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SAUTERIA 1 1986 211 - 222

ON KARYOTYPE EVOLUTION IN *CYCLAMEN* L. SUBGEN. *PSILANTHUM* SCHWZ. (PRIMULACEAE)

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K e y w o r d s : *Cyclamen*, Primulaceae, karyotypes, Robertonian translocation.

The present contribution deals with karyotypic differentiation of the six morphologically or chromosomally distinguishable taxonomic units in *Cyclamen* subgen. *Psilanthum*, namely *C. balearicum* (2n=20, 2n=20+B), two sports of *C. repandum* (2n=20), *C. rhodium* (2n=20), and two chromosomal races of *C. creticum* (2n=20, 2n=22). In contradistinction to a hypothesis forwarded by LEPPER (1964, 1975), karyotypes with 2n=22 in *C. creticum* and 2n=20 in the other species show a Robertsonian relationship. I. e., two telocentric chromosome pairs in *C. creticum* (2n=22) are replaced by one metacentric pair in the other species. In *C. creticum* with 2n=20, the analyzed karyotype is neither directly comparable with the other 2n=20 karyotypes, nor does it show a simple relationship to the 2n=22 karyotype in *C. creticum*. On the other hand, the arm ratios of several chromosomes, especially NOR-chromosomes, discriminate *C. creticum* from all other taxa in *Cyclamen* subgen. *Psilanthum*. *C. creticum* (2n=20) is not identical with *C. rhodium* as suggested by LEPPER (1975).

Überblick

Die vorliegende Untersuchung beschäftigt sich mit der Karyotypstruktur bei *Cyclamen* subgen. *Psilanthum*. Von 28 Herkünften werden Chromosomenzahlen mitgeteilt. Von je einem Exemplar der 6 morphologisch oder karyologisch unterscheidbaren Arten bzw. subspezifischen Sippen wurde eine Karyogramm erstellt, nämlich von *C. balearicum* (2n=20, 2n=20+B), zwei Formen von *C. repandum* ("Normalform" und "Mistras-Form", 2n=20), *C. rhodium* (2n=20, und von zwei chromosomalen Rassen von *C. creticum*, eine mit 2n=20, die andere mit 2n=22.

Nach Ansicht der Monographen der Gattung *Cyclamen*, SCHWARZ (1964) und LEPPER (1964, 1975) ist der Karyotyp mit 2n=20 strukturell bereits tetraploid gemäß der Formel 2n=4x=4(ABCDE), während bei *C. creticum* die Zahl 2n=22 durch Duplikation des größten, metazentrischen Chromosoms, d.h. des A-Chromosoms, enstanden sein soll, was sich mit der Formel 2n=4x=4(ABCDE)+2A ausdrücken läßt.

Da jedoch von diesen Arten somatische Karyotypen nicht publiziert worden waren, schien eine Chromosomenanalyse der Mühe wert zu sein. Die Schlußfolgerungen des Verfassers lassen sich folgendermaßen zusammenfassen:

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(i) Es gibt keine schlüssigen Hinweise für eine tetraploide Struktur des *Psilanthum* - Grundkaryotyps, wie er sich in praktisch identischer Form bei *C. balearicum, C. repandum* und *C. rhodium* findet.

(ii) Das bei *C. creticum* mit 2n=20 ermittelte Karyogramm ist nicht identisch mit dem *Psilanthum* - Grundkaryotyp.

(iii) Bei beiden chromosomalen Rassen von *C. creticum* sind mehrere heterobrachiale Chromosomenpaare asymmetrischer als im *Psilanthum*-Grundkaryotyp. Insbesondere ist die Morphologie des NOR-Chromosoms für *C. creticum* s.l. von diagnostischem Wert. Dies steht im Gegensatz zur Ansicht von LEPPER (1975), der das *C. creticum* mit 2n=20 wegen gleicher Karyotypstruktur und großer morphologischer Ähnlichkeit zu *C. rhodium* stellen möchte.

(iv) Im Karyotyp von *C. creticum* mit 2n=22 liegen zwei acro- bis telozentrische Chromosomenpaare vor, die weder bei *C. creticum* mit 2n=20 noch im *Psilanthum*-Grundkaryotyp vorhanden sind. Dafür fehlt eines der beiden metazentrischen Chromosomen, die für den *Psilanthum*-Grundkaryotyp charakteristisch sind. Offensichtlich besteht zwischen den beiden Chromosomenzahlen ein Robertsonisches Verhältnis; d.h., eine zentromerische Fusion oder Fission ist für die unterschiedliche Chromosomenzahl verantwortlich, und nicht eine Chromosomenverdopplung.

Dies dürfte ziemlich sicher für die Beziehung von *C.creticum* mit 2n=22 zum *Psilanthum*-Grundkaryotyp gelten. Wie das Verhältnis dieser beiden Karyotypen zum *C. creticum*-Karyotyp mit 2n=20 ist, bedarf noch weiterer Untersuchung. Es ist noch offen, ob dieser Karyotyp auf der Basis des Grundkaryotyps nur etwas umgebaut wurde, oder ob beide Karyotypen mit 2n=20 parallel entwickelt wurden.

(v) *C. creticum* mit 2n=20 wurde bisher nur im Westen Kretas in der Region um das Lefka-Gebirge gefunden. Dort gibt es jedoch auch Herkünfte mit 2n=22. Eine deutliche geografische Trennung der beiden Rassen ist somit nicht sichtbar. Eine morphologische Trennung scheint derzeit ebenfalls nicht durchführbar.

Introduction

The present analysis of karyotypes in *Cyclamen* subgen. *Psilanthum* is intended as a contribution to an improved understanding of karyotype evolution and phylogenetic relationships in this genus. This endeavour is not rendered superfluous by the detailed hypotheses on chromosome evolution, which have been forwarded by the monographers of the genus, SCHWARZ (1964), and LEPPER (1964, 1975), since karyotypes have not been available in the literature, except an interpretative trawing of a *C. repandum* karyotype by LEGRO (1959).

Cyclamen subgen. *Psilanthum* is an assemblage of phenotypically similar spring-flowering taxonomic species and races, for which only the chromosome numbers 2n=20 and 2n=22 have been reliably reported (see LEPPER 1964, 1975). The only more widely distributed species is *C. repandum* (syn. *C. vernale*), which occurs in S France, Corse, Italy, and parts of the Balkanian Peninsula. *C. rhodium*, an endemic of Rhodes, was raised to formal species level only recently (SCHWARZ and LEPPER 1975), and was formerly treated as a form of *C. repandum*. Very similar to *C. rhodium* is a sport of *C. repandum* from the Taigetos mountains of the Peloponnesos, which we call here "Mistras-form", with reference to the locality Mistras, where our first specimens of this race have been collected. These particular plants have been noticed for some

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time and have been dubbed "Peloponnesos-Form" by SAUNDERS (1975). However, we found that plants from the Peloponnesian Parnon mountains were much alike *C. repandum* from Yugoslavia, Italy, or Corse, so that the term would be misleading.

In addition to *C. repandum* and *C. rhodium* there are only two further species, *C. balearicum* and *C. creticum*, both white-flowered endemics of the Baleares and Crete, respectively.

The chromosome number in *C. repandum*, *C. rhodium* and *C. balearicum* is 2n=20. In *C. creticum* up to recently only 2n=22 has been known. A new situation emerged when LEPPER (1975) reported 2n=20 in plants from three localities on Crete. This author stated a strong morphological similarity and a perfect karyological congruence of these plants with *C. rhodium*, and finally decided to adjoin these plants from Crete with *C. rhodium*. Therefore, according to LEPPER (1975) there are two species of *Cyclamen* subgen. *Psilanthum* found on Crete: *C. creticum* s.str. with 2n=22, and *C. rhodium* with 2n=20.

I will show in the following that the 2n=20 karyotype from Crete is not the same as that of *C. rhodium* from Rhodes, and that there is no reason to adjoin these two biologically separated units. A distribution map of *C. creticum* (2n=20, 2n=22) is given. Further points of revision are LEPPER's hypothesis of a basically tetraploid structure of the *Psilanthum* karyotype, and his model for the origin of 2n=22 from 2n=20 by duplication of a metacentric chromosome. I will show that there is little conclusive evidence for a tetraploid karyotype structure, and that the change in chromosome number is better explained by a Robertsonian event, i. e. centromeric fission or fusion.

Materials and Methods

Root tips were harvested from potted plants, pretreated in 0.1% colchicine for approximately two hours at room temperature, and fixed in methanol/glacial acetic acid (3:1) at least overnight. Meristems were stained in 2% acetocarmine, heated gently over a flame, softened in 45% acetic acid for approx. 45 minutes, and squashed under a coverslip. After freezing the slides over a cold plate and detaching the coverslip, they were passed through ethanol/glacial acetic acid (3:1) and 96% ethanol, and mounted with Euparal.

Karyograms were constructed from single plants in the following way. 9 or 10 well spread metaphase plates were drawn at a linear magnification of 2500 x on a standard Zeiss microscope equipped with a drawing apparatus. In each invidual one plate was selected, the chromosomes cut out from a xerox copy of the drawing, and ordered to pairs according to greatest similarity, with repeated resorting to the microscopie aspect. The remaining plates were ordered according to the resulting schedule. The length of the chromosome arms was measured with a cog wheel mounted on a rod, and within each plate the values were normalized by taking the whole somatic karyotype length as 200%. Centromere positions are calculated as L x 100 : T (L = length of the long arm, T = length of the whole chromosome). Means ($\bar{x}$) and standard deviations (s_x) were calculated therefore from 18 or 20 supposed homologues.

One should note that the values given in Table 1 refer to length and should not be translated directly to DNA quantity in the present

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situation, where many chromosome arms are small and therefore do not conform well to cylindrical shape. It is also obvious that in several chromosomes of the various karyotypes error-free chromosome recognition is not possible. This is also true of the individual arms of one strictly metacentric chromosome occurring in most karyotypes. Karyograms have been drawn from the values in their original form. Table 1 includes only values from individually identifiable chromosome types.

Giemsa C-banding was attempted sporadically but was found to be not very informative due to the small amount of constitutive heterochromatin and the lack of intercalary bands.

List of Provenances and Chromosome Numbers

The following is a list of provenances where chromosome numbers have been established during the present investigation. Herbarium specimens are deposited in the private herbaria of F. SPETA (Sp) and M. A. FISCHER, or in the herbarium of the Institute of Botany, University of Vienna (WU), as indicated in the following.

Cyclamen balearicum WILLK. 2n=20, 2n=20+B.
1) Mallorca, NW side. A. SCHATTANEK 1970 (Sp). 2n=20, 2n=20+B.
2) Mallorca, between Lluch and the cross-road to Cala de Calobra, along the road C 710 near Casa Nova; long. 2° 50', lat. 39° 49'30'', 600 m. M. KIEHN 2.4.1983. 2n=20.

Cyclamen repandum SIBTH. et SMITH, "standard form" (petals carmine red, see Saunders 1975). 2n=20.
3) Italy, Gargano peninsula, Rodi di Gargano, W. VÖTH 1969 (Sp).
4) Italy, Prov. Campania, Cape Palinuro, F. SPETA 1979 (Sp).
5) Greece, Peloponnesos, Parnon Oros, Mt. Megaturla, S. Platanakion, 1800 m, F. SPETA 1978 (Sp).

Cyclamen repandum SIBTH. et SMITH, "Mistras form" (petals white and mouth dark red, leaves dark green and speckled and dashed with cream, see SAUNDERS 1975). 2n=20.
6) Greece, Peloponnesos, Taigetos mountains, near Mistras, W of the ruins, approx. 600 m. W. VÖTH 4.4.1970 (Sp).
7) Greece, Peloponnesos, Taigetos mountains, near Kalamata, M. A. FISCHER 1972 (M. A. FISCHER).

Cyclamen rhodium R. GORER. 2n=20.
8) Greece, Rhodes, near Salakos, Mt. Prophitis Ilias. Northern side, 400 m; south-western side, 500 m; near the summit, 800-900 m. W. VÖTH 21.4.1971 (Sp).

Cyclamen creticum (DÖRFL.) HILDEBR. 2n=20.
9) Crete, 3 km S. Topolia, along the rivulet Tiflos in a plane tree forest, 350 m. A. SCHATTANEK 1981 (WU).
10) Crete, W Lefka mountains, above Ag. Irini, on the road to Omalos, 900 m. A. SCHATTANEK 1981 (WU).
11) Crete, Lefka mountains, N Samaria, near Ag. Nikolaos, in steep slopes around the well, under Pinus brutii, 800-900 m. A. SCHATTANEK and Gerlinde ANDERKA, 5.4.1971 (WU).
12) Crete, on the road between Rethimno and Hania, at milestone "km 28.5", near Alikambos, not far from a monastery, in a forest,

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under *Cupressus sempervirens* var. *horizontalis*, *Platanus orientalis*, and savaged *Olea europaea*, approx. 100 m. A. SCHATTANEK, Gerlinde ANDERKA and W. VÖTH, 5.4.1971 (Sp).

Cyclamen creticum (DÖRFL.) HILDEBR. 2n=22.
13) Crete, Lefka mountains, north side, 1 km N Theriso, in the gorge Elefterias Venizelous, 700 m. A. SCHATTANEK 1981 (WU).
14) Crete, Lefka mountains, between Imbros and Petres, 1 km S Petres, 750-900 m. A. SCHATTANEK 1981 (WU).
15) Crete, near Skaloti, 4.5 km E of Frangokastello, 10 m. A. Schattanek 1981 (WU).
16) Crete, 1 km N K. Moni Preveli, 150 m. A. Schattanek 1981 (WU).
17) Crete, Mt. Kedros, near Gerakari, 700-1000 m. A. SCHATTANEK (WU).
18) Crete, Idi mountains, NW Psiloritis, near M. Arkadiou, in a forest, under *Quercus coccifera*, 600 m. A. SCHATTANEK 1981 (WU).
19) Crete, N Idi mountains, 5 km E Anogia, between Gonies and Anogia, 800 m. A. SCHATTANEK 1981 (WU).
20) Crete, on the road between Iraklio and Rethimno, between Sises and Pelagia, approx. 3 km west of the cross road to Fodhele, 50 m. A. WEBER 28.3.1983 (WU).
21) Crete, near Ag. Varvara, 1 km W of Ag. Thomas, 600 m. A. SCHATTANEK 1981 (WU).
22) Crete, Dikti mountains, Lasithion plateau, 800 m north of the height of the pass between Pinakiano and Kera, 900 m. H. SEEBAUER, march 1982 (WU).
23) Crete, Dikti mountains, Lasithion plateau, W Psihro, near the cavity, 1000 m. A. SCHATTANEK 1981 (WU).
24) Crete, on the road between Anatoli and Males, 1.5 km W Anatoli, 600 m. A. SCHATTANEK 1981 (WU).
25) Crete, 15 km E Ierapetra, on the road between Ag. Fotia and Ag. Ioannis, 1.5 km N Ag. Fotia, 200 m. A. SCHATTANEK 1981 (WU).
26) Crete, (a) S Kavousi, locality Afendis Kavousi, approx. 400 m, A. SCHATTANEK 1981 (WU); (b) near Thripti, 700-800 m, white and pink flowering plants occur here in a ratio of approx. 20:1, A. SCHATTANEK, Gerlinde ANDERKA, and W. VÖTH, 13.4.1971 (Sp).
27) Crete, on the road between Makrigialos and Ag. Stefanos, 3 km N Makrigialos, 100 m. A. SCHATTANEK 1981 (WU).
28) Crete, on the road between Pilalimata and Lithines, 2 km SW of Lithines, 300 m. A. SCHATTANEK 1981 (WU).

Results

Cyclamen balearicum, C. repandum and *C. rhodium*

In all samples the somatic chromosome number was 2n=20, with the exception of one individual of *C. balearicum*, where one telocentric B- or fragment chromosome was found. This element evidently corresponded to the short arm of a chromosome with a nucleolar organizing region, because a secondary constriction was always present (Fig. 1 a, b).

In all provenances of these taxa the karyotypes were very similar (Figs. 1 a-d, 2 a, b). Karyograms are presented in Figs. 4 and 5. The general shape of these karyotypes is referred to in this paper as "basic *Psilanthum* karyotype", because of its wider geographic and taxonomic distribution, but without reference to a primitive character condition. There are two metacentric pairs in each karyotype, which can be distinguished in most cases, because one pair

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is strictly metacentric, the other slightly asymmetric. The third chromosome pair is distinctly heterobrachial and always easily identified by its relatively long short arm. Chromosome pairs no. 4, 5 and 6 form a group of similar chromosomes, as do the pairs 7, 8 and 9. In the latter group pair no. 8 is consistently nucleolus-organizing. Pair no. 10 may be called a true telocentric although a very small short arm or centromeric filament is often seen.

Cyclamen creticum (2n=20)

The chromosome number 2n=20 was stated only in four localities in the western part of Crete (localities 9 - 12 in Materials and Methods and in Fig.6). As to now, a karyogram has been established only in a plant from the Lefka mountains, gorge F. Samarias, locality 11 (Fig. 3b and Fig. 5).

Despite an overall resemblance of this karyotype to the "basic *Psilanthum* karyotype" as found in the preceding taxa, some differences are found. Chromosome pair 1 is markedly more heterobrachial, pair 2 is metacentric and only slightly heterobrachial, but smaller than its presumed homoeologues no. 1 or 2 in the "basic karyotype". Pair 3 and the group 4 - 6 are similar to their counterparts. Among the remaining chromosome pairs, no. 7 is conspicuous for its relatively large long arm. The short arm of the NOR-chromosome is markedly smaller than in the "basic *Psilanthum* karyotype". Furthermore, the short arms in pairs no. 4, 5, 6 and 9 too are noticeably smaller than in the reference chromosomes of the "basic karyotype". Pair no. 10 is an acrocentric and not a telocentric as in the foregoing taxa.

Cyclamen creticum (2n=22)

This chromosome number was stated in most of the localities, and also in the plants from the locality Afendis Kavousi, where LEPPER (1975) reports 2n=20.

Quantification was undertaken in one karyotype from a pink flowering plant collected on the Afendis Kavousi, near Thripti (locality no. 26, see Materials and Methods, and Fig. 6; a representative metaphase plate is presented in Fig. 3 a). It can be seen from Fig. 7 that a comparison of this karyotype is easier with *C. balearicum*, *C. repandum* and *C. rhodium* than with *C. creticum* (2n=20).

There are two pairs of strictly telocentric chromosomes, numbered 1 and 10 in Fig. 5 and Fig. 7, and there is an acrocentric chromosome, the smallest in the complement, which is placed before no. 1 in the karyogram. The choice of these positions rests on similarity in relative chromosome length (Tab. 1) and is therefore largely hypothetical. As will be discussed later, probably two of these three acro/telocentric elements correspond to one metacentric chromosome of the "basic karyotype", but it is unclear which ones. Pair no. 2 is a true metacentric, and no. 3 is a submetacentric, perhaps somewhat more asymmetric than in *C. repandum* and *C. rhodium*. The chromosomes 4 - 9 too follow the pattern found in these species, but are specifically different in their markedly smaller short arms. In this respect *C. creticum* with 2n=22 conforms much to *C. creticum* with 2n=20.

A homozygously modified karyotype was observed in one plant with white flowers from the Afendis Kavousi (locality 26). There was no metacentric chromosome pair, and only one strictly telocentric. The simplest interpretation would be a translocation of a third part of a chromosome arm from the metacentric to the centromere of one of

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the true telocentrics. The occurrence and distribution of such modified karyotypes is subject of further investigations.

Discussion

A documented karyotype comparison in *Cyclamen* subgen. *Psilanthum* has been lacking until now. While the chromosome numbers published by LEPPER (1964, 1975, see here also a discussion of the older literature) are confirmed, with the only exception of *C. creticum* from the locality Afendis Kavousi a Crete (locality 26), the present interpretation of karyotype structure differs in essential parts from that given by LEPPER (1964, 1975).

(1) LEPPER (1964) suggested, as already LEGRO (1959), that 2n=20 is already at the tetraploid level, despite of the fact that a basic number of x=5 lacks in Primulaceae altogether, and despite of a completely normal meiosis. An inspection of the somatic karyotypes in *C. repandum*, *C. rhodium* and *C. balearicum* demonstrates that this assumption is unsupported by facts (Figs. 4 and 5). In particular, it seems that the smallest telocentric chromosome pair (no. 10) has not been identified as a telocentric.

(2) According to LEPPER (1964), the chromosome number 2n=22 in *C. creticum* was accomplished by duplication of one metacentric chromosome of the original karyotype with two metacentrics, so that three metacentrics are expected to be found in *C. creticum*. However, what is found is one metacentric chromosome pair less. Instead of this , we find two acro/telocentric chromosomes, which lack in the karyotypes of *C. repandum*, *C. rhodium* and *C. balearicum*. Although it is presently uncertain which of the three acro/telocentric elements truly correspond to the metacentric element which is replaced in *C. creticum*, it is evident that it was rather a fusion/fission than a duplication event, which led to the change of chromosome number from 2n=20 to 2n=22 or vice versa.

(3) Another point concerns the taxonomic significance of the occurrence of 2n= 20 and 2n=22 in *Cyclamen* provenances from Crete. LEPPER (1975) made the following statements:

(a) *C. rhodium* has a chromosome number of 2n=20 and shows, like *C. creticum* (2n=22), weakly asymmetric A-chromosomes, in contrast to *C. repandum*, where these are metacentric.

(b) *Cyclamen* specimens from 3 localities on Crete, namely the lowlands between Rethymnon and Chania, from the gorge F. Samarias, and from the locality Afendis Kavousi, show a chromosome number of 2n=20 and the same modified asymmetric A-chromosomes like *C. rhodium*.

(c) Therefore, the *Cyclamen* with 2n=20 from Crete has to be identified as *C. rhodium*, despite of its great similarity with *C. creticum* (2n=22).

Since incidentally material of the same collection of plants (by A. SCHATTANEK, G. ANDERKA and W. VÖTH) was available for the present study, it was possible to revise these proposals. The karyotype of *C. rhodium* is practically congruent with the basic *Psilanthum* karyotype as found also in *C. repandum* and *C. balearicum*, and therefore has no modified "A chromosomes", at least in our specimens. Second, the chromosome number of Cretan Cyclamen from the Afendis Kavousi is 2n=22 and not 2n=20.

Our plants have been collected at two different occasions and are, like LEPPER's plants, partly flowering pink, so that a confusion of provenances is not likely. Third, the karyotype shape in Cretan

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Cyclamen with 2n=20 is not the same as in *C. rhodium*. In particular, the NOR-chromosome has a diagnostically small short arm in both Cretan Cyclamen races with 2n=20 and 2n=22. Therefore, there is no karyological reason to lump *C. rhodium* and *C. creticum* (2n=20) together. It is left to future systematic treatments whether the two chromosomal races *C. creticum* should be separated taxonomically.

It remains an open question what the cytogenetic relationship of the 2n=20 karyotype in *C. creticum* is to the "basic *Psilanthum* karyotype" on the one hand, and to the 2n=22 *C. creticum* karyotype on the other hand. It is possible that 2n=20 has been achieved phylogenetically only once. However, since the present karyogram in *C. creticum* (2n=20) is not the same as the basic *Psilanthum* - karyogram, it is also possible that this chromosome number was achieved twice.

Acknowledgements

I wish to express my special thanks to Mr. A. SCHATTANEK und his wife, Mrs. Gerlinde SCHATTANEK-ANDERKA, and Mr. W. VÖTH (Vienna), for their meritorious efforts in collecting living *Cyclamen* material. Sincere thanks go also to Univ.-Doz. Dr. M. A. FISCHER, Prof. Dr. A. WEBER, cand. phil. M. KIEHN, Dr. E. VITEK (Institute of Botany, Vienna), Mr. H. SEEBAUER (Füssen), and Univ.-Doz. Dr. F. SPETA (O.Ö. Landesmuseum, Linz). I am grateful to cand. phil. Sabine STREHL for doing part of the chromosome measurements and calculations. The study has been stimulated by Prof. Dr. F. EHRENDORFER (Institute of Botany, University of Vienna). Associated taxonomic work by him and Univ.-Doz. Dr. F. SPETA will be communicated on a different occasion.

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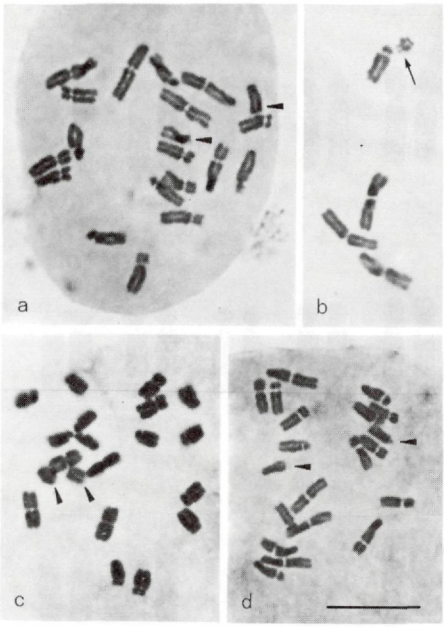


Fig. 1.
(a) *Cyclamen balearicum*, 2n=20, provenance no.1,
(b) *C. balearicum*, provenance no.1, partial metaphase of a plant with one B- or fragment chromosome (filamentous centromere arrowed),
(c) *C. repandum*, "standardform", 2n=20, provenance no. 3,
(d) *C. repandum*, "Mistras form", 2n=20, provenance no.7. Arrowheads mark telocentric chromosomes no. 10. - Bar: 10 µm.

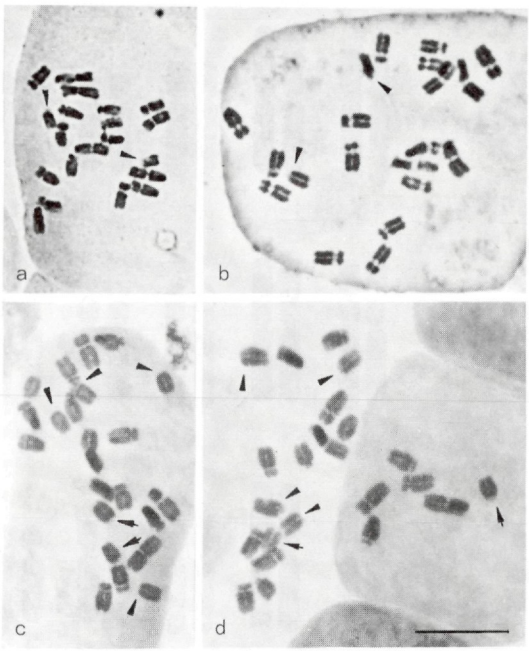


Fig. 2.
(a) *Cyclamen repandum*, "Mistras form", 2n=20, provenance no.6,
(b) *C. rhodium*, 2n=20, provenance no. 8, top region of Mt. Prophitis Ilias,
(c) *C. creticum*, 2n=22, provenance no. 26 a,
(d) *C. creticum*, 2n=22, provenance 15. Arrowheads mark telocentric chromosomes, arrows mark acrocentrics. - Bar: 10 µm.



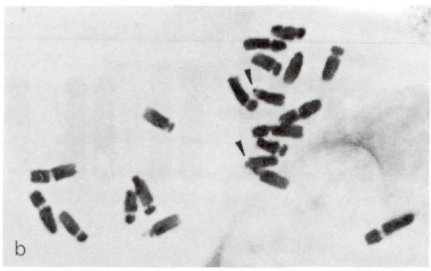


Fig. 3.
(a) *Cyclamen creticum*, 2n=22, provenance no. 26 a,
(b) *C. creticum*, 2n=20, provenance 11. Arrowheads mark telocentric chromosomes, arrows mark acrocentrics. - Bar: 10 µm.

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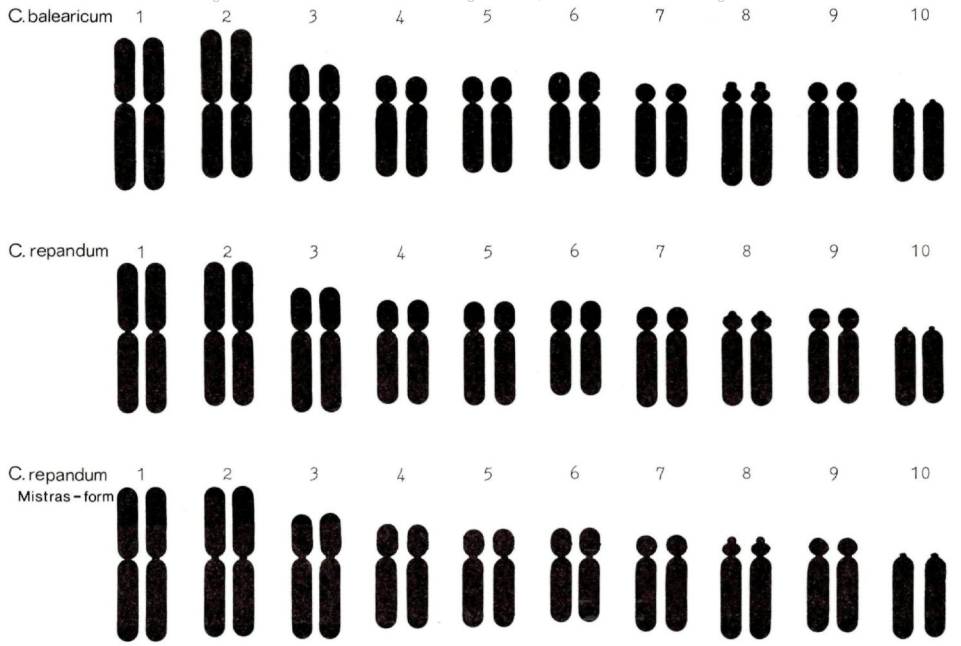


Fig. 4. Karyograms of *Cyclamen balearicum*, provenance no. 1; *C. repandum*, "standard form", provenance no. 5; *C. repandum*, "Mistras form", provenance no. 7.

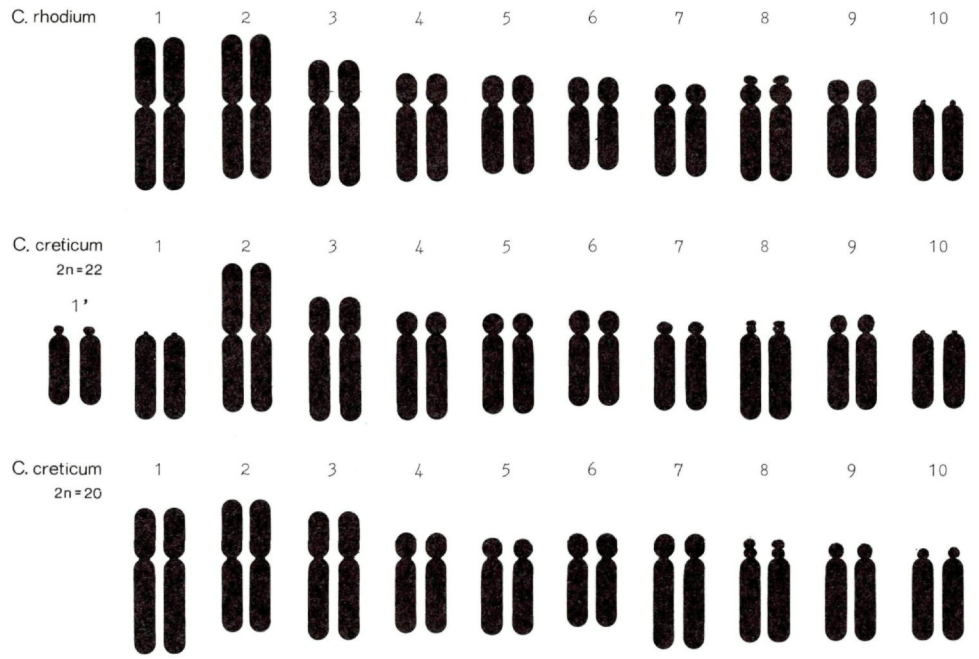


Fig. 5. Karyograms of *Cyclamen rhodium*, provenance no. 8; *C. creticum*, 2n=22, provenance no. 26 b (pink flowering individual); *C. creticum*, 2n=20, provenance no. 11.

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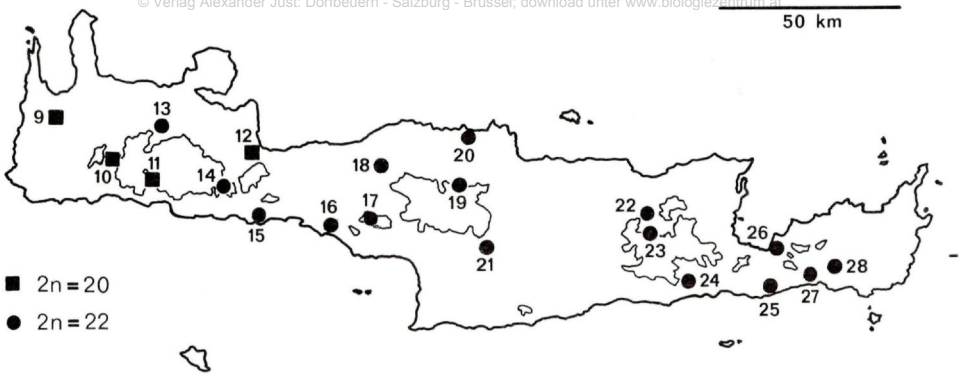


Fig. 6. Distribution map of *Cyclamen creticum* on Crete. Numbers refer to numbering of provenances in "Materials and Methods".

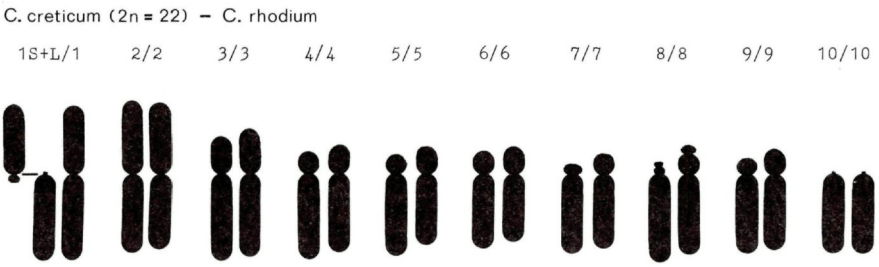


Fig. 7. Comparison of karyotype structure in *Cyclamen creticum* (2n=22) and *C. rhodium*. The right chromosome in each pair is from *C. rhodium*. For discussion see text.

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Species (no. of provenance)	N	Karyotype length (µm)		Chromosome measurements							
				1'	1	2	3	7	8	9	10
C. balearicum (1)	9	124.1±21.1	S		6.1±0.3	~6.8	3.5±0.4		1.8±0.4		0.1±0.2
			L		8.0±0.5	~6.9	7.3±0.5		7.8±0.6		7.4±0.4
			T		14.1±0.6	13.6±0.9	10.8±0.6		9.5±0.7		7.5±0.5
			C_i		56.8±1.7	~50.0	67.6±3.2		81.4±3.8		98.7±3.1
C. repandum (5) standard form	10	133.7±26.3	S		6.4±0.5	~6.6	4.1±0.4		1.7±0.5		0.3±0.3
			L		7.5±0.7	~6.6	7.4±0.5		6.8±0.6		6.8±0.5
			T		13.9±1.1	13.2±0.9	11.5±0.6		8.6±0.7		7.1±0.5
			C_i		54.2±2.1	~50.0	64.1±2.7		79.5±4.1		96.5±4.2
C. repandum (7) "Mistras form"	9	127.4± 8.8	S		6.6±0.3	~6.9	4.1±0.6		1.6±0.3		0.1±0.3
			L		7.6±0.4	~6.9	7.4±0.5		7.5±0.5		7.4±0.7
			T		14.1±0.5	13.8±0.8	11.5±0.7		9.1±0.6		7.5±0.8
			C_i		53.5±1.7	~50.0	64.8±4.6		82.3±3.4		98.6±4.1
C. rhodium (8)	10	113.1± 8.7	S		6.3±0.5	~6.6	4.0±0.4		2.7±0.6		0.4±0.4
			L		7.4±0.7	~6.6	7.4±0.4		7.0±0.4		7.0±0.4
			T		13.7±1.0	13.2±0.7	11.4±0.7		9.7±0.8		7.4±0.5
			C_i		54.0±2.6	~50.0	64.7±2.1		72.2±4.4		94.8±5.5
C. creticum (26b) 2n=22	10	124.3±12.0	S	0.8±0.2	0.0	~6.8	3.4±0.5	1.1±0.3	1.2±0.3		0.0
			L	6.3±0.4	7.6±0.4	~6.8	8.0±0.6	7.0±0.6	7.9±0.7		6.9±0.5
			T	7.1±0.4	7.6±0.4	13.6±0.7	11.4±0.7	8.0±0.6	9.1±0.8		6.9±0.5
			C_i	88.6±2.8	100.0	~50.0	69.9±0.3	86.3±3.1	87.2±2.7		100.0
C. creticum (11) 2n=20	10	135.8±13.4	S		4.6±0.2	5.3±0.4	4.1±0.3	2.2±0.4	1.7±0.4	1.2±0.3	0.9±0.4
			L		8.7±0.5	6.6±0.4	7.5±0.3	8.3±0.5	7.7±0.7	7.6±0.4	7.5±0.5
			T		13.3±0.5	11.9±0.7	11.6±0.6	10.5±0.6	9.3±0.9	8.8±0.5	8.4±0.5
			C_i		65.3±1.5	55.8±1.8	64.7±1.6	79.3±3.1	82.2±3.8	86.3±3.3	89.3±4.6

Table 1. Chromosome measurements in *Cyclamen* karyotypes. Presented are the number of metaphase plates evaluated (N), the length of the diploid karyotype, relative length (the diploid karyotype taken as 200%) of the short arm (S), the long arm (L), and the whole chromosome (T), and centromere position (C_i) of the individually recognizable chromosome types. Measurement data are given as arithmetical means and standard deviation ($\bar{x} \pm s_x$). For further details see Materials and Methods.

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Zeitschrift/Journal: Sauteria-Schriftenreihe f. systematische Botanik, Floristik u. Geobotanik

Jahr/Year: 1986

Band/Volume: 1

Autor(en)/Author(s): Greilhuber Johann

Artikel/Article: On karyotype evolution in Cyclamen 1. Subgen. Psilanthum schwz. (Primulaceae) 211-222