We prefer to regard the diploid and tetraploid perennial taxa of boreal-arctic-alpine *Anthoxanthum* as distinct species, since we do not find the arguments by Hylander, Hultén or Böcher and Jones, for reducing the diploid to synonymy or subspecific rank, respectively, convincing. They have different chromosome numbers, and although no single character serves to separate the diploid completely from *A. odoratum*, the combination of (small size, few and short stolons, narrow panicle with few or no flowers, and compact, bulbil-like buds clustered at the ends of the branches) is not matched in any form of *A. odoratum* (cf. Weiss 1963, Fl. Eur. Nat. Syst. 2, p. 198-199).

Jervis, R.A. & Buell, M.F. 1964:

Acorus calamus in New Jersey. – Bull. Torrey Bot. Cl. 91: 334:

– Introduced in N. Am. ? – .
Seed-producing in north-central U.S. & N. Jersey.
Non-seed producing clones occur in the eastern seaboard of the U.S.

"Since the biochemical approach has been very useful in elucidating and substantiating relationships among plant species (Alston & Turner 1963a; Alston, Mabry & Turner 1963 [Perspectives in chemotaxonomy]; Turner 1967), the study of natural products was chosen as an adjunct to my morphological and ecological investigations. Flavonoids were studied because they have proven to be useful in the analysis of closely related taxa (Alston & Turner 1963b)."

Alston, R.E., Mabry, T.J. & Turner, B.L. 1963: Perspectives in chemotaxonomy. — Science 152: 545–552.

A. & T. 1963a: Biochem. Syst.

— & T. 1963b: Natural hybridization among four species of _Baptisia_ (Leguminosae). — Am. J. Bot. 50: 159–173.

Comparable clarity in the classification of species extends only to the broadest principle of its definition: a species ~~is the~~ by the Linnaean and evolutionary account is a reproductively isolated gene pool. This is the property which makes studies of chromosome numbers so important in the delimitation of species, because differences in the number of chromosomes are the strongest indicators known for the occurrence of a very effective reproductive isolation. ~~This~~ ~~Since all~~ kinds of polyploidy ~~are not as~~ equally

Polyploid chromosome variations have, therefore, been instrumental not only in the discovery of taxa previously unobserved by aid of observational methods, or in the recovery of specific status for taxa ignored by authors of manuals who appreciate many morphological differences between taxa so accepted, but also in the recognition of identity of ~~[illegible]~~ taxa described as endemic varieties from different regions. This is still not universally accepted, because ~~morph~~ ~~morphologically~~ ~~taxonomically~~ ~~[illegible]~~ classically trained taxonomists do not always realize that small morphological discontinuities ~~[illegible]~~

Separating different levels of
ploidy are no less significant
for in evolutionary classification
than are great discontinuities
between old gradual species.
~~And only evolutionary classification
is scientific and an acceptable
background for studies of historical
biogeography and other~~
And classification which ignores
evolutionary clarity is unscientific
and indeed misleading.

[illegible]

Chemotaxonomy of a polyploid series in Acorus.

1. Introduction.

Most chemotaxonomical work emphasizes qualitative characters, (characteristics?) or the occurrence of a chemical (cf. Alston & Turner . . .) in supposedly related taxa at various levels. When such studies are made of a polyploid series within a genus (cf. Lin & ... 1949) however, quantitative differences are to be expected, and there may be of a considerable ~~taxonomic~~ significance in distinguishing the taxa of the series ~~and separating species which~~ and as an additional character in separating species which are reproductively isolated but morphologically similar.

A polyploid series which we have studied from various points of view for almost two decades, is frequently identified by taxonomists and ecologists — three continents as the very collective species Acorus calamus L. To regard it as a very collective taxon is upheld by the fact, that morphological taxonomists have divided into numerous species, which others claim inability to see, but it is also supported by the discovery that this ~~[illegible]~~ widespread taxon actually consists of a ~~polyploid series~~ number of restricted taxa that differ in chromosome number. (Wulff, L. 2L. . . .). The existence of this polyploid series is generally ignored by those discussing the taxonomy of the genus. ~~which~~ According to Engler (1905) and Airy-Shaw (1966) the genus includes only two species, whereas Hara (1968) and Larsen (1969) accept three, two very closely related and endemic in Asia, and their very collective A. calamus from Eurasia and North America.

~~Although~~ Cytotaxonomical work has demonstrated (Wulff ... Löve & Löve) that the collective taxon still named A. calamus by most taxonomists actually consists of three species, two of which are diploid (2n=24) and one tetraploid (2n=48) and all dispersing by aid of seeds, and of a couple of sterile hybrids (~~2n=~~ 44) or triploids (2n=36) that have attained considerable areas of distribution because of dispersal of rootstocks and other somatic diaspores which are spread by water, frequently by aid of human activities. ~~The diploids~~ One of the diploids ~~(2n=24)~~ is the eastern Asiatic A. cochinchinensis (Lour.) Schott, ~~[illegible]~~ the other is the North American A. americanus Rafin., whereas the tetraploid is the eastern Asiatic and Siberian A. triquetor Turcz. The hybrid derivatives with 2n=42-44 chromosomes are eastern Asiatic and may be identical with A. spurius Schott and A. asiaticus Nakai; they may have been produced ~~by hybridization of the~~ through fertilization of the tetraploid, or of an unreduced gamete of the diploid, by an occasionally fertile pollen grain from the otherwise completely sterile triploid (of this taxon — we have observed only two individuals so they are available for this analysis). But the triploid, which is either an autotriploid of A. cochinchinensis or ~~[illegible]~~ a primary hybrid between the Asiatic diploid and tetraploid, are originally from ~~Vietnam~~ Indochina, but it has (by man) gained considerable distribution in India together with cultivated races of its diploid parent,

~~where~~ because of its supposed medicinal attributes (Wein...); ~~it was evidently cultivated in Turkey in the 16th century from where it was~~

No species of *Acorus* is indigenous in Europe, but the diploid *A. cochinchinensis* was apparently introduced into parts of southern Russia, eastern Poland and the southern parts of the Baltic States through the Tatar invasion in the 14th? 13th? century (Wein... cf. Kozlowski 1958:), though it has not gained a wide distribution. The triploid, which is the ~~plant given~~ the ~~name~~ *A. calamus* by Linnaeus (1753), however, was ~~apparently~~ introduced from Constantinople in 1562 to the Botanical Garden in Prague, from where it since has spread to almost every river system in central and western Europe and even to some places near the eastern seaboard of North America (Buell...). It never sets seeds. The approximative areas of distribution of these taxa are shown in Fig. 1.

The genus *Acorus* also includes ~~small dip~~ a much smaller eastern Asiatic diploid species, which was named *A. gramineus* already by Solander (...), but later renamed *A. tatarinowii* by Schott (1895); it is a variable species, ~~which~~ a variety of which has recently been named *A. ...* by Hu (1968); the plant named *A. flexilis* by ~~Rafin~~ Rafinesque (18...) from southeastern North America may also belong ~~here~~ to this diploid complex and be identical with / similar to the plant found

(1.5 ± 0.02 cm) (1.9 ± 0.04 cm)

in the early Tertiary layers studied by Berry (1937) not far from the southern shores of the previous Tethys Sea. As shown by Wulff (1954), and confirmed by the present writer, the two diploid species, *A. cochinchinensis* and *A. americanus*, are separable by aid of the larger and narrower leaves of the former, which also has a considerably thinner spathe. The tetraploid *A. triqueter* has leaves that are →

2. Aetherials. The rootstocks of the collective *Acorus calamus* have been used for medical purposes from times immemorial, although the effects of its aromatic oils still are doubtful. When these oils were held in highest esteem, the dried rootstocks were transported over land from the Orient to western Europe. At that time, the wealthy knew that chewing the rootstock was a certain remedy for toothache, and the juice, when swallowed, was useful as a cure for disorders of the stomach, such as flatulency and wind colics in infants and sailors, to quote Rafinesque (1828). Others claimed it as effective against the dreadful cholera, and the extract also relieved dizziness of whatever kind and was regarded as the best and most unfailing remedy against indigestion, an eternal trouble of human beings. Some Europeans preferred to use it constantly as a kind of tea, whereas others candied the rootstocks and chewed them as gum. The aqueous extract of the rootstock is pleasantly warm and bitter, whereas its alcoholic extract has a nauseous flavor. Nevertheless, some of the finest of liqueurs, such as Benedictine and Chartreuse, derive part of the flavor from the rootstocks of triploid *Acorus*.

longer than those of both the diploids (140 ± 2.5 cm as compared to 115 ± 2.3 cm) but only slightly longer than those of the triploid (136 ± 2.7 cm). The leaves of the tetraploids are, however, almost twice as (broad) wide as those of the diploid (2.6 ± 0.04 cm), whereas the triploid has ~~almost equally broad leaves~~ slightly broader leaves (2.7 ± 0.04 cm). In addition, the leaves of the diploids ~~are considerably~~ have ~~of~~ considerably longer attenuated tips than has the tetraploid, whereas the triploid is easily distinguished from either the diploids or the tetraploid by the almost 1/3 wider angle of the ~~its spathe to its~~ spadix to its spathe, in addition to the fact ~~that seeds are~~ that the spadix of the triploid never develop ripe seeds. ~~The diploids, however, can most easily be distinguished from each other by~~

The diploid A. americanus differs from A. cochinchinensis by having broader leaves and thicker spadix, and when cultivated under the same conditions, it ~~the~~ has a significantly longer ~~growth and~~ growth and flowering period. As a more qualitative difference is the distinctly red-colored leaf base of A. americanus, whereas the leaf bases of A. cochinchinensis always are green, or only slightly colored, when cultivated under the same conditions.

It was pointed out by Wulff (1948, 1950 ...) and Wulff & Fritz (1958) that the amount of aromatic oils in the different taxa of ~~Acorus~~ the polyploid series of *Acorus* varies in correlation with ~~polyploidy~~ the level of polyploidy. This was confirmed by Löve & Löve (1957). Later investigations, based on sizeable rootstock material of the diploids, triploid and tetraploid from between ten and fifty localities from various places on three continents have shown the following:

1) There is a considerable variation in the content of the aromatic oils in the rootstock of the same ~~individual~~ specimen at different times of the day (cf. Kozlowski 1958: ...) and also on days that differ in temperature and cloudcover. These variations can be of the magnitude of more than the double in the same plant.

2) There is also a clear correlation between the time of the summer when the samples have been taken, lowest in the spring and highest in August in temperate North America. A rather steady content was observed in the month of July. ~~at which detailed [illegible]~~ However, samples taken at the same time from any of the members of the polyploid series always gave a statistically significant difference between the diploids, triploid and tetraploid taxa.

3) The content of the aromatic oils is strongly affected by the water content of the soil, and it reaches its highest point in any individual at any time of the summer in soils that ~~are either be soggy with water~~. have been soggy with water for several days.

4) At any particular time, there is considerable variation in oil content between and within populations of diploid and tetraploid _Acorus calamus_ s. lat., ~~as could be expected for cross-fertilizing species with normal seed-production~~, whereas when populations of the triploid taxon from widely separate localities are cultivated under the same conditions and sampled at the same time, the variation in oil content is significantly narrower. This is in conformity with the fact that all triploid _Acorus_ in Europe and America and probably also India are somatic derivatives of the same single plant which has never ~~set developed seed~~, produced seed, whereas the variability of the diploids and tetraploid is that of normal cross-fertilized populations.

5) When ~~taken~~ (twenty) ~~[illegible]~~ populations of each taxon were sampled in the early afternoon in mid-July ~~[illegible]~~ from a well-sapped culture after ~~an unbroken~~ ~~[illegible]~~ an unbroken week of sunshine, the following results were obtained:

Acorus americanus (2x): 2.3% ± 0.21%

Acorus cochinchinensis (2x): 2.9% ± 0.23%

Acorus calamus (3x): 3.9% ± 0.11%

Acorus triqueter (4x): 7.2% ± 0.26%

Since these differences between the three polyploid stages are statistically significant, they are an ~~evidently valuable~~ ~~distinct~~ characteristical character that ~~[illegible]~~ ~~[illegible]~~ confirms the ~~distinctness of~~ distinctness of the three main taxa. All are bitter, ~~but~~ the tetraploid more noticeably so, if a fresh root is tasted, but less so in dry material. The (slightly) less ~~[illegible]~~ significant differences between the ~~[illegible]~~ two diploid taxa are of ~~[illegible]~~ importance as an indicator of the distinctness of these species, though ~~though they may indicate that~~ ~~these [illegible] they still [illegible]~~ ~~it would be of interest to study their artificially produced hybrids closer, although transfer this may or may not indicate that these taxa [illegible] still have not differentiated~~ ~~in this connection,~~ though they may ~~perhaps~~ be of interest when more detailed studies of the reproductive processes of ~~these~~ ~~the~~ ~~artific~~ rather easily produced artificial hybrids between North American and eastern Asiatic diploids, ~~can be studied in detail~~ are needed to ascertain in what degree these taxa have become genetically diversified since they became isolated in the early Tertiary.

Conclusions and Summary.

When these chemical observations are added to previous morphological, geographical and cytotaxonomical studies of the taxa, which still is named as Acorus calamus by most taxonomists, the following conclusions seem to be warranted:

1) In addition to the remotely related A. gramineus Sol., the genus Acorus includes three fully fertile but reproductively isolated species. Two of these are diploid, one tetraploid.

2) The diploid Asiatic representative of the ~~[illegible]~~ complex is A. cochinchinensis (Lour.) Schott, which also grows as an early introduction in parts of eastern Europe. The diploid North American species is A. americanus Rafin., which is typical of waters in ~~temperate~~ N. the temperate parts of the continent, introduced in Alaska (cf. Hultén 1968) and affected by human agencies in peripheral parts of its distribution. These species are morphologically and chemically somewhat different and can ~~easily~~ be distinguished ~~by~~ ~~when cultivated~~ by a trained taxonomist even when cultivated under similar conditions.

3) The tetraploid species, A. triqueter Turcz., is an eastern Asiatic-Siberian plant which is morphologically ~~and chemically~~ easily distinguished from both the diploids, ~~and chemically very distinct~~ from which it is chemically very distinct so that they can be easily separated even by taste by a somewhat trained observer.

~~4) The triploid plant~~

4) The triploid plant, which is A. calamus L. s. str., is a ~~[illegible]~~ morphologically and chemically very uniform taxon which apparently is of an ancient oriental origin, either ~~[illegible]~~ from hybridization of A. cochinchinensis and A. triqueter or, more likely, ~~a triploid [illegible]~~ a very occasional ~~[illegible]~~ autotriploid of the former. Because of its higher content of the aetheric oils (than the diploid), as confirmed in the present study, it was early cultivated in India, from where the dried rootstocks were imported to Europe until the plant was introduced there in 1562; it has also been introduced to some few places on the eastern North American seaboard. The contents of the aetheric oil of the triploid is distinctly higher than that of the diploid, whereas it is much lower than that of the tetraploid. Since the triploid has become widespread because of human activities, it is convenient to use for it a binary nomenclature, though it ought to be kept in mind that it actually is a freak of nature or a hybrid, which otherwise would not merit to be so distinguished.

5) As a general conclusion it should be emphasized that the present ~~study~~ chemotaxonomical study gives a quantitative confirmation of previous results of ~~combined~~ morphological and cytotaxonomical investigations of this remarkable plant. Although qualitative studies of the occurrence of certain chemicals are a valuable tool for studies of relationships at the generic and family level, (cf. Alston & Turner etc.) ~~as [illegible]~~ it is apparent that quantitative studies of chemicals may also be a valuable method for investigations of differences between ~~species [illegible]~~ species of the same genus, at least when these have developed strongly through polyploidy (cf. Löve 1964).

Jervis, R. A. & Buell, M. F. 1964: Acorus calamus in New Jersey. — Bull. Torrey Bot. Cl. 91: 334.

Wulff, H. D. 1954: Zur Zytologie, geographischen Verbreitung und Morphologie des Kalmus. — Archiv der Pharmazie 287./59. Bd. pp. 529–541.

— 1946: Der Ölgehalt verschiedenchromosomiger Rassen vom Kalmus. — Zeitschr. f. Naturforschung 1. pp. 600–603.

Wulff, H. D. & Fritz, E. 1958: Untersuchungen an einem variegaten Kalmus (Acorus Calamus L.). — Flora 146, pp. 328–339.

Wulff, H. D. & Hoffmann, B. 1957: Kalziumoxalat-Gehalt und Polyploidie bei Rosa und Acorus. — Ber. Dtsch. Bot. Ges. 70, pp. 383–388.

Larsen, K. 1969: ~~Cytology of Vasc~~ Studies in the flora of Thailand 54. Cytology of Vascular plants, III. — Dansk Bot. Arkiv. 27, 1, pp. 39–59

Hu, S. Y. 1968: Studies in the flora of Thailand 41. Araceae. — D.B.A. 23, pp. 409–457.

Löve, Á. & Löve, D. 1957: Drug content and polyploidy in Acorus. — Proc. Genet. Soc. Canada 2, pp. 14–17.

Kozlowski, J. 1958: Dobowe wahania zawartości olejku w kłączach tataraku (Acorus Calamus L.). — Biul. I.R.L. 5 ~~1958~~, pp. 1–9.

— 1960: Badania nad krajowym olejkiem tatarakowym. — Biul. I.R.L. 6, pp. 155–163.

Grochmalicka, J. & Kozlowski, J. 1959: Dobowe wahania zawartości kwasu askorbinowego w kłączach tataraku. — Biul. I.R.L. 5, pp. 34–39.

Wulff, H. D. 1940: Über die Ursache der Sterilität des Kalmus (Acorus calamus L.). — Planta 31, pp. 478–491.

Löve, Á. & Löve, D. 1957: Biosystématique du genre *Acorus*. — Ann. de l'ACFAS 23, p. 100

Wein, K. 1939–1941: Die älteste Einführungs- und Ausbreitungsgeschichte von *Acorus Calamus*. I–3. — Hercynia I, II, III, pp. 367–450, 72–128, 241–291.

1) Hybrids between the American and East Asiatic diploids are fertile — only small differences. (Biochemically similar)

2) Triploid with a high degree of trivalents — not hybrid.

3) Tetraploid with a low degree of multivalents — hemialloploid

4) Hybrids between Arctic diploid and tetraploid highly fertile, but with fewer trivalents than the triploid?

(Müntzing's Dactylis?

Dryopteris assimilis S. Walker.

Voucher:

Athyrium distentifolium

Voucher:

Cryptogramma acrostichoides

Voucher:

Pinus ponderosa

Voucher:

CU Proposal No. 72.5.192
4/72

A Proposal to the

NATIONAL SCIENCE FOUNDATION

U.S.-JAPAN COOPERATIVE SCIENCE PROGRAM

for support of

Biosystematic and Evolutionary Studies on Critical Taxa of the Gentianinae

Name and Address of Institution: The Regents of the
University of Colorado
Boulder, Colorado 80302

Desired Starting Date: September 1, 1972

Amount Requested from NSF: $75,005

Time Period for Which Support is Requested: Two Years

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Áskell Löve
Co-Principal Investigator

Doris Löve
Co-Principal Investigator

Hobart Smith, Chairman
Department of Biology

I certify that the distribution of costs between the direct and indirect categories as shown in the proposal conforms to the usual accounting practices of the institution and to the distribution used by the cognizant Federal audit agency.

Lawson Crowe
Provost and Vice President
for Research

ABSTRACT

This is a proposal for intense and cooperative research into the biosystematic and evolutionary basis for a revised classification of the tribe Gentianinae of the family Gentianaceae, which the Co-Principal Investigators have been studying with the aid of classical and cytotaxonomical methods for two decades. The study will use morphological, geographical, cytotaxonomical, palynological, and mathematical methods and will employ the modern techniques of the computer and electron scanning microscope, and various chemical techniques, in order to find a satisfactory basis for a firm evolutionary classification of this important tribe. Considerable herbarium and cytological material collected in various countries during the past two decades will be used, augmented by new collections of some important taxa and by collections from the past available in the major herbaria in America. The work will be in cooperation with Dr. Hideo Toyokuni and Dr. Yanagi Toyokuni, Professors at the Asahikawa University in Hokkaido in Japan, who have applied for support from the U.S.-Japan Cooperative Program in Japan for an almost two years' stay in Boulder. It is expected that for the last stages of the completion of the study the cooperative work may have to be moved to a Japanese institution for some few months, though presently it is not possible to make plans so far into the future.

I. Background of the Project

The family Gentianaceae includes about 800 described species, which in the past have been classified into a various number of tribes and genera depending upon the point of approach of each monographer. Traditionally and conservatively it includes about sixty genera, some of which are large and heterogenous, although most are limited to smaller and more homogenous groups. Many of these genera have been cultivated as ornamentals, and some have been well known for their pharmaceutical properties since time immemorial.

The name-giving and typical genus *Gentiana* was accepted by Linnaeus (1753 and earlier) in the same meaning as given to it by Tournefort in 1700. Tournefort, in turn, had adapted it from Celsus and Scribonius Largus. The family is represented by many genera in the Balkan peninsula, but it is not certain that the plant so named from the ancient area of Illyria by Scribonius Largus in commemoration of the ancient King Gentius really was a *Gentiana* in the present sense.

Of the presently known genera of Gentianaceae, Linnaeus (1753) accepted only *Gentiana* and *Swertia*, both in a very wide sense. Necker (1790), in *Elementa Botanica*, proposed the division of the former into *Gentiana*, *Pneumonanthe*, *Anthopogon*, *Spirogyne*, and *Thyrophora*, all but *Gentiana* invalid names, according to the present Code of Botanical Nomenclature, except when they have later been validated by others. A few years later, Moench (1794) separated the genus *Gentianella* from *Gentiana* proper, whereas two years after that, Borckhausen (1796) and Schmidt (1796) independently divided the Linnaean *Gentiana* into thirteen and six smaller genera respectively, on the basis of morphological differences alone. The *Gentianella* of Moench included the species related to *G. campestris*, which Link (1829) later named as the genus *Amarella*, but Moench's genus also comprised the fringed gentians, which Froelich (1796), the first real monographer of the group, described as the group *Crossopetalum* of *Gentiana* s.str.; this group was later given sectional status by Grisebach in Hooker's *Flora Boreali-Americana* in 1837, whereas Roth (1827) regarded it as wiser to accept it as a distinct genus *Crossopetalum*. Since this is a homonym previously proposed for a genus of Celastraceae, the fringed gentians are presently included in the genus *Gentianopsis*, described by Ma (1951).

Conceptual and nomenclatural confusion dominated most of the treatments of the family during the entire nineteenth century, so when Gilg (1895) and Kusnetzov (1896-1904) monographed the genera involved, they accepted a conservative point of view and tried to accommodate the immense diversity in sections of large and collective genera, rather than to split them into perhaps disputable genera of more limited size. Kusnetzov (1896) divided *Gentiana* into the subgenera *Eugentiana* and *Gentianella*, each of which was subdivided into a number of sections. Most authors of flora manuals published during the first half of the twentieth century accepted the opinion of Kusnetzov, frequently with the addition of the section *Comastoma* proposed by Wettstein (1896) to accommodate *Gentiana tenella* and three related species.

Around and after the passing of the first quarter of the present century, and especially after the first half of the century had been reached, so much new morphological, cytological, and palynological evidence on the diversity of Gentianaceae had accumulated that the need for a drastic revision of the conservative generic limits became increasingly evident. Although other taxa were critically evaluated and cautiously divided by some authors, most of the studies that resulted in splitting were made on the extremely heterogenous *Gentiana* in the Kusnetzov sense. This started by the resurrection of *Gentianella* Moench by Schuster (1923), a procedure generally accepted after Smith (1936 and later) demonstrated the occurrence of numerous characteristics that differentiate these taxa.

Smith (in Nilsson, 1967) has revised the variation of the important subtribe Gentianinae, which in his opinion is best accommodated as the following genera: *Ixanthus* Griseb., *Jaeschkea* Kurz, *Crawfurdia* Wall. (with the two sections *Crawfurdia* and *Protocrawfurdia* H. Sm.), *Tripterospermum* Blume, *Gentiana* L. (with the sections *Coelanthe* Ren.; Kusnetzov = *Gentiana*; *Pneumonanthe* Neck., *Otophora* Kusn., *Stenogyne* Franch.; Kusn., *Frigida* Kusn. *Aptera* Kusn., *Chondrophylla* Bg., *Thylacites* Ren., and *Cyclostigma* Griseb.), *Gentianella* Moench (with the sections *Crossopetalum* Froel., *Arctophila* Griseb., *Amarella* Griseb., *Comastoma* Wettst., *Antarctophila* Griseb., and *Andicola* Griseb.), *Lomatogonium* A. Br., *Swertia* L. (with the sections *Euswertia* C.B. Clarke = *Swertia*, and *Ophelia* Benth. and Hook.), *Latouchea* Franch., *Veratrilla* Baill., *Megacodon* H.Sm., and *Halenia* Borckh. This system clearly goes as far as morphological studies alone could reach, and it ignores considerable evidence on cytology, palynology, and chemotaxonomy of the various groups that had been collected during the past generation.

After detailed cytological studies of Gentianaceae by Favarger (1949), Rork (1949), Skalińska (1951), and D. Löve (1953), it was argued by D. Löve (1953), reviewing all the then available cytological knowledge of the Gentianinae, that especially the genera Gentiana and Gentianella in the Kusnetzov and Smith sense are collective taxa which seem to be made up of several natural units that are characterized by distinct karyotypes and different basic chromosome numbers. She advised a division of these collective genera into smaller genera, or at least closer investigations that might keep that possibility in mind. Studies by later authors heeding this advice, and especially studies by Löve and Löve (1956, 1961a,b, 1972), Gillett (1957, 1963), Fabris (1958, 1960), Toyokuni (1961, 1963, 1965, 1967, 1968), Iltis (1965), Mayer (1954, 1968, 1969), Holub (1967, 1968), and Ikonnikov (1970), have resulted in the acceptance of the more strict genera Gentianopsis, Hippion, Ericala, Pneumonanthe, Dasystephana, Comastoma, Favargera, and Gentianodes, for numerous of the sections of Gentiana and Gentianella of previous authors, although this still seems to leave certain parts of these two last more collective genera in some state of evolutionary heterogeneity.

Similar problems are involved in some of the other genera of Gentianinae, but although H. and Y. Toyokuni have investigated some of these, the more or less intensive studies by A. and D. Löve during the past two decades have mainly been concerned with the cytotaxonomy and morphological distinction of the collective genera Gentiana and Gentianella in the alpine regions of the world. The cytological methods have proven of immense value in determining generic boundaries, since there is, in these taxa, a distinct connection between clusters of morphological characteristics and the basic number of chromosomes; in addition, karyotypic variations have been found to be of value for specific demarcations. Nevertheless, cytological characteristics are not a sufficient additional background for a thorough revision of such a complex into fully natural genera, as shown among others by our experience from the section Comastoma of Gentiana which Wettstein (1896) originally described on the basis of morphology alone and found to be closely related to the genus Lomatogonium. We confirmed that observation by aid of macro-characteristics, and also found the basic chromosome number to be the same in both groups and the karyotype similar or close to identical. On this basis, we united both groups in the genus Lomatogonium (Löve and Löve 1956). However, Toyokuni (1961) investigated both groups in greater detail, putting stronger emphasis on micro-characteristics. He came to the conclusion that although these groups are related, their differences are clear evidence of separate evolutionary history that warrants an acceptance of both at the generic level. That conclusion has later been confirmed with the aid of palynological evidence by Nilsson (1967), and we have added preliminary and still unpublished observations with the aid of paper chromatography, detailed studies of hairs and pollen morphology, and a computerized comparison of numerous details that all clearly substantiate the conclusion by Toyokuni.

Although both we and Toyokuni have accumulated considerable material of Gentianinae during the past two decades, both herbarium plants and cytological preparations, it has become evident to all of us that a concerted effort utilizing every available method is needed to solve the classificatory problems of the Gentianinae in a satisfactory way. The methods which we visualize as necessary for this work must include classical and modern herbarium techniques strengthened by modern computer techniques, which D. Löve has studied and worked with in great detail. Cytological techniques have proven indispensible for this kind of work, but palynological studies are clearly of no less importance, especially when augmented with the techniques of the electron scanning microscope, which also ought to be used for detailed comparisions of hairiness, of epidermal characteristics of various organs, and of the seed coat, which has long been recognized as an important characteristic of this group. In addition, preliminary investigations with the aid of various chemotaxonomical methods clearly indicate the importance of isoenzyme studies and observations of various other chemical attributes for the understanding of sectional and higher categories of this taxon, so such methods ought also to be employed.

Since the material and apparatus for such an approach are already available at Boulder, along with the University's excellent computer center, an electron scanning microscope in the Department of Molecular, Cellular and Developmental Biology, and good chemical and biochemical facilities at the Department of Chemistry, Dr. Toyokuni has proposed that the era of piecemeal investigations by various more or less isolated workers who cooperate only through letters ought to be replaced by intense cooperation characterized by well-planned teamwork that would be best located at Boulder. Therefore, he has applied for support from the Japan Society for the Promotion of Science for such a cooperative project requiring an almost two years' stay for H. and Y. Toyokuni at the University of Colorado, with shorter visits to the best herbaria in America. The present proposal is designed to match the Japanese one, in order to make this highly promising cooperation possible, although we and our students would be able to add considerable contributions towards the solution of the problems in question even without such a long visit by the Japanese investigators.

Although we plan to synthesize the results with close cooperation among all four investigators, we expect that the cytological and computer work will mainly be taken care of by Y. Toyokuni and D. Löve, perhaps aided by one graduate research assistant if available, and that the morphological, taxonomical, and geographical viewpoints will be worked out by H. Toyokuni and Á. Löve, perhaps aided by one student who would employ scanning electron microscope and chemical methods on some of the problems. The entire team will take part in other approaches, discuss theoretical viewpoints, and draw taxonomical conclusions as to generic and specific delimitations.

It ought to be emphasized that the significance of this teamwork will be taxonomic and evolutionary, since the results will demonstrate the possibilities of an evolutionarily sound monographing even of the taxonomically most difficult families of angiosperms, with the aid of such a concerted effort employing numerous available modern methods in addition to the classical ones. At the same time, we expect the work to be of significance also for pharmaceutical plant breeding work, because although the gentians are medicinally important, faulty taxonomy in the past has caused great difficulties in their improvement. Preliminary studies indicate that the drug content can be greatly increased by aid of polyploidy, and then especially alloploidy between species that may be most correctly placed in different genera. The role of polyploidy in the speciation within some of these genera is considerable, whereas in others it is negligible as far as our experience goes, and the evolutionary significance of some of the variations described at specific or subspecific levels from North America and eastern Asia needs to be evaluated on the basis of new methods.

We expect to publish some of the results of these studies in several journal articles during the investigations, but they will all be synthesized in a modern monograph of the group when all details have been collected and evaluated.

II. Summary of Procedure

1) The aim of the work proposed is to synthesize modern knowledge and understanding of the Gentianinae in a monograph in which all categories will be as exactly defined as possible on basis of their evolutionary history.

2) Material to be used for this work is in part herbarium plants collected during the past two decades on three continents by the four cooperating botanists, augmented with older and newer collections from official herbaria, in part cytological material and pickled plant organs collected during the same period, and in part fresh and living material grown from seeds in experimental plots and growth chambers for various kinds of cytogenetical and other experiments.

3) Ordinary morphological observations and measurements will be made on this extensive material in order to ascertain similarities and differences at various levels.

4) Observations on detailed morphology of hairs, epidermis, seed coats, and other minor characteristics of importance will be made with the aid of the scanning electron microscope, in addition to the ordinary microscope.

5) Cytological studies will concentrate on chromosome morphology and number, relations between different basic numbers and their possible phylogeny, karyotypes, meiotic pairing, and sterility of populations and their hybrids at various levels, and on general observations of other meiotic and mitotic characteristics that could be of value for the understanding of the evolutionary history and status of the taxa.

6) Palynological methods, including the use of the scanning electron microscope, will be employed in every case where such approaches seem necessary or promising.

7) The chemical similarities and dissimilarities of the different taxa will be investigated with the aid of modern chemotaxonomical methods, especially by aid of paper chromatography.

8) The distribution of the taxa will be studied with the aid of literature and herbarium material, and will be used as a basis for an interpretation of the possible evolutionary history and dispersal of the taxa in light of modern theories of continental drift.

9) During the work, and especially during the final synthesis of all these observations, computer methods and modern taximetrics will be utilized.

10) Although details observed during the process of the studies will be published separately in journal articles during the investigation, and some

of these used for thesis work of graduate students, all our observations and those of previous workers will in the end be synthesized into a thoroughly modern taxonomical monograph on the entire tribe.

III. Some Pertinent Bibliographic References

BENTHAM, G. and HOOKER, J.B. 1876. Gentianaceae. - Genera Plantarum 2: 799-820.

BORCKHAUSEN, M.B. 1796. Ueber Linné's Gattung Gentiana. - Archiv f. Botanik (ed. ROEMER), 1: 23-32.

BURTT, B.L. 1965. Notes, chiefly nomenclatural, on Gentianaceae of Pakistan and India. - Notes Royal Bot. Garden, Edinb., 26: 269-278.

CARD, H.H. 1931. A revision of the genus Frasera. - Ann. Missouri Bot. Garden 18: 245-282.

De CANDOLLE, A.P. 1845. Prodromus systematis naturalis regni vegetabilis 9. - Paris.

ENGLER, A. and PRANTL, K. 1895. Die natürlichen Pflanzenfamilien. 4. - Leipzig.

FABRIS, H.A. 1958. Notas sobre Gentianella del Peru. - Bol. Soc. Argent. Bot. 7: 68-93.

FABRIS, H.A. 1960. El genero Gentianella en Ecuador. - Bol. Soc. Argent. Bot. 8: 160-192.

FAVARGER, C. 1949. Contribution à l'étude caryologique des Gentianacées. - Ber. Schweiz. Bot. Ges. 59: 62-86.

FROELICH, J.A. 1796. De Gentiana libellus sistens specierum cognitarum descriptiones cum observationibus. - Erlangae.

GILG, E. 1895. Gentianaceae. - Die natürlichen Pflanzenfamilien 4(2): 50-108.

GILLETT, J.M. 1957. A revision of the North American species of Gentianella Moench - Ann. Missouri Bot. Garden 44: 195-269.

GILLETT, J.M. 1963. The gentians of Canada, Alaska and Greenland. - Canada Dept. of Agric. Publ. No. 1180. Ottawa.

GRISEBACH, A.H.R. 1839. Genera et species Gentianearum. - Stuttgartiae.

GRISEBACH, A.H.R. 1845. Gentianaceae. - In De Candolle: Prodromus 9: 38-141.

GROSSHEIM, A.A. 1952. Gentianaceae. - Flora USSR 18: 525-640.

HEGI, G. 1926-1927. Gentianaceae. - Illustrierte Flora von Mitteleuropa 5: 1953 - 2047.

HOLUB, J. 1967. Neue Namen innerhalb der Gattungen Gentianella Moench, Gentianopsis Ma und Comastoma (Wettst.) Toyokuni. - Folia Geobot. Phytotax. 2: 155-120.

HOLUB, J. 1968. Einige neue nomenklatorische Kombinationen innerhalb der Gentianinae. - Folia Geobot. Phytotax. 3: 217-218.

HYLANDER, N. 1945. Nomenklatorische und systematische Studien über nordische Gefässpflanzen. - Uppsala Univ. Arsskr. 1945, 7: 1-377.

ILTIS, H. 1965. The genus Gentianopsis (Gentianaceae): transfers and phytogeographic comments. - Sida 2: 129-154.

KNOBLAUCH, E. 1894. Beiträge zur Kenntnis der Gentianaceae. - Bot. Centralbl. 60: 386-398.

Kusnetzov, N.J. 1896 - 1904. Subgenus Eugentiana Kusnezow generis Gentiana Tournef. - Acta Horti Petrop. 15: 1-507.

LÖVE, Á. and LÖVE, D. 1956. Cytotaxonomical conspectus of the Icelandic flora.- Acta Horti Gotob. 20: 65-291.

LÖVE, Á and LÖVE, D. 1961a. Some nomenclatural changes in the European flora. I. Species and supraspecific categories. - Bot. Notiser 114: 33-47.

LÖVE, Á and LÖVE, D. 1961b. Chromosome numbers of central and northwest European plant species. - Opera Botanica 5: 1-581.

LÖVE, D. 1953. Cytotaxonomical remarks on the Gentianaceae. - Hereditas 39: 225-235.

LÖVE, Á. and LÖVE, D. 1972. Favargera and Gentianodes, two new genera of alpine Gentianaceae. - Bot. Notiser (in press).

MA, Y.-C. 1951. Gentianopsis - a new genus of the Gentianaceae. - Acta Phytotax. Sinica 1: 5-19.

MARQUARD, C.V.B. 1937. The gentians of China. - Kew Bull. Misc. Inf. 3: 134-191.

MASON, C.T. and ILTIS, H.H. 1965. Preliminary report on the flora of Wisconsin. No. 53. Gentianaceae and Menyanthaceae. - Trans. Wisc. Acad. Sci., Arts and Lett. 54: 295-329.

MAYER, E. 1954. Pripravljalna dela za floro Slovenije. 1. Gentiana L. sect. Endotricha Froel. - Slv. Akad. Znanosti in Umetnosti, Cl. Iv, Razprava 92: 47-74.

MAYER, E. 1969. Zur Kenntnis der Gattung Gentianella Moench in Jugoslawien. I. Der G. anisodonta-Komplex. - Osterr. Bot. Zeitschr. 116: 393-399.

MAYER, E. 1968. Zur Kenntnis der Gattung Gentianella Moench. II. Der G. aspera - G. germanica und G. austriaca-Komplex. - Biol. Vestnik 16: 23-28.

MOENCH, C. 1794. Methodus plantas horti botanici et agri Marburgensis. - Marburgi Cafforum.

NECKER, N.J. 1790. Elementa botanica. 2. - Neuwied.

NILSSON, S. 1964. On the pollen morphology in Lomatogonium A. Br. - Grana Palynol. 5: 298-329.

NILSSON, S. 1967a. Pollen morphological studies in the Gentianaceae-Gentianinae.- Grana Palynol. 7: 46-145.

NILSSON, S. 1967b. Notes on pollen morphological variation in Gentianaceae - Gentianinae. - Pollen et Spores 9: 49-58.

NILSSON, S. 1968. Pollen morphology in the genus Macrocarpaea (Gentianaceae) and its taxonomical significance. - Svensk Bot. Tidskr. 62: 338-364.

NILSSON, S. 1970a. Pollen morphological contributions to the taxonomy of Lisianthus L. s. lat. (Gentianaceae). - Svensk Bot. Tidskr. 64: 1-43.

NILSSON, S. 1970b. Pollen morphological studies in the Gentianaceae. - Acta Univ. Upsaliensis, Abstr. of Uppsala Diss. in Science 165: 1-18.

PERRY, J.D. 1971. Biosystematic studies in the North American genus Sabatia (Gentianaceae). - Rhodora 73: 309-369.

RORK, C.L. 1949. Cytological studies in the Gentianaceae. - Amer. Journ. Bot. 36: 687-701.

ROTH, A.W. 1827. Enumeratio plantarum phanerogamerum in Germania sponte nascentium. I. - Lipsiae.

SCHMIDT, F.W. 1796. Kritische Betrachtung der Enzianen. - Archiv f. Botanik (ed. Roemer) 1: 3-23.

SCHUSTLER, F. 1923. Some remarks to the system of Gentianae. - Vêstn. 1. Sjezdu Ceskoslav. Bot. v. Praze I: 32-34.

SKALINSKA, M. 1951. Cytological studies in Gentiana species from the Tatra and Pieniny Mountains. - Bull. Acad. Pol. B, 1951: 119-136.

SMITH, H. 1936. Gentianaceae. - Symb. Sinica 7: 950-988.

SMITH, H. 1965. Notes on Gentianaceae. - Notes Royal Bot. Garden Edinb. 25: 237-258.

St. JOHN, 1941. Revision of the genus Swertia of the Americas and the reduction of Frasera. - Amer. Midl. Nat. 26: 1-29.

TOYOKUNI, H. 1961. Separation de Comastoma, genre nouveau, d'avec Gentianella. - Bot. Mag. Tokyo 74: 198.

TOYOKUNI, H. 1962. Further remarks to the genus Comastoma. - Acta Phytotax. Geobot. 20: 136-138.

TOYOKUNI, H. 1963. Conspectus Gentianacearum Japonicorum. - Journ. Fac. Sci. Hokkaido Univ. Ser. 5 (Bot.) 7: 137-259.

TOYOKUNI, H. 1965. Systema Gentianinarum novissimum. - Symb. Asahikaw. 1: 147-158.

TOYOKUNI, H. 1967. Notes on Gentianopsis with special reference to Japanese species. 1. - Symb. Asahikaw. 2: 57-72.

TOYOKUNI, H. 1968. Notes on Gentianopsis with special reference to Japanese species. 2. - Symb. Asahikaw. 3: 137-146.

WAGENITZ, G. 1964. Gentianales. - Engler's Syllabus der Pflanzenfamilien 2: 405-424.

WETTSTEIN, R. v. 1896. Die Gattunszugehörigkeit und systematische Stellung der Gentiana tenella Rottb. und G. nana Wulf. - Österr. Bot. Zeitschr. 46: 172-176.

IV. Facilities

All major equipment needed for these studies is available in the Department of Biology or in other departments of the University where it can be made available for those concerned. The same applies to herbarium and library facilities in Boulder.

V. Personnel Data

The Japanese Investigators are:

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The American Investigators are:

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Vitae of the American investigators are found on the following pages.

VI. Current Support and Pending Applications

Current Support:

Smithsonian Institution Grant SFG-1-5484, "Cooperative Studies on the Cytotaxonomy of the Yugoslavian Flora," 6/1/71 to 5/31/72, $50,720; Co-Principal Investigators' time-commitments: 100 percent, three months summer. A proposal for renewal of this grant is currently under review.

Pending Applications:

None.

No other support is currently available for the proposed research. This proposal is being submitted only to NSF.

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Education:

B.A., Reykjavik College, 1937
M.S., Cytogenetics, Botany, Zoology, University of Lund, Sweden, 1941
Ph.D., Cytogenetics, Botany, University of Lund, Sweden, 1942
D.Sc., Cytogenetics, University of Lund, Sweden, 1943

Employment Record:

Research Associate, Institute of Genetics, University of Lund, 1942-45
Research Worker (on leave), University of Iceland Research Institute, Reykjavik, 1942-45
Director, Institute of Botany and Genetics, University of Iceland Research Institute, Reykjavik, 1945-51
Associate Professor of Botany, University of Manitoba, Winnipeg, 1951-56
Research Professor of Biosystematics, Institut Botanique, Université de Montréal, 1956-63
Associate Professor, Department of Biology, Unierstiy of Colorado, 1964-66
Chairman, Department of Biology, University of Colorado, 1966-1970
Professor, Department of Biology, University of Colorado, 1966-present

Fellowships and Professional Honors:

Fellow, Icelandic Academy of Learning since 1946; corresponding member since 1951
Permanent member of the Board of the International Association of Plant Geographers since 1953
Rapporteur and Vice President, Section of Cytology, VIIIth International Botanical Congress, Paris, 1954
Member, International Committee for Genetical Nomenclature and Symbolization (I.U.B.S.), 1956-58
Member of the Editorial Board of the journal Nucleus since 1958
Technical Consultant on Cytotaxonomy for Flora Europaea since 1955
President, International Organization of Biosystematists, 1960-64
Honorary Foreign Member, Swedish Phytogeographical Society since 1960
President, Symposium on North Atlantic Biota and their History, Reykjavik, July 1962
Vice President, International Committee on Chemotaxonomy, 1964-1969, President 1969-
John Simon Guggenheim Memorial Fellow, 1963-64.
Honorary Foreign Member, Czechoslovak Botanical Society since 1968

Selected Publications,

Cytogenetic studies in Rumex. Botaniska Notiser, 157-169 (1940).

Études cytogénétiques des Rumex. II. Polyploidie geographique-systématique du Rumex subgenus Acetosella. Botaniska Notiser, 155-172 (1941).

Polyploidy in Polygonum Convolvulus L. s. lat. Hereditas 28, 227-228 (1942).

Cytotaxonomic studies on boreal plants. I. Some observations on Swedish and Icelandic plants. Kungliga Fysiografiska Sallskapets i Lund Forhandlingar 12 (6), 1-19 (1942), with D. Löve.

Chromosome numbers of Scandinavian plant species. Botaniska Notiser, 19-59 (1942), with D. Löve.

Cytogenetic studies in Rumex. III. Some notes on the Scandinavian species of the genus. Hereditas 28, 289-296 (1942).

Different chromosome numbers within the collective species Carex polygama. Hereditas 28, 495-496 (1942), with A. Levan.

The significance of differences in distribution of diploids and polyploids. Hereditas 29, 145-163 (1943), with D. Löve.

Cytogenetic studies on Rumex subgenus Acetosella. Hereditas 30, 1-136 (1943).

The dioecious forms of Rumex subgenus Acetosa in Scandinavia. Botaniska Notiser, 23?-254 (1944).

Cytotaxonomical studies on boreal plants. II. Some notes on the chromosome numbers of Juncaceae. Arkiv for Botanik 31B (1), 1-6 (1944), with D. Löve.

Cytotaxonomical studies on boreal plants. III. Some new chromosome numbers of Scandinavian plants. Arkiv for Botanik 31A (12), 1-22 (1944), with D. Löve.

A new triploid Betula verrucosa. Svensk Botanisk Tidsskrift 38, 381-393 (1944).

Islenzkar jurtir (Icelandic flora). E. Munksgaard, Copenhagen 1945, pp. 281.

Studies on the origin of the Icelandic flora. I. Cyto-ecological investigations on Cakile. Iceland University Institution of Applied Sciences, Department of Agriculture, Reports B2, 1-29 (1947), with D. Löve.

Chromosome numbers of Northern plant species. Iceland University Institution of Applied Sciences, Department of Agriculture, Reports B3, 1-131 (1948), with D. Löve.

The geobotanical significance of polyploidy. I. Polyploidy and latitude. Portugaliae Acta Biologica (B), R.B. Goldschmidt Jubilee Volume, 273-352 (1949), with D. Löve.

Some innovations and nomenclatural suggestions in the Icelandic flora. Botaniska Notiser, 24-60 (1950).

Taxonomical evaluation of polyploids. Caryologia 3, 263-284 (1951).

Studies on the origin of the Icelandic flora. II. Saxifragaceae. Svensk Botanisk Tidsskrift 45, 368-399 (1951), with D. Löve.

The Icelandic type of Glyceria fluitans. Botaniska Notiser 1951, 229-240 (1951).

Preparatory studies for breeding Icelandic Poa irrigata. Hereditas 38, 11-32 (1952).

The geobotanical significance of polyploidy. Proceedings of the VIth International Grassland Congress, State College, Pennsylvania, 1952, 240-246 (1953), with D. Löve.

Subarctic polyploidy. Hereditas 39, 113-124 (1953).

Studies on Bryoxiphium. Bryologist 56, 73-94, 183-203 (1953), with D. Löve.

Cytotaxonomical remarks on some American species of circumpolar taxa. Svensk Botanisk Tidsskrift 48, 211-232 (1954).

Cytotaxonomical studies on the northern bedstraw. American Midland Naturalist 52, 88-105 (1954), with D. Löve.

Cytotaxonomical evaluation of corresponding taxa. Vegetatio 5 (6), 212-224 (1954).

The foundations of cytotaxonomy. VIII^{e} Congrès International de Botanique Paris, 1954. Rapports et Communications, Sec. 9-10, 59-66 (1954).

Cytotaxonomical notes on the Icelandic Papaver. Nytt Magasin for Botanikk 4, 5-18 (1955).

Biosystematic remarks on vicariism. Acta Soc. Vanamo 72 (15), 1-14 (1955).

Cytotaxonomical conspectus of the Icelandic flora. Acta Horti Gotoburgensis 20, 65-291 (1956), with D. Löve.

Chromosomes and taxonomy of eastern North American Polygonum. Canadian Journal of Botany 34, 501-521 (1956), with D. Löve.

Chromosomes and relationships of Koenigia islandica. Canadian Journal of Botany 35, 507-514 (1957), with P. Sarkar.

Cytotaxonomy of Carex section Capillares. Canadian Journal of Botany 35, 715-761 (1957), with D. Löve and M. Raymond.

Drug content and polyploidy in Acorus. Proceedings of the Genetics Society of Canada 2, 14-17 (1957), with D. Löve.

Arctic polyploidy. Proceedings of the Genetics Society of Canada 2, 23-27 (1957), with D. Löve.

Taxonomic and biosystematic categories. Brittonia 10, 153-166 (1958), with D.H. Valentine.

The American element in the flora of the British isles. Botaniska Notiser 111, 376-388 (1958), with D. Löve.

An unusual polyploid series in Triglochin maritimum agg. Proceedings of the Genetics Society of Canada, 3, 2, 19-21 (1958), with D. Löve.

Cytotaxonomy and classification of Lycopods. Nucleus 1, 1-10 (1958), with D. Löve.

Biosystematics of Triglochin maritimum agg. Naturaliste Canadien 85, 156-165 (1958), with D. Löve.

The origin of the Arctic flora. Problems of the Pleistocene and Arctic. Publications of the McGill University Museum 1, 82-95 (1959).

Cytotaxonomy of Cerastium holosteoides. Phyton 8, 38-42 (1959), with M.S. Chennaveeraiah.

Biosystematics of the black crowberries in America. Canadian Journal of Genetics and Cytology 1, 34-38 (1959), with D. Löve.

Biosystematics and the processes of speciation. In: "Evolution: its science and doctrine," Royal Society of Canada, Studia Varia 4, 115-122 (1960).

Biosystematics and classification of apomicts. Feddes Repertorium 62, 136-148 (1960).

Taxonomy and chromosomes - a reiteration. Feddes Repertorium 62, 192-202 (1960).

Some nomenclatural changes in the European flora. I. Species and supra-specific categories. Botaniska Notiser 114, 33-47 (1961), with D. Löve.

Some nomenclatural changes in the European flora. II. Subspecific categories. Botaniska Notiser 114, 48-56 (1961), with D. Löve.

Some chromosome numbers of Icelandic ferns and fern-allies. American Fern Journal 51, 127-128 (1961), with D. Löve.

Some notes on Myriophyllum exalbescens. Rhodora 63, 139-145 (1961).

Chromosome numbers of Central and Northwest European plant species. Opera Botanica 5, ~~I-VIII~~, 1-581 (1961), with D. Löve.

Hylandra, a new genus of Cruciferae. Svensk Botanisk Tidsskrift 55, 211-217 (1961).

A note on amphi-pacific Lysichitum. Journal of Japanese Botany 36, 359-361 (1961), with S. Kawano.

The biosystematic species concept. Preslia 34, 127-139 (1962).

Typification of Papaver radicatum - a nomenclatural detective story. Botaniska Notiser 115, 113-136 (1962).

Cytotaxonomy of the Isoetës echinospora complex. American Fern Journal 52, 113-123 (1962).

Cytotaxonomy and generic delimitation. Regnum Vegetabile 27, 45-51 (1963).

Biosystematische Analyse der Elytrigia Junceae Gruppe. Die Kulturpflanze, Beiheft 3, 74-85 (1962).

North Atlantic Biota and Their History. Pergamon Press, Oxford (1963), editor together with D. Löve.

Chromosome numbers of some Carex species from Spain. Botaniska Notiser 116, 241-248 (1963), with E. Kjellqvist.

Chromosome numbers of some Iberian Cistaceae. Portugaliae Acta Biologica (A) 8, 69-80 (1964), with E. Kjellqvist.

The biological species concept and its evolutionary structure. Taxon 13, 33-45 (1964).

The evolutionary framework of the biological species concept. Genetics Today II, 409-414 (1965).

The North Atlantic flora - its history and late evolution. Tenth International Botanical Congress (1964), Abstracts, 139-140 (1965), with D. Löve.

Taxonomic remarks on some American alpine plants. University of Colorado Studies, Series in Biology 17, 1-43 (1965), with D. Löve.

Chromosome numbers from central northern Canada. Canadian Journal of Botany 44, 429-439 (1966), with J.C. Ritchie.

Cytotaxonomy of the alpine vascular plants of Mount Washington. University of Colorado Studies, Series in Biology 24, 1-74 (1966), with D. Löve.

An alloploid Ophioglossum. Nucleus 9, 132-138 (1966), with B.M. Kapoor.

The variations of Blechnum Spicant. Botanisk Tidsskrift 62, 186-196 (1966), with D. Löve.

Íslenski dílaburknin (Dryopteris assimilis S. Walker in Iceland). Flóra, Journal of Icelandic Botany 4, 5-9 (1966), with D. Löve.

Biosystematics of widely disjunctive taxa. Die Naturwissenschaften 54, 24-25 (1967), with D. Löve.

The highest plant chromosome number in Europe. Svensk Botanisk Tidsskrift 61, 29-32 (1967), with B.M. Kapoor.

Polyploidy and altitude: Mt. Washington. Biologisches Zentralblatt 86, Beiheft, 307-312 (1967), with D. Löve.

The evolutionary significance of disjunctions. Taxon 16, 324-333, 1967.

Continental drift and the origin of the arctic-alpine flora. Revue Roumaine de Biologie, Serie Botanique 12, 163-169 (1967), with D. Löve.

Evolution and the Linhaean species. Univ. Babes Bolayi din Cluj, Grâd. Bot., Contrib. Bot. 1967, 203-210 (1967), with D. Löve.

The taxonomic status of Rumax paucifolius. Taxon 16:423-425, 1967 with V. Evanson.

The Origin of the North Atlantic flora. Aquilo. Ser. Bot. 6, 52-66 (1967), with D. Löve.

New combinations in Carpogymnia. - Taxon 16:191-192, 1967, with D. Löve.

Cytotaxonomy of Blechnum Spicant. Collectanea Botanica 7, 665-676 (1968), with D. Löve.

Cytotaxonomical notes on some American orchids. Southw. Natural. 13, 355-342 (1968), with W. Simon.

A Chromosone atlas of the collective genus Rumex. - Cytologia 32:328-342 with B.M. Kapoor.

Remarks on the Cytotaxonomy of Mediterranean plants. - Publ.Univ. Sevilla 1969:285-291, with D. Löve.

Íslenzk ferdaflora. (Icelandic Excursion flora).-Reykjavík 1970, 428 pages.

Cytotaxonomy of Rocky Mountain Ranúnculus.- Cariológia 23:575-594, 1970 with B.M. Kapoor.

Cytotaxonomy of a century of Rocky Mountain orophytes.- Arctic and Alpine Research 3:139-165, 1976 with D. Löve and B.M. Kapoor.

Polyploidie et géobotanique.-Naturaliste Canadien 98:489-494, 1971, with D. Löve.

115 chromosome numbers from Yugoslavia.-Taxon 20:788-791, 1971, (with D. Löve, M. Lovka and F. Susnik.

Cytotaxonomical indication of the genus Conosilene.- Journal of the Indian Botanical Society. Jubilee Volume 1971, with E. Kjellqvist.

Cytotaxonomy of Spanish plants. I. Introduction, Pteridophyta and Gymnospermae.- Lagascalia 2, 1972. with E. Kjellqvist.

Cytotaxonomy of Yugoslavian plants. I. Introductory remarks.-Scopolia 1, 1972, with D. Löve, E. Mayer, and F. Susnik.

Favargera and Gentianodes. Two new genera of Alpine Gentianaceae.- Bot. Notizer 125, 1972, with D. Löve.

As comprehensive computerized chromosome atlas of the world. I. Pteridophyta.- 1972, with D. Löve and R.E.G. Pichi-Sermollia.

A computerized chromosome checklist of the flora of Slovenia.- 1972, with D. Löve.

B. LÖVE, Doris

Born: 2 January 1918

Position: Faculty Research Associate, Department of Biology, University of Colorado

Education:

B.S., Kristianstad College, Sweden, 1937
M.S., Cytogenetics, Botany, Geography, University of Lund, Sweden, 1941
Ph.D., Cytogenetics, Botany, University of Lund, Sweden, 1943
D.Sc., Cytogenetics, University of Lund, Sweden, 1944

Employment Record:

Instructor (amanuensis), Institute of Genetics, University of Lund, 1940-43
Research Associate, Institute of Genetics, University of Lund, 1943-45
Geneticist, University of Iceland Research Institute, Reykjavik, 1945-51
Herbarium Curator, University of Manitoba, Winnipeg, Canada, 1951-56
Associate Professor (research), Institut Botanique, Université de Montréal, Canada, 1956-63
Faculty Research Associate, Department of Biology, Institute of Arctic and Alpine Research, and University Museum, University of Colorado, 1964-

Fellowships and Professional Honors:

Fellow, Mendelian Society of Lund, Sweden since 1941
Several research scholarships and awards from the Royal Physiographic Society of Lund, Lund Botanical Society, and the Swedish Academy of Sciences, 1941-45
Research Fellowship from the Icelandic Cultural Fund, 1945-50
British Council invitation to visit British institutions in genetics and plant breeding, Summer 1949
Research grants from the National Research Council of Canada, 1956-64, and the National Science Foundation, 1967

Selected Publications:

Some contributions to the cytology of Silenoideae. Svensk Botanisk Tidsskrift 36, 262-270 (1940).

Cytotaxonomic studies on boreal plants. I. Some observations on Swedish and Icelandic plants. Kungliga Fysiografiska Sällskapets i Lund Förhandlingar 12 (6), 1-19 (1942), with Á. Löve.

Chromosome numbers of Scandinavian plant species. Botaniska Notiser 1942, 19-59 (1942), with Á. Löve.

The significance of differences in distribution of diploids and polyploids. Hereditas 29, 145-163 (1943), with Á. Löve.

Cytogenetic studies on dioecious *Melandrium*. Botaniska Notiser 1944, 125-213 (1944).

Cytotaxonomical studies on boreal plants. II. Some notes on the chromosome numbers of Juncaceae. Arkiv för Botanik 31B (1), 1-6 (1944), with Á. Löve.

Cytotaxonomical studies on boreal plants. III. Some new chromosome numbers of Scandinavian plants. Arkiv för Botanik 31A (12), 1-22 (1944), with Á. Löve.

Studies on the origin of the Icelandic flora. I. Cyto-ecological investigations on *Cakile*. Iceland University Institute of Applied Sciences, Department of Agriculture, Reports B, 2, 1-29 (1947), with Á. Löve.

Chromosome numbers of Northern plant species. Iceland University Institute of Applied Sciences, Department of Agriculture, Reports, B, 3, 1-131 (1948), with Á. Löve.

The geobotanical significance of polyploidy. I. Polyploidy and latitude. Portugaliae Acta Biologica (B), R.B. Goldschmidt Jubilee Volume, 273-352 (1949), with Á. Löve.

Studies on the origin of the Icelandic flora. II. Saxifragaceae. Svensk Botanisk Tidsskrift 45, 368-399 (1951), with Á. Löve.

The geobotanical significance of polyploidy. Proceedings of the VIth International Grassland Congress, State College, Pennsylvania (1952), 240-246 (1953), with Á. Löve.

Cytotaxonomical remarks on Gentianaceae. Hereditas 39, 225-235 (1953).

Studies on *Bryoxiphium*. Bryologist 56, 73-94, 183-203 (1953), with Á. Löve.

Cirsium Flodmanii (Rydb.) Arth. f. *albiflora*, forma nova. Rhodora 55, 362-363 (1953).

Cytotaxonomical studies on the northern bedstraw. American Midland Naturalist 52, 88-105 (1954), with Á. Löve.

A plant collection from SW Yukon. Botaniska Notiser 109, 153-211 (1956), with N.J. Freedman.

Cytotaxonomical conspectus of the Icelandic flora. Acta Horti Gotoburgensis 20, 65-291 (1956), with Á. Löve.

Chromosomes and taxonomy of eastern North American *Polygonum*. Canadian Journal of Botany 34, 501-521 (1956), with Á. Löve.

Rumex stenophyllus in North America. Rhodora 60, 54-57 (1958), with J.P. Bernard.

Cytotaxonomy of *Carex* section *Capillares*. Canadian Journal of Botany 35, 715-761 (1957), with Á. Löve and M. Raymond.

Drug content and polyploidy in *Acorus*. Proceedings of the Genetics Society of Canada 2, 14-17 (1957), with Á. Löve.

Arctic polyploidy. Proceedings of the Genetics Society of Canada 2, 23-27 (1957), with Á. Löve.

A plant collection from interior Quebec. Naturaliste Canadien 85, 25-69 (1958), with G. Johnston and J. Kucyniak.

The American element in the flora of the British Isles. Botaniska Notiser 111, 376-388 (1958), with Á. Löve.

An unusual polyploid series in *Triglochin maritimum* agg. Proceedings of the Genetics Society of Canada 3, 2, 19-2[illegible] (1958), with Á. Löve.

Cytotaxonomy and classification of Lycopods. Nucleus 1, 1-10 (1958), with Á. Löve.

Biosystematics of *Triglochin maritimum* agg. Naturaliste Canadien 85, 156-165 (1958), with Á. Löve.

Biosystematic studies in *Xanthium*: Taxonomic appraisal and ecological status. Canadian Journal of Botany 37, 173-208 (1959), with P. Dansereau.

The post-glacial development of the flora of Manitoba: a discussion. Canadian Journal of Botany 37, 547-585 (1959).

Biosystematics of the black crowberries in America. Canadian Journal of Genetics and Cytology 1, 34-38 (1959), with Á. Löve.

Flora and vegetation of Otterburne, Manitoba, Canada. Svensk Botanisk Tidsskrift 53, 335-461 (1959), with J.P. Bernard.

The red-fruited crowberries in North America. Rhodora 62, 265-292 (1960).

Some nomenclatural changes in the European flora. I. Species and supraspecific categories. Botaniska Notiser 114, 33-47 (1961), with Á. Löve.

Some nomenclatural changes in the European flora. II. Subspecific categories. Botaniska Notiser 114, 48-56 (1961), with Á. Löve.

Some chromosome numbers of Icelandic ferns and fern-allies. American Fern Journal 51, 127-128 (1961), with Á. Löve.

Chromosome numbers of Central and Northwest European plant species. Opera Botanica 5, I-VIII, 1-581 (1961), with Á. Löve.

The Hutchinson polygraph, a method for simultaneous expression of multiple and variable characters. Canadian Journal of Genetics and Cytology 3, 289-294 (1961), with L. Nadeau.

Triglochin gaspense, a new species of arrowgrass. Canadian Journal of Botany 39, 1261-1272 (1961), with H. Lieth.

Quelques mots sur la flore alpine de Mt. Washington, N.H. Annales de l'ACFAS 28, 38 (1962).

North Atlantic Biota and their History. Pergamon Press, Oxford (1963), editor with Á. Löve.

Dispersal and survival of plants. North Atlantic Biota and their History, 189-205 (1963).

Streptopus oreopolus Fern., a hybrid taxon. Rhodora 56, 310-317 (1963), with H. Harries.

The North Atlantic flora - its history and late evolution. Tenth International Botanical Congress (1964), Abstracts, 139-140 (1965), with Á. Löve.

Taxonomic remarks on some American alpine plants. University of Colorado Studies, Series in Biology 17, 1-43 (1965), with Á. Löve.

Cytotaxonomy of the alpine vascular plants of Mount Washington. University of Colorado Studies, Series in Biology 24, 1-74 (1966), with Á. Löve.

Vaccinium gaultherioides Bigel. - an arctic-alpine species. Revue Roumaine de Biologie, Série Botanique 11, 295-305 (1966), with N. Boşcaiu.

The variations of Blechnum Spicant. Botanisk Tidsskrift 62, 186-196 (1966), with Á. Löve.

Íslenski dílaburkninn (Dryopteris assimilis S. Walker in Iceland). Flóra, Journal of Icelandic Botany 4, 5-9 (1966), with Á. Löve.

Biosystematics of widely disjunctive taxa. Die Naturwissenschaften 54, 24-25 (1967), with Á. Löve.

Polyploidy and altitude: Mt. Washington. Biologisches Zentralblatt 86, Beiheft, 307-312 (1967), with Á. Löve.

Continental drift and the origin of the arctic-alpine flora. Revue Roumaine de Biologie, Série Botanique 12, 163-169 (1967), with Á. Löve.

Evolution and the Linnaean species. Univ. Babes Bolayi din Cluj, Grǎd. Bot. Contrib. Bot. 1967, 203-210 (1967), with Á. Löve.

The origin of the North Atlantic flora. Aquilo, Ser. Bot. 6, 52-66 (1967), with Á. Löve.

New combinations in Carpogymnia.-Taxon 16:191-192, 1967, with Á. Löve.

Cytotaxonomy of _Blechnum Spicant_. Collectanea Botanica 7, 665-676 (1968), with Á. Löve.

The diploid perennial _Anthoxanthum_. Science in Iceland 1968, 26-30 (1968), with Á. Löve.

Papaver at high altitudes in the Rocky Mountains. Brittonia 21, 1-10 (1969).

Remarks on the cytotaxonomy of Mediterranean plants.-Publ. Univ. Sevilla 1969:285-291, with Á. Löve.

Subarctic and subalpine - where and what? - Journal of Arctic and Alpine Research 2:63-73, 1970.

Coumarin and coumarin derivatives in various growth-types of Engelmann Spruce.-with Svenik Bot. Tidskrift 64: 284-295, 1970. with C. McLellan and I. Gamow.

Reflections around a mutilated tree - Biol. Conservation 3:274-278, 1971.

Cytotaxonomy of a century of Rocky Mountain orophytes. - Arctic and Alpine Research 3: 139-165, 1971, with Á. Löve and B.M. Kapoor.

Polyploidie et géobotanique.- Naturaliste Canadien 98:469-494, 1971, with Á. Löve.

115 chromosome numbers from Yugoslavia.-Taxon 20:788-791, 1971, with Á. Löve, M. Lovka, and F. Susnik.

Cytotaxonomy of Yugoslavian plants. I. Introductory remarks.- Scopolia, 1972, with A. Löve, E. Mayer, and F. Susnik.

Favargera and _Gentianodes_, two new genera of alpine Gentianaceae.- Bot. Notiser 125, 1972, with Á. Löve.

A comprehensive computerized chromosome atlas of the world. I. Pteridophytes. 1972, with Á. Löve and R.E.G. Pichi-Sermolli.

A computerized chromosome checklist of the flora of Slovenia.-1972, with Á. Löve.

CU Proposal No. 72.5.192
4/72

NATIONAL SCIENCE FOUNDATION

Research Grant Budget

Institution: The Regents of the University of Colorado, Boulder, Colorado 80302

Title: Biosystematic and Evolutionary Studies on Critical Taxa of the Gentianinae

Starting Date: September 1, 1972

Duration: Two Years

Co-Principal Investigators: Áskell Löve, Doris Löve

	1st year	2nd year
A. Salaries and Wages		
Co-Principal Investigators:		
Áskell Löve		
25% time, 9 mos. A.Y.	$ -0-	$ -0-
100% time, 3 mos. summer	6,675(3MM)	7,210(3MM)
Doris Löve		
33 1/3% time, 9 mos. A.Y.	6,000(3MM)	6,480(3MM)
Graduate Research Assistants (2)		
50% time, 9 mos. A.Y.	6,400(9MM)	6,400(9MM)
100% time, 3 mos. summer	4,260(6MM)	4,260(6MM)
Total Salaries and Wages	23,335	24,350
B. Fringe Benefits		
TIAA: 7% of faculty salaries	465	505
C. Permanent Equipment		
None	-0-	-0-
D. Expendable Supplies and Equipment		
Chemicals, film, etc.	700	700
E. Travel		
Domestic: to herbaria and for field collection	700	700
F. Publication Costs		
Page costs and reprints	600	1,000
G. Other Direct Costs		
Mailing of herbarium material	200	200

	1st year	2nd year
Other Direct Costs Continued:		
Computer costs: CDC 6400 @ $60/hr. peripheral time, $300/hr. central processing, plus keypunching costs	$ 1,000	$ 1,000
Total Other Direct Costs	1,200	1,200
H. Total Direct Costs	$ 27,000	$ 28,455
I. Indirect Costs		
On campus: 41% of Salaries and Wages	9,565	9,985
J. Total Costs	$36,565	$38,440

TOTAL REQUESTED FROM NSF FOR TWO YEARS: $75,005

This institution will cost-share in compliance with NSF policy.

Budget Justification

The Japanese investigators will have separate finances. The budget proposed for the American investigators assumes that Doris Löve, who is most essential for this study since her work on the family actually initiated the wave of studies of the group almost two decades ago, will be paid for one-third time during the academic year and nothing during the summers, although she certainly will work considerably more on the project. Áskell Löve, however, plans to spend 25 percent of his research time on the project during the academic year, with salary contributed by the University, and three months summers salaried through the project.

Salaries are also asked for for two graduate research assistants. Although both will be required to assist in various phases of the project, one is supposed to work intensely with cytological and computer work, whereas the other will spend more time on scanning electron microscopy and on chemotaxonomy. It is assumed that both will use some of the material for their Ph.D. theses on some problems in the Gentianaceae pertinent to the project.

The need for expendable supplies and equipment in form of chemicals, films, etc. is self-explanatory, and so also is the request for funds for page charges and reprints and for computer costs (including keypunching). Mailing costs for herbarium material are necessary because of the policy of herbaria to require the payment of such costs by the borrower, especially when large quantities of material are involved. The cost for field collections and visits to herbaria is the minimum visualized, although the main cost of such visits will be carried by the Japanese investigators.

UNIVERSITY OF COLORADO PARTICIPATION

		1st year	2nd year
A.	Salaries and Wages		
	Co-Principal Investigator: Á. Löve 25% time, 9 mos. A.Y.	$ 5,005(2MM)	$ 5,405(2MM)
B.	Fringe Benefits		
	TIAA: 7% of faculty salaries	350	380
C.	Tuition Waiver*		
	Graduate Research Assistants (2)	940	940
D.	Indirect Costs		
	On campus: 41% of Salaries and Wages	2,050	2,215
	TOTALS	$8,345	$8,940

TOTAL C.U. PARTICIPATION FOR TWO YEARS: $17,285

*The University waives the difference between out-of-state and in-state tuition for research assistants. The average cost of such waivers for all research assistants is $470 per research assistant per year, which is shown as a University contribution. This amount will be adjusted periodically to reflect actual experience.

CU Proposal No. 69.5.53
2/69

A Proposal to the

National Science Foundation

for

STUDIES OF THE CYTOTAXONOMY
of the
ARCTIC-ALPINE FLORA
(Continuation of GB-3371 and GB-6299)

Name and Address of Institution: The Regents of the University of Colorado, Boulder, Colorado 80302

Desired Starting Date: 1 July 1969, or as soon thereafter as possible

Amount Requested from NSF: $110,925

Time Period for which Support is Requested: Two Years

Co-Principal Investigators:

Doris Löve, Research Associate
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Institute of Arctic and Alpine Research
University of Colorado
Boulder, Colorado 80302
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Askell Löve, Professor and Chairman
Department of Biology
University of Colorado
Boulder, Colorado 80302
Telephone: (303) - 443-2211, Ext. 7325

Doris Löve
Co-Principal Investigator

Askell Löve, Co-Principal Investigator
Chairman, Department of Biology

I certify that the distribution of costs between the direct and indirect categories as shown in the proposal conforms to the usual accounting practices of the institution and to the distribution used by the cognizant Federal audit agency.

Thurston E. Manning
Vice President for Academic Affairs

ABSTRACT

This is a proposal for continuation of cytotaxonomical studies of the arctic-alpine flora, which the applicants and their students have performed for the past twenty-odd years, with special emphasis on the Rocky Mountain populations related to or supposedly identical with circumpolar arctic-alpine or arctic-boreal-asiatic plants. The long-term object of these investigations concerns the history and origin of the arctic-alpine flora, the restoration of which is one of the most interesting adventures of evolutionary biogeography. This includes a complete cytotaxonomical review of the arctic-alpine flora, a project for many years of study. The short-term object is a closer cyto-taxonomical study of the alpine flora of the southern Rocky Mountains. An analysis of the chromosome numbers of the flora at large is being made in certain sections of the mountains, but more detailed trans-plant and hybridization experiments are made and planned for selected groups, which are grown in the new experimental garden of the University of Colorado at Boulder and in the alpine transplant gardens of the Institute of Arctic and Alpine Research on Niwot Ridge.

STUDIES OF THE CYTOTAXONOMY
of the
ARCTIC-ALPINE FLORA

Background of Proposed Research

The basic objective of the proposed research is to continue investigations into the origin and evolutionary history of the arctic-alpine flora, which the investigators have performed in various places since 1940, with support from Scandinavian funds, the National Research Council of Canada, NATO Science Division, the John Simon Guggenheim Memorial Foundation, and, during the past four years, by aid of grants GB-3371 and GB-6299 from the National Science Foundation. These problems have been approached by aid of combined cytogenetical, morphological, and geographical procedures, though the basic methods used have been those of cytotaxonomy. Although we like to believe that our contributions to this universal boreal problem have met with certain success already, we are well aware of the fact that much still remains unknown before this extremely complicated phenomenon can be regarded as satisfactorily understood. Since it is among the outstanding problems of historical phytogeography and evolution, its solution is of an utmost importance, as shown by the fact that many botanists from several countries have tried to solve it by aid of various methods for more than a century. Since the total number of species involved is counted in hundreds rather than in thousands, it is perhaps permissible to hope that an acceptable explanation of the evolutionary history of the arctic-alpine flora may come within our reach earlier than that of other floras. We are convinced that such an explanation can be found only by aid of reconstructing the evolutionary history of the component elements of this flora; though this can be done, and has been done, by aid of other methods, we know no other approach which is as effective in such work as are the modern methods of cytotaxonomy combined with those of evolutionary phytogeography.

Before going into some detail regarding the possible origins of the arctic-alpine flora, it may be worthwhile to mention that although the term arctic-alpine flora might seem to be self-explanatory, i.e., it should mean the flora of the Arctic and its representatives in more southern mountains, such a facile and obvious way of defining these plants is far from being acceptable. It is on the definition of the Arctic this depends; though it may seem to be geographically simplest and perhaps most accurate to define this region as the parts of the world north of the Polar Circle, as was done by the phytogeographer Hooker (1881), very few modern biologists would be able to accept such a demarcation. We have tried to avoid the semantic pitfalls of other definitions by regarding the Arctic as identical with the region characterized by tundra in the wide sense of the word, since that concept is reasonably well understood by northern phytogeographers. The essential of that definition is its exclusion of the subarctic with its great mixture of extraneous elements from regions further south, more or less stunted in growth because of adverse climatical influence. However, this delimitation does include at the southern boundary of the Arctic a zone of varying width in which mainly arctic elements protrude into more favorable conditions, which may be climatically more subarctic, to form the region very appropriately termed the hemiarctic zone by Rousseau. This much too little known zone may well be the clue to some of the more critical ecological and dispersal problems of the arctic plants. The most appropriate definition of the arctic flora, however, may be that it is the flora of the arctic islands, since only when separated from the continents by wide and open sea can this flora be properly protected from invasion of southern elements.

The flora of the arctic regions is represented in mountains far south in the boreal and temperate zones, and in a few cases in tropical and austral regions, by a number of alpine populations, some of which are so closely related to the northern plants that they cannot be separated by aid of morphological methods. This arctic-alpine flora should not be confused with alpine floras on recently risen or formed mountains of subtropical or tropical regions which apparently have evolved from the floras surrounding these mountains as long ago postulated by Hooker, since that is a problem of another magnitude, though its basic processes may be similar. The southern alpine representatives of the northern flora have interested phytogeographers for a long time, since it has been realized that these populations may carry the clue to the history of the arctic flora itself. The main question, which phytogeographers of the past hundred or so years have constantly asked, is, if the alpine flora did move out of the Arctic under the influence of the Pleistocene glaciations to climb the mountains and become isolated there following the amelioration of the climate after the glaciations ended, or if an ancient Tertiary alpine flora already existed in the more temperate mountains and later dispersed northwards, leaving some populations behind in the southern and boreal mountains. Both these ideas have had and still have their vigorous supporters, and both certainly may seem to be perfectly logical explanations of observations made by critical specialists. It seems to us, however, that a third possibility ought to be kept in mind, making the history and evolution of this flora considerably more complex than either one of these opinions suggests. The lands where the arctic flora now dominates have always formed the northern rim of the continents, according to geologists, though their climate before and during most of the Tertiary was considerably more amiable than it is at present. Still increasing evidence indicates that these lands once were a single continent, Laurasia, which was situated a good deal further south than at present. This continent disintegrated into the present northern continents and islands in the early or middle Tertiary by aid of continental drift triggered by the impact of the southern lands which had started to drift apart much earlier. Considerable arctic and boreal paleobotanical evidence indicates very strongly that the northern shores of Laurasia were covered by temperate and mesophytic vegetation during the early and middle Tertiary. Conditions for the development of a chionophilous flora were absent or of a very limited occurrence except in mountains until the North Atlantic was formed and the continents were pushed northwards into climates which forced the nemoral vegetation to disperse southwards until it reached its present isolated locations in western Europe, eastern and western North America, and eastern Asia. It is our opinion, still supported by meager evidence, that the conifers which grew in a mixture with the nemoral plants in the early Tertiary in the northlands, actually found a zone more favorable for their dominance just north of the regions where the nemoral plants now grow, when the climate of the present coniferous belt was created by northwards drift of the lands in the middle or late Tertiary. Likewise, the chionophilous species which were mixed with the nemoral plants or surrounded by them in isolated mountain localities in the early Tertiary, could survive the hardships of the increasing severity of the northern climate and stay where they originated when the more heat-loving plants were forced to escape southwards. Arctic plants are known to include considerably higher frequency of polyploids than are the nemoral plants, and since the split areas of certain of the northern plants can be regarded as an evidence for their being old species, it is not a far-fetched idea to suggest that they were already polyploid before they were left behind by the nemoral plants and could survive in the northlands thanks to this characteristic. This leads to the most interesting conclusion that the polyploids stayed where they were while the diploids and lower polyploids moved southwards, quite contrary to most earlier speculations on the history of the polyploids of arctic lands. We do not feel forced to retract our earlier explanations of the high frequency of polyploids in the northlands because of this hypothesis, though we realize that it is in better concordance with the geological history of the regions in question than were all earlier explanations.

This third hypothesis, naturally, affects our ideas as to the history of the alpine outposts of the arctic plants. It is not only possible but highly probable that some of the chionophilous species, which had been formed prior to the southward dispersal of the nemoral and may be regarded as paleo-polyploids in the terminology of Favarger (1961, 1964), have accompanied the nemoral plants southwards on the shores and in the hills and later found their more appropriate conditions in southern mountains, at the same time as other populations of the same species stayed behind in the arctic lands. Other alpine plants may belong to species which could not accompany the nemoral plants on their dispersal to warmer climates but later developed an ability to disperse into more austral conditions, perhaps in connection with some of the climatical changes during the Pleistocene. Some such plants may, then, have come to the southern mountains already during the early Pleistocene, whereas others came later, when the environmental conditions made some austral areas and dispersal routes available to chionophilous taxa for long enough periods. The third group of arctic-alpine plants may have developed in certain temperate mountains and then invaded the Arctic during the Pleistocene when such a dispersal became possible and then especially into regions with arctic climates but in direct land connection with other more equitable regions, like in Siberia and some parts of North America. We are of the opinion that we have already studied examples of all these three kinds of chionophilous plants cytotaxonomically from various regions, though this information still remains unpublished. We also maintain, on basis of our studies and those of some other colleagues working on arctic plants, that polyploidy has had much to do with the survival of the arctic plants after they became isolated, whereas we doubt that polyploidy has directly influenced the dispersal ability of these species or their diploid or less polyploid nemoral relatives. Cytotaxonomical and genecological studies of these possibilities are the main objectives of our investigations, which are likely to reveal if our hypothesis is as well founded as we think it is, or if the two other explanations are more correct, or if all three have to be replaced by a theory which may or may not make use of all or some of these ideas, all of which still are to be regarded as working hypotheses only.

The idea here expressed as to the probable origin of the arctic-alpine flora is in concordance with recent phytogeographical work by Hultén and Tolmatchev, who doubtlessly are the leading specialists on the arctic-alpine flora at present. It is also in agreement with findings of several recent authors, and then especially Böcher, Favarger, Holmen, Löve and Löve, Packer and Johnson, Sokolovskaja, and Tolmatchev, who all have emphasized the importance of combined cytotaxonomical and phytogeographical studies of the problems of the arctic-alpine plants. Tolmatchev and Favarger have recently tried to use cytological data as a basis for distinguishing species of various age classes in arctic and alpine regions, and they and Packer and Johnson have laid a firm foundation for further studies of the history of the evolution and dispersal of species now met with both in the Arctic and in boreal mountains. Several studies by the present applicants and their students, mainly on arctic material and plants from eastern American mountains but also on selected groups from the Rocky Mountains (unpublished), have demonstrated beyond doubt that cytotaxonomical methods are not only useful in this kind of phytogeographical investigations, but indeed more useful for our understanding of the relationships and development of these floras than are any of the methods used by earlier phytogeographers.

We would like to stress that although studies of frequencies and dominant types of polyploids are important in investigations of the history of flora regions, such studies ought not to be overemphasized. It is more important in studies of floras like the arctic-alpine plants to investigate carefully the morphological and genetical relations of the isolated populations and the individual species and genera, and then pay attention even to the smallest differences which may occur within and between these populations. Although general studies of the frequency of certain phenomena within these floras have formed the basis for our present understanding of their possible history, special studies of selected groups are more likely to give us definite answers to some of the most crucial questions raised. Nevertheless, such special cases cannot easily be selected before certain general studies have been made, and so we are forced to spend considerable time to complete the general survey of the cytotaxonomy of these floras before we can concentrate on special cases. However, special groups are being selected from time to time whenever species or genera are found to be promising for detailed studies by aid of transplant and hybridization experiments.

We and other cytotaxonomists working with the arctic-alpine plants regard it as most important to get information about the chromosome number of all the species of this element as soon as possible, to secure the use of the biological species concept as a background for these general and special investigations on the history and origin of the flora as a whole. Thanks to several cytotaxonomists in many lands, much of this basic work has already been accomplished. The chromosome number is now known in more than eighty per cent of the species of the arctic and hemi-arctic zones, somewhat less in Asia, somewhat more in the Atlantic sector, and up to one hundred per cent in Iceland, which has been studied by us. The chromosome numbers of some Asiatic mountain plants have been thoroughly counted by Sokolovskaja and Strelkova, those of the plants of the Alps are being studied by Favarger and his group, and those of the plants of the Polish Tatra Mountains by Skalińska and her associates, continued under the guidance of our former associate , Pogan. Most other boreal mountain floras remain very insufficiently known. Some Japanese botanists, mainly Funabiki and our former students Kawano and Tateoka, have made pilot studies of the chromosome numbers of Japanese alpine plants, and our one-time associate, Packer, has made reasonably intensive studies of the chromosome numbers of plants from alpine situations in Alberta and Alaska. We and our associates in Montreal and Boulder have made certain introductory studies of the alpine floras of the Sierra Nevada complex in Spain, in the mountains of Gaspé, the Green Mountains of Vermont, and in the Alberta and Colorado Rockies, and completed an analysis of the cytotaxonomy of the entire flora of alpine plants on Mt. Washington in the White Mountains of New Hampshire. Contrary to some of the plants that we have already observed in the Colorado Rockies, the alpine flora of the White Mountains in the East seems to have dispersed southwards from the northlands at a relatively late date.

We have been working for some time on a cytotaxonomical review of the arctic flora, similar to the chromosome list which we published in 1961 for the flora of northwest and central Europe. This checklist will not only give complete listings of all the biological species and subspecies of the entire circumpolar arctic flora, with simple designations of their distribution as in our Scandinavian chromosome list from 1948, but also informations on synonymy, and references to all publications on chromosome numbers of the taxa listed with a critical evaluation when appropriate. This work is being done by aid of the modern retrieval methods of Dr. David J. Rogers of the Taximetrics Laboratory of the Department of Biology, in connection with the creation of a complete data bank on all plant chromosome numbers published. The arctic list certainly will be useful as a manual for other cytotaxonomists and phytogeographers, at the same time as it will be a gold mine for those who want to study various aspects of chromosome numbers and polyploidy and their connections with various phytogeographical phenomena.

No checklist has ever been made of the strictly alpine plants of the mountains in the boreal zone in either hemisphere. Since we have spent considerable time on studying the cytotaxonomy of such plants in western Eurasia and eastern North America before commencing our present work in western North America, we are composing such a list, in order to be able to add to it chromosome information in a way similar to that mentioned for the Arctic. We do not expect to be able to complete even a preliminary list for all the boreal alpine plants for several years to come, but are first trying to complete such lists for more limited parts of the area. We have published preliminarily on the cytotaxonomy of the alpine plants of Mt. Washington, N.H., and a book by Doris Löve reviewing the constitution of that flora and our background studies of its evolutionary history is in a completed manscript which still waits for support for publication. However, most of our work in the Rocky Mountains is still at a preliminary stage and only partially published.

It is our intention to use a small part of the support asked for in this proposal to work on these chromosome lists and the chromosome number bank, and to complete some of the studies which we have made in other areas and not yet published. Most of the support will, however, be used for intensive and detailed investigations of the arctic-alpine and montane plants of the southern Rocky Mountains and their evolutionary relationships as mirrored in their cytotaxonomy and genecology, since we believe that such studies are likely to help us to a better understanding not only of the history of this isolated flora, but also of the evolution and dispersal of the boreal arctic-alpine flora in general.

Our plans are to make cytotaxonomical studies of the alpine flora of the Rocky Mountains at large, because it is necessary for the general understanding of its problems to know the chromosome numbers of all the species and delimit them on basis of the biological species concept, before the results can be used for further discussions on their history as a whole. At the same time, we plan to put a somewhat stronger emphasis on endemics of the circumpolar and arctic-boreal-asiatic elements in the Rockies, since these two groups may be of special interest because of their supposed relative ancientness. But we are also selecting some special groups for genecological and detailed cytogenetical analysis because we realize the need for such studies of selected species which may lend themselves better than others for experimental work. When possible, these plants will also be studied intensely in specialized greenhouses and growth chambers so that their variability under certain conditions becomes somewhat better understood.

We have tried to mention some approaches to the problem of the origin and history of the arctic-alpine flora which we believe may help us to a better understanding of these important groups of plants. The importance of such studies for various problems of evolutionary biology is obvious. However, we are aware of the fact that in fundamental research on the outskirts of knowledge there are often no fixed subjects or rules, and the decisive advances will frequently be due to the disregard of conventional approaches. Nowhere is freedom more important than where ignorance is greatest and where nobody can predict what lies ahead. Everything is drifting, plants and continents no less than the transitory theories of science. Therefore, we realize that it may be necessary to change entirely the background for our working hypothesis when more knowledge has been collected in this field, though we believe that our cytotaxonomical and genecological approach will result in evidence that can be used also for confirmation of other ideas. It is our experience that only if the researcher feels free to depart from proposed lines of approach when he sees other more promising directions can he expect to reach conclusions more realistic than those any good prophet can ever foresee.

Short Bibliography of Pertinent Contributions

BEAMAN, J.H., DE JONG, D.C.D., and STOUTAMIRE, W.P., 1962: Chromosome studies in the alpine and subalpine floras of Mexico and Guatemala. Amer. Journ. Bot. 49, 41-50.

BELL, C.R., 1964: Incidence of polyploidy correlated with ecological gradients. Evolution 18, 510-512.

BLACKETT, P.M.S., BULLARD, E., and RUNCORN, S.K. (ed.), 1965: A symposium on continental drift. Roy Soc. London, Philos. Transact. 1088, 1-323.

BÖCHER, T.W., 1951: Distribution of plants in the circumpolar area in relation to ecological and historical factors. Journ. Ecol. 39, 376-395.

BÖCHER, T.W., 1960: Experimental and cytological studies on plant species. V. The *Campanula rotundifolia* complex. Dansk Vidensk. Selsk. Biol. Skr. 11 (4), 1-69.

BÖCHER, T.W. and LARSEN, K., 1950: Chromosome numbers of some arctic or boreal flowering plants. Medd. om Grönl. 147 (6), 1-32.

BULLARD, E., EVERETT, J.E., and SMITH, A.G., 1965: The fit of the continents around the Atlantic. Roy. Soc. London, Philos. Transact. 1088, 41-51.

CAIN, S.A., 1944: Foundations of plant geography. New York.

CAREY, S.W. (ed.), 1958: Continental drift, a symposium. Hobart.

CLAUSEN, J., 1951: Stages in the evolution of plant species. Ithaca.

CLAUSEN, J., KECK, D.D., and HIESEY, W.M., 1940: Experimental studies on the nature of species. I. Effect of varied environments on western North American plants. Carnegie Inst. Wash. Publ. 520, 1-452.

CLAUSEN, J., KECK, D.D., and HIESEY, W.M., 1945: Experimental studies on the nature of species. II. Plant evolution through amphiploidy and autoploidy, with examples from the *Madiinae*. Carnegie Inst. Wash. Publ. 564, 1-174.

CLAUSEN, J., KECK, D.D., and HIESEY, W.M., 1948: Experimental studies on the nature of species. III. Environmental responses of climatic races of *Achillea*. Carnegie Inst. Wash. Publ. 581, 1-129.

CLAUSEN, J. and HIESEY, W.M., 1958: Experimental studies on the nature of species. IV. Genetic structure of ecological races. Carnegie Inst. Wash. Publ. 615, 1-312.

CLELAND, R.E., 1954: Evolution of the North American Euoenotheras: the strigosas. Proc. Amer. Philos. Soc. 98, 189-203.

DAHL, E., 1946: On different types of unglaciated areas during the Ice Ages and their significance to phytogeography. New Phytol. 45, 225-242.

EINARSSON, T., 1964: On the question of late-Tertiary or Quaternary land connection across the North Atlantic, and the dispersal of biota in that area. Journ. Ecol. 52, 617-626.

FAVARGER, C., 1961: Sur l'emploi des nombres de chromosomes en géographie botanique historique. Ber. Geobot. Inst. Rubel. 32, 119-146.

FAVARGER, C., 1964a: Cytotaxinomie et endémisme. C. r. Soc. Biogéogr. 357, 23-44.

FAVARGER, C., 1964b: Die zytotaxonomische Erforschung der Alpenflora. Ber. Deutsch. Bot. Ges. 77, 73-83.

FAVARGER, C. and CONTANDRIOPOULOS, J., 1961: Essai sur l'endémisme. Ber. Schweiz. Bot. Ges. 71, 384-408.

FERNALD, M.L., 1924: Isolation and endemism in northeastern America and their relation to the age and area hypothesis. Amer. Journ. Bot. 11, 558-572.

FERNALD, M.L., 1925: Persistence of plants in unglaciated areas of boreal America. Amer. Acad. Arts and Sci. Mem. 15, 241-342.

FERNALD, M.L., 1926: The antiquity and dispersal of vascular plants. Quart. Rev. Biol. 1, 212-245.

FITCH, F.J., 1965: The structural unity of the reconstructed North Atlantic continent. Roy. Soc. London, Philos. Transact. 1088, 191-193.

FLOVIK, K., 1940: Chromosome numbers and polyploidy within the flora of Spitzbergen. Hereditas 26, 430-440.

FUNABIKI, K., 1960: Polyploidy in relation to vegetational zonation in the western United States. Bull. Fac. Agric. Niigata Univ. 12, 176-200.

FUNABIKI, K., 1964: On the relationship between frequency of polyploid species and latitude and warmth index. La Kromosomo 57-59, 1876-1882.

FUNABIKI, K., 1967: A study on the relationship between vegetation zones and chromosome features of flora along the Japanese islands. Mem. Fac. Agric. Niigata Univ. 6, 1-203.

HANELT, P., 1966: Polyploidie-Frequenz und geographische Verbreitung bei höheren Pflanzen. Biol. Rundschau 4, 183-196.

HEDBERG, O., 1967: Chromosome numbers of vascular plants from arctic and subarctic North America. Arkiv. of Botanik, N.S. 6, 309-326.

HIITONEN, I., 1950: Über die gemeinsamen Züge der Floren von Nordamerika und Fennoskandien. Mem. Soc. Fauna et Flora Fenn. 25, 72-86.

HÖEG, O.A., 1946: The present and past vegetation of Spitsbergen. Proc. Linn. Soc. London 166, 144-149.

HOLMEN, K., 1952: Cytological studies in the flora of Peary Land, North Greenland. Medd. om Gronl. 128 (5), 1-40.

HOLMEN, K., 1962: Chromosome studies in some arctic Alaskan Leguminosae. Bot. Not. 115, 87-92.

HOLMEN, K., 1964: Cytotaxonomical studies in the arctic Alaskan flora. The genus Festuca. Bot. Not. 117, 109-118.

HOOKER, J.D., 1862: Outlines of the distribution of arctic plants. Transact. Linn. Soc. London 23, 251-348.

HOOKER, J.D., 1881: On geographical distribution. Rep. Brit. Assoc. 1881, 727-738.

HULTÉN, E., 1937: Outline of the history of arctic and boreal biota during the Quaternary period. Stockholm.

HULTÉN, E., 1955: The isolation of the Scandinavian mountain flora. Acta Soc. Fauna et Flora Fenn. 72 (8), 1-22.

HULTÉN, E., 1958: The amphi-atlantic plants and their phytogeographical connections. Kgl. Svenska Vetensk. Akad. Handl. Ser. IV 7 (1), 1-340.

HULTÉN, E., 1962: The circumpolar plants. I. Vascular cryptograms, conifers, monocotyledons. Kgl. Svenska Vetensk. Akad. Handl. Ser. IV 8 (5), 1-275.

HULTÉN, E., 1968: Flora of Alaska and neighboring territories. Stanford.

JOHNSON, A.W.and PACKER, J.G., 1965: Polyploidy and environment in arctic Alaska. Science 148, 237-239.

JOHNSON, A.W. and PACKER, J.G., 1968: Chromosome numbers in the flora of Ogotoruk Creek, N.W. Alaska. Bot. Not. 121, 403-456.

JOHNSON, A.W., PACKER, J.G., and REESE, G., 1965: Polyploidy, distribution, and environment. The Quaternary of the United States, 497-507.

JÖRGENSEN, C.A., SÖRENSEN, T., and WESTERGAARD, M., 1958: The flowering plants of Greenland. A taxonomical and cytological survey. Dansk Vidensk. Selsk. Biol. Skr. 9 (4), 1-172.

KNABEN, G., 1961: Cyto-ecologic problems in Norwegian flora groups. Distribution and significance of polyploidy. Hereditas 47, 451-479.

KNABEN, G. and ENGELSKJÖN, T., 1967: Chromosome numbers of Scandinavian arctic-alpine plant species. II. Acta Borealia A. Scientia 21, 1-57.

LAANE, M., 1966: Chromosome numbers in the flora of Finnmark. I. Blyttia 24, 270-276.

LAANE, M., 1967: Chromosome numbers in the flora of Finnmark. II. Blyttia 25, 45-54.

LÖVE, A., 1953: Subarctic polyploidy. Hereditas 39, 113-124.

LÖVE, A., 1954: Cytotaxonomical evaluation of corresponding taxa. Vegetatio 5 (6), 212-224.

LÖVE, A., 1955: Biosystematic remarks of vicariism. Acta Soc. Fauna et Flora Fenn. 72 (15), 1-14.

LÖVE, A., 1959: Origin of the arctic flora. Publ. McGill Univ. Museum 1, 82-95.

LÖVE, A., 1964: The biological species concept and its evolutionary structure. Taxon 13, 33-45.

LÖVE, A., 1967: The evolutionary significance of disjunctions. Taxon 16, 324-333.

LÖVE, A. and LÖVE, D., 1942: Chromosome numbers of Scandinavian plant species. Bot. Notiser 1942, 19-59.

LÖVE, A. and LÖVE, D., 1948: Chromosome numbers of Northern plant species. Icel. Univ. Inst. Appl. Sci. Dept. Agric. Rep. B 3, 1-131.

LÖVE, A. and LÖVE, D., 1949: The geobotanical significance of polyploidy. I. Polyploidy and latitude. Portug. Acta Biol. (B), R.B. Goldschmidt, Jub. Vol., 273-352.

LÖVE, A. and LÖVE, D., 1956: Cytotaxonomical conspectus of the Icelandic flora. Acta Horti. Gotob. 20, 65-291.

LÖVE, A. and LÖVE, D., 1957: Arctic polyploidy. Proc. Genet. Soc. Canada 2, 23-27.

LÖVE, A. and LÖVE, D., 1961: Chromosome numbers of central and northwest European plant species. Opera Botanica 5, 1-581.

LÖVE, A. and LÖVE, D. (ed.), 1963: North Atlantic Biota and their History. Oxford.

LÖVE, A. and LÖVE, D., 1966: Cytotaxonomy of the alpine vascular plants of Mt. Washington. Univ. of Colo. Studies, Series in Biol. 24, 1-74.

LÖVE, A. and LÖVE, D., 1967: Polyploidy and altitude: Mt. Washington. Biol. Zentralbl. 86, Beiheft, 307-312.

LÖVE, A. and LÖVE, D., 1967: Biosystematics of widely disjunctive taxa. Naturwiss. 54, 24-25.

LÖVE, A. and LÖVE, D., 1967: Continental drift and the origin of the arctic-alpine flora. Rev. Roum. Biol., Ser. Bot. 12, 163-169.

LÖVE, A. and LÖVE, D., 1967: Evolution and the Linnaean species. Univ. Babes Bolayi din Cluj, Grăd. Bot., Contrib. Bot. 1967, 203-210.

LÖVE, A. and LÖVE, D., 1967: The origin of the North Atlantic flora. Aquilo, Ser. Bot. 6, 52-66.

LÖVE, A. and LÖVE, D., 1968: The diploid perennial *Anthoxanthum*. Science in Iceland 1968, 26-30.

LÖVE, D., 1962: Plants and Pleistocene. Publ. McGill Univ. Museum 2, 17-39.

LÖVE, D. and BOSÇAIU, N., 1966: Vaccinium gaultherioides Bigel., an arctic-alpine species. Rev. Roum. Biol., Ser. Bot. 11, 295-305.

MAYR, E., 1963: Animal species and evolution. Cambridge, Mass.

MOSQUIN, T. and HAYLEY, D., 1966: Chromosome numbers and taxonomy of some Canadian arctic plants. Canad. Journ. Bot. 44, 1209-1218.

PACKER, J.G., 1964: Chromosome numbers of taxonomic notes of western Canadian and arctic plants. Canad. Journ. Bot. 42, 473-494.

RAUP, H.M., 1941: Botanical problems in boreal America. Bot. Rev. 7, 147-248.

REESE, G., 1958: Polyploidie und Verbreitung. Zeitschr. f. Bot. 46, 339-354.

REESE, G., 1961: Geobotanische Bedeutung der Chromosomenzahl und Chromosomenstruktur. Naturwiss. Rundschau 14, 140-145.

ROUSSEAU, J., 1952: Les zones biologiques de la péninsule Québec-Labrador, et l'hémiarctique. Canad. Journ. Bot. 30, 436-474.

SKALIŃSKA, M., 1963: Cytological studies in the flora of the Tatra Mts. A synthetic review. Acta Biol. Cracov., Ser. Bot. 6, 203-233.

SOKOLOVSKAJA, A.P., 1955: Velichina pyl'tscvych zeren i chisla khromosom u nekotorych arkticheskich vidov zlakov. Bot. Zhurn. 40, 850-853.

SOKOLOVSKAJA, A.P., 1960a: Chisla khromosom u predstaviteley sakhalinskovo krupnotpav'ya. Vestnik Leningr. Univ., Ser. Biol. 2 (9), 135-137.

SOKOLOVSKAJA, A.P., 1960b: Geograficheskoye rasprostraneny poliploidnich vidov rasteny (issledovanie flory o. Sakhalina). Vestnik Leningr. Univ., Ser. Biol. 15 (3), 133-138.

SOKOLOVSKAJA, A.P., 1963: Geograficheskoye rasprostranenie poliploidnykh vidov rasteniy (issledovanie flory poluostrova Kamchatki). Vestnik Leningr. Univ., Ser. Biol., 1963 15, 38-52.

SOKOLOVSKAJA, A.P., 1966: Geograficheskoye rasprostranenie poliploidnykh vidov rasteniy (issledovanie flory Primoreskiy). Vestnik Leningr. Univ., Ser. Biol. 1966 (3), 92-106.

SOKOLOVSKAJA, A.P. and STRELKOVA, O.S., 1938: Polyploidy of the high mountain regions of Pamir and Altai. Doklady Akad. Nauk SSSR, N.S. 21, 68-71.

SOKOLOVSKAJA, A.P. and STRELKOVA, O.S., 1940: Karyological investigations of the alpine flora on the main Caucasus range and the problems of geographical distribution of polyploids. Doklady Akad. Nauk, SSSR, N.S. 29, 415-418.

SOKOLOVSKAJA, A.P. and STRELKOVA, O.S., 1941: Polyploidy and karyological races under conditions in the Arctic. Doklady Akad. Nauk, SSSR, N.S. 32, 144-147.

SOKOLOVSKAJA, A.P. and STRELKOVA, O.S., 1960: Geograficheskoye rasprostranie poliploidnich vidov rasteniy v evrasiatskoy arktike. Bot. Zhurn. 45, 369-381.

SOKOLOVSKAJA, A.P. and STRELKOVA, O.S., 1962: O zakonomernostaykh geografich rasprostraneniya poliploidnykh vĭdov rasteny. Transact. Moscow Soc. Natural. 5, 83-89.

STEBBINS, G.L., 1942a: The genetic approach to problems of rare and endemic species. Madroño 6, 241-258.

STEBBINS, G.L., 1942b: Polyploid complexes in relation to ecology and the history of floras. Amer. Natural. 76, 36-45.

STEBBINS, G.L., 1950: Variation and evolution in plants. New York.

STEBBINS, G.L., 1954: Les processus de l'évolution aux hautes montagnes. Étude Botanique de l'Étage Alpin, particulierement en France, 135-140.

STEBBINS, G.L. and MAJOR, J., 1965: Endemism and speciation in the California flora. Ecol. Monogr. 35, 1-35.

TOIT, A.L. du, 1937: Our wandering continents. Edinburgh.

TAYLOR, R.L. and MULLIGAN, G.A., 1968: Flora of the Queen Charlotte Islands. Part 2. Cytological aspects of the vascular plants. Ottawa.

TOLMATCHEV, A.I., 1960a: Der autochtone Grundstock der arktischen Flora und ihre Beziehungen zu den Hochgebirgsfloren Nord- und Zentralasiens. Bot. Tidsskr. 55, 269-276.

TOLMATCHEV, A.I., 1960b: O proiskhozndenii arkticheskoy flory. Voprosy Botaniki 5, 72-74.

TOLMATCHEV, A.I., 1966: Die Evolution der Pflanzen in arktisch-Eurasien während und nach der quaternären Vereisung. Bot. Tidsskr. 62, 27-36.

TOLMATCHEV, A.I., 1966: Progressive Erscheinungen und Konservatismus in der Entwicklung der arktischen Flora. Acta Bot. Acad. Sci. Hung. 12, 175-197.

TURESSON, G., 1922: The genotypic response of the plant species to the habitat. Hereditas 3, 211-350.

TURESSON, G., 1925: The plant species in relation to habitat and climate. Hereditas 9, 81-101.

TURESSON, G., 1931: The selective effect of climate upon plant species. Hereditas 15, 99-152.

WEGENER, A., 1915: Die Entstehung der Kontinente. Braunschweig.

WIENS, D. and HALLECK, D.K., 1962: Chromosome numbers in Rocky Mountain plants. I. Bot. Not. 115, 455-464.

WULFF, E.V., 1943: An introduction to historical plant geography. Waltham, Mass.

WULFF, E.V., 1944: Istoricheskaya gegrafija rasteniy. Moskva, Leningrad.

WYNNE-EDWARDS, V.C., 1939: Some factors in the isolation of rare alpine plants. Transact. Roy. Soc. Canada, Ser. 3, 33 (5), 35-42.

ZHUKOVA, P.G., 1965: Kariologicheskaya kharakteristika nekotorykh rasteniy Chukotskogo poluostrova. Bot. Zhurn. 50, 1001-1004.

ZHUKOVA, P.G., 1965: Kariologicheskaya kharakteristika nekotorykh vidov rasteniy ostrova Vrangelja. Bot. Zhurn. 50, 1320-1322.

ZHUKOVA, P.G., 1966: Chisla khromosom u nekotorykh vidov rasteniy severo-vostoka SSSR. Bot. Zhurn. 51, 1511-1516.

ZHUKOVA, P.G., 1967: Chisla khromosom u nekotorykh vidov rasteniy severo-vostoka SSSR. II. Bot. Zhurn. 52, 983-987.

ZHUKOVA, P.G., 1968: Chisla khromosom u nekotorykh vidov rasteniy serveo-vostoka SSSR. III. Bot. Zhurn. 53, 365-368.

Summarized Outline of the Planned Work

We propose that during the next two years the following ought to be done, provided that adequate support will be forthcoming and time is sufficient:

1. Continuation of the determination of the chromosome number of as many species as possible from various regions with alpine floras in Colorado. Fixations are made in nature or from potted plants, and careful records are kept from each locality. Voucher specimens of fixed and studied material are kept, and also collections of representative samples to show the possible variability of each species for more detailed biometric studies, when necessary.

2. Living material for special studies in the experimental garden and the transplant gardens is being selected. Efforts are being made to find representative samples of diploid and polyploid species which are plastic, rigid, or intermediate, from ecologically and geographically somewhat different localities. It is not expected that the long-time garden experiments will be completely laid out during this time, since it has been found to be difficult to select the most appropriate material for such studies.

3. A few species are being selected for detailed experimental and cytogenetical analysis. These southern populations are contrasted to and will later be crossed with their more northern and arctic relatives, insofar as both can be kept alive under the conditions available at Boulder and in our mountains.

4. Observations are being made on reproductive mechanisms and dispersal mechanisms of the alpine plants, for later experimental investigations.

5. During the entire study, efforts will be made to contrast the results obtained with any of the three main working hypotheses, and also with results of other workers published during the investigations.

6. The data bank of chromosome numbers will be completed as to previous reports, and then constantly supplemented with newly published or counted numbers. In connection with and on basis of the bank, work will continue on various phytogeographical studies of the significance of polyploidy and its frequency. The chromosome checklist of the arctic flora will be completed as soon as possible, and work commence on a chromosome list of the Rocky Mountain flora and, if possible, on other alpine floras of arctic relationship.

Report of Research Supported by GB-3371 and GB-6299

The work on the cytotaxonomy of the arctic-alpine flora has been carried out by the applicants for a number of years. The following papers, printed or accepted for publication, have been completed with partial or complete support from GB-3371 and GB-6299.

1. LÖVE, A. and LÖVE, D., 1965: Taxonomic remarks on some American alpine plants. University of Colorado Studies, Series in Biology 17, 1-43.

2. LÖVE, A. and RITCHIE, J.C., 1966: Chromosome numbers from central northern Canada. Canadian Journal of Botany 44, 429-439.

3. LÖVE, A. and LÖVE, D., 1966: Cytotaxonomy of the alpine vascular plants of Mount Washington. University of Colorado Studies, Series in Biology 24, 1-74.

4. LÖVE, D. and BOŞCAIU, N., 1966: Vaccinium gaultherioides Bigel. - an arctic-alpine species. Revue Roumaine de Biologie, Serie Botanique 11, 295-305.

5. LÖVE, A. and KAPOOR, B.M., 1966: An alloploid Ophioglossum. Nucleus 9, 132-138.

6. LÖVE, A. and LÖVE, D., 1966: The variations of Blechnum Spicant. Botanisk Tidsskrift 62, 186-189.

7. LÖVE, A. and LÖVE, D., 1966: Islenzki dilaburknínn (Dryopteris assimilis, S. Walker in Iceland). Flóra, Journal of Icelandic Botany 4, 5-9.

8. LÖVE, A. and LÖVE, D., 1967: Biosystematics of widely disjunctive taxa. Die Naturwissenschaften 54, 24-25.

9. LÖVE, A. and KAPOOR, B.M., 1967: The highest plant chromosome number in Europe. Svensk Botanisk Tidsskrift 61, 29-32.

10. LÖVE, A. and LÖVE, D., 1967: Polyploidy and altitude: Mt. Washington. Biologisches Zentralblatt 86, Beiheft, 307-312.

11. LÖVE, A., 1967: The evolutionary significance of disjunctions. Taxon 16, 324-333.

12. LÖVE, A. and LÖVE, D., 1967: Continental drift and the origin of the arctic-alpine flora. Revue Roumaine de Biologie, Serie Botanique 12, 163-169.

13. LÖVE, A. and LÖVE, D., 1967: New combinations in Carpogymnia. Taxon 17, 191-192.

14. LÖVE, A. and LÖVE, D., 1967: Evolution and the Linnaean species. Univ. Babes Bolayi din Cluj, Grǎd. Bot., Contrib. Bot. 1967, 203-210.

15. LÖVE, D., 1968: Some nomenclatural notes on Mt. Washington plants. Taxon 17, 89.

16. LÖVE, A. and LÖVE, D., 1967: The origin of the North Atlantic flora. Aquilo, Ser. Bot. 6, 52-66.

17. LÖVE, A. and LÖVE, D., 1968: Cytotaxonomy of Blechnum Spicant. Collectanea Botanica 7, 665-676.

18. LÖVE, A. and SIMON, W., 1968: Cytotaxonomical notes on some American orchids. Southwestern Naturalist 13, 335-342.

19. SIMON, W., 1968: Chromosome numbers and B-chromosome in Listera. Caryologia 21, 181-189.

20. LÖVE, A. and LÖVE, D., 1968: The diploid perennial Anthoxanthum. Science in Iceland 1968, 26-30.

21. LÖVE, D., 1969: Papaver at high altitudes in the Rocky Mountains. Brittonia (in press).

22. LÖVE, A. and LÖVE, D., 1969: Remarks on the cytotaxonomy of Mediterranean plants (in press: Flora Europaea Symposium).

23. LÖVE, D., 1969: Mount Washington and its alpine flora. Manuscript of about 600 pages accepted for publication and waiting for a subsidy.

The results from studies of several other groups, by the applicants and several graduate students and associates, are nearing completion, and will result in several papers which will soon be submitted for publication. In addition, Doris Löve has completed a 600 page manuscript of a large book on the history and evolution of the vegetation and flora of Mt. Washington in which she reviews our present knowledge not only of the biota of the mountain but also of the environmental conditions which have led to the present state of this vegetation. It is hoped that this work will receive publication support through this project this year, since it is a unique contribution to the history of alpine floras based on detailed cytotaxonomical investigations that were carried out for almost a decade.

The following personnel have participated in the work on the cytotaxonomy of the arctic-alpine flora in Boulder for longer or shorter periods, with or without support from the NSF funds:

Askell Löve, Doris Löve, Brij M. Kapoor, M. Bowers, Aparna Mukherjee, S. Patil, W. Simon, Virginia Evenson, Mary Gillio, Lee Snyder, Sandy Shellworth-Hildner, Tom Defler, Camille Rousseau, Pierre Vaillancourt, and Ole Kaersvarg. Also, F. Susnik, an exchange scholar (1968) from Liubljana in Yugoslavia, J.P. Packer, on sabbatical leave (1967-68) from the University of Alberta in Canada, and John Rattenbury, on sabbatical leave (1968-69) from the University of Auckland, New Zealand, have assisted with the solution of several problems.

Facilities

Good laboratory facilities for cytotaxonomical work have been built up at the Department of Biology during the past few years. We also have adequate garden space close to the building, whereas greenhouse facilities for alpine plants are very limited as they are shared with plant physiologists who cannot easily give away the much too small space they have for their own research and teaching. No greenhouses made specially for growing alpine and arctic plants are available in Boulder, and growth chambers for such research are also missing. Such facilities are not included in this project. Adequate library facilities are available in the University Library, complemented by the substantial personal library of the co-principal investigators.

We have put into order the transplant gardens which the Institute of Arctic and Alpine Research has long had in various localities on the way up to the summit of the Niwot Ridge on the Continental Divide, and we will share their use with the plant physiologists of the department. We have also been able to use other facilities at the Mountain Research Station of the Institute for Arctic and Alpine Research for ourselves and our students.

BIOGRAPHICAL SKETCHES AND BIBLIOGRAPHIES

LÖVE, Askell

Born: 20 October 1916

Position: Professor and Chairman, Department of Biology, University of Colorado

Education:

B.A., Reykjavik College, 1937
M.S., Cytogenetics, Botany, Zoology, University of Lund, Sweden, 1941
Ph.D., Cytogenetics, Botany, University of Lund, Sweden, 1942
D.Sc., Cytogenetics, University of Lund, Sweden, 1943

Employment Record:

Research Associate, Institute of Genetics, University of Lund, 1942-45
Research Worker (on leave), University of Iceland Research Institute, Reykjavik, 1942-45
Director, Institute of Botany and Genetics, University of Iceland Research Institute, Reykjavik, 1945-51
Associate Professor of Botany, University of Manitoba, Winnipeg, 1951-56
Research Professor of Biosystematics, Institut Botanique, Université de Montréal, 1956-63
Associate Professor, Department of Biology, University of Colorado, 1964-66
Professor and Chairman, Department of Biology, University of Colorado, 1966-

Fellowships and Professional Honors:

Fellow, Icelandic Academy of Learning since 1946; corresponding member since 1951
Permanent member of the Board of the International Association of Plant Geographers since 1953
Rapporteur and Vice President, Section of Cytology, VIIIth International Botanical Congress, Paris, 1954
Member, International Committee for Genetical Nomenclature and Symbolization (I.U.B.S.), 1956-58
Member of the Editorial Board of the journal Nucleus since 1958
Technical Consultant on Cytotaxonomy for Flora Europaea since 1955
President, International Organization of Biosystematists, 1960-64
Honorary Foreign Member, Swedish Phytogeographical Society since 1960
President, Symposium on North Atlantic Biota and their History, Reykjavik, July 1962
Vice President, International Committee on Chemotaxonomy, 1964-
John Simon Guggenheim Memorial Fellow, 1963-64
Honorary Foreign Member, Czechoslovak Botanical Society since 1968

Selected Publications, Relevant to the Proposed Project:

Cytogenetic studies in Rumex. Botaniska Notiser, 157-169 (1940).

Études cytogénétiques des Rumex. II. Polyploidie geographique-systématique du Rumex subgenus Acetosella. Botaniska Notiser, 155-172 (1941).

Polyploidy in Polygonum Convolvulus L. s. lat. Hereditas 28, 227-228 (1942).

Cytotaxonomic studies on boreal plants. I. Some observations on Swedish and Icelandic plants. Kungliga Fysiografiska Sallskapets i Lund Forhandlingar 12 (6), 1-19 (1942), with D. Löve.

Chromosome numbers of Scandinavian plant species. Botaniska Notiser, 19-59 (1942), with D. Löve.

Cytogenetic studies in Rumex. III. Some notes on the Scandinavian species of the genus. Hereditas 28, 289-296 (1942).

Different chromosome numbers within the collective species Carex polygama. Hereditas 28, 495-496 (1942), with A. Levan.

The significance of differences in distribution of diploids and polyploids. Hereditas 29, 145-163 (1943), with D. Löve.

Cytogenetic studies on Rumex subgenus Acetosella. Hereditas 30, 1-136 (1943).

The dioecious forms of Rumex subgenus Acetosa in Scandinavia. Botaniska Notiser, 237-254 (1944).

Cytotaxonomical studies on boreal plants. II. Some notes on the chromosome numbers of Juncaceae. Arkiv for Botanik 31B (1), 1-6 (1944), with D. Löve.

Cytotaxonomical studies on boreal plants. III. Some new chromosome numbers of Scandinavian plants. Arkiv for Botanik 31A (12), 1-22 (1944), with D. Löve.

A new triploid Betula verrucosa. Svensk Botanisk Tidsskrift 38, 381-393 (1944).

Islenzkar jurtir (Icelandic flora). E. Munksgaard, Copenhagen 1945, pp. 281.

Studies on the origin of the Icelandic flora. I. Cyto-ecological investigations on Cakile. Iceland University Institution of Applied Sciences, Department of Agriculture, Reports B2, 1-29 (1947), with D. Löve.

Chromosome numbers of Northern plant species. Iceland University Institution of Applied Sciences, Department of Agriculture, Reports B3, 1-131 (1948), with D. Löve.

The geobotanical significance of polyploidy. I. Polyploidy and latitude. Portugaliae Acta Biologica (B), R.B. Goldschmidt Jubilee Volume, 273-352 (1949), with D. Löve.

Some innovations and nomenclatural suggestions in the Icelandic flora. Botaniska Notiser, 24-60 (1950).

Taxonomical evaluation of polyploids. Caryologia 3, 263-284 (1951).

Studies on the origin of the Icelandic flora. II. Saxifragaceae. Svensk Botanisk Tidsskrift 45, 368-399 (1951), with D. Löve.

The Icelandic type of Glyceria fluitans. Botaniska Notiser 1951, 229-240 (1951).

Preparatory studies for breeding Icelandic Poa irrigata. Hereditas 38, 11-32 (1952).

The geobotanical significance of polyploidy. Proceedings of the VIth International Grassland Congress, State College, Pennsylvania, 1952, 240-246 (1953), with D. Löve.

Subarctic polyploidy. Hereditas 39, 113-124 (1953).

Studies on Bryoxiphium. Bryologist 56, 73-94, 183-203 (1953), with D. Löve.

Cytotaxonomical remarks on some American species of circumpolar taxa. Svensk Botanisk Tidsskrift 48, 211-232 (1954).

Cytotaxonomical studies on the northern bedstraw. American Midland Naturalist 52, 88-105 (1954), with D. Löve.

Cytotaxonomical evaluation of corresponding taxa. Vegetatio 5 (6), 212-224 (1954).

The foundations of cytotaxonomy. VIIIe Congrès International de Botanique Paris, 1954, Rapports et Communications, Sec. 9-10, 59-66 (1954).

Cytotaxonomical notes on the Icelandic Papaver. Nytt Magasin for Botanikk 4, 5-18 (1955).

Biosystematic remarks on vicariism. Acta Soc. Vanamo 72 (15), 1-14 (1955).

Cytotaxonomical conspectus of the Icelandic flora. Acta Horti Gotoburgensis 20, 65-291 (1956), with D. Löve.

Chromosomes and taxonomy of eastern North American Polygonum. Canadian Journal of Botany 34, 501-521 (1956), with D. Löve.

Chromosomes and relationships of Koenigia islandica. Canadian Journal of Botany 35, 507-514 (1957), with P. Sarkar.

Cytotaxonomy of Carex section Capillares. Canadian Journal of Botany 35, 715-761 (1957), with D. Löve and M. Raymond.

Drug content and polyploidy in Acorus. Proceedings of the Genetics Society of Canada 2, 14-17 (1957), with D. Löve.

Arctic polyploidy. Proceedings of the Genetics Society of Canada 2, 23-27 (1957), with D. Löve.

Taxonomic and biosystematic categories. Brittonia 10, 153-166 (1958), with D.H. Valentine.

The American element in the flora of the British isles. Botaniska Notiser 111, 376-388 (1958), with D. Löve.

An unusual polyploid series in Triglochin maritimum agg. Proceedings of the Genetics Society of Canada, 3, 2, 19-21 (1958), with D. Löve.

Cytotaxonomy and classification of Lycopods. Nucleus 1, 1-10 (1958), with D. Löve.

Biosystematics of Triglochin maritimum agg. Naturaliste Canadien 85, 156-165 (1958), with D. Löve.

The origin of the Arctic flora. Problems of the Pleistocene and Arctic. Publications of the McGill University Museum 1, 82-95 (1959).

Cytotaxonomy of Cerastium holosteoides. Phyton 8, 38-42 (1959), with M.S. Chennaveeraiah.

Biosystematics of the black crowberries in America. Canadian Journal of Genetics and Cytology 1, 34-38 (1959), with D. Löve.

Biosystematics and the processes of speciation. In: "Evolution: its science and doctrine," Royal Society of Canada, Studia Varia 4, 115-122 (1960).

Biosystematics and classification of apomicts. Feddes Repertorium 62, 136-148 (1960).

Taxonomy and chromosomes - a reiteration. Feddes Repertorium 62, 192-202 (1960).

Some nomenclatural changes in the European flora. I. Species and supra-specific categories. Botaniska Notiser 114, 33-47 (1961), with D. Löve.

Some nomenclatural changes in the European flora. II. Subspecific categories. Botaniska Notiser 114, 48-56 (1961), with D. Löve.

Some chromosome numbers of Icelandic ferns and fern-allies. American Fern Journal 51, 127-128 (1961), with D. Löve.

Some notes on Myriophyllum exalbescens. Rhodora 63, 139-145 (1961).

Chromosome numbers of Central and Northwest European plant species. Opera Botanica 5, I-VIII, 1-581 (1961), with D. Löve.

Hylandra, a new genus of Cruciferae. Svensk Botanisk Tidsskrift 55, 211-217 (1961).

A note on amphi-pacific Lysichitum. Journal of Japanese Botany 36, 359-361 (1961), with S. Kawano.

The biosystematic species concept. Preslia 34, 127-139 (1962).

Typification of Papaver radicatum - a nomenclatural detective story. Botaniska Notiser 115, 113-136 (1962).

Cytotaxonomy of the Isoetës echinospora complex. American Fern Journal 52, 113-123 (1962).

Cytotaxonomy and generic delimitation. Regnum Vegetabile 27, 45-51 (1963).

Biosystematische Analyse der Elytrigia Junceae Gruppe. Die Kulturpflanze, Beiheft 3, 74-85 (1962).

North Atlantic Biota and Their History. Pergamon Press, Oxford (1963), editor together with D. Löve.

Chromosome numbers of some Carex species from Spain. Botaniska Notiser 116, 241-248 (1963), with E. Kjellqvist.

Chromosome numbers of some Iberian Cistaceae. Portugaliae Acta Biologica (A) 8, 69-80 (1964), with E. Kjellqvist.

The biological species concept and its evolutionary structure. Taxon 13, 33-45 (1964).

The evolutionary framework of the biological species concept. Genetics Today II, 409-414 (1965).

The North Atlantic flora - its history and late evolution. Tenth International Botanical Congress (1964), Abstracts, 139-140 (1965), with D. Löve.

Taxonomic remarks on some American alpine plants. University of Colorado Studies, Series in Biology 17, 1-43 (1965), with D. Löve.

Chromosome numbers from central northern Canada. Canadian Journal of Botany 44, 429-439 (1966), with J.C. Ritchie.

Cytotaxonomy of the alpine vascular plants of Mount Washington. University of Colorado Studies, Series in Biology 24, 1-74 (1966), with D. Löve.

An alloploid Ophioglossum. Nucleus 9, 132-138 (1966), with B.M. Kapoor.

The variations of Blechnum Spicant. Botanisk Tidsskrift 62, 186-196 (1966), with D. Löve.

Íslenski dílaburkninn (Dryopteris assimilis S. Walker in Iceland). Flóra, Journal of Icelandic Botany 4, 5-9 (1966), with D. Löve.

Biosystematics of widely disjunctive taxa. Die Naturwissenschaften 54, 24-25 (1967), with D. Löve.

The highest plant chromosome number in Europe. Svensk Botanisk Tidsskrift 61, 29-32 (1967), with B.M. Kapoor.

Polyploidy and altitude: Mt. Washington. Biologisches Zentralblatt 86, Beiheft, 307-312 (1967), with D. Löve.

The evolutionary significance of disjunctions. Taxon 16, 324-333, 1967.

Continental drift and the origin of the arctic-alpine flora. Revue Roumaine de Biologie, Série Botanique 12, 163-169 (1967), with D. Löve.

Evolution and the Linaean species. Univ. Babes Bolayi din Cnuj. Grǎd. Bot. Contrib. Bot. 1967, 203-210 (1967), with D. Löve.

The origin of the North Atlantic flora. Aquilo. Ser. Bot. 6, 52-66 (1967), with D. Löve.

Cytotaxonomy of Blechnum Spicant. Collectanea Botanica 7, 665-676 (1968), with D. Löve.

The diploid perennial Anthoxanthum. Science in Iceland 1968, 26-30 (1968), with D. Löve.

Cytotaxonomical notes on some American orchids. Southw. Natural. 13, 335-342 (1968), with W. Simon.

LÖVE, Doris

Born: 2 January 1918

Position: Faculty Research Associate, Department of Biology, University of Colorado

Education:

B.S., Kristianstad College, Sweden, 1937
M.S., Cytogenetics, Botany, Geography, University of Lund, Sweden, 1941
Ph.D., Cytogenetics, Botany, University of Lund, Sweden, 1943
D.Sc., Cytogenetics, University of Lund, Sweden, 1944

Employment Record:

Instructor (amanuensis), Institute of Genetics, University of Lund, 1940-43
Research Associate, Institute of Genetics, University of Lund, 1943-45
Geneticist, University of Iceland Research Institute, Reykjavik, 1945-51
Herbarium Curator, University of Manitoba, Winnipeg, Canada, 1951-56
Associate Professor (research), Institut Botanique, Université de Montréal, Canada, 1956-63
Faculty Research Associate, Department of Biology, Institute of Arctic and Alpine Research, and University Museum, University of Colorado, 1964-

Fellowships and Professional Honors:

Fellow, Mendelian Society of Lund, Sweden since 1941
Several research scholarships and awards from the Royal Physiographic Society of Lund, Lund Botanical Society, and the Swedish Academy of Sciences, 1941-45
Research Fellowship from the Icelandic Cultural Fund, 1945-50
British Council invitation to visit British institutions in genetics and plant breeding, Summer 1949
Research grants from the National Research Council of Canada, 1956-64, and the National Science Foundation, 1967

Selected Publications, Relevant to the Proposed Project:

Some contributions to the cytology of Silenoideae. Svensk Botanisk Tidsskrift 36, 262-270 (1940).

Cytotaxonomic studies on boreal plants. I. Some observations on Swedish and Icelandic plants. Kungliga Fysiografiska Sällskapets i Lund Förhandlingar 12 (6), 1-19 (1942), with A. Löve.

Chromosome numbers of Scandinavian plant species. Botaniska Notiser 1942, 19-59 (1942), with A. Löve.

The significance of differences in distribution of diploids and polyploids. Hereditas 29, 145-163 (1943), with A. Löve.

Cytogenetic studies on dioecious Melandrium. Botaniska Notiser 1944, 125-213 (1944).

Cytotaxonomical studies on boreal plants. II. Some notes on the chromosome numbers of Juncaceae. Arkiv för Botanik 31B (1), 1-6 (1944), with A. Löve.

Cytotaxonomical studies on boreal plants. III. Some new chromosome numbers of Scandinavian plants. Arkiv för Botanik 31A (12), 1-22 (1944), with A. Löve.

Studies on the origin of the Icelandic flora. I. Cyto-ecological investigations on Cakile. Iceland University Institute of Applied Sciences, Department of Agriculture, Reports B, 2, 1-29 (1947), with A. Löve.

Chromosome numbers of Northern plant species. Iceland University Institute of Applied Sciences, Department of Agriculture, Reports, B, 3, 1-131 (1948), with A. Löve.

The geobotanical significance of polyploidy. I. Polyploidy and latitude. Portugaliae Acta Biologica (B), R.B. Goldschmidt Jubilee Volume, 273-352 (1949), with A. Löve.

Studies on the origin of the Icelandic flora. II. Saxifragaceae. Svensk Botanisk Tidsskrift 45, 368-399 (1951), with A. Löve.

The geobotanical significance of polyploidy. Proceedings of the VIth International Grassland Congress, State College, Pennsylvania (1952), 240-246 (1953), with A. Löve.

Cytotaxonomical remarks on Gentianaceae. Hereditas 39, 225-235 (1953).

Studies on Bryoxiphium. Bryologist 56, 73-94, 183-203 (1953), with A. Löve.

Cirsium Flodmanii (Rydb.) Arth f. albiflora, forma nova. Rhodora 55, 362-363 (1953).

Cytotaxonomical studies on the northern bedstraw. American Midland Naturalist 52, 88-105 (1954), with A. Löve.

A plant collection from SW Yukon. Botaniska Notiser 109, 153-211 (1956), with N.J. Freedman.

Cytotaxonomical conspectus of the Icelandic flora. Acta Horti Gotoburgensis 20, 65-291 (1956), with A. Löve.

Chromosomes and taxonomy of eastern North American Polygonum. Canadian Journal of Botany 34, 501-521 (1956), with A. Löve.

Rumex stenophyllus in North America. Rhodora 60, 54-57 (1958), with J.P. Bernard.

Cytotaxonomy of Carex section Capillares. Canadian Journal of Botany 35, 715-761 (1957), with A. Löve and M. Raymond.

Drug content and polyploidy in Acorus. Proceedings of the Genetics Society of Canada 2, 14-17 (1957), with A. Löve.

Arctic polyploidy. Proceedings of the Genetics Society of Canada 2, 23-27 (1957), with A. Löve.

A plant collection from interior Quebec. Naturaliste Canadien 85, 25-69 (1958), with G. Johnston and J. Kucyniak.

The American element in the flora of the British Isles. Botaniska Notiser 111, 376-388 (1958), with A. Löve.

An unusual polyploid series in Triglochin maritimum agg. Proceedings of the Genetics Society of Canada 3, 2, 19-21 (1958), with A. Löve.

Cytotaxonomy and classification of Lycopods. Nucleus 1, 1-10 (1958), with A. Löve.

Biosystematics of Triglochin maritimum agg. Naturaliste Canadien 85, 156-165 (1958), with A. Löve.

Biosystematic studies in Xanthium: Taxonomic appraisal and ecological status. Canadian Journal of Botany 37, 173-208 (1959), with P. Dansereau.

The post-glacial development of the flora of Manitoba: a discussion. Canadian Journal of Botany 37, 547-585 (1959).

Biosystematics of the black crowberries in America. Canadian Journal of Genetics and Cytology 1, 34-38 (1959), with A. Löve.

Flora and vegetation of Otterburne, Manitoba, Canada. Svensk Botanisk Tidsskrift 53, 335-461 (1959), with J.P. Bernard.

The red-fruited crowberries in North America. Rhodora 62, 265-292 (1960).

Some nomenclatural changes in the European flora. I. Species and supraspecific categories. Botaniska Notiser 114, 33-47 (1961), with A. Löve.

Some nomenclatural changes in the European flora. II. Subspecific categories. Botaniska Notiser 114, 48-56 (1961), with A. Löve.

Some chromosome numbers of Icelandic ferns and fern-allies. American Fern Journal 51, 127-128 (1961), with A. Löve.

Chromosome numbers of Central and Northwest European plant species. Opera Botanica 5, I-VIII, 1-581 (1961), with A. Löve.

The Hutchinson polygraph, a method for simultaneous expression of multiple and variable characters. Canadian Journal of Genetics and Cytology 3, 289-294 (1961), with L. Nadeau.

Triglochin gaspense, a new species of arrowgrass. Canadian Journal of Botany 39, 1261-1272 (1961), with H. Lieth.

Quelques mots sur la flore alpine de Mt. Washington, N.H. Annales de l'ACFAS 28, 38 (1962).

North Atlantic Biota and their History. Pergamon Press, Oxford (1963), editor with A. Löve.

Dispersal and survival of plants. North Atlantic Biota and their History, 189-205 (1963).

Streptopus oreopolus Fern., a hybrid taxon. Rhodora 56, 310-317 (1963), with H. Harries.

The North Atlantic flora - its history and late evolution. Tenth International Botanical Congress (1964), Abstracts, 139-140 (1965), with A. Löve.

Taxonomic remarks on some American alpine plants. University of Colorado Studies, Series in Biology 17, 1-43 (1965), with A. Löve.

Cytotaxonomy of the alpine vascular plants of Mount Washington. University of Colorado Studies, Series in Biology 24, 1-74 (1966), with A. Löve.

Vaccinium gaultherioides Bigel. - an arctic-alpine species. Revue Roumaine de Biologie, Série Botanique 11, 295-305 (1966), with N. Boşcaiu.

The variations of Blechnum Spicant. Botanisk Tidsskrift 62, 186-196 (1966), with A. Löve.

Íslenski dílaburkninn (Dryopteris assimilis S. Walker in Iceland). Flóra, Journal of Icelandic Botany 4, 5-9 (1966), with A. Löve.

Biosystematics of widely disjunctive taxa. Die Naturwissenschaften 54, 24-25 (1967), with A. Löve.

Polyploidy and altitude: Mt. Washington. Biologisches Zentralblatt 86, Beiheft, 307-312 (1967), with A. Löve.

Continental drift and the origin of the arctic-alpine flora. Revue Roumaine de Biologie, Série Botanique 12, 163-169 (1967), with A. Löve.

Evolution and the Linnaean species. Univ. Babes Bolayi din Cluj, Grǎd. Bot. Contrib. Bot. 1967, 203-210 (1967), with A. Löve.

The origin of the North Atlantic flora. Aquilo, Ser. Bot. 6, 52-66 (1967), with A. Löve.

Cytotaxonomy of Blechnum Spicant. Collectanea Botanica 7, 665-676 (1968), with A. Löve.

The diploid perennial Anthoxanthum. Science in Iceland, 26-30 (1968), with A. Löve.

Papaver at high altitudes in the Rocky Mountains. Brittonia (in press, 1969).

Mount Washington and its alpine flora. Manuscript of about 600 pages accepted for publication and waiting for a subsidy.

Justification of the Budget

Only a small part of the budget concerns costs other than salaries; since these are mainly self-explanatory spendings and based on the experience from the last four years, we hope that it will be agreed that these low sums need no justification.

Most of the cost goes for salaries. Askell Löve expects to spend 25 per cent of his time during the academic year on this project, and one hundred per cent during the two summer months, as he has done for the last four years. Doris Löve has spent full-time for the last four years on the project and on supervision of the assistants. It is deemed reasonable to request for her a salary for full-time intensive work, lower than even a salary for an assistant professor for nine month's service, including all summer months each year, since she will continue to carry a heavy load of this research.

The project has raised a considerable interest among undergraduate and graduate students in the department. The University has made available, during the past four years, a grant for experimentation in teaching, and since the students involved have concentrated their work on the cytotaxonomy of alpine plants, this may well be regarded as a contribution to this project.

We ask for support for two graduate research assistants for the two years to come. In addition, our teaching assistants have been working on the project though they are paid by the University only for their services during the academic year. The part-time secretary asked for is to work on the completion of the data bank for chromosome numbers for past publications and for the continuous additions that are needed to keep it up-to-date.

The only substantial costs other than salaries are page charges and reprints ($600), and especially, a subsidy for the printing of the book on the Mount Washington flora ($10,000) by D. Löve, likely with the Columbia University Press. This book, which includes the first cytotaxonomical attempt to clarify the evolutionary history of any alpine flora, is certainly unique and very important. Since the work on which it is based was partially supported through the NSF grants GB-3371 and GB-6299, we hope it will be regarded as reasonable when we ask that this subsidy for its publication be added to the present project so that this valuable result of this investigation may become available to others. Doris Löve has applied for a separate grant for this subsidy from the NSF more than a year ago (with all pertinent details), but since a long delay is apparently unavoidable through the Division approached, this subsidy is asked for also through the present channel. It is evident that if this support is made available, the usual rules for such a subsidy will be adhered to by the publisher.

Current Support

This project is to continue the work which has been supported by NSF grants GB-3371 and GB-6299 since the spring of 1965. Other recent grant requests by Askell Löve to the National Science Foundation have been turned down. A request for support from the National Institutes of Health for studies on the connection between chromosome fragmentation and aging is pending and will probably not be granted; if so, however, it will not affect the time to be used for the present proposal.

CU Proposal No. 69.5.53
2/69

NATIONAL SCIENCE FOUNDATION

Research Grant Budget

Institution: The Regents of the University of Colorado Boulder, Colorado 80302

Title: Studies of the Cytotaxonomy of the Arctic-Alpine Flora (Continuation of GB-3371 and GB-6299)

Co-Principal Investigators: Askell Löve, Doris Löve

Starting Date and Duration: 1 July 1969 (Two Years)

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	1st Yr. NSF	1st Yr. CU	2nd Yr. NSF	2nd Yr. CU
A. Salaries and Wages				
Senior Personnel				
Co-Principal Investigator: A. Löve				
25% time, 9 mos. AY	$ 2,250(1MM)	$ 2,250(1MM)	$ 2,430(1MM)	$ 2,430(1MM)
100% time, 2 mos. summer	4,000(2MM)		4,320(2MM)	
Co-Principal Investigator: D. Löve				
100% time, 12 mos.	10,500(12MM)		11,350(12MM)	
Other Personnel				
(2) Graduate Research Assistants				
50% time, 9 mos. AY	5,700(9MM)	940*	6,000(9MM)	940*
100% time, 3 mos. summer	3,780(6MM)		3,990(6MM)	
Secretary (for chromosome data bank)				
75% time, 12 mos.	3,600(9MM)		3,815(9MM)	
Total Salaries and Wages	29,830	3,190	31,905	3,370
B. Fringe Benefits				
TIAA - 7% of faculty salaries	1,175	160	1,265	170
PERA - 6% of staff salaries	215		230	
Total Fringe Benefits	1,390	160	1,495	170
C. Permanent Equipment	-0-		-0-	
D. Expendable Supplies and Equipment	500		500	

CU Proposal No. 69.5.53
Budget Con't.

	1st Yr. NSF	1st Yr. CU	2nd Yr. NSF	2nd Yr. CU
E. Travel (Domestic)				
Scientific meetings	300		300	
Field collections and visits to herbaria	300		300	
Total Travel	600		600	
F. Publication Costs				
Page charges and reprints	600		600	
Subsidy for printing book on Mt. Washington flora	10,000		-0-	
Total Publication Costs	10,600		600	
G. Other Costs *	-0-		-0-	
H. Total Direct Costs	42,920	3,350	35,100	3,540
I. Indirect Costs				
On Campus: 53.3% of salaries and wages	15,900	1,200	17,005	1,295
J. Total Costs	58,820	4,550	52,105	4,835

Total Requested from NSF for Two Years: $110,925

*The University waives the difference between out-of-state and in-state tuition for research assistants. The average cost of such waivers for all research assistants is $470 per research assistant per year which is shown as a University contribution. This amount will be adjusted periodically to reflect actual experience.

CU Proposal No. 70.5.7
1/70

A Proposal to the

National Science Foundation

for

COMPLETION OF STUDIES OF THE CYTOTAXONOMY OF THE ARCTIC-ALPINE FLORA OF COLORADO

(Continuation of GB-3371 and GB-6299)

<u>Name and Address of Institution</u>: The Regents of the
University of Colorado
Boulder, Colorado 80302

<u>Desired Starting Date</u>: 1 March 1970

<u>Amount Requested from NSF</u>: $72,485

<u>Time Period for Which Support is Requested</u>: Three Years

<u>Co-Principal Investigators</u>: Áskell Löve, Professor and Chairman
Department of Biology

Doris Löve, Faculty Research Associate
Department of Biology
University of Colorado
Boulder, Colorado 80302
Telephone: 303-443-2211, Ext. 7325 & 7921

Áskell Löve
Chairman and Co-Principal Investigator

Doris Löve
Co-Principal Investigator

I certify that the distribution of costs between the direct and indirect categories as shown in the proposal conforms to the usual accounting practices of the institution and to the distribution used by the cognizant Federal audit agency.

~~Thurston E. Manning~~
~~Vice-President for Academic Affairs~~
Eugene H. Wilson
Vice President for Business Affairs

ABSTRACT

This proposal is for completion of studies of the cytotaxonomy of the alpine flora of the Rocky Mountains of Colorado, which the Co-Principal Investigators have been working on since the spring of 1965. Since more than half of this flora has now been cytologically determined, it is anticipated that all its species will have been included in this project, their chromosomes counted, and the material processed for publication in three years' time, provided that moderate support is made available. This flora will be the second such alpine flora to be fully known from these points of view, and thus mature for more detailed ecological and historical geobotanical investigations that require an exact and evolutionary determination of the taxa involved.

I. Background of the Project

Few ecosystems offer better opportunities for the study of historical geobotany and speciation than those inhabiting the uppermost parts of high mountains in the temperate zone, especially those of mountain chains that have high altitude connections from the cold zone to the tropical zone, so that at least dispersal from high to low and from low to high latitudes has been periodically possible. The Rocky Mountains are such chains, but although they are situated closer to civilization than most such regions, studies of their ecosystem and its evolution are still only beginning.

It is generally recognized by geobotanists that the utmost care must be used in the determination of taxa at all levels before any wider explanations can be offered on the history and evolution of any particular ecosystem. Fallacious conclusions have frequently been drawn through lack of such care, especially in the delimitation of the all-important category of species, because if genetical and evolutionary heterogeneity is allowed to be included in such a unit, its different constituents may have very different origins and history. In order to avoid this cause of uncertainty, taxonomists and geobotanists of the pre-genetical era tried to select only the most restricted taxa for their geobotanical investigations. The result of this perhaps overcautious approach is seen in the Wettstein-Komarov species concept, which resulted in extreme splitting on the basis of geographical distribution of even small morphological variants, based on the conviction that it is always a lesser evil to keep taxa separated which may be identical than to identify those that may be distinct. But even such cautiousness does not suffice for studies of the geobotanical history and evolution of distinct ecosystems, because too limited categories may induce reasoning that prevents seeing the real entire picture.

Ths most sophisticated modern approach to the delimitation of evolutionary species is based on cytogenetical experiments combined with chemotaxonomical, taximetric, and classical methods of study. Unfortunately, such exact methods are tedious and facilities to apply them to all the components of even small alpine ecosystems are rarely available. Therefore, the approach that comes closest to allowing a biological delimitation of the species on a scale large enough to be geobotanically useful is that of cytotaxonomy, which puts a strong emphasis on chromosome studies of native material combined with classical morphological observations and studies of distribution. That approach has already resulted in chromosome number determinations for perhaps one-fourth of the biological species of the higher plants of the earth, and some smaller floras of northern and temperate regions have become taxonomically and geobotanically considerably better understood during the past decade or two, thanks to a complete or almost complete knowledge of their chromosome numbers. Cases in point, which the Co-Principal Investigators are well acquainted with, are the floras of Iceland, Greenland, the Faeroes, and Scandinavia, and the flora of Mt. Washington in New Hampshire, which is the only mountain flora the history of which is well understood from this point of view.

It was with this need of an exact delimitation of the alpine taxa in mind that the Co-Principal Investigators began their intensive studies of the alpine flora of Colorado some five years ago. Although these studies still are incomplete, they have already shown several discrepancies in earlier explanations of the history of this ecosystem, and it has become evident that numerous species that were thought to be identical with arctic-alpine taxa actually are much older remnants of an alpine flora of a southern, Tethyan, origin, whereas still others seem to be the results of more recent evolution from taxa of the surrounding desert or prairie lowlands. Such conclusions may, however, be premature as long as all the several hundred alpine species have not been cytologically investigated, and so we regard it as of the utmost importance to complete this cytotaxonomical phase by counting the chromosome numbers of numerous representative samples of the remaining species.

In our earlier proposals, and also in several of our papers, we have discussed the importance of a thorough knowledge of the history of alpine floras in general and that of the southern Rockies in particular for the understanding of the evolutionary history of the flora of the northern temperate regions. We want to emphasize that the results of our cytotaxonomical studies of these plants are only partially useful as long as the entire flora has not been so investigated. We feel that we can complete these studies within the next three years if the support applied for is made available early enough to enable us not only to complete the counting of all the samples collected last summer but also to continue collecting new species from various localities as early as possible during the coming summer and the following two seasons.

II. Summarized Outline

1) We have already determined the chromosome numbers of more than half the species of the alpine flora of Colorado, including all the more common taxa. Every species has been studied from samples of several populations, and reasonable-sized voucher collections have been made for the study of their morphological variability. All this material has been fixed directly in the field, and the root-tips have been mashed or prepared according to the paraffin technique.
2) Numerous collections from last summer have been processed during this winter, though a number of fixations still remain uncounted; this we plan to do in the early spring if possible.
3) Most of the species which we have not yet fixed and counted are rare and only met with in a few localities and in small populations; we have tried to fix several of them in the field, but with little or no success. Therefore, we plan to collect living specimens for cultivations in our walk-in growth chamber, which will be standardized for alpine-arctic climates. To complete the collections of the remaining species requires considerable travel in the mountains by us, our graduate students, and our technical assistant, at times when live material is available or seeds are ripe. This material will be fixed when growing normally under these artificial conditions, both root-tips and flower buds as appropriate.
4) We are confident that during the coming three years we can not only complete the chromosome countings of the alpine plants, but also prepare at least most of the material for publication, either in a single long paper or in several smaller reports.

III. Short Bibliography of Pertinent Contributions

BEAMAN, J.H., DE JONG, D.C.D., and STOUTAMIRE, W.P., 1962: Chromosome studies in the alpine and subalpine floras of Mexico and Guatemala Amer. Journ. Bot. 49, 41-50.

BÖCHER, T.W., 1951: Distribution of plants in the circumpolar area in relation to ecological and historical factors. Journ. Ecol. 39, 376-395.

BÖCHER, T.W. and LARSEN, K., 1950: Chromosome numbers of some arctic or boreal flowering plants. Medd. om Grönl. 147 (6), 1-32.

FAVARGER, C., 1961: Sur l'emploi des nombres de chromosomes en géographie botanique historique. Ber. Geobot. Inst. Rubel. 32, 119-146.

FAVARGER, C., 1964a: Cytotaxinomie et endémisme. C. r. Soc. Biogéogr. 357, 23-44.

FAVARGER, C., 1964b: Die zytotaxonomische Erforschung der Alpenflora. Ber. Deutsch. Bot. Ges. 77, 73-83.

FAVARGER, C. and CONTANDRIOPOULOS, J., 1961: Essai sur l'endémisme. Ber. Schweiz. Bot. Ges. 71, 384-408.

FERNALD, M.L., 1924: Isolation and endemism in northeastern America and their relation to the age and area hypothesis. Amer. Journ. Bot. 11, 558-572.

FERNALD, M.L., 1925: Persistence of plants in unglaciated areas of boreal America. Amer. Acad. Arts and Sci. Mem. 15, 241-342.

FERNALD, M.L., 1926: The antiquity and dispersal of vascular plants. Quart. Rev. Biol. 1, 212-245.

FUNABIKI, K., 1960: Polyploidy in relation to vegetational zonation in the western United States. Bull. Fac. Agric. Niigata Univ. 12, 176-200.

HANELT, P., 1966: Polyploidie-Frequenz und geographische Verbreitung bei höheren Pflanzen. Biol. Rundschau 4, 183-196.

HEDBERG, O., 1967: Chromosomes numbers of vascular plants from arctic and subarctic North America. Arkiv. of Botanik, N.S. 6, 309-326.

HOLM, T., 1923: The vegetation of the alpine region of the Rocky Mountains in Colorado. Mem. Natl. Acad. Sci. 19, 1-45.

HOLMEN, K., 1964: Cytotaxonomical studies in the arctic Alaskan flora. The genus *Festuca*. Bot. Not. 117, 109-118.

KNABEN, G. and ENGELSKJÖN, T., 1967: Chromosome numbers of Scandinavian arctic-alpine plant species. II. Acta Borealia A. Scientia 21, 1-57.

LAANE, M., 1966: Chromosome numbers in the flora of Finnmark. I. Blyttia 24, 270-276.

LAANE, M., 1967: Chromosome numbers in the flora of Finnmark. II. Blyttia 25, 45-54.

LÖVE, Á., 1964: The biological species concept and its evolutionary structure. Taxon 13, 33-45.

LÖVE, Á., 1967: The evolutionary significance of disjunctions. Taxon 16, 324-333.

LÖVE, Á. and LÖVE, D., 1966: Cytotaxonomy of the alpine vascular plants of Mt. Washington. Univ. of Colo. Studies, Series in Biol. 24, 1-74.

LÖVE, Á. and LÖVE, D., 1967: Polyploidy and altitude: Mt. Washington. Biol. Zentralbl. 86, Beiheft, 307-312.

LÖVE, Á. and LOVE, D., 1967: Biosystematics of widely disjunctive taxa. Naturwiss. 54, 24-25.

LÖVE, Á. and LÖVE, D., 1967: Continental drift and the origin of the arctic-alpine flora. Rev. Roum. Biol., Ser. Bot. 12, 163-169.

LÖVE, D. 1969: Papaver at high altitudes in the Rocky Mountains. Brittonia 21, 1-10.

LOVE, D. and BOSCAIU, N., 1966: Vaccinium gaultherioides Bigel., an arctic-alpine species. Rev. Roum. Biol., Ser. Bot. 11, 295-305.

SKALIŃSKA, M., 1963: Cytological studies in the flora of the Tatra Mts. A synthetic review. Acta Biol. Cracov., Ser. Bot. 6, 203-233.

SOKOLOVSKAJA, A.P. and STRELKOVA, O.S., 1938: Polyploidy of the high mountain regions of Pamir and Altai. Doklady Akad. Nauk SSSR, N.S. 21, 68-71.

SOKOLOVSKAJA, A.P. and STRELKOVA, O.S., 1940: Karyological investigations of the alpine flora on the main Caucasus range and the problems of geographical distribution of polyploids. Doklady Akad. Nauk, SSSR, N.S. 29, 415-418.

TOLMATCHEV, A.I., 1960a: Der autochtone Grundstock der arktichen Flora und ihre Beziehungen zu den Hochgebirgsfloren Nord- und Zentralasiens Bot. Tidsskr. 55, 269-276.

WEBER, W.A., 1961: Additions to the flora of Colorado. III. Univ. of Colorado Studies, Series in Biology No. 7, 1-26.

WEBER, W.A. 1966: Additions to the flora of Colorado. IV. Univ. of Colorado Studies, Series in Biology No. 23, 1-24.

WIENS, D. and Halleck, D.K., 1962: Chromosome numbers in Rocky Mountain plants. I. Bot. Not. 115, 455-464.

WULFF, E.V., 1943: An introduction to historical plant geography. Waltham, Mass.

WULFF, E.V., 1944: Istoricheskaya gegrafija rasteniy. Moskva, Leningrad.

WYNNE-EDWARDS, V.C., 1939: Some factors in the isolation of rare alpine plants. Transact. Roy. Soc. Canada, Ser. 3, 33 (5), 35-42.

IV. Facilities

Reasonable facilities for cytotaxonomical work have been built up at the Department of Biology during the past few years. This includes some garden space close to the Biology Building, small experimental gardens in the mountains, a small greenhouse, and a walk-in growthchamber. Laboratory facilities, including three research microscopes, are also available, and our library is fully adequate for all kinds of taxonomical and evolutionary studies of plants.

V. Personnel Data

A. LÖVE, Áskell

Born: 20 October 1916

Position: Professor and Chairman, Department of Biology, University of Colorado

Education:

B.A., Reykjavik College, 1937
M.S., Cytogenetics, Botany, Zoology, University of Lund, Sweden, 1941
Ph.D., Cytogenetics, Botany, University of Lund, Sweden, 1942
D.Sc., Cytogenetics, University of Lund, Sweden, 1943

Employment Record:

Research Associate, Institute of Genetics, University of Lund, 1942-45
Research Worker (on leave), University of Iceland Research Institute, Reykjavik, 1942-45
Director, Institute of Botany and Genetics, University of Iceland Research Institute, Reykjavik, 1945-51
Associate Professor of Botany, University of Manitoba, Winnipeg, 1951-56
Research Professor of Biosystematics, Institut Botanique, Université de Montréal, 1956-63
Associate Professor, Department of Biology, University of Colorado, 1964-66
Professor and Chairman, Department of Biology, University of Colorado, 1966-

Fellowships and Professional Honors:

Fellow, Icelandic Academy of Learning since 1946; corresponding member since 1951
Permanent member of the Board of the International Association of Plant Geographers since 1953
Rapporteur and Vice President, Section of Cytology, VIIIth International Botanical Congress, Paris, 1954
Member, International Committee for Genetical Nomenclature and Symbolization (I.U.B.S.), 1956-58
Member of the Editorial Board of the journal Nucleus since 1958
Technical Consultant on Cytotaxonomy for Flora Europaea since 1955
President, International Organization of Biosystematists, 1960-64
Honorary Foreign Member, Swedish Phytogeographical Society since 1960
President, Symposium on North Atlantic Biota and their History, Reykjavik, July 1962
Vice President, International Committee on Chemotaxonomy, 1964-
John Simon Guggenheim Memorial Fellow, 1963-64
Honorary Foreign Member, Czechoslovak Botanical Society since 1968

Selected Publications, Relevant to the Proposed Project:

Cytogenetic studies in *Rumex*. Botaniska Notiser, 157-169 (1940).

Études cytogénétiques des *Rumex*. II. Polyploidie geographique-systématique du *Rumex* subgenus *Acetosella*. Botaniska Notiser, 155-172 (1941).

Polyploidy in *Polygonum Convolvulus* L. s. lat. Hereditas 28, 227-228 (1942).

Cytotaxonomic studies on boreal plants. I. Some observations on Swedish and Icelandic plants. Kungliga Fysiografiska Sallskapets i Lund Forhandlingar 12 (6), 1-19 (1942), with D. Löve.

Chromosome numbers of Scandinavian plant species. Botaniska Notiser, 19-59 (1942), with D. Löve.

Cytogenetic studies in *Rumex*. III. Some notes on the Scandinavian species of the genus. Hereditas 28, 289-296 (1942).

Different chromosome numbers within the collective species *Carex polygama*. Hereditas 28, 495-496 (1942), with A. Levan.

The significance of differences in distribution of diploids and polyploids. Hereditas 29, 145-163 (1943), with D. Löve.

Cytogenetic studies on *Rumex* subgenus *Acetosella*. Hereditas 30, 1-136 (1943).

The dioecious forms of *Rumex* subgenus *Acetosa* in Scandinavia. Botaniska Notiser, 237-254 (1944).

Cytotaxonomical studies on boreal plants. II. Some notes on the chromosome numbers of Juncaceae. Arkiv for Botanik 31B (1), 1-6 (1944), with D. Löve.

Cytotaxonomical studies on boreal plants. III. Some new chromosome numbers of Scandinavian plants. Arkiv for Botanik 31A (12), 1-22 (1944), with D. Löve.

A new triploid *Betula verrucosa*. Svensk Botanisk Tidsskrift 38, 381-393 (1944).

Islenzkar jurtir (Icelandic flora). E. Munksgaard, Copenhagen 1945, pp. 281.

Studies on the origin of the Icelandic flora. I. Cyto-ecological investigations on *Cakile*. Iceland University Institution of Applied Sciences, Department of Agriculture, Reports B2, 1-29 (1947), with D. Löve.

Chromosome numbers of Northern plant species. Iceland University Institution of Applied Sciences, Department of Agriculture, Reports B3, 1-131 (1948), with D. Löve.

The geobotanical significance of polyploidy. I. Polyploidy and latitude. Portugaliae Acta Biologica (B), R.B. Goldschmidt Jubilee Volume, 273-352 (1949), with D. Löve.

Some innovations and nomenclatural suggestions in the Icelandic flora. Botaniska Notiser, 24-60 (1950).

Taxonomical evaluation of polyploids. Caryologia 3, 263-284 (1951).

Studies on the origin of the Icelandic flora. II. Saxifragaceae. Svensk Botanisk Tidsskrift 45, 368-399 (1951), with D. Löve.

The Icelandic type of Glyceria fluitans. Botaniska Notiser 1951, 229-240 (1951).

Preparatory studies for breeding Icelandic Poa irrigata. Hereditas 38, 11-32 (1952).

The geobotanical significance of polyploidy. Proceedings of the VIth International Grassland Congress, State College, Pennsylvania, 1952, 240-246 (1953), with D. Löve.

Subarctic polyploidy. Hereditas 39, 113-124 (1953).

Studies on Bryoxiphium. Bryologist 56, 73-94, 183-203 (1953), with D. Löve.

Cytotaxonomical remarks on some American species of circumpolar taxa. Svensk Botanisk Tidsskrift 48, 211-232 (1954).

Cytotaxonomical studies on the northern bedstraw. American Midland Naturalist 52, 88-105 (1954), with D. Löve.

Cytotaxonomical evaluation of corresponding taxa. Vegetatio 5 (6), 212-224 (1954).

The foundations of cytotaxonomy. VIII[e] Congrès International de Botanique Paris, 1954, Rapports et Communications, Sec. 9-10, 59-66 (1954).

Cytotaxonomical notes on the Icelandic Papaver. Nytt Magasin for Botanikk 4, 5-18 (1955).

Biosystematic remarks on vicariism. Acta Soc. Vanamo 72 (15), 1-14 (1955).

Cytotaxonomical conspectus of the Icelandic flora. Acta Horti Gotoburgensis 20, 65-291 (1956), with D. Löve.

Chromosomes and taxonomy of eastern North American Polygonum. Canadian Journal of Botany 34, 501-521 (1956), with D. Löve.

Chromosomes and relationships of Koenigia islandica. Canadian Journal of Botany 35, 507-514 (1957), with P. Sarkar.

Cytotaxonomy of Carex section Capillares. Canadian Journal of Botany 35, 715-761 (1957), with D. Löve and M. Raymond.

Drug content and polyploidy in Acorus. Proceedings of the Genetics Society of Canada 2, 14-17 (1957), with D. Löve.

Arctic polyploidy. Proceedings of the Genetics Society of Canada 2, 23-27 (1957), with D. Löve.

Taxonomic and biosystematic categories. Brittonia 10, 153-166 (1958), with D.H. Valentine.

The American element in the flora of the British isles. Botaniska Notiser 111, 376-388 (1958), with D. Löve.

An unusual polyploid series in Triglochin maritimum agg. Proceedings of the Genetics Society of Canada, 3, 2, 19-21 (1958), with D. Löve.

Cytotaxonomy and classification of Lycopods. Nucleus 1, 1-10 (1958), with D. Löve.

Biosystematics of Triglochin maritimum agg. Naturaliste Canadien 85, 156-165 (1958), with D. Löve.

The origin of the Arctic flora. Problems of the Pleistocene and Arctic. Publications of the McGill University Museum 1, 82-95 (1959).

Cytotaxonomy of Cerastium holosteoides. Phyton 8, 38-42 (1959), with M.S. Chennaveeraiah.

Biosystematics of the black crowberries in America. Canadian Journal of Genetics and Cytology 1, 34-38 (1959), with D. Löve.

Biosystematics and the processes of speciation. In: "Evolution: its science and doctrine," Royal Society of Canada, Studia Varia 4, 115-122 (1960).

Biosystematics and classification of apomicts. Feddes Repertorium 62, 136-148 (1960).

Taxonomy and chromosomes - a reiteration. Feddes Repertorium 62, 192-202 (1960).

Some nomenclatural changes in the European flora. I. Species and supraspecific categories. Botaniska Notiser 114, 33-47 (1961), with D. Löve.

Some nomenclatural changes in the European flora. II. Subspecific categories. Botaniska Notiser 114, 48-56 (1961), with D. Löve.

Some chromosome numbers of Icelandic ferns and fern-allies. American Fern Journal 51, 127-128 (1961), with D. Löve.

Some notes on Myriophyllum exalbescens. Rhodora 63, 139-145 (1961).

Chromosome numbers of Central and Northwest European plant species. Opera Botanica 5, I-VIII, 1-581 (1961), with D. Löve.

Hylandra, a new genus of Cruciferae. Svensk Botanisk Tidsskrift 55, 211-217 (1961).

A note on amphi-pacific Lysichitum. Journal of Japanese Botany 36, 359-361 (1961), with S. Kawano.

The biosystematic species concept. Preslia 34, 127-139 (1962).

Typification of Papaver radicatum - a nomenclatural detective story. Botaniska Notiser 115, 113-136 (1962).

Cytotaxonomy of the *Isoetës echinospora* complex. American Fern Journal 52, 113-123 (1962).

Cytotaxonomy and generic delimitation. Regnum Vegetabile 27, 45-51 (1963).

Biosystematische Analyse der *Elytrigia Junceae* Gruppe. Die Kulturpflanze, Beiheft 3, 74-85 (1962).

North Atlantic Biota and Their History. Pergamon Press, Oxford (1963), editor together with D. Löve.

Chromosome numbers of some *Carex* species from Spain. Botaniska Notiser 116, 241-248 (1963), with E. Kjellqvist.

Chromosome numbers of some Iberian Cistaceae. Portugaliae Acta Biologica (A) 8, 69-80 (1964), with E. Kjellqvist.

The biological species concept and its evolutionary structure. Taxon 13, 33-45 (1964).

The evolutionary framework of the biological species concept. Genetics Today II, 409-414 (1965).

The North Atlantic flora - its history and late evolution. Tenth International Botanical Congress (1964), Abstracts, 139-140 (1965), with D. Löve.

Taxonomic remarks on some American alpine plants. University of Colorado Studies, Series in Biology 17, 1-43 (1965), with D. Löve.

Chromosome numbers from central northern Canada. Canadian Journal of Botany 44, 429-439 (1966), with J.C. Ritchie.

Cytotaxonomy of the alpine vascular plants of Mount Washington. University of Colorado Studies, Series in Biology 24, 1-74 (1966), with D. Löve.

An alloploid *Ophioglossum*. Nucleus 9, 132-138 (1966), with B.M. Kapoor.

The variations of *Blechnum Spicant*. Botanisk Tidsskrift 62, 186-196 (1966), with D. Löve.

Íslenski dílaburkninn (*Dryopteris assimilis* S. Walker in Iceland). Flóra, Journal of Icelandic Botany 4, 5-9 (1966), with D. Löve.

Biosystematics of widely disjunctive taxa. Die Naturwissenschaften 54, 24-25 (1967), with D. Löve.

The highest plant chromosome number in Europe. Svensk Botanisk Tidsskrift 61, 29-32 (1967), with B.M. Kapoor.

Polyploidy and altitude: Mt. Washington. Biologisches Zentralblatt 86, Beiheft, 307-312 (1967), with D. Löve.

The evolutionary significance of disjunctions. Taxon 16, 324-333, 1967.

Continental drift and the origin of the arctic-alpine flora. Revue Roumaine de Biologie, Serie Botanique 12, 163-169 (1967), with D. Löve.

Evolution and the Linaean species. Univ. Babes Bolayi din Cnuj Grăd. Bot. Contrib. Bot. 1967, 203-210 (1967), with D. Löve.

The Origin of the North Atlantic flora. Aquilo. Ser. Bot. 6, 52-66 (1967), with D. Löve.

Cytotaxonomy of Blechnum Spicant. Collectanea Botanica 7, 665-676 (1968), with D. Löve.

The diploid perennial Anthoxanthum. Science in Iceland 1968, 26-30 (1968), with D. Löve.

Cytotaxonomical notes on some American orchids. Southw. Natural. 13, 335-342 (1968), with W. Simon.

Chromosome numbers of Orchidaceae. Taxon 18, 312 (1969) with D. Löve.

Íslenzk ferdaflóra (Icelandic excursionsflora). Reykjavik 1970 (in press).

B. LÖVE, Doris

Born: 2 January 1918

Position: Faculty Research Associate, Department of Biology, University of Colorado

Education:

B.S., Kristianstad College, Sweden, 1937
M.S., Cytogenetics, Botany, Geography, University of Lund, Sweden, 1941
Ph.D., Cytogenetics, Botany, University of Lund, Sweden, 1943
D.Sc., Cytogenetics, University of Lund, Sweden, 1944

Employment Record:

Instructor (amanuensis), Institute of Genetics, University of Lund, 1940-43
Research Associate, Institute of Genetics, University of Lund, 1943-45
Geneticist, University of Iceland Research Institute, Reykjavik, 1945-51
Herbarium Curator, University of Manitoba, Winnipeg, Canada, 1951-56
Associate Professor (research), Institut Botanique, Université de Montréal, Canada, 1956-63
Faculty Research Associate, Department of Biology, Institute of Arctic and Alpine Research, and University Museum, University of Colorado, 1964-

Fellowships and Professional Honors:

Fellow, Mendelian Society of Lund, Sweden since 1941
Several research scholarships and awards from the Royal Physiographic Society of Lund, Lund Botanical Society, and the Swedish Academy of Sciences, 1941-45
Research Fellowship from the Icelandic Cultural Fund, 1945-50
British Council invitation to visit British institutions in genetics and plant breeding, Summer 1949
Research grants from the National Research Council of Canada, 1956-64, and the National Science Foundation, 1967

Selected Publications, Relevant to the Proposed Project:

Some contributions to the cytology of Silenoideae. Svensk Botanisk Tidsskrift 36, 262-270 (1940).

Cytotaxonomic studies on boreal plants. I. Some observations on Swedish and Icelandic plants. Kungliga Fysiografiska Sällskapets i Lund Förhandlingar 12 (6), 1-19 (1942), with Á. Löve.

Chromosome numbers of Scandinavian plant species. Botaniska Notiser 1942, 19-59 (1942), with Á. Löve.

The significance of differences in distribution of diploids and polyploids. Hereditas 29, 145-163 (1943), with Á. Löve.

Cytogenetic studies on dioecious Melandrium. Botaniska Notiser 1944, 125-213 (1944).

Cytotaxonomical studies on boreal plants. II. Some notes on the chromosome numbers of Juncaceae. Arkiv för Botanik 31B (1), 1-6 (1944), with Á. Löve.

Cytotaxonomical studies on boreal plants. III. Some new chromosome numbers of Scandinavian plants. Arkiv för Botanik 31A (12), 1-22 (1944), with Á. Löve.

Studies on the origin of the Icelandic flora. I. Cyto-ecological investigations on Cakile. Iceland University Institute of Applied Sciences, Department of Agriculture, Reports B, 2, 1-29 (1947), with Á. Löve.

Chromosome numbers of Northern plant species. Iceland University Institute of Applied Sciences, Department of Agriculture, Reports, B, 3, 1-131 (1948), with Á. Löve.

The geobotanical significance of polyploidy. I. Polyploidy and latitude. Portugaliae Acta Biologica (B), R.B. Goldschmidt Jubilee Volume, 273-352 (1949), with Á. Löve.

Studies on the origin of the Icelandic flora. II. Saxifragaceae. Svensk Botanisk Tidsskrift 45, 368-399 (1951), with Á. Löve.

The geobotanical significance of polyploidy. Proceedings of the VIth International Grassland Congress, State College, Pennsylvania (1952), 240-246 (1953), with Á. Löve.

Cytotaxonomical remarks on Gentianaceae. Hereditas 39, 225-235 (1953).

Studies on Bryoxiphium. Bryologist 56, 73-94, 183-203 (1953), with Á. Löve.

Cirsium Flodmanii (Rydb.) Arth.f. albiflora, forma nova. Rhodora 55, 362-363 (1953).

Cytotaxonomical studies on the northern bedstraw. American Midland Naturalist 52, 88-105 (1954), with Á. Löve.

A plant collection from SW Yukon. Botaniska Notiser 109, 153-211 (1956), with N.J. Freedman.

Cytotaxonomical conspectus of the Icelandic flora. Acta Horti Gotoburgensis 20, 65-291 (1956), with Á. Löve.

Chromosomes and taxonomy of eastern North American *Polygonum*. Canadian Journal of Botany 34, 501-521 (1956), with Á. Löve.

Rumex stenophyllus in North America. Rhodora 60, 54-57 (1958), with J.P. Bernard.

Cytotaxonomy of *Carex* section *Capillares*. Canadian Journal of Botany 35, 715-761 (1957), with Á. Löve and M. Raymond.

Drug content and polyploidy in *Acorus*. Proceedings of the Genetics Society of Canada 2, 14-17 (1957), with Á. Löve.

Arctic polyploidy. Proceedings of the Genetics Society of Canada 2, 23-27 (1957), with Á. Löve.

A plant collection from interior Quebec. Naturaliste Canadien 85, 25-69 (1958), with G. Johnston and J. Kucyniak.

The American element in the flora of the British Isles. Botaniska Notiser 111, 376-388 (1958), with Á. Löve.

An unusual polyploid series in *Triglochin maritimum* agg. Proceedings of the Genetics Society of Canada 3, 2, 19-21 (1958), with Á. Löve.

Cytotaxonomy and classification of Lycopods. Nucleus 1, 1-10 (1958), with Á. Löve.

Biosystematics of *Triglochin maritimum* agg. Naturaliste Canadien 85, 156-165 (1958), with Á. Löve.

Biosystematic studies in *Xanthium*: Taxonomic appraisal and ecological status. Canadian Journal of Botany 37, 173-208 (1959), with P. Dansereau.

The post-glacial development of the flora of Manitoba: a discussion. Canadian Journal of Botany 37, 547-585 (1959).

Biosystematics of the black crowberries in America. Canadian Journal of Genetics and Cytology 1, 34-38 (1959), with Á. Löve.

Flora and vegetation of Otterburne, Manitoba, Canada. Svensk Botanisk Tidsskrift 53, 335-461 (1959), with J.P. Bernard.

The red-fruited crowberries in North America. Rhodora 62, 265-292 (1960).

Some nomenclatural changes in the European flora. I. Species and supraspecific categories. Botaniska Notiser 114, 33-47 (1961), with Á. Löve.

Some nomenclatural changes in the European flora. II. Subspecific categories. Botaniska Notiser 114, 48-56 (1961), with Á. Löve.

Some chromosome numbers of Icelandic ferns and fern-allies. American Fern Journal 51, 127-128 (1961), with Á. Löve.

Chromosome numbers of Central and Northwest European plant species. Opera Botanica 5, I-VIII, 1-581 (1961), with Á. Löve.

The Hutchinson polygraph, a method for simultaneous expression of multiple and variable characters. Canadian Journal of Genetics and Cytology 3, 289-294 (1961), with L. Nadeau.

Triglochin gaspense, a new species of arrowgrass. Canadian Journal of Botany 39, 1261-1272 (1961), with H. Lieth.

Quelques mots sur la flore alpine de Mt. Washington, N.H. Annales de l'ACFAS 28, 38 (1962).

North Atlantic Biota and their History. Pergamon Press, Oxford (1963), editor with Á. Löve.

Dispersal and survival of plants. North Atlantic Biota and their History, 189-205 (1963).

Streptopus oreopolus Fern., a hybrid taxon. Rhodora 56, 310-317 (1963), with H. Harries.

The North Atlantic flora - its history and late evolution. Tenth International Botanical Congress (1964), Abstracts, 139-140 (1965), with Á. Löve.

Taxonomic remarks on some American alpine plants. University of Colorado Studies, Series in Biology 17, 1-43 (1965), with Á. Löve.

Cytotaxonomy of the alpine vascular plants of Mount Washington. University of Colorado Studies, Series in Biology 24, 1-74 (1966), with Á. Löve.

Vaccinium gaultherioides Bigel. - an arctic-alpine species. Revue Roumaine de Biologie, Série Botanique 11, 295-305 (1966), with N. Boşcaiu.

The variations of Blechnum Spicant. Botanisk Tidsskrift 62, 186-196 (1966), with Á. Löve.

Íslenski dílaburkninn (Dryopteris assimilis S. Walker in Iceland). Flóra, Journal of Icelandic Botany 4, 5-9 (1966), with Á. Löve.

Biosystematics of widely disjunctive taxa. Die Naturwissenschaften 54, 24-25 (1967), with Á. Löve.

Polyploidy and altitude: Mt. Washington. Biologisches Zentralblatt 86, Beiheft, 307-312 (1967), with Á. Löve.

Continental drift and the origin of the arctic-alpine flora. Revue Roumaine de Biologie, Série Botanique 12, 163-169 (1967), with Á. Löve.

Evolution and the Linnaean species. Univ. Babes Bolayi din Cluj, Grǎd. Bot. Contrib. Bot. 1967, 203-210 (1967), with Á. Löve.

The origin of the North Atlantic flora. Aquilo, Ser. Bot. 6, 52-66 (1967), with Á. Löve.

Cytotaxonomy of Blechnum Spicant. Collectanea Botanica 7, 665 - 676 (1968), with Å. Löve.

The diploid perennial *Anthoxanthum*. Science in Iceland 1968, 26 - 30 (1968), with Á. Löve.

Chromosome numbers of Orchidaceae. Taxon 18, 312 (1969), with Á. Löve.

Papaver at high altitudes in the Rocky Mountains. Brittonia 21, 1 - 10 (1969).

Subarctic and subalpine - where and what? - Journal of Arctic and Alpine Research 2 (1970) (in press).

VI. Explanation of the Budget

Only a small part of the budget concerns costs other than salaries; these are mainly self-explanatory and are based on experience from the last five years. We ask for a salary for Doris Löve, who has a non-salaried appointment as a Research Associate with the Department of Biology, and who has carried the heaviest load of these investigations for the past five years with only nominal remuneration compared with others possessing similar qualifications. We also ask for support for one technical assistant, since such support is not available from the University. This assistant will take care of the plants and prepare them for cytological studies, and also assist in collecting work, with us and alone. Á. Löve expects to spend a full three months every summer on this project, as well as most of his normal research time during winters.

VII. Other Support

We have no other support for our research work at present.

CU Proposal No. 70.5.7
1/70

NATIONAL SCIENCE FOUNDATION

VIII. BUDGET

Institution: The Regents of the University of Colorado Boulder, Colorado 80302

Title: Completion of Studies of the Cytotaxonomy of the Arctic-Alpine Flora of Colorado

Co-Principal Investigators: Áskell Löve, Doris Löve

Starting Date & Duration: 1 March 1970 (3 years)

	1st Yr.		2nd Yr.*	
	NSF	CU	NSF	CU
A. Salaries and Wages				
Senior Personnel				
Co-Principal Investigator: Á. Löve				
100% time, 3 mos. summer	$ 5,670(3MM)		$ 6,120(3MM)	
25% time, 9 mos. A.Y.		$ 4,080(2MM)		$ 4,410(2MM)
Co-Principal Investigator: D. Löve				
100% time, 12 mos.	10,500(12MM)		11,350(12MM)	
Other Personnel				
Technical Assistant				
100% time, 12 mos.	6,000(12MM)		6,000(12MM)	
Total Salaries and Wages	$22,170	$ 4,080	$23,470	$ 4,410
B. Fringe Benefits				
TIAA - 7% of faculty salaries	1,130	285	1,220	310
PERA - 8% of staff salaries	480		480	
Total Fringe Benefits	$ 1,610	$ 285	$ 1,700	$ 310
C. Permanent Equipment - None	-0-	-0-	-0-	-0-
D. Expendable Supplies and Equipment	500		500	
E. Travel				
Domestic: Field collections and visits to herbaria	400		400	

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CU Proposal No. 70.5.7
Budget Cont'd

	1st Yr. NSF	1st Yr. CU	2nd Yr. NSF	2nd Yr. CU
F. Publication Costs				
Page charges and reprints	$ 600		$ 600	
G. Other Costs - None	-0-	-0-	-0-	-0-
H. Total Direct Costs	$25,280	$ 4,365	$26,670	$ 4,720
I. Indirect Costs				
On campus: 45% of salaries & wages	9,975	1,835	10,560	1,985
J. Total Costs	$35,255	$ 6,200	$37,230	$ 6,705

TOTAL REQUESTED FROM NSF FOR TWO YEARS: $72,485

*This budget covers the first two years of an anticipated three-year project.

Izvestiya Akademii Nauk SSSR (News from the Acad. Sci. USSR) Biol. Ser.
nr 3, 1960: 429 - 442.

B.A. Tikhomirov, V.F. Shamurin, V.S.Shtepa:

The temperature of arctic plants.

Introduktion.

Review of previous works by various authors (Gorodkov, 1932; Zubkov, 1932, 1955; Sörensen, 1941; Franssila, 1945; Tikhomirov, 1952, 1956, Bliss, 1956; Grigor'ev 1946, 1956:, Sokolovskaya 1932; Wilson 1957; Krog, 1954; Lorenson, 1957; Budyko 1959; Wallace and Clum 1938; Tiessen, 1912)

The authors investigated ca. 40 species, including such as: Lloydia serotina, Polygonum ellipticum, Claytonia arctica, Minuartia arctica, M. microcarpa, Papaver lapponicum, Rhodiola borealis, Saxifraga caespitosa, S. flagellaris, Sieversia /Geum/ glacialis, Dryas punctata, Astragalus umbellatus, Oxytropis nigrescens, Cassiope tetragona, Diapensia obovata, Lagotis minor, Pedicularis Adamsii, P. capitata, P. Oederi, Senecio atropurpureum etc.

Temperature in organs above ground.

The temperature of leaves were measured on July 7, 1955. Solar radiation intensity 1.o cal/cm^2/min, slight NE winds.

Table 1. Data of temp. measurements of leaves. (°C)

	Dryas punct.	Siov. glac.	Cassio. tetrag.	Astr. umb.	Oxytr. nigr.	Pedic. Oed.
Upper leaf-surface	16.o	11.8	12.o	14.2	15.6	13.4
Surrounding air	10.6	9.8	10.5	12.8	10.8	9.6
Diff. in temp. leaf/air	4.4	2.o	1.5	1.4	4.8	3.8
Air at 1.5 m	5.2	5.2	5.2	5.2	5.2	5.2
Diff. in temp. leaves/air at 1.5 m	9.8	6.6	6.8	9.o	10.4	8.2

"surrounding air" is measured at the same level as the leaves at a distance from the leaves of 1 - 1.5 cm.

All measurments are made with thermo-couples.

Table 2. Temp. measurements on some lichen surfaces.

species	surface of lich.	surr. air	temp. diff.	air at 1.5 m	diff. lich/air1.5	remarks
Cetraria chrysantha	13.8	8.4	5.4	5.o	8.8	top of lichen
Stereocaulon paschale	7.7	6.1	1.6	5.o	2.o	d:o
Duforea arctica	11.6	10.4	1.2	5.o	6.6	d:o
d:o	12.6	10.4	2.2	5.o	7.6	cavity in lichen

The measurements of tables 3 and 4 were made between 14 - 15 hrs (= 2 and 3 p.m.) on July 6, 1955 at an air temperature of 7° C at 1.5 m. above ground, in a light NE wind. Table 3 shows a correlation between temperature of flower and the petal-color; the darker the flower, the warmer it is. Table 4 shows no such correlation in buds (cf. Yurtsev, 1959).

Table 3. Results of measurements of flowers.

species	temp. inside flower	air temp at level of flower	diff. in temp.	flower color
Draba sp.	8.3	7.6	0.7	white
Cassiope tetr.	11.1	10.1	1.o	"
Lloydia serotl	11.2	9.6	1.6	"
Minuartia arct.	11.2	9.2	2.0	"
Sieversia glac.	7.o	9.o	2.o	yellow
Rhodiola bor.	8.3	6.o	2.3	yellow-rosy
Lagotis minor	12.4	9.o	3.4	blue
Oxytropis nigr.	15.2	11.o	4.2	lilac

Table 4. Results of measurements of buds.

species	temp. inside bud	air temp. around bud	diff. in temp.	color of corolla
Dryas punct.	12.2	10.2	2.o	white
Polygonum ellipt.	11.o	8.4	2.6	rosy
Minuartia arct.	12.o	9.2	2.8	white
Rhodiola borealis	8.8	6.o	2.8	yellow-rosy
Pedicularis capit.	13.1	9.9	3.2	white
Astragalus umb.	11.1	7.8	3.3	yellow
Claytonia arct.	13.2	9.1	4.1	rosy-white

The temperature can vary at the same time in different parts of the same ~~fix~~ plant as expressed in table 5:

(Solar-intensity radiation was measured with the albedometric systeme of Yanishevskovo- Kalitina)

Table 5. Temperature measurement data in diff. parts of the flower.

date	July 7, 1955						July 10, 1955					
weather	sunny, NE wind 1.5-2 m/sec						cloudy, light NE wind, fog					
time	15.30			16 30			14 30			17 00		
radiation cal/mm²/min	0.969			0.782			0.578			—		
	Dryas punct.	Cass. tetr.	Oxyt. nigr.	Dryas punct.	Cass. tetr.	Diap. obov.	Dryas punct.	Sax. flag.	Diap. oboc.	Sax. caes.	Papav. lapp.	Min. arct.
surr. air	9.2	10.5	10.8	18.o	13.o	16.6	10.o	9.5	9.2	5.6	6.o	7.1
diff. air/ flower: outside calyx	0.8	1.7	8.1	0.o	0.2	-2.8	-0.7		0.3	0.5		
outside corolla		0.o	0.6	0.8	0.6	0.3		0.o			-0.1	
inside "		0.7		1.2		0.9	0.2			-0.2	-0.1	-0.1
stamen surface	0.2			3.2		0.8	0.2	-0.4		0.5		0.o
pistill "	1.o			1.2		0.6		-0.5		0.5		
inside ovary (punctured)	2.1			0.6			0.2					
inx cavity of flower	o.o		7.8		0.9	1.4		-0.6	0.o	2.4	o.6	2.2

Obs! In table 5 no absolute figures for temperatures in flowers, only the difference between surrounding airtemperature and the floral parts.

It was of interest to know the temperature of fruits in plants with wind-dispersed seeds, so Sieversia glacialis was measured (Table 6).

Table 6. Temperature of surface of fruits between pappus of Sieversia glacialis.

	date and time					
	6. July		7. July		12. July	
	14 00	15 00	15 30	17 15	9 30	12 00
surface of fruit	12.2	9.2	16.8	12.4	10.6	15.5
air around fr. head	8.6	7.o	10.5	8.4	7.4	11.1
temp. diff.	3.6	2.2	6.3	4.o	3.2	4.4

Temperature of organs under ground.

Root temperature, cf. Huber, 1935

We measured the temperature of root surfaces and inside roots, puncturing the tissue. Table 7.

Table. 7. Temperatures of roots and soil.

species	depth from soil surface	temp. roots	temp. soil	temp. diff. root/ soil
Diapensia obov.	5 cm	10.8	6.8	4.0
Cassiope tetr.	5	11.8	7.4	4.4
Pedicularis Ad.	5	9.6	7.2	2.4
Oxytropis nigr.	10	5.6	5.6	0.0
Sieversia glac.	10	5.2	4.8	0.4
" "	10	6.4	5.6	0.8
Astragalus umb.	10	6.3	5.2	1.1
" "	10	7.o	5.o	2.o

Temperature gradients in different parts of the plants.

cf. Geiger, 1931, Wilson 1957.

Fig. 1 shows temperature gradient on a sunny day, July 6, 1955 with a NE wind of 1 - 2 m/sec. The time, 14, 15 and 16 hrs (= 2,3,4 p.m.)

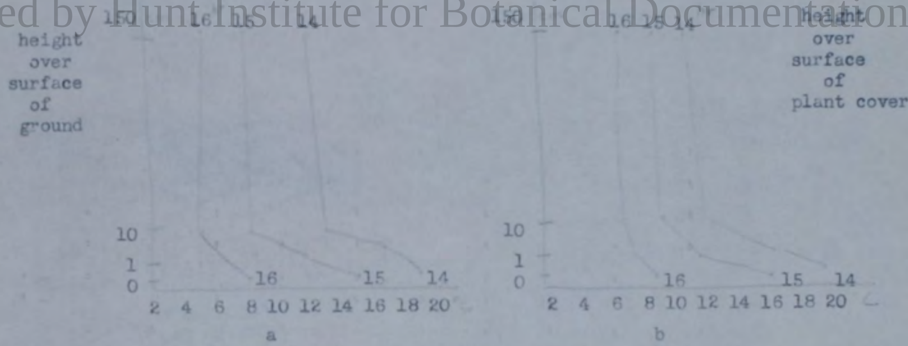


Fig. 1. Temperature gradient in air above ground: a over an open spot, b. over a vegetation cover (a copse of Dryas punctata).

As an example of how temperatures can vary in different parts of the same plant at the same time, we measured various parts of Sieversia glacialis (table 8.) . The highest temperatures were found in parts near the ground, in rosett leaves and stemparts.

Table. 8. Temperature gradients in separate parts of Sieversia glacialis.

date	July 6		July 7		July 12	
weather	sunny NE wind		sunny NE wind		light fog NE wind sun shining through	
radiation intensity	—	—	0.969	0.782	0.714	0.714
time	14^{00}	17^{10}	15^{30}	17^{15}	12^{00}	12^{10}
air at 1.5 m	7.o	2.4	5.2	5.o	12.3	12.3
air at 15 cm	8.6	4.6	10.8	8.4	14.7	14.7
inside head	12.2	8.3	16.8	12.4	15.5	15.3
stalk under head	10.9	6.2	10.6	-	14.8	16.o
stalk, lower part	8.4	5.1	9.8	8.6	13.3	16.5
rosett leaves	10.8	5.5	11.8	9.8	18.9	18.6
root neck	7.8	-	14.6	-	16.8	18.o
root stock	10.4	4.4	9.o	-	6.3	5.5
roots at 5 cm	8.7	2.9	7.o	-	4.8	4. 8
roots at 10 cm	8.o	2.1	4.6	6.4	3.3	3.7

Fig. 2. Schema of the distribution of intensity of life processes depending on the thermal regimen in the biosphere of the Arctic. 1-thermal air minimum, 2- level of max. plant growth, 3-,4-,5- max. intensity of life processes and max. accumulation of plant matter, 6- level of permafrost, max penetrance of roots. 7- thermal min. in pedosphere.

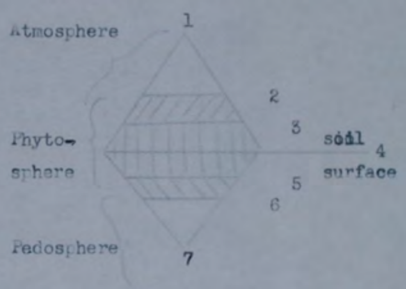
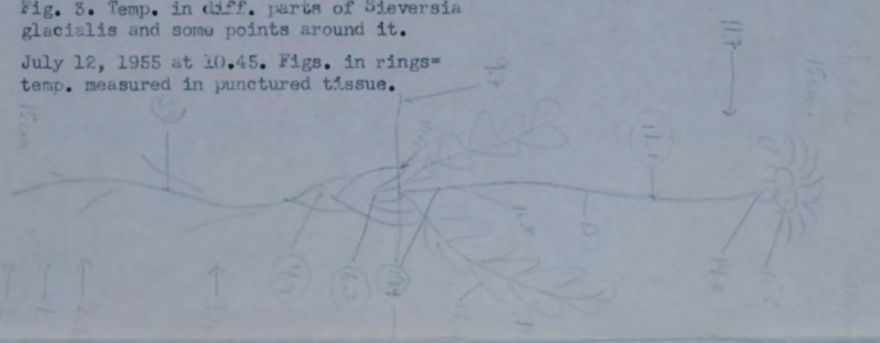


Fig. 3. Temp. in diff. parts of Sieversia glacialis and some points around it.
July 12, 1955 at 10.45. Figs. in rings= temp. measured in punctured tissue.



It was found that there is not only a vertical temperature gradient but also a lateral one depending on the sun and shade. Fig. 3 and table 9.

Table 9. Temperature on sunny and shady sides of the flower head of *Pedicularis Adamsii* (°C)

	inside the flowers				on the pubescens			
	top fl.	3rd fl. from top	middle fl.	basal fl.	top fl.	3rd fl. from top	middle fl.	basal fl.
sunny side	8.4	9.6	14.o	12.2	15.4	14.6	14.2	15.5
shade "	5.8	5.4	5.o	4.8	12.o	12.o	11.1	10.6
diff.	2.6	4.2	9.o	7.4	3.4	2.6	3.2	4.9
air temp around plant		8.o				13.5		

Summary (in improved English):

In 1955 a number of Arctic plants have been subjected to temperature measurements of different parts with a microthermocouple (microxxxxxx electrothermometer)prepared at the Inst. of Agrophysics (Leningrad). The investigations were carried out in the environment of Tiksi, Yakutsk, ASSR (71°35'N. L.).

Plants are highly dependent on solar radiation. This was proved. In sunny days the temperature of leaves and other parts of the plant exceeded by a few degrees (2 - 5°C) the surrounding air. On cloudy days the temperature of leaves, flowers etc. may fall below that of the air.

The extremely uneven temperature of a plant due to vertical temp. gradients of the surrounding air is conspicuous. The highest temp. in a plant is recorded near the soil surface (in rosett leaves etc.).

The uneven heating of a plant is also due to a xxxxxa lateral gradient due to sun, shade and wind conditions.

The temperature of the flower is correlated to its color, dark flowers being warmer than lightcolored.

Pubescens has a heatpreserving effect favorable for bud-development and ripening of the seeds in pubescent racemes.

This is a preliminary report. Further investigations on the temp. of Arctic plants are indespensable in order to provide complete thermal characteristics of the Arctic.plant associations and to evaluate the relation between air and plants in diff. environments. (Transl. Doris Löve)

Literature cited:

Andreyev V.N. & Vakhtina, G.V., 1959: The influence of the near-ground climate on the phenology of plants in the Subarctic. Priroda 6. (Russian)

Budyko, M.I., 1959: On heat balance in living organisms. - Izv. Ac. Sci. USSR, Geogr. ser. 1. (Russ.)

Geiger, R., 1931: The climate of the air xxxx layer near the ground. - Trud. SOPS Ac. Sci USSR, "Northern" ser. 1, Leningrad (Russ.)

Grigor'ev, A.A. 1946: The Subarctic. Ed. by Ac. Sci. USSR, Moscow-Leningrad. - 1956. The Subarctic. 2nd. Ed. Geografy. Moscow. (Russ.)

Dadykin, V.P. and Stanko, S.A., Gorbunova, G.S. and Igumnova, Z.S., 1957: On the utilisation of light by plants in Yakutsk and Tiski. - Dokl. Ac. Sci. USSR, 115. (Russ.)

Zubkov, A.I., 1932: Tundra of the Gusini Zemlya (Goose-land). - Trud. Bot. Mus. Ac. Sci. USSR, 25 (1935). (Russ.)

Kalitin, N.N., 1933: The scattered radiation in the atmosphere under Arctic conditions. - Izv. Ac. Sci. USSR, Dept. of Math. and Nat. Sci., ser. geogr. and geofys., 2 - 3. (Russ.)

Middendorff, A.F., 1860 - 1867: Expedition to northern and eastern Siberia. SP 6. (Russ.)

Sokolovskaya, A.P., 1932: On the problem of the action of solar radiation on the temperature of some plants on the puszta of Kara-Koum. - Trud. po priklimat. bot. - 1933: Investigation of solar radiation, as well as of some micriklimatical factors in the temperature regimen of plants. - Bot. Zhurn USSR 18, 5. (Russ.)

Strelkova, I.D. 1940: Investigation of solar radiation on the ecology of some alpine insects. - Zool. zhizn XIX, 2. (Russ.)

Tikhomirov, B.A., 1951: On the correlation of the height of stems and plants in the Far North at the time of flowering and fruiting. - Priroda 5. - 1952: Investigation of the moss-cover for the life of plants in the Far North. - Bot. Zhurn. 37, 5. - 1956: Some peculiarities of the tundra snow cover and its importans for the existence of plants. - In the book: "Snow and melt water", ed. In-ta geogr. Ac. Sci. USSR, Moscow. (Russ.)

Chikireba, G.A., 1952: On measurements of the temperature on "flat" lichens. - Trud. Gl. geogr. observ., 29 (91). (Russ.)

Shamurin, V.F., 1958: On the daily rythm and the ecology of flowers of some arctic plants. - Bot. Zhurn., XVIII, 8. (Russ.)

Yurtzev, B.A., 1959: Material for the knowledge of arctic Oxytropis. - Bot. Mat. Herb. XIX, Moscow-Leningrad. (Russ.)

Bliss, L.C., 1956: A comparison of plant development in microenvironments of Arctic and Alpine tundras. - Ecol. Monographs, 26, 4.

Franssila, M., 1945: Mikroklimatische Temperaturmessungen in Sodankylä. - Mitt. Met. Zentr. Anst. Helsingfors, 26.

Huber, B., 1935. Der Wärmehaushalt der Pflanzen.

Krog, J. 1955: Notes on temperature measurments indicative of special organization in Arctic and Subarctic plants for utilization of radiated heat from the sun. - Plant. Physiol. 8, 4.

Lorenzen, H. 1957: Wärmeausnutzung der arktischen Pflanzen. - Naturwiss. Rundschau, 10, 6.

Shaw, R.H., 1954: Leaf and air temperatures under freezing conditions. - Plant. Physiol., 29.

Sörensen, Th., 1941: Temperature relation and phenology of the northeast Greenland flowering plants. - Medd. om Groenl. 125, 9.

Tiessen, H. 1912: Über die Pflanzengewebe nach Verletzungen auftretende Wundwärme. - Beitr. biol. Pfl., II.

Wallace, R.H. and Clum, H.H., 1938: Leaf temperatures. - Am. J. Bot. 25.

Wilson, J.W., 1957: Observations on the temperature of Arctic plants and their environment. - Journ. Ecol. 35, 2.

Bot. Inst., Ac. Sci. USSR.

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The ~~xxpxintxxpxxxxxfxxx~~ paper was delivered to the printer on 25.VIII.1959

V. A. Gavriliok: Duration of the period of fruiting and seed production in plants from SE Chukotk.

(Bot. Journ. vol. XLVI: (1): 90 - 97. 1961.)

Introduction.

Historical review (Middendorff, Kjellman, Kihlman, Ekstam in 19th cent.; Tikhomirov 1950, 1951, 1956 a & b; Höeg, 1932; Söyrinki, 1939).

The flora of Chukotk has ca. 300 species (Sochava 1944, Tikhomirov 1956).

The vegetation period under most favorable conditions (on a S-facing slope and a snow cover of 40 cm. - 1 m. during winter) lasts 100 - 110 days. In other cases, when the snow is very thick (in places up to 10 ÷ 12 m), the duration of the vegetation period is less than 30 days, most of it in August (from the end of the summer to the beginning of the fall). The average seems to be 90 - 100 days. The best growth is found in plants which have there vegetation period from the latter part of june and throughout July. This data coincide with such given by other investigators (Sörensen, 1941, Billings and Eliss, 1959) and are important for the life of Arctic plants, where snow cover is one of the important ecological factors.

On the other hand a very great depth of snow (7 - 9 m. or more) can delay the beginning of the vegetationperiod due to lack of heat. Some temperature data are given by Tikhomirov in 1957.

The plants of Chukotk can be divided into groups according to the length of their vegetation and fruiting periods.(cf. table 1.)

It is interesting to note that in Chukotk most Ericaceae belong to group I (plants with soft berries such as Arctous alpina, Vaccinium uliginosus, Vacc. Vitis Ideae, Rubus Chamaemorus, though the last two rarely fruit in our area). Very juicy berry-producers such as Empetrum hermaphroditum takes 58 - 54 days ~~to fruit~~ for the fruits to ripen, but its darkpurple (almost black) colored fruits remain on the bush and keep all winter and part of the spring next year.

The shortest time to produce is taken by species of small, dry seeds from families such as Caryophyllaceae, Portulaccaeeae, Compositae, some Crusiferae (Cochlearia, Draba) etc. Also by all Gentianaceae, esp. Gentiana Tenella, auriculata and nutans.

Table 1. Duration of fruiting period in some plants f om Chukotk.

group	species	duration of vegetation periods	duration of fruiting periods	% time for fruiting of all veget. time
I	Cassiope tetragona	112	72	64.o
	Loiseleuria procumbens	118	50	42.o
	Ledum decumbens	102	65	63.7
	Rhododendron kamchaticum	90	60	66.6
II	Diapensia obovata	112	48	42.8
	Dryas punctata	118	40	34.o
	Silene acaulis	96	40	41.6
	Saxifraga oppositifolia	96	42	43.7
III	Acomastylis rossii	86	34	39.o
	Anemone parviflora	65	38	58.o
	Minuartia arctica	79	35	45.5
	Salix reticulata	70	38	54.3
IV	Draba pseudopilosa	95	28	27.3
	Minuartia rubella	73	20	22.o
	Parnassia kotzebui	78	28	34.o
	Gentiana nutans	65	20	29.2

I - plants with very long fruiting period (50 - 75 days)

II- plants with a long fruiting period (40 - 50 days)

III- plants with a medium long fruiting period (30 - 40 days)

IV - plants with a short fruiting period (less than 30 days).

The vegetation period depends on the snow-cover. On some southfacing slopes up to 12 meter can collect, but a cover of 6 - 7 meter on a N-facing slope has as much effect on the retardation of plant growth in this area. Some species are dependent on a snow-cover for their existence, such as Cassiope tetragona, Phyllodoce coerulea and Acomastylis rossii.

Fig. 1. Duration of fruiting time op three species on 6 diff. localities.

loc.	Empetrum herm. date	Empetrum herm. days	Cassiope tetr. date	Cassiope tetr. days	Acomastylis rossii date	Acomastylis rossii days
I	29/V - 2/VIII	65	23/VI - 3/IX	72	3/VII - 13/VIII	41
II	10/VI- 2/VIII	54	10/VII- 7/IX	59	12/VII - 13/VIII	32
III	12/VI -2/VIII	52	14/VII-13/IX	61	21/VII - 13/VIII	23
IV	1/VII -23/VIII	53	17/VII- 13/IX	58	18/VII - 16/VIII	29
V	3/VII - 30/VIII	58	21/VII- 13/IX	54	23/VII - 28/VIII	36
VI			24/VII - 15/IX	51	25/VII - 28/VIII	34

The production of fruits and seeds in a given place depends on one or more of the following limiting factors a - c:

a) Meteorological factors:

Strong winds in some places destroy flowers and plants having high flower stalks (9 - 10 cm or more) e.g. Sieversia glacialis. But this species is also depending on the wind for its fertilisation. Thick, freezing fog, lasting for more than a week at a time, hurts the flowers and prevents the bumblebees from working. Short time night frost at the flowering time does not seem to influence fruitsetting.

b) Insect-pollination:

Bombys lapponicus and B. hyperborea (bumblebees) are very important. 20 species depend solely on them for fertilisation, especially Phyllodoce, Lagotis, Dryas, Leguminose plants, Vaccinium, Arctous etc. Oxytropis Maydelliana and O. borealis were isolated, and produced no fruits without the aid of the bees. Bombys hyperborea was observed to visit not less than 24 flowers of Dryas pr minute, or 29 phyllodoce flowers.

(Fig. 2. Dryas punctata massflowering on S-facing slope.

Fig. 3. Cassiope tetragona do on S.facing slope.)

Much pollen (Dryas) or nectar (Phyllodoce, Loiseleuria, Vaccinium) attracts the bees. Strong scent in Eritrichium and Parrya nudicaulis has similar attraction. The bees do not work in temperatures below 4 - 5°C, or in frosty fog. If e.g. Dryas flowers too early (24 - 29/VI) it does not get fertilized. The best time for insect fertilisation is in the beginning of july.

c) Importance of other animals:

Many small birds live off the seeds and fruits of e.g. Sieversia, Acomastylis and Oxytropis. Gophers(Citellus undulatus) collect much berries, e.g. of Empetrum, Coelopleurum, Phyllodoce, and often destroy roots and devore legumes. Considerable damage is done by the larva of Cidaria caesiata (the inchworm?) living in the fruiting parts of Dryas. It does not touch petals and sepals, and flower can florish as usually but sets no seeds.

All factors a - c cause a decrease in quantity of generative diaspores and lead sometimes to a complete destruction of the plants in a place.

Observations of the seasonal variation in certain plants and its association to data observed on fruit production give some general information:

A very big production of fruits and a steady one is accomplished by some wide-spread and well-established species such as Emeptrum and certain Cyperaceae.

Rare species, e.g. such as originate from boreal areas, and having special ecological habitats, produce seeds more sporadically (Chamaepericlymenum/Cornus/ suecica, Polygonum tripterocarpum, etc.) and som do not fruit at all (Chamaenerium/Epilobium/ angustifolium, Galium boreale) in our area, or very rarely as Veratrum oxysepala. Some xxxtax alluvial meadow-plants have succeded to penetrate into some tundra associations along rivers and fruit energetically near the rivers (Primula arctica, Minuartia macrocarpa, Carex marina). Aconitum delphinifolium has been observed also in the phytocoenoses covering the tundra, but fruits only in the gallery associations along rivers.

More concrete data on seed production is given in Table 2.

Table 2.

Seed production in some SE Chukotk plants.

species	nr plants m^2	date of anth.	nr fl. m^2	date of ripe fruit	nr. fl. set fruit	% of anth.	nr seeds m^2	total seed weight	one seed gram	habitat
Loiseleuria proc.	2	24/VI	1049	15/IX	347	33.1	12130	0.204 g	0.0000168	lichen-scrub
Anemone sibirica	121	25/VI	258	15/VIII	258	100.o	2641	4.778	0.00181	spotted ass. slop.riv.bank
Phyllodoce coer.	1	12/VII	442	29/VIII	337	76,2	60977	0.530	0.0000087	open ass. on slop. riv.bank
Ranunculus lapp.	78	29/VI	100	28/VIII	100	100.o	1499	3.082	0.002055	Sphagn.-segde ass. on riv.bar
Coelopleurum gmel.	25	30/VI	18255	4/IX	18167	99.5	36334	130.803	0.0036	covering alluv. river meadow
Primula arctica	100	24/VII	759	4/IX	613	80.7	46913	9.331	0.000199	
Chrysanth. arct.	50	16/VII	50	6/IX	50	100.o	3967	1.190	0.0003	
Loydia serotina	100	16/VI	100	28/VIII	2	2.o	?	-	-	
Acomastylis ross.	-	30/VI	500	16/VIII	405	81.o	5725	6.240	0.00109	grass-shrub ass. on slope 50 m. above sealevel.

Some sedds are very light and easily carried by wind, e.g. those of Phyllodoce (0.000 008 7 g pr seed) and Loiseleuria (0.000 016 8 g pr seed). Cf. also Porsild, 1951, Tikhomirov 1951 b.

Table 3. illustrates different mechanisms of seed-dispersal and there occurence in our area.

Table 3.

Groups of plants according to dissemination of seeds and fruits.

group	nr of species	% of total nr of sp.
Hydrochores	30	10.o
Anemochores	251	83.5
Zoochores	9	3.o
Autochores	6	2.o
Div. types	5	1.5
total	301	100.o %

Summary:

1) According to the duration of the fruiting period plants from SE Chukotk can be divided into some groups: Thoses with very long fruiting time (50 - 75 days), long time (40 - 50 days), averagex time (30 - 40 days) and short time (less than 30 days).

2) To a certain degree the development of seeds on plants of the first and second groups (very long and long time) speed up their seed ri ening at the time of the autumnal fall of the temperature and arrival of frost. This phenomenon stands in relation to the ability of the arctic plants to ripen their fruits under the snow.

3) The duration of the fruiting time in the plants investigated varies depending on the time of the beginning of their vegetation period. This is determindd not only by the biological characteristics of the plant, but also to a considerable degree by the depth of the snow cover and the exposure of the slope. The most optimal conditions presents themselves to plants for which the ripening period occurs in the second half of June and throughout July. If flowering occurs too early or very late a delay in seed ripening is suffered.

4) The majority of species in SE Chukotk yield mature fruits at the onslaught of winter. The most abundantly and steadily fruiting are representatives of the families Empetraceae and Cyperaceae. Very little fruits are produced by the seldom widespread species of the families Cornaceae, Violaceae and some others. Some species often set no seed at all (Chamaepericlymenum angustifolium, Rumus arcticus, Elymus mollis, Galium boreale) and some do not even flower (Comarum palustre).

5. Productivity of seeds varies with diff. species, due to their genetics, but also ecology and biotal factors. Even after intense flowering seed-setting does not necessarily become high.

(transl. D. Löve)

Literature cited:

Beideman, I.N., 1954: Phenological observation methods for geobotanical investigations (Russ.)

Rabotnov, T.A., 1950: The life cycles of perennial grass-species in meadow coenoses. - Trud. BIN Ac. Sci. USSR, ser. III, 6. (Russ.)

Sochava, V.B., 1944: On the pioneer flora of northern polar countries. - Priroda 4.(Russ.)

Tikhomirov, B.A., 1950: On the biology of plants in the Far North. - Biol. MOIP, dept. of biol., 55 (4) . - 1951a: On the correlation of heights in stems and plants in the Far North xxx at the time of flowering and fruiting. - Priroda 5. - 1951 b: On the role of wind for the dispersal of plants in the Far North. Priroda 8. - 1956: Some peculiarities of the tundra snow cover and its importance for the existence of the vegetation. - In the book: "Snow and melt water". - 1957: On the characteristica of flora and vegetation around the hot springs in Chukotk. - Bot. Zhurn. 9. (Russ.)

Billings, B.D. and Bliss, L.C., 1959: An alpine snowbank environment and its effect on vegetation, plant development and productivity. Ecology, 40, 3.

Eklund, O. 1929: Die quantitative Diasporenproduktion einiger Angiospermen. - Mem. Soc. p. Fauna and Flora Fenn. 5.

Ekstam, O. 1897: Bl-tenbiologischen Beobachtungen auf Novaja Semlja. - Aftr. a Tromsö Mus. Aarsh. 18.

Höeg, O.A., 1932: Bl-tenbiologische beobachtungen aus Spitzbergen. - Medd. om Groenl., 16.

Kihlman, A.O. 1890: Pflanzenbiologischen Studien aus Russisch Lappland.- Acta Soc. p. Fauna et Flora Fenn. VI, 3.

Kjellman, F.R., 1885: Aus dem Leben der Polarpflanzen. Leipzig.

Liipmaa, Th., 1929: Pflanzenökologische Untersuchungen aus Norvegisch- und Finnish-Lappland under besonderer Ber-chsichtigung der Lichtfrage. - Act. Inst. et Hort. Bot. Univ. Tartuensis. -

Perttula, U., 1941: Untersuchungen -ber die generative und vegetative Vermehrung der Bl-tenpflanzen in der Wald-, Hein-, Wiesen- und Heinfelsenvegetation. - Ann. Acac. Sci. Fenn. ser. A, LVIII, 1.

Porsild, A.E. 1920 Sur les poides et les dimension des grenes arctiques. - Rev. Gen. de Bot. 32. - 1951: Plant life in the Arctic. - Plants and Garden, N.S. 7, 4, new ser.

Sörensen, Th., 1941: Temperature relations and phenology of the northeast Greenland flowering plants. Medd. om Groenl. 125.

Söyrinki, N., 1939: Studien -ber die generative und vegetative Vermehrung der Samenpflanzen in der alpinen Vegetation Petsamo-Lapplands. - Bot.Soc.Zool-Bot. Fenn. 14.,1.