AMBIGUOUS DEPENDENCE OF MINIMAL PLANT GENERATION TIME ON NUCLEAR DNA CONTENT

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The minimum generation time (MGT) of plant development was suggested to depend on nuclear DNA content, which varies in plants over wide limits[1]. In ephemeral species with the shortest MGT, the average C values were significantly lower than in annual species, whereas the average C values in annual species were lower than those in perennial plants. However, nobody has paid attention to the ratio of annual to perennial species number as a function of C values. Here I show that with increasing C the ratio of annual to perennial species increases to C values equal to 7-8 pg (monocots) and 6-7 pg (eudicots) and then decreases and that the fraction of annuals is abundant not at the lowest, but at some higher C levels. Hence, C value increase exerts an ambiguous effect on MGT. The C value is not the only factor, which determines the duration of the plant development. Nevertheless, the nuclear DNA content exerts a pronounced effect on MGT together with other diverse factors affecting the rate of plant development, especially at higher C values.

In plants, nuclear DNA content varies over wide limits. The lowest DNA amount in the haploid chromosome set (C) was found in *Genlisea margaretae* (0.1 pg), whereas the greatest (127.4) was recorded in *Fritillaria assyrica*[2].

Bennett (1972)[1] was the first to suggest that the minimum generation time (MGT) depended on C value. For example, in ephemeral species with the shortest MGT, the average C values were significantly lower than in annual species. In turn, the average C values in annual species were lower than those in perennial plants. At C values exceeding a definite threshold (monocots (*Triticale* - 25.98 pg) and eudicots (*Vicia faba* – 27.4 pg), annuals were absent and only perennials were found. In accordance to the Bennett hypothesis, the prolongation of the plant generation time at higher C values correlates with the prolongation of mitotic cycles, meiosis and other processes responsible for MGT [1,3-6].

After the publication of Bennett (1972), C values were `determined in many species and these data were accumulated on the site (www.rbgkew.org.uk/cval/database1.html, Release 4.0;October2005) maintaining by Kew Botanical garden. The data on C values in monocots and eudicots from this site are presented in Table 1. Their analysis confirmed that the average C values were higher in perennials than in annuals and that the differences in C values between annuals and perennials were more pronounced in monocots than in eudicots. However , the differences between average C values of annuals and perennials are not so great, if we compare average values of annuals and perennials at C values not exceeding the maximal C values of annuals. The differences between average C values of monocots and eudicots result from the greater number of monocot species with C values exceeding the maximal C values of annuals. It is worth mentioning that there are not only obligate perennials, but facultative perennials which can flower in first year too. However, up to now there is no data available to compare facultative and obligate perennials.

Let us analyze now the data on the site in order to clarify how the number of annuals and perennials depends on C values. Figs. 1 and 2 show the number of annuals and perennials as a function of C values in them. In both monocots and eudicots, the most annual species have the C values exceeding than 1 pg, whereas maximal number of perennials has C values below 1 pg. As follows from Figs. 1 and 2, the number of perennials in each range of C values decreases with increasing C. This decrease occurs more sharply in eudicots than in monocots.

However, nobody has paid attention to the ratio of annuals to perennials number as a function of C increase. Figs. 3 and 4 demonstrate

how these ratios varied in monocots and eudicots as their C values increased. The greatest ratios between annual and perennial species are observed at C equal to 7-8 pg (monocots) and 6-7 pg (eudicots). Therefore, the fraction of annuals is abundant not at the lowest, but at higher C level. Although the comparison of ephemers with minimal C values and obligate perennials with higher C values has led to the opinion that MGT depends on C value [2], now it is clear that this dependence is not so simple and direct.

Similar results were earlier obtained by Ivanov[7] who analyzed the species within some families, and they are supported by recent data concerning the same families (Table 2). Among Poaceae, Ranunculaceae, Compositae and Fabaceae, the ratios of annual to perennial species number may be greater not at the lowest but at some higher C values. Among the species of the same genus, some annuals can have greater C values than the perennials [8 – 11].

The conclusion is: although ephemeral species have the lowest C values, the fraction of annual species increases with C, but only within certain limit, above which it decreases. At C values higher than 25.98 pg (*Triticale*) among monocots and 27.4 (*Vicia faba*) among eudicots, the annual species are absent.

However, it should be pointed out that C values were determined only in 2.5% of all plant species. Unfortunately, most tropical plants mainly including the perennials were not studied.

The above mentioned data suggest that the correlation between nuclear DNA content and MGT is not so simple, as it previously seemed. On the one hand, the plants with the shortest MGT (ephemers) possess low C amounts. If C amount exceeds a certain threshold, annual plants are absent. On other hand, the fraction of annuals among all plant species responds to C increase by an increase to 25,98 – 27,4 pg and then decreases. Increasing C value affects MGT especially clearly at higher C values. Hence, C increase exerts an ambiguous effect on MGT.

Why increasing C exerts more than one effect on MGT? Ephemers are of small size and their ecological niches are limited. During the vegetation season, they usually develop earlier than most other plants. Therefore, the competition with other annuals and perennials is not of crucial importance for them. For most annuals which develop later than ephemers, the competition with perennials and other annuals is more critical. The increase in C not only retards some processes determining the rate of development (mitotic cycle, meiosis, seed germination time) but induces also greater cell size [12], seed weight [13] etc. These both permit plants to grow at a higher rate, especially at early ontogeny. Therefore, increasing C causes more rapid growth rate as it was clearly demonstrated, for example, by Grime et al.[14] who compared some British grassland species co-existing in the same turf. Moreover, enlarged nuclear DNA content is in some way related to the capacity for growth at low temperatures [15].

The C value is not the only factor, which determines the duration of the plant development. For example, some trees exhibit C values, which are lower or similar to ephemeral species. Nevertheless, the nuclear DNA content exerts a pronounced effect on MGT, especially at high C values, together with other diverse factors affecting the rate of plant development.

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Table 1. Average DNA amount (C) (pg) in annual and perennial plants

	Number of species	$C_{average}$	C_{min}	C_{max}	σ
monocots					
annuals	203	6.26	0.36	25.98	4,84
perennials	1609	11.77	0.15	127.4	13.83
$perennials^{x}$	1451	8.3	0.15	25.88	6.97
eudicots					
annuals	522	3,01	0,16	27.4	2.8
perennials	1659	3.51	0.11	79.33	5.13
$perennials^{x}$	1653	3.35	0.1	26.9	4.27

$perennials^{x}$ - perennials with C value not exceeding C_{max} of annuals

Table 2. Ratio of annuals to perennials in some plant families as a function of nuclear DNA content

C pg	Number of annuals	Number of perennials	annuals/perennials
Fabaceae			
0 -5	110	311	0.35
5 - 10	51	17	3
10 - 15	4	6	0.67
Poaceae			
0 -5	89	134	0.66
5 -10	63	67	0.95
10 -15	26	25	1.04
15 - 20	8	6	1.33
20 -25	1	3	0.33
Ranunculaceae			
0 -5	8	23	0.35
5 -10	9	53	0.17
10 -15	3	22	0.14
15-20	1	17	0.06
20 -25	0	3	0
Compositae			
0-5	73	112	0.65
5-10	20	50	0.4
10 – 15	3	8	0.38

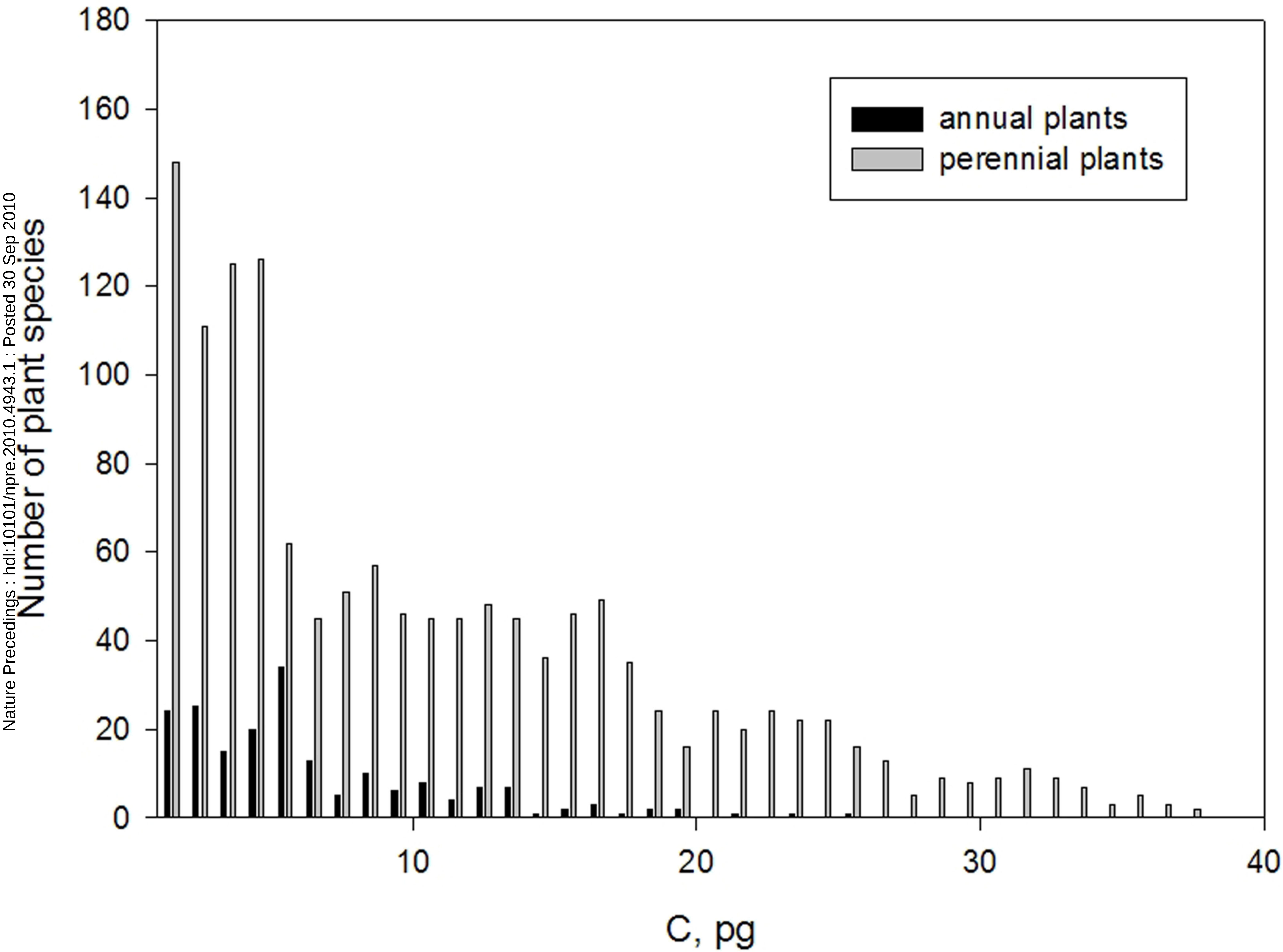
Figure legend to paper of V.Ivanov **AMBIGUOUS DEPENDENCE OF MINIMAL PLANT GENERATION TIME ON NUCLEAR DNA CONTENT**

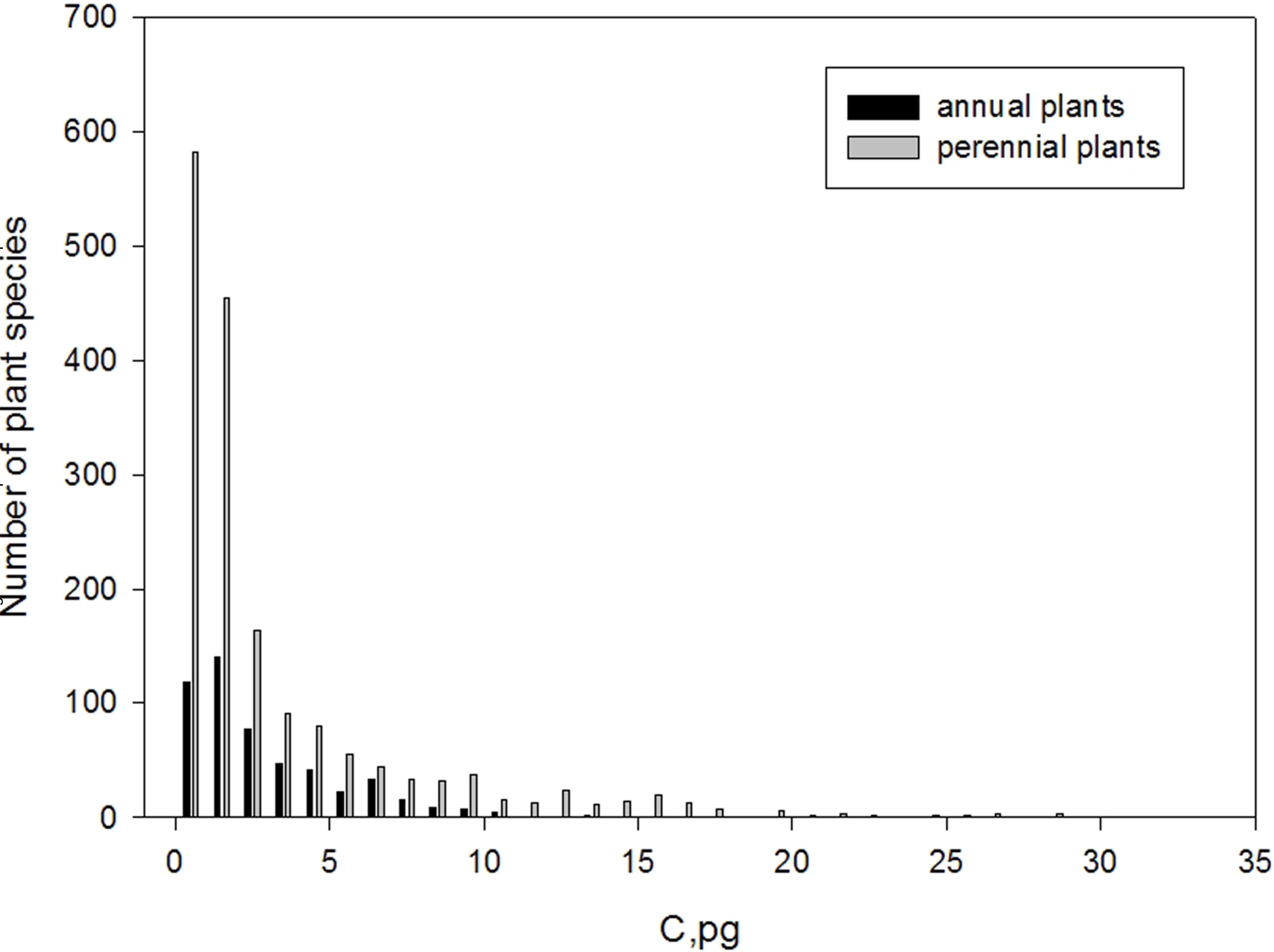
Fig.1. Dependence of monocot plant species number on nuclear DNA amount. For this figure, as well as for all others, the data were used accumulated on the site (www.rbgkew.org.uk/cval/database1.html, Release 4.0;October2005) maintaining by Kew Botanical garden.

Fig. 2. Dependence of eudicot plant species number on nuclear DNA amount.

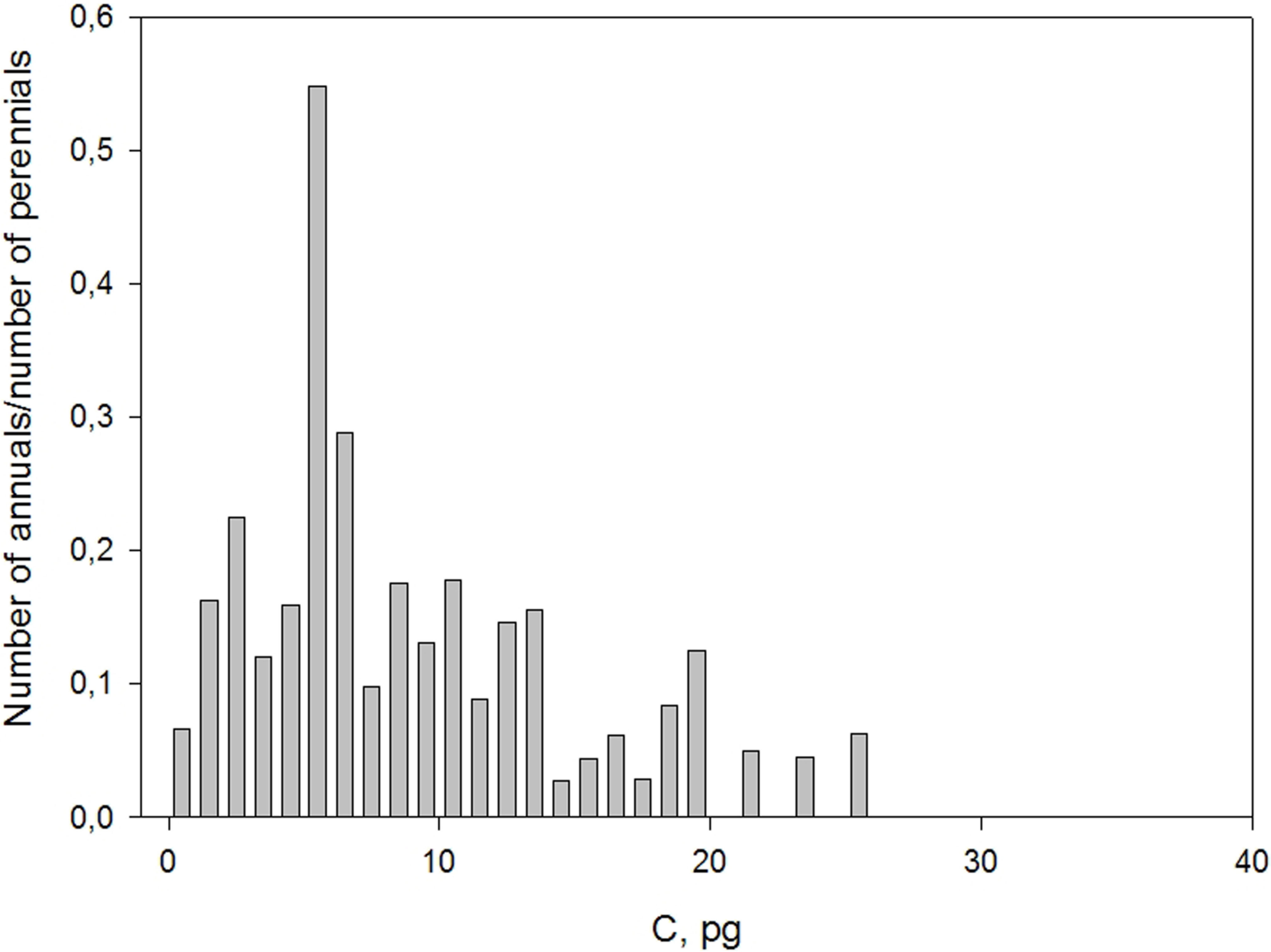
Fig.3. Dependence of the ratio of annuals to perennials number in monocots on nuclear DNA content.

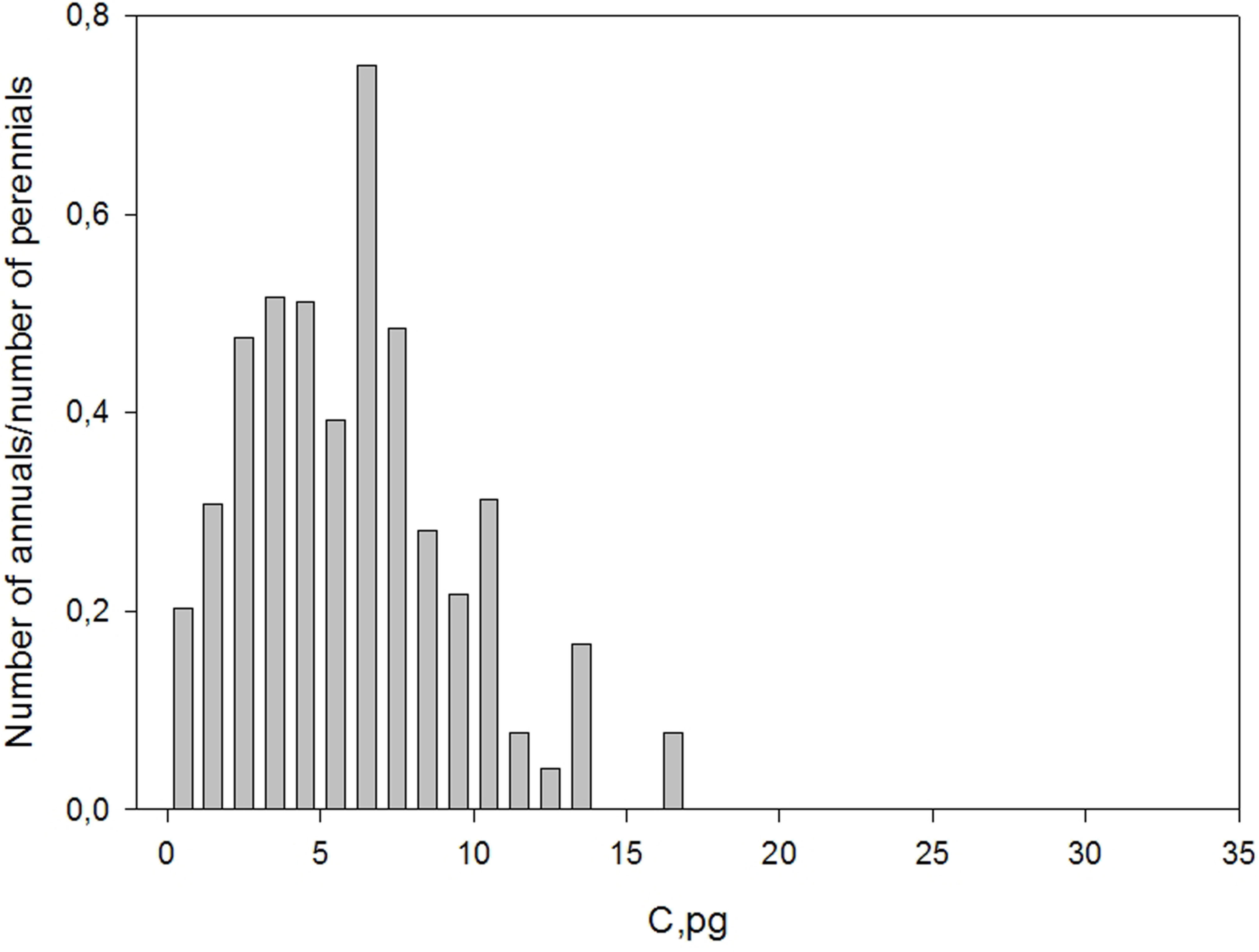
Fig. 4. Dependence of the ratio of annuals to perennials number in eudicots on nuclear DNA content.


annual plants
perennial plants
Number of plant species
C, pg
0
20
40
60
80
100
120
140
160
180
10
20
30
40



700
600
500
400
300
200
100
0
Number of plant species
0
5
10
15
20
25
30
35
C,pg
annual plants
perennial plants


Number of annuals/number of perennials
0,0
0,1
0,2
0,3
0,4
0,5
0,6
0
10
20
30
40
C, pg


Number of annuals/number of perennials
0,0
0,2
0,4
0,6
0,8
0
5
10
15
20
25
30
35
C,pg