe.
727c	*V. narbonensis* L.	Leguminosae	D	14	2	A	6.4	12.7	19.1	25.4	—	20	C¹	C	Fe.
727d	*V. narbonensis* L.	Leguminosae	D	14	2	A	7.0	14.0	21.0	28.0	—	53	O	Mouse	Fe.
728	*V. neglecta* Hanelt. et Mettin.	Leguminosae	D	12	2	A	4.7	9.4	14.1	18.9	—	21	C	C	Fe.

No.	Species	Family		2n											
729	*V. orobus* DC. in Lam. & DC.	Leguminosae	D	12	2	P	5.4	10.7	16.1	21.5	—	21	C	C	Fe.
730	*V. pannonica* Crantz.	Leguminosae	D	12	2	A	6.8	13.6	20.3	27.1	—	21	C	C	Fe.
731	*V. peregrina* L.	Leguminosae	D	14	2	A	9.5	18.9	28.4	37.9	—	21	C	C	Fe.
732	*V. picta* Fisch. & Mey.	Leguminosae	D	14	2	A	2.1	4.1	6.2	8.2	—	20	C[t]	C	Fe.
733	*V. pisiformis* L.	Leguminosae	D	12	2	P	6.6	13.3	19.9	26.6	—	21	C	C	Fe.
734	*V. pubescens* (DC.) Link.	Leguminosae	D	14	2	A	2.6	5.3	7.9	10.5	—	21	C	C	Fe.
735	*V. ramuliflora* (Maxim.) Ohwi	Leguminosae	D	12	2	P	4.7	9.3	14.0	18.7	—	21	C	C	Fe.
736a	*V. sativa* L.	Leguminosae	D	12	2	A	2.3	4.5	6.8	9.0	—	20	C[t]	C	Fe.
736b	*V. sativa* L.	Leguminosae	D	12	2	A	2.8	4.9	7.4	9.9	—	19	C	C	Fe.
736c	*V. sativa* L.	Leguminosae	D	12	2	A	2.0	4.0	6.0	8.0	—	53	O	Mouse	Fe.
737	*V. sativa* L. ssp. *angustifolia* (L.) Gaudin	Leguminosae	D	12	2	A	3.1	6.1	9.2	12.3	—	21	C	C	Fe.
738	*V. sativa* L. ssp. *cordata* (Wulfen ex. Hoppe) Ascherson & Graebner	Leguminosae	D	10	2	A	2.3	4.6	6.9	9.2	—	21	C	C	Fe.
739	*V. sativa* L. ssp. *macrocarpa* (Moris) Arcangeli	Leguminosae	D	12	2	A	2.6	5.1	7.7	10.3	—	21	C	C	Fe.
740	*V. sativa* L. ssp. *pilosa*	Leguminosae	D	14	2	A	2.5	5.0	7.5	10.1	—	21	C	C	Fe.
741	*V. sativa* L. ssp. *sativa*	Leguminosae	D	12	2	A	2.6	5.3	7.9	10.5	—	21	C	C	Fe.
742a	*V. sepium* L.	Leguminosae	D	14	2	P	4.7	9.4	14.1	18.9	—	21	C[t]	C	Fe.
742b	*V. sepium* L.	Leguminosae	D	14	2	P	7.2	14.4	21.5	28.7	—	20	C	C	Fe.
743	*V. sylvatica* L.	Leguminosae	D	14	2	P	8.6	17.2	25.8	34.4	—	21	C	C	Fe.
744	*V. tenuifolia* Roth.	Leguminosae	D	24	4	P	4.7	9.5	14.2	18.9	—	21	C	C	Fe.
745	*V. tetrasperma* (L.) Schreber	Leguminosae	D	14	2	P	3.7	7.4	11.1	14.8	—	21	C	C	Fe.
746	*V. unijuga* A. Br.	Leguminosae	D	12	2	P	4.8	9.7	14.5	19.3	—	21	C	C	Fe.
747	*V. villosa* Roth.	Leguminosae	D	14	2	A	2.0	4.0	5.9	7.9	—	53	O	Mouse	Fe.
748	*V. villosa* Roth. ssp. *dasycarpa*	Leguminosae	D	14	2	A	3.2	6.5	9.7	13.0	—	21	C	C	Fe.
749	*V. villosa* Roth. ssp. *eriocarpa* (Hausskn.) P. W. Ball	Leguminosae	D	14	2	A	2.1	4.2	6.3	8.4	—	21	C	C	Fe.
750	*V. villosa* Roth. ssp. *villosa*	Leguminosae	D	14	2	A	2.3	4.5	6.8	9.1	—	21	C	C	Fe.
751	*Vigna sinensis* (L.) Savi ex. Hassk. var. *sinensis*	Leguminosae	D	22	2	A	0.5	1.1	1.6	2.2	—	2	O	B	Fe.
752	*Weberbaureocereus winterianus*[k]	Cactaceae	D	88	8	P	7.1	14.2	21.3	28.4	—	31	C	F	Fe.
753a	*Zea mays* L.	Gramineae	M	20	2	A	2.4	4.7	7.1	9.4	—	2	O	B	Fe.
753b	*Z. mays* L.	Gramineae	M	20	2	A	5.5	11.0	16.5	22.0	14.1	7	O	B	Fe.
753c	*Z. mays* L.	Gramineae	M	20	2	A	—	—	—	—	14.1	9	O	—	Ch.
753d	*Z. mays* L.	Gramineae	M	20	2	A	—	—	—	4.4	4.4	11	O	B	Fe.
753e	*Z. mays* L.	Gramineae	M	20	2	A	—	—	—	—	15.5	14	O	—	Ch.
753f	*Z. mays* L.	Gramineae	M	20	2	A	3.9	7.8	11.8	15.7	—	22	R	B	Fe.
753g	*Z. mays* L.	Gramineae	M	20	2	A	—	—	—	—	30.2	23	O	—	Ch.
753h	*Z. mays* L. cv. Golden Bantam	Gramineae	M	20	2	A	3.3	6.5	9.8	13.1	—	31	C	F	Fe.

9. Notes to table 8

(a) The key to the original references for species DNA amounts given in table 8 is as follows:

1. Bennett (1972)
2. Bennett & Smith (1976)
3. Furuta (1970)
4. Rees & Walters (1965)
5. Jones & Rees (1968)
6. Van't Hof (1965)
7. Evans et al. (1972)
8. Rothfels et al. (1966)
9. Sparrow & Mischke (1961)
10. Baetcke et al. (1967)
11. Rasch & Woodard (1959)
12. Van't Hof & Sparrow (1963)
13. McLeish & LaCour (private communication)
14. McLeish & Sunderland (1961)
15. Rees & Hazarika (1969)
16. Ruch & Rosselet (1970)
17. Jones & Rees (1967)
18. Paroda & Rees (1971)

19. Martin & Shanks (1966)
20. Rees et al. (1966)
21. Chooi (1971)
22. Ingle & Sinclair (1972)
23. Martin (1966)
24. Sunderland & McLeish (1961)
25. Owens (1974)
26. Kadir (1974)
27. Verma & Rees (1974)
28. Ayonoadu (1974)
29. Wallace et al. (1972)
30. Price et al. (1972)
31. P. Barlow (private communication)
32. Nagl & Ehrendorfer (1974)
33. Narayan & Rees (1974)
34. Bullen & Rees (1972)
35. Iiyama & Grant (1972)
36. Barlow & Nevin (1976)
37. P. Barlow (1975 a)

38. Cheng & Grant (1973)
39. Rothfels & Heimberger (1968)
40. Southern (1967)
41. Murray (1975)
42. Brown & Jones (private communication)
43. Capesius et al. (1975)
44. Goepfert (1974)
45. Owens (private communication)
46. Smith & Bennett (1975)
47. Price & Bachmann (1975)
48. Bachmann, Price & Bierweiler (private communication)
49. Kaltsikes (1971)
50. Bennett & Smith (1971)
51. Borsos (1973)
52. Guervin et al. (1975)
53. Maher & Fox (1973)
54. Lyndon (1963)

(b) If a species was calibrated in direct comparison with one of the 8 standard species, the standard species used is identified in column 14 by the appropriate capital letter given to it in table 7, i.e. A = *T. aestivum*, B = *Allium cepa*, etc. If a species was calibrated subject to the procedures described in § 7 (*c*) (iii) and (iv), then the original standard species is identified first as described above, and the intermediate standard species used to calibrate those species listed with it is also denoted by its number in table 8, column 1. For instance, standard A (*T. aestivum*) was used to calibrate *Aegilops speltoides* (species no. 13 in table 8), which was then used as an intermediate assumed standard to calibrate other *Aegilops* species given by Furuta (1970). The calibration standard for such *Aegilops* species is therefore given as A-13. If a species was calibrated using an animal standard then the species is named in column 14 of table 8.

(c) 2*C* DNA estimates for *Avena* species given by Bullen & Rees (1972) in arbitrary units (a.u.) were converted to absolute units using the conversion factor, 1 pg = 0.60 a.u. This factor was obtained as the mean ratio of results for *A. brevis*, *A. longiglumis*, *A. barbata*, *A. sativa*, and *A. sterilis* measured by Bullen & Rees (1972) and the present authors (table 8).

(d) DNA estimates for *Avena* species given by Iiyama & Grant (1972) in arbitrary units (a.u.) were converted into absolute units using the conversion factor 1 pg = 0.1155 a.u. This factor was obtained as the mean ratio for results for *A. longiglumis*, *A. strigosa*, *A. barbata*, and *A. sterilis* measured by Iiyama & Grant (1972) and the present authors (table 8).

(e) 4*C* DNA estimates given by Guervin et al. (1975) in arbitrary units (a.u.) for *Callisia* species were calibrated using the correction factor 1 pg = 136.5 a.u. This factor was obtained as the mean ratio of estimates for *C. elegans* and *C. repens* given by Guervin et al. and the present authors (table 8).

(f) 4*C* DNA estimates for *Phalaris* species given by Kadir (1974) in arbitrary units (a.u.) were converted to absolute units using the conversion factor 1 pg = 18.088 a.u. This conversion factor was obtained as the mean ratio of results for *P. paradoxa* and *P. arundinacea* (6x) given by Kadir and the present authors (table 8).

(g) 2*C* DNA estimates for *Tulipa* species given by Southern (1967) in arbitrary units (a.u.) were converted to absolute units using the conversion factor 1 pg = 0.2342 a.u. This factor was obtained as the mean ratio of results for *T. biflora*, *T. saxatilis* and *T. turkestanica* (4x) measured by Southern and the present authors (table 8).

(h) Intraspecific variation in nuclear DNA content may occur in this species. Consequently the values given in table 8 should not be assumed to be correct for all genotypes of the species (see § 5).

(i) DNA amounts for *Vicia* species (including *V. faba*) given by Rees et al. (1966) were estimated graphically from their figure 3 in arbitrary units, and then calibrated using the present standard for *V. faba* (see table 7).

(j) This is a dioecious species. It should be noted that a possible source of intraspecific variation in DNA content exists in dioecious species, especially those with dimorphic X and Y chromosomes or different chromosome numbers in male and female plants. These conditions are rare in angiosperms, but some examples are *Melandrium* and *Rumex* species (Stebbins 1971). Anisimov (1973) has found differences in DNA content between two classes of spermatozoids occurring in equal numbers in the animal *Ascaris suum*, but no similar measurements have been reported for dioecious plant species with dimorphic sex chromosomes. Estimates for DNA amounts in dioecious plant species should always specify the sex of the material measured.

(k) The authority of this species is either unknown or unclear to the present authors.

(l) Species no. 176 was obtained from Station Nationale d'Essais de Semances, La Miniere 78000 Versailles, France, as *Bromus* aff. *valdivianus* and therefore, the identity of this genotype has not been definitely established.

(m) There is no obvious basic number for the genus *Luzula* and it is impossible to allocate *Luzula* species with high chromosome numbers to one ploidy level with any certainty.

(n) *Ranunculus falcatus* is often included in the genus *Ceratocephalus*. Goepfert (1974) considers it to be a modified hexaploid based on $x = 7$, however, it might be a pentaploid based on $x = 8$.

(o) DNA amounts for several species in the Compositae given by Bachmann, Price and Bierweiler (private communication) clearly indicate that plants at two or three ploidy levels were measured, e.g. species nos, 213–4; 313–5; 343–5; 371–2; 373–4; 502–3; 504–5; 646–7. As their data did not include chromosome counts, it is impossible to state with certainty the ploidy levels of the plants involved. In some instances the most likely ploidy levels have been indicated. For instance, as counts of 12 and 24 are recorded for *Leontodon autumnalis* (Darlington & Wylie 1955), the values given by

Bachmann *et al.* have been tentatively assigned to diploid and tetraploid races, respectively. Darlington & Wylie (1955) give only a single chromosome number for *Crepis biennis* ($2n = 40$); *Lactuca serriola* ($2n = 18$); *Picris echioides* and *P. hieracioides* (both $2n = 10$); and *Sonchus asper* ($2n = 18$). Thus in these cases, the DNA amounts may constitute evidence for the existence of a race with the ploidy level different from that noted in chromosome counts hitherto.

(p) There is probably an error in the original estimate for *Aegilops cylindrica* given by Furuta (1970). This tetraploid species is thought to have the genomic constitution CD, yet summing Furuta's estimates of the DNA contents of the respective diploids (C- *Ae. caudata*, 161 a.u.; D- *Ae. squarrosa* 126-171 a.u.) gives a much higher expected DNA amount for *Ae. cylindrica* (287-332 a.u.) than was obtained (162 a.u.). No value is given for the species *Ae. triuncialis* ssp. *orientalis* Eig. var. *persica* (Boiss.) Eig (listed immediately above *Ae. cylindrica* (table 1 in – Furuta *loc. cit.*). Perhaps the value for this species became substituted for the value for *Ae. cylindrica* which was accidentally omitted?

(q) The DNA content per isolated nucleus for *Anemone virginiana* (21.0 pg) given by Rothfels *et al.* (1966) is mistakenly quoted as the $4C$ value for that species by Goepfert (1974). Thus, the $4C$ DNA amounts for *Ranunculus* species given by Goepfert (1974) relative to the standard $4C$ *A. virginiana* = 1.0 (in a.u.) should not be converted to absolute units using the per cell DNA value of Rothfels *et al.* (1966), although they may be converted using the $4C$ value for *A. virginiana* given by the present authors (table 7).

(r) Some doubt has arisen concerning the identification of this *Luzula* species (P. Barlow, private communication).

REFERENCES

Abbott, A. J. 1971 *In vitro* loss of nucleic acids from cells of aseptically excised pea roots. *Planta (Berl.)* **100**, 268–271.

Abrahamson, S., Bender, M. A., Conger, A. D. & Wolff, S. 1973 Uniformity of radiation-induced mutation rates among different species. *Nature, Lond.* **245**, 460–462.

Anisimov, A. P. 1973 Distinctions in spermatozoa of different sex classes of *Ascaris suum* (Nematoda) according to their DNA content and nucleus size. *Tsitologiya* **15**, 1162–1165. (In Russian.)

Ayonoadu, U. W. U. 1974 Nuclear DNA variation in *Phaseolus*. *Chromosoma (Berl.)* **48**, 41–49.

Baetcke, K. P., Sparrow, A. H., Nauman, C. H. & Schwemmer, S. S. 1967 The relationship of DNA content to nuclear and chromosome volumes and to radiosensitivity (LD_{50}). *Proc. natn. Acad. Sci. U.S.A.* **58**, 533–540.

Barlow, P. 1975 *a* The polytene nucleus of the giant hair cell of *Bryonia* anthers. *Protoplasma* **83**, 339–349.

Barlow, P. 1975 *b* The root cap. In *The development and function of roots* (ed. J. G. Torrey & D. T. Clarkson), pp. 21–54. New York & London: Academic Press.

Barlow, P. W. & Nevin, D. 1976 Quantitative karyology of some species of *Luzula*. *Plant Systematics and Evolution* (In the Press).

Bedi, K. S. & Goldstein, D. J. 1974 Cytophotometric factors causing apparent differences between Feulgen DNA contents of different leucocyte types. *Nature, Lond.* **251**, 439.

Bennett, M. D. 1971 The duration of meiosis. *Proc. R. Soc. Lond.* B **178**, 259–275.

Bennett, M. D. 1972 Nuclear DNA content and minimum generation time in herbaceous plants. *Proc. R. Soc. Lond.* B **181**, 109–135.

Bennett, M. D. 1973 The duration of meiosis. In *The cell cycle in development and differentiation* (ed. M. Balls & F.S. Billet), pp. 111–131. Cambridge University Press.

Bennett, M. D. & Jellings, A. J. 1975 DNA content of colchicine induced endopolyploid nuclei in *Vicia faba* L. *Heredity* **35**, 261–272.

Bennett, M. D., Rao, M. K., Smith, J. B. & Bayliss, M. W. 1973 Cell development in the anther, the ovule, and the young seed of *Triticum aestivum* L. var. Chinese Spring. *Phil. Trans. R. Soc. Lond.* B **266**, 39–81.

Bennett, M. D. & Smith, J. B. 1971 The $4C$ nuclear DNA content of several *Hordeum* genotypes. *Can. J. Genet. Cytol.* **13**, 607–611.

Bird, A. P. & Birnstiel, M. L. 1971 A timing study of DNA amplification in *Xenopus laevis* öocytes. *Chromosoma (Berl.)* **35**, 300–309.

Borsos, O. Sz. 1973 Cytophotometric studies on the DNA content of diploid *Lotus* species. *Acta bot. hung.* **18**, 49–58.

Bowen, H. M. J. 1962 Radiosensitivity of higher plants and correlations with cell weight and DNA content. *Radiat. Bot.* **1**, 223–228.

Brown, R. 1951 The effects of temperature on the durations of the different stages of cell division in the root-tip. *J. exp. Bot.* **2**, 96–110.

Brown, R. & Rickless, P. 1949 A new method for the study of cell division and cell extension with some preliminary observations on the effect of temperature and of nutrients. *Proc. R. Soc. Lond.* B **136**, 110–125.

Bullen, M. R. & Rees, H. 1972 Nuclear variation in *Avena*. *Chromosoma (Berl.)* **39**, 93–100.

Burton, K. 1956 A study of the conditions and mechanism of the diphenylamine reaction for the colorimetric estimation of deoxyribonucleic acid. *Biochem. J.* **62**, 315–323.

Burton, K. 1968 Determination of DNA concentration with diphenylamine. In *Methods in enzymology*, XII B. (ed. L. Grossman & K. Moldave), pp. 163–166. New York & London: Academic Press.

Capesius, I., Bierweiler, B., Bachmann, K., Rücker, W. & Nagl, W. 1975 An A + T-rich satellite DNA in a monocotyledonous plant, *Cymbidium*. *Biochim. Biophys. Acta* **395**, 67–73.

Cheng, R. I. & Grant, W. F. 1973 Species relationships in the *Lotus corniculatus* group as determined by karyotype and cytophotometric analysis. *Can. J. Genet. Cytol.* **15**, 101–105.

Chooi, W. Y. 1971 Variation in nuclear DNA content in the genus *Vicia. Genetics* **68**, 195–211.

Collins, G. B., Anderson, M. K. & Legg, P. D. 1970 Cytophotometric determination of DNA content in *Nicotiana* megachromosomes. (Abstract). *Can. J. Genet. Cytol.* **12**, 377–378.

Cullis, C. A. 1973 DNA differences between flax genotrophs. *Nature, Lond.* **243**, 515–516.

Cullis, C. A. 1975 Ribosomal RNA cistron number in *Nicotiana* species and derived haploids. *Chromosoma (Berl.)* **50**, 435–441.

Darlington, C. D. & Wyllie, A. P. 1955 *Chromosome atlas of flowering plants*, 2nd ed. London: Allen & Unwin.

Deeley, E. M. 1955 An integrating microdensitometer for biological cells. *J. Sci. Instrum.* **32**, 263–267.

Deitch, A. D., Wagner, D. & Richart, R. M. 1968 Conditions influencing the intensity of the Feulgen reaction. *J. Histochem. Cytochem.* **16**, 371–379.

Deka, P. C. & Sen, S. K. 1973 Decrease in chromosomal DNA content at higher polyploidy level in *Vicia faba* root meristems. *Can. J. Genet. Cytol.* **15**, 863–865.

Durrant, A. 1971 Induction and growth of flax genotrophs. *Heredity* **27**, 277–298.

Durrant, A. & Jones, T. W. A. 1971 Reversion of induced changes in amount of nuclear DNA in *Linum. Heredity* **27**, 431–439.

Evans, G. M. 1968 Nuclear changes in flax. *Heredity* **23**, 25–28.

Evans, G. M., Durrant, A. & Rees, H. 1966 Associated nuclear changes in the induction of flax genotrophs. *Nature, Lond.* **212**, 697–699.

Evans, G. M. & Rees, H. 1971 Mitotic cycles in dicotyledons and monocotyledons. *Nature, Lond.* **233**, 350–351.

Evans, G. M., Rees, H., Snell, C. L. & Sun, S. 1972 The relation between nuclear DNA amount and the duration of the mitotic cycle. *Chromosomes Today* **3**, 24–31. London: Longmans.

Feulgen, R. & Rössenbeck, H. 1924 Mikroskopisch – chemischer Nachweiss einer Nucleinsäure von Typus der Thymonucleinsäure und die darauf beruhende elective Färbung von Zellkernen in mikroskopischen präparaten. *Hoppe-Seyler's Z. physiol. Chem.* **135**, 203–248.

Flavell, R. B. & Smith, D. B. 1974 Variation in nucleolar organiser rRNA gene multiplicity in wheat and rye. *Chromosoma (Berl.)* **47**, 327–334.

Fox, D. P. 1968 Some characteristics of the cold hydrolysis technique for staining plant tissues by the Feulgen reaction. *J. Histochem. Cytochem.* **17**, 266–272.

Furuta, Y. 1970 DNA content per nucleus in *Aegilops* species. *Wheat Inf. Serv.* **30**, 20–22.

Furuta, Y., Haji, T. & Nishikawa, K. 1975 Nuclear DNA content of Einkorn wheat. *Wheat Inf. Serv.* **40**, 15–16.

Furuta, Y., Nishikawa, K. & Tanino, T. 1974 Stability in DNA content of AB genome component of common wheat during the past seven thousand years. *Jap. J. Genet.* **49**, 179–187.

Gerstel, D. U. & Burns, J. A. 1967 Phenotypic and chromosomal abnormalities associated with the introduction of heterochromatin from *Nicotiana otophora* into *N. tabacum. Genetics* **56**, 483–502.

Goepfert, D. 1974 Karyotypes and DNA content in species of *Ranunculus* L. and related genera. *Bot. Notiser* **127**, 464–489.

Goldstein, D. J. 1970 Aspects of scanning microdensitometry. I. Stray light (glare). *J. Microsc.* **92**, 1–16.

Grant, W. F. 1969 Decreased DNA content of Birch (*Betula*) chromosomes at high ploidy level as determined by cytophotometry. *Chromosoma (Berl.)* **26**, 326–336.

Guervin, C., Le Coq, C. & Laroche, J. 1975 Etude de la garniture chromosomique et des quantites d'ADN nucléaire: Application à l'évolution du genre *Callisia* (Commélinacees). *Caryologia* **28**, 45–56.

Heslop-Harrison, J. 1972 Sexuality in angiosperms. In *Plant physiology. A Treatise*, VIc (ed. F. C. Steward), pp. 133–289. New York & London: Academic Press.

Hotchkiss, R. D. 1955 The biological rule of the deoxypentose nucleic acids. In *The nucleic acids*, II (ed. E. Chargaff & J. N. Davidson), pp. 435–473. New York & London: Academic Press.

Hourcade, D., Dressler, D. & Wolfson, J. 1973 The amplification of ribosomal RNA genes involves a rolling circle intermediate. *Proc. natn. Acad. Sci. U.S.A.* **70**, 2926–2930.

Iiyama, K. & Grant, W. F. 1972 A correlation of nuclear DNA content and thin layer chromatographic patterns in resolving genome relationships in *Avena. Can. J. Bot.* **50**, 1529–1545.

Ingle, J. & Sinclair, J. 1972 Ribosomal RNA genes and plant development. *Nature, Lond.* **235**, 30–32.

Joarder, I. O., Al-Saheal, Y., Begum, J. & Durrant, A. 1975 Environments inducing changes in amount of DNA in flax. *Heredity* **34**, 247–253.

Jones, G. H. & Rees, H. 1967 Chromosome evolution in *Lolium. Heredity* **20**, 1–18.

Jones, R. N. & Rees, H. 1968 Nuclear DNA variation in *Allium. Heredity* **23**, 591–605.

Kadir, Z. B. A. 1974 DNA values in the genus *Phalaris* (Gramineae). *Chromosoma (Berl.)* **45**, 379–386.

Kaltsikes, P. J. 1971 The mitotic cycle in an amphiploid (*Triticale*) and its parental species. *Can. J. Genet. Cytol.* **13**, 656–662.

Kao, K. N., Miller, R. A., Gamborg, O. L. & Harvey, B. L. 1970 Variations in chromosome number and structure in plant cells grown in suspension cultures. *Can. J. Genet. Cytol.* **12**, 297–301.

Leuchtenberger, C. 1958 Quantitative determination of DNA in cells by Feulgen microspectrophotometry. In *General cytochemical methods*, vol. 1 (ed. J. F. Danielli), pp. 219–278. New York: Academic Press.

List, A. 1963 Some observations on DNA content and nuclear volume growth in the developing xylem cells of certain higher plants. *Am. J. Bot.* **50**, 320–329.

Lyndon, R. F. 1963 Changes in the nucleus during cellular development in the pea seedling. *J. exp. Bot.* **14**, 419–430.

Maher, E. P. & Fox, D. P. 1973 Multiplicity of ribosomal RNA genes in *Vicia* species with different nuclear DNA contents. *Nature, New Biol.* **245**, 170–172.

Martin, P. G. 1966 Variation in the amounts of nucleic acids in the cells of different species of higher plants. *Expl. Cell Res.* **44**, 84–98.

Martin, P. G. & Shanks, R. 1966 Does *Vicia faba* have multistranded chromosomes? *Nature, Lond.* **211**, 650–651.

McCarthy, B. J. 1969 The evolution of base sequences in nucleic acids. In *Handbook of molecular cytology* (ed. A. Lima-de-Faria), pp. 4–20. Amsterdam & London: North Holland Publishing Co.

McLeish, J. 1964 DNA in plant nucleoli. *Nature, Lond.* **204**, 36–39.

McLeish, J. & Sunderland, N. 1961 Measurements of deoxyribosenucleic acid (DNA) in higher plants by Feulgen photometry and chemical methods. *Expl. Cell Res.* **24**, 527–540.

Miksche, J. P. 1968 Quantitative study of intraspecific variation of DNA per cell in *Picea glauca* and *Pinus banksiana*. *Can. J. Genet. Cytol.* **10**, 590–600.

Miksche, J. P. 1971 Intraspecific variation of DNA per cell between *Picea sitchensis* (Bong.) Carr. Provenances. *Chromosoma (Berl.)* **32**, 343–352.

Mittwoch, U. 1969 Scope and limitation of Feulgen microdensitometry. *Chromosomes Today* **2**, 90–98. Edinburgh: Oliver & Boyd.

Murray, B. G. 1975 The cytology of the genus *Briza* L. (Gramineae). *Chromosoma (Berl.)* **49**, 299–308.

Nagl, W. & Ehrendorfer, F. 1974 DNA content, heterochromatin, mitotic index and growth in perennial and annual *Anthemideae (Asteraceae)*. *Plant Syst. Evol.* **123**, 35–54.

Narajan, R. K. J. & Rees, H. 1974 Nuclear DNA, heterochromatin and phylogeny in *Nicotiana* amphiploids. *Chromosoma (Berl.)* **47**, 75–83.

Nishikawa, K. 1971 DNA content of individual chromosomes and genomes in wheat and its relatives. *Seiken Ziho* **22**, 57–65.

Nishikawa, K. & Furuta, Y. 1967 Comparison of DNA content per nucleus between Japanese and U.S. varieties of common wheat. *Jap. J. Breed.* **18**, 30–31.

Nishikawa, K. & Sawai, Y. 1969 Relative amount of nuclear DNA in tetraploid wheat. *Wheat Inf. Serv.* **29**, 2–3.

Owens, S. 1974 An examination of the floral biology, breeding system and cytology in species of the genus *Daucus* and related genera in the tribe Caucealidea (Umbelliferae). Ph.D. Thesis, University of Reading.

Pai, R. A., Upadhya, M. D., Bhaskavan, S. & Swaminathan, M. S. 1961 Chromosome diminution and evolution of polyploid species in *Triticum*. *Chromosoma (Berl.)* **12**, 398–409.

Paroda, R. S. & Rees, H. 1971 Nuclear DNA variation in Eu-*Sorghums*. *Chromosoma (Berl.)* **32**, 353–363.

Patau, K. 1952 Absorption microphotometry of irregular shaped objects. *Chromosoma (Berl.)* **5**, 341–362.

Perkins, J. M., Eglington, E. & Jinks, J. C. 1971 The nature of the inheritance of permanently induced changes in *Nicotiana rustica*. *Heredity* **27**, 441–457.

Phillips, R. L., Kleese, R. A. & Wang, S. S. 1973 The nucleolus organiser region (NOR) of maize. *Genetics* **74**, Suppl. 2, 212.

Pollister, A. W., Swift, H. & Rasch, E. M. 1969 Microphotometry with visible light. In *Physical techniques in biological research* (ed. G. Oster & A. W. Pollister), pp. 201–250. New York: Academic Press.

Price, H. J. & Bachmann, K. 1975 DNA content and evolution in the *Microseridinae*. *Am. J. Bot.* **62**, 262–267.

Price, H. J., Levis, R. W., Coggins, L. W. & Sparrow, A. H. 1972 High DNA content of *Sprekelia formosissima* Herbert (Amaryllidaceae) and *Ophioglossum petiolatum* Hook. (Ophioglossaceae). *Expl Cell Res.* **73**, 187–191.

Price, H. J., Sparrow, A. H. & Nauman, A. F. 1973 Evolutionary and developmental considerations of the variability of nuclear parameters in higher plants. I. Genome volume, interphase chromosome volume and estimated DNA content of 236 gymnosperms. *Brookhaven Symp. Biol.* **25**, 390–421.

Pritchard, H. N. 1964 A cytochemical study of embryo sac development in *Stellaria media*. *Am. J. Bot.* **51**, 371–378.

Rasch, E. & Woodard, J. W. 1959 Basic proteins of plant nuclei during normal and pathological cell growth. *J. biophys. biochem. Cytol.* **6**, 263–276.

Rees, H., Cameron, F. M., Hazarika, M. H. & Jones, G. H. 1966 Nuclear variation between diploid Angiosperms. *Nature, Lond.* **211**, 828–830.

Rees, H. & Hazarika, M. H. 1969 Chromosome evolution in *Lathyrus*. *Chromosomes today* **2** (ed. C. D. Darlington & K. R. Lewis), pp. 158–165. Edinburgh: Oliver & Boyd.

Rees, H. & Jones, R. N. 1972 The origin of the wide species variation in nuclear DNA content. *Int. Rev. Cytol.* **32**, 53–92.

Rees, H. & Walters, M. R. 1965 Nuclear DNA and the evolution of wheat. *Heredity* **20**, 73–82.

Ris, H. & Mirsky, A. E. 1949 Quantitative cytochemical determination of desoxyribonucleic acid with Feulgen nucleal reaction. *J. gen. Physiol.* **33**, 125–145.

Rothfels, K., Sexsmith, E., Heimburger, M. & Krause, M. O. 1966 Chromosome size and DNA content of species of *Anemone* L. and related genera (Ranunculaceae). *Chromosoma (Berl.)* **20**, 54–74.

Rothfels, K. & Heimburger, M. 1968 Chromosome size and DNA values in Sundews (*Droseraceae*). *Chromosoma* (*Berl.*) **25**, 96–103.

Ruch, F. & Rosselet, A. 1970 Cytochemical study of euchromatin and heterochromatin in roots of *Rhoeo discolor*. *Expl Cell Res.* **62**, 219–227.

Schmidt, G. & Thannhauser, S. J. 1945 A method for the determination of desoxyribonucleic acid, ribonucleic acid, and phosphoproteins in animal tissues. *J. biol. Chem.* **161**, 83–89.

Schweizer, D. & Davies, D. R. 1972 Nuclear DNA contents of *Pisum* genotypes grown *in vivo* and *in vitro*. *Planta* (*Berl.*) **106**, 23–29.

Smith, J. B. & Bennett, M. D. 1975 DNA variation in the genus *Ranunculus*. *Heredity* **35**, 231–239.

Southern, D. I. 1967 Species relationships in the genus *Tulipa*. *Chromosoma* (*Berl.*) **23**, 80–94.

Sparrow, A. H., Baetcke, K. P., Shaver, D. L. & Pond, V. 1968 The relationship of mutation rate per roentgen to DNA content per chromosome and to interphase chromosome volume. *Genetics* **59**, 65–78.

Sparrow, A. H. & Miksche, J. P. 1961 Correlation of nuclear volume and DNA content with higher plant tolerance to chronic radiation. *Science, N.Y.* **134**, 282–283.

Sparrow, A. H. & Nauman, A. F. 1973 Evolutionary change in genome and chromosome sizes and in DNA content in the grasses. *Brookhaven Symp. Biol.* **25**, 367–389.

Sparrow, A. H., Price, H. J. & Underbrink, A. G. 1972 A survey of DNA content per cell and per chromosome of prokaryotic organisms: some evolutionary considerations. *Brookhaven Symp. Biol.* **23**, 451–494.

Stebbins, G. L. 1971 *Chromosome evolution in higher plants*. London: Edward Arnold.

Strauss, N. A. 1971 Comparative DNA renaturation kinetics in Amphibians. *Proc. natn. Acad. Sci. U.S.A.* **68**, 799–802.

Stroun, M., Charles, P., Anker, P. & Pelc, S. R. 1968 Metabolic DNA in heart and skeletal muscle and in the intestine of mice. *Nature, Lond.* **216**, 716–717.

Sunderland, N. & McLeish, J. 1961 Nucleic acid content and concentration in root cells of higher plants. *Expl Cell Res.* **24**, 541–554.

Swift, H. 1950 The constancy of desoxyribose nucleic acid in plant nuclei. *Proc. natn. Acad. Sci. U.S.A.* **36**, 643–654.

Swift, H. 1953 The quantitative aspects of nuclear nucleoproteins. *Int. Rev. Cytol.* **2**, 1–76.

Swift, H. 1955 Cytochemical techniques for nucleic acids. In *The Nucleic Acids*, II (ed. E. Chargaff & J. N. Davidson, pp. 51–92. New York: Academic Press.

Teoh, S. B. & Rees, H. 1976 Nuclear DNA amounts in populations of *Picea* and *Pinus* species. *Heredity* **36**, 123–137.

Timmis, J. N. & Ingle, J. 1973 Environmentally induced changes in r-RNA gene redundancy. *Nature, Lond.* **244**, 235–236.

Timmis, J. M. & Ingle, J. 1974 The nature of the variable DNA associated with environmental induction in flax. *Heredity* **33**, 339–346.

Underbrink, A. G., Sparrow, A. H. & Pond, V. 1968 Chromosomes and cellular sensitivity. II. Use of interrelationships among chromosome volume, nucleotide content and D_0 of 120 diverse organisms in predicting radiosensitivity. *Radiat. Bot.* **8**, 205–238.

Upadhya, M. D. & Swaminathan, M. S. 1963 Deoxyribonucleic acid and the ancestry of wheat. *Nature, Lond.* **200**, 713–714.

Van't Hof, J. 1965 Relationships between mitotic cycle duration, S period duration and the average rate of DNA synthesis in the root meristem cells of several plants. *Expl Cell Res.* **39**, 48–58.

Van't Hof, J. & Sparrow, A. H. 1963 A relationship between DNA content, nuclear volume, and minimum mitotic cycle time. *Proc. natn. Acad. Sci. U.S.A.* **49**, 897–902.

Vendrely, R. & Vendrely, C. 1956 The results of cytophotometry in the study of deoxyribonucleic acid (DNA) content of the nucleus. *Int. Rev. Cytol.* **5**, 171–197.

Verma, S. C. & Rees, H. 1974 Nuclear DNA and the evolution of allotetraploid *Brassicae*. *Heredity* **33**, 61–68.

Wallace, H., Sparkes, C. A. & Maden, M. 1972 Nuclear DNA content of three *Crepis* species. *Heredity* **29**, 367–373.

Warden, J. 1974 Urea and pyridine in Feulgen staining of *Bryophyllum*. *Acta histochem.* **50**, 98–104.

Webster, P. L. & Davidson, D. 1968 Evidence from thymidine-H³-labelled meristems of *Vicia faba* of two cell populations. *J. Cell Biol.* **39**, 332–338.

Yang, D. P. & Dodson, E. O. 1970 The amounts of nuclear DNA and the duration of DNA synthesis period (S) in related diploid and autotetraploid species of oats. *Chromosoma* (*Berl.*) **31**, 309–320.

Zakirowa, R. O. & Vakhtina, L. I. 1974 Cytophotometrical and caryological investigation of some species of the genus *Allium*, subgenus *Melanocrommyum* (Webb et Berth.) Wendelbo, Sect. *Melanocrommyum*. *Bot. Zh. S.S.S.R.* **12**, 1819–1827.