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MONOGRAPHING IN THE 1980s[1]

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ABSTRACT

The production of taxonomic monographs is discussed in light of the modern tools that are available for their preparation. There is a great need for more monographs since much of the world's flora is not treated in contemporary revisions. These should be a balance between the traditional aspects that must still be employed such as the nomenclatural framework and the consultation of type specimens, and the use of modern techniques, computer data analysis and field work. The importance of field studies in association with monographic studies is stressed both to give a better understanding of traditional morphological features and to collect material for such aspects as cytology, anatomy, and pollen studies. Techniques that are particularly helpful include chemosystematics, SEM work, anatomy, embryology, palynology, and chloroplast DNA. The availability of computers has come at a good time when there are many more data to analyze. Monographers should use computers both for word processing and data analysis. It is hoped that the new methods and tools will not become an end in themselves since there are still many large plant groups in urgent need of monographs.

Key words: Caryocaraceae, Chrysobalanaceae, computerization, field work, Lecythidaceae, monographs.

INTRODUCTION

The production of scholarly monographs of different plant groups should continue to be a high priority for contemporary systematics. It is surprising that for many large and important plant groups we are still relying on monographs produced in the nineteenth century or early part of the twentieth century. This is especially true for large tropical families. At the present time when there are numerous local floristic projects in progress around the tropics where deforestation is rampant, it is particularly important to have the sound monographic groundwork upon which these regional floras can be based. The tools, techniques, and sources of data available for monographers have increased remarkably during the last 50 years. Consequently, the synthesis of data represented in a contemporary monograph can be more accurate than in the past because it is based on so much additional information. Concomitant with this is the problem of the synthesis of so many data and, also, their use in producing a product that is usable by the field worker and local residents. For these reasons I want to address here some of the steps involved in the production of a monograph based on my experience with such families as the Chrysobalanaceae and Lecythidaceae and to look at both potential sources of data and their synthesis.

THE NEED FOR MORE MONOGRAPHS

I should begin by stressing the need for further monographic work and the need for major botanical gardens such as Rancho Santa Ana Botanic Garden to emphasize this as a major part of their research program. My experience with a large general collecting program in Amazonian Brazil that has yielded a vast number of herbarium specimens in need of identification has shown me that the majority of monographs of tropical plant families are out of date. When I undertook work on the Neotropical Chrysobalanaceae in 1963, I was updating the treatment of Joseph Hooker (1867) published in Martius's *Flora Brasiliensis* almost a century earlier. Between 1867 and 1972 when my monograph was published, information about the Chrysobalanaceae was widely scattered in the botanical literature of many different countries. It is not surprising that my overall treatment involved both the description of 84 new species and the reduction to synonymy of an even greater number mainly described in local floras. In the case of the Lecythidaceae the last monograph was produced hastily by Reinhardt Knuth (1939) in the troubled times of Germany leading up to World War II when travel and consultation of specimens was virtually impossible. The result was a product with keys that were quite unusable and many species described from utterly inadequate material such as an empty pyxidium without even an herbarium specimen with leaves. These are two families that have now been monographed. My concern here is for the large number of groups in the Neotropics for which no modern treatments are available such as Lauraceae, Rubiaceae, Sapindaceae, Arecaceae, and many others.

Many of the groups most in need of being monographed were last treated taxonomically without the benefit of field work and without the extensive and representative collections available today. Also, they were done without the use of modern techniques such as the electron microscopy or biochemical analyses. This is illustrated by the fact that only 4169 species of the approximately 90,000 (or 4.63%) flowering plants of the Neotropics have been treated so far in the first 39 volumes of *Flora Neotropica,* 1968–1984 (Table 1).

The type of institutions capable of supporting such work are largely botanical gardens and museums having adequate herbaria and libraries and staffs dedicated to research rather than full-time teaching. Gardens like the one we are in today have the responsibility of providing definitive monographic treatments of the world's flora.

TRADITIONAL ASPECTS THAT MUST PERSIST

Certain aspects of the synthesis of data for monographic work, which have been carried out for many years, must still be used. Since they are well known to the present audience, I need only repeat that there is no substitute for the initial bibliographic search of the literature needed to collect the protologues of all names or for the detailed study of types and other herbarium specimens to establish a nomenclatural framework in accordance with the *International code of botanical nomenclature.* However, things have progressed greatly in the last few years to speed up bibliographic aspects. Today photocopies make the gathering of protologues faster and easier than when I did my doctoral thesis and had to copy out and type all the descriptions of Chrysobalanaceae. The availability of on-line-computer library catalogs has also greatly facilitated accumulation of data. At present it is still necessary to consult a rather cumbersome *Index Kewensis* and the *Gray Herbarium Card Index* to gather data about references. However, I understand, that this will be changed soon as the *Index Kewensis* becomes computerized. The recently issued microfiche edition of Kew's cumulated copy of the index is a great help (Library 1983).

There are also numerous other more recent abstracting journals, bibliographies,

Table 1. Number of flowering plant species described in published monographs of *Flora Neotropica.*

Volume	Author(s)	Taxonomic group	Number of species
1	Cowan (1968)	*Swartzia*	127
2	Cuatrecasas (1970)	Bromelliaceae	50
7	Berg (1972)	Olmedieae-Brosimeae	68
8	Maas (1972)	Costoideae	41
9	Prance (1972*a*)	Chrysobalanaceae	328
10	Prance (1972*b*)	Dichapetalaceae	39
11	Prance (1972*c*)	Rhabdodendaceae	3
12	Prance and Silva (1973)	Caryocaraceae	23
13	Rogers and Appan (1973)	*Manihot*/Manihotoides	99
14a	Smith and Downs (1974)	Pitcairnoideae	731
14b	Smith and Downs (1977)	Tillandsioideae	815
14c	Smith and Downs (1983)	Bromelioideae	557
15	Morley (1976)	Memecyleae	81
18	Maas (1977)	Zingiberoideae	61
19	Lleras (1978)	Trigoniaceae	26
20	Johnston and Johnston (1978)	*Rhamnus*	21
21	Prance and Mori (1979)	Lecythidaceae I.	63
22	Sleumer (1980)	Flacourtiaceae	271
23	Hansen (1980)	Balanophoraceae	15
25	Gentry (1980)	Bignoniaceae I.	34
26	Mesa (1981)	Nolanaceae	18
27	Poppendieck (1981)	Cochlospermaceae	8
28	Pennington (1981)	Meliaceae	122
29	Landrum (1981)	*Myrceugenia*	38
30	Gates (1982)	*Banisteriopsis* & *Diplopteris*	96
31	Kubitzki and Renner (1982)	Lauraceae I.	62
33	Kaastra (1982)	Pilocarpinae	45
34	Daniel (1983)	*Carlowrightia*	20
35	Luteyn (1983)	*Cavendishia*	100
36	Forero (1983)	Connaraceae	101
38	Sleumer (1984)	Olacaceae	87
39	Rogers (1984)	Rubiaceae: Henriquezieae	19
			4169

and indexes that facilitate the work of the contemporary monographer such as the useful *Kew Record of Taxonomic Literature,* the *Jodrell Index,* and the *Taxonomic Literature* of Stafleu and Cowan (1976–85).

It is most important to realize that despite extravagant claims made in the early stages of numerical taxonomy, whatever techniques we use in the preparation of our monographs, there will be no substitute for the consultation of a large amount of herbarium material. In the study of such material we should become involved both in modern methods of data synthesis and in new research techniques.

COLLECTION OF DATA

Apart from the traditional study of herbarium material, many other aspects of the collection of data are important for the preparation of contemporary monographs. In general the more possible sources of data that are considered the better the classification that can be obtained. It will be possible to understand evolutionary relationships better when a variety of data sources such as cytology, chemistry, and anatomy are compared with the basic morphological data.

Field work

Elsewhere (Prance 1977, 1984), I have pointed out that the status of botanical inventory of tropical areas is far from adequate. A recent report compiled by three major botanical institutions in this country for the World Wildlife Fund emphasizes that there are many gaps in our collecting (Campbell, in prep.). We are working with an incomplete and uneven specimen sample. We must underline the need for monographers to carry out vigorous field studies, not only to collect the specimens needed for their work, but also to understand the biology of their group before writing their monograph. The end product will be much more useful and accurate when the taxonomic characters used for flower and fruit descriptions are understood in their functional role as structures adapted for pollination and seed dispersal. In addition to the functional aspect it is often hard to recognize the genuine species from herbarium material alone. This was brought home to me strongly on a recent field trip to Peru when a local botanist suggested that from his field observations the specimens which I had placed in *Caryocar glabrum* (Aubl.) Pers. in my monograph of the Caryocaraceae (Prance and da Silva 1973), were in fact two species. We were able to visit an area containing several individuals of both types and it soon became apparent to me that the local botanist was quite right. The main features distinguishing the two species are the sort of characters that do not appear readily on dried herbarium specimens, i.e., curved versus straight petioles, red versus yellow flowers, round versus angled peduncles, convex versus concave stipels, and very different bark exudates. The only way in which we have been able to interpret the species of Lecythidaceae (Prance and Mori 1980; Mori and Prance, in prep.) is through extensive field work. The unusable monograph of Knuth (1939) was the result of a study that did not involve field work and thus had no understanding of the biological species. For example, I found five of the "species" of *Allantoma,* as defined by Knuth, growing on a single tree near Manaus, Brazil. The species were based mainly on different stages of development and decomposition of fruit. An extensive field study of the large and complicated genus *Eschweilera* in French Guiana is the only way in which we have been able to resolve the taxonomy of that genus where there are few leaf characters to separate the species. Study of the complicated androecium and of bark structure has enabled us to sort out the species. Our work on Lecythidaceae was based on a large collection of pickled flowers accumulated over a ten-year period in many places by two investigators.

Our studies of French Guianan species of Lecythidaceae (Mori and Prance, in prep.) have shown that species which are superficially similar when only herbarium material is available may have consistent floral and fruit differences when studied in the field. Moreover, other features not found in specimens or recorded on labels, such as bark morphology, may be extremely useful in separating closely related species. Observations on habitat preference, phenology, or anatomy—information usually not gathered by the general collector—may provide the clue which finally indicates that a species should or should not be recognized. Here are several examples of how our field work in French Guiana has helped solve taxonomic problems.

In *Eschweilera*, the presence of flowers and fruits that turn bluish green had previously been known only in *E. decolorans* Sandw., but it soon became apparent that two groups of trees at La Fumée Mountain, Saül, in French Guiana produced this kind of flower. When we arrived in Saül both groups were in flower, but because the flowers are so similar, it wasn't until we studied the external morphology of the bark that we had any indication that two species were involved. Later we learned that the internal bark anatomy of the two groups was also different. When fruit was set, we also noted that the fruits were differently shaped. One of the species is *E. decolorans* but the other is a previously undescribed species which will be described in our work on the Lecythidaceae of French Guiana.

Other field characters useful in solving species problems are habit and habitat. For example, in the Lecythidaceae of French Guiana some species are emergents, others trees of the canopy, and still others species of the understory. Moreover, some species of Lecythidaceae at La Fumée Mountain possess buttresses and others do not. We have also demonstrated that some species prefer ridge tops whereas others are found mostly in lower areas. A striking example of such habitat separation is found in the closely related species pair *Couratari gloriosa* Sandw./*C. guianensis* Aubl. The former is always found in wet places along streams, whereas the latter occurs in well-drained sites. This separation of species pairs between flood plain and terra firme was first pointed out by Ducke (1948) and later by Pires and Prance (1977).

Phenological patterns are also useful in determining if one or several taxa are represented. Clear phenological separation is often, but not always, displayed by two closely related taxa. It was only after studying the phenology of *Lecythis idatimon* Aubl. that we were convinced that two taxa of this species are present at La Fumée Mountain. An early to late dry-season bloomer, var. *idatimon,* and a late dry- to early wet-season bloomer, var. *anomala* Mori. We have chosen to recognize these taxa at the varietal level because most collections of them are difficult to assign to a variety.

It is apparent that field studies are vital in solving many taxonomic problems. In order to obtain the sort of information useful for taxonomy, detailed local studies such as we made at La Fumée Mountain are necessary.

Another important advantage of field work by the specialist is that it also enables the collection of much ancillary material that usually is not collected by general collectors. Such collections include pickled flowers, wood, viable seeds, material for cytological studies, fixed material for morphological work, and dried leaves for biochemical analyses.

Varied Data Sources

Since it is preferable to obtain data from as many sources as possible, we have found that it is most useful to work in teams with collaborators from various specialties. The options of different data sources open to the contemporary systematist are legion, and the individual cannot expect to master them all. Furthermore, one will not have time to investigate all areas of specialization and still produce a monograph within a reasonable time period. In recent years there have been various notable contributions to taxonomy where a number of specialists in different fields have combined their efforts upon the same plant group, for example in the genus *Erythrina* (Raven 1974 and other papers in same volume) and other legumes, a concerted effort in the Onagraceae coordinated by Peter Raven, e.g., using evidence from floral anatomy (Eyde and Morgan 1973), wood anatomy (Carlquist 1975*a*); cytology (Kurabayashi, Lewis and Raven 1962), leaf architecture (Hickey 1980), pollen (Nowicke, Skvarla, Raven and Berry 1984), and flavonoid chemistry (Averett and Raven 1984), and for the Myrtales in a recent *Annals of the Missouri Botanical Garden.* Our study of the Lecythidaceae has been improved by collaboration with a palynologist in the Netherlands, a floral anatomist in Brazil, and a wood anatomist in Syracuse, New York. It is more exciting to have other people with whom to discuss one's work intelligently than it is to be the sole world specialist with whom no one can debate in an informed manner. Another advantage of such an effort is that it can often call on local resident botanists to make useful contributions, as those are dependent upon observations made over an extended period, e.g., phenology, pollination, and dispersal or even the simple act of matching the flowering material with the correct fruits and preparing more complete field-based descriptions of individual species.

It is extremely important to correlate herbarium study with modern techniques. Rancho Santa Ana Botanic Garden is a good place to stress this because of the impressive and detailed anatomical studies of Sherwin Carlquist (e.g., Carlquist 1975*a, c,* 1981).

Some of the areas that are important for the monographer to examine as potential sources of data are summarized briefly below. Most universities and other institutions offering graduate degrees in taxonomy will not consider a thesis that is only a traditional study of herbarium material. Most theses must involve one or more of these ancillary fields.

Chemosystematics.—The possibilities in this field have increased vastly over the past few years so that much more than flavonoids are now being considered. Some more recent reviews of chemotaxonomy include Bisby, Vaughan and Wright (1980), Harborne (1968), Harborne and Turner (1984), Swain (1973), and other books covering other possible approaches include Harborne, Mabry and Mabry (1975) for flavonoids, Fairbrothers (1968) for serology, and Hurka (1980) for electrophoresis.

An excellent review of the use of protein and nucleic acids in plant systematics was provided by Jensen and Fairbrothers (1983). The use of isozyme and electrophoretic studies have been particularly important. For example, Bosbach (1983) showed that by separating rabisco subunits into their polypeptides not only can hybrids be detected but the female parent known. Gottlieb (1983) gave a good review of the use of isozymes and Petersen (1983) provided a review of the use of pollen proteins in taxonomic studies of the Julianiaceae and Leitneriaceae.

The examination of nuclear DNA is becoming increasingly more feasible with such approaches as the study of heterochromatin banding through the use of Giemsa staining techniques, DNA/RNA hydridization, restriction endonuclease digestion, DNA cloning, etc. An excellent review of this subject is that of Ehrendorfer (1983).

The involvement of chemistry in monographic studies is particularly pertinent when it is also linked to the ecology of the group under investigation and its relationship to animals, since most of the compounds used as taxonomic markers serve as defense against herbivores.

Scanning electron microscopy (SEM) and surface anatomy.—The availability of scanning electron microscopes has increased and the price of these machines lowered over the last few years. This has made this useful tool much more accessible. The ability to study leaf surfaces and pollen grains has been particularly instructive for systematists. A good example of this application and of sources of information about the characteristics used are in the publications of Hardin and others (Hardin 1979; Hardin and Pilatowski 1981; Hardin and Stone 1984). Stace (1984) gave an excellent review of the taxonomic importance of leaf surface characters in taxonomy from both SEM and light microscope work. One of our collaborators working with Lecythidaceae has found that the SEM is most helpful in showing many features of the wood anatomy (C. De Zeeuw, pers. comm.). Another area in which the SEM has been particularly valuable taxonomically is in the study of seed surfaces.

Anatomy.—This is one of the areas where Rancho Santa Ana Botanic Garden has taken a lead, and I need only point out that systematic anatomy is still one of the most useful sources of information to the monographer, particularly for establishing evolutionary relationships—hence the title *Ecological strategies of xylem evolution* (Carlquist 1975*b*). Anatomy has certainly proved extremely valuable in any group which I have studied (e.g., for *Stylobasium,* Prance 1965; and *Rhabdodendron,* Prance 1968). Most recently we have found bark anatomy to be of special importance in the study of Lecythidaceae (S. A. Mori, pers. comm.). Nodal anatomy is another area where particularly useful data can be found, e.g., Neubauer (1981) in the Rubiaceae.

Embryology.—This is a much neglected field in tropical botany, partly because of the difficulty in obtaining adequate sequential material for embryological studies. Palser (1975) gave a good review of the potential of embryology, especially at the higher levels of the taxonomic hierarchy. Good examples of its use are Tobe and Raven (1983) in the Myrtales and Tobe and Raven (1984) in Chrysobalanaceae.

Palynology.—This is another area that has been greatly expanded by means of both transmission and scanning electron microscopy. The use of the SEM in palynology is well summarized by Blackmore (1984). A good example of the utility of pollen in monographic studies is found in the Gentianaceae (Maguire 1981).

Chromosome studies.—Today it is possible to expand the conventional study of chromosome number and gross morphology of the chromosome. Such techniques as heterochromatin banding and DNA contents of species has revolutionized cytotaxonomy. The techniques have been well reviewed by Greilhuber (1984).

Chloroplast DNA.—Another method that is proving of considerable use in systematics is the study of chloroplast DNA. Palmer (in press) has outlined the advantages of using chloroplast DNA for botanical systematics. The chloroplast genome is highly conserved, relatively small, yet contains enough variation for the resolution of closely related genera and species. Analysis of chloroplast DNA by restriction-site mutation can be used to construct phylogenies that are essentially free of problems caused by parallelism and convergence. Extraction and analysis using modern methods are quick and easy, especially when compared to nuclear DNA hydridization. Good examples of this type of analysis are found in Rhodes, Zhu and King (1981) with *Nicotiana,* Palmer and Zamir (1982) with *Lycopersicon,* and Palmer, Shields, Cohen and Orton (1983) with *Brassica.*

The above seven areas which I have selected as important sources of data show the variety of approaches available to the contemporary systematist. It is hardly surprising that modern methods of data synthesis have become increasingly more important in systematic studies.

DATA SYNTHESIS

The quantity of data available to the systematist has increased spectacularly over the past decades both from a large quantity of herbarium specimens and from a larger range of techniques providing new data. It is fortunate that at the same time technology has also provided new means for the synthesis of these data. The days of drawer after drawer of 3 in. × 5 in. index cards is ending because of the availability of computers. Every institution that is involved in systematic research should ensure that all its systematists have a microcomputer or access to a mainframe computer via a terminal in their office. The difference in efficiency with and without a computer is like night and day.

The computer should be used both during the research phase of a monographic project and during write-up. The systematist has a vast quantity of data that needs to be recorded and analyzed and the computer is ideal for this purpose. Today's monographer will compile records of specimens in an information retrieval system rather than on cards. Once these data are in machine-readable form they can be sorted in many ways to produce lists of exsiccatae for each species, indexes, and even distribution maps. It is not really important which computer or which software is used, it is more important that a computer be made available to the monographer. However, systems within an institution should be made compatible. A good review of the use of databases in systematics is that of Allkin and Bisby (1984).

Apart from the data management function the computer has already been much used for data analysis. It is beyond the scope of this paper to enter into lengthy arguments about which method to use, phenetics versus cladistics, etc., but there is no doubt that through the use of computers one can make more comparisons more objectively than was possible before the computer age. The danger is that the tool becomes the object of research instead of the plants. It is significant that many monographs of large groups are still being produced with little or no use of the computer, whereas many systematists using the computer have produced revisions of only small groups because they have become too enmeshed in arguments about the theory of methods used. This, however, should not put off the monographer from using the computer, which is a very helpful tool when regarded as such, as are microscopes, SEM's, mass spectrophotometers, etc.

I do not know of any critical attempt to apply cladistic methods in toto to a large, widespread, taxonomically complex, and recently revised tropical group of plants such as the Lecythidaceae or Chrysobalanaceae. Some cladists, e.g., Bremer and Wanntorp (1978), mention the possible limitations of cladistics, but they seem to consider them unimportant. Bremer and Wanntorp point out two limitations, namely the widespread occurrence of parallelism and a lack of sufficient recognizable advanced characters (apomorphies). A third and most important limitation is the frequent impossibility of detecting suitable sister groups. However, once methodological controversies have died down, I am sure that cladistics will become more an important part of monographic work enabling better understanding of evolutionary patterns.

In spite of my earlier reference to the extravagant beginnings of numerical taxonomy, it has come of age and is an important tool for the monographer. Some of the uses and methods are elegantly summed up by Dunn and Everitt (1982) in their *An introduction to mathematical taxonomy,* and recent advances in the field are given in Felenstein (1983). The use of the computer in systematics is still largely neglected by monographers of large groups because of notable failures of projects where it has been applied, such as the first two attempts at the production of a North American flora, and the extravagant claims made by its earlier proponents. In spite of this I would not be without a microcomputer in my office, and I find an increasingly large number of uses for it. It also can enable us to produce products more appropriate for the users of our taxonomy, a subject that is often forgotten!

Some systematists have also found the computer helpful in drawing up identification keys (e.g., Pankhurst 1975). Keys can be examined closely and experimented with on the computer, but we must remember that a key is an artificial product, which serves as the best way to identify species, and the objectivity obtained on the computer does not always result in the most usable key. However, keys can be experimented with on the computer by varying the input data, and computer-generated keys will often result in a more clearly thought-out final product.

Whether or not a monographer uses the computer for the actual analysis of data, all monographers today should use one for the writing-up process. Easy-to-use word processing programs make the word processor as easy to use as a typewriter, and vastly increases efficiency. I well remember the agony of having to reread various drafts of my monograph of the Chrysobalanaceae prepared in 1970. Each new draft was retyped, and, as errors were corrected, many new typos crept in. Thus, much time was lost in proofreading. Today manuscripts can be typed straight into diskettes at the first draft so that subsequent alterations can be made without changing the other text. The Lecythidaceae monograph, which we have nearly completed, is all on diskettes. At the present more and more printing firms are accepting diskettes for direct computer type setting, which will even further reduce or eliminate errors.

The word processor has many other applications for the monographer such as the preparation of the various indexes required in a monograph list of exsiccatae, and especially for the efficient organization of specimen citations. It can also be programmed to search automatically for consistency in descriptions. If one forgets to describe the leaf venation in one description, one can be reminded by the computer.

One of the most useful techniques available to monographers is that of computer-generated distribution maps. This not only saves time, but also helps one produce more accurate maps because of the necessity to pinpoint localities with the great precision necessary for entry into the computer.

Monographs produced in a machine-readable form are more readily updatable and thus of more use to the consumer of monographic data.

CONCLUSIONS

I would like to end where I began, by stressing the need for further monographic studies. Use of the new techniques mentioned here has often obscured the underlying need for basic monographic work. There are so many large tropical plant families in need of taxonomic revision that this should be made a major priority of any botanical institution. I hope that we can overcome the temptation to be dazzled by and obsessed with exciting new techniques. Rather we should use them as tools in attaining the goal of adequately monographing the world's flora. We should also give much greater heed to those who will be the users of our monographs and present our data in a format that will make them available to the forester, agriculturalist, medicinal plant specialist, and others. The need for generating floras and monographs is much greater for tropical regions because, unlike most temperate ecosystems, the tropical plant communities are threatened with mass extinctions. Monographs are most urgently needed to form the data base from which centers of endemism and diversity and of active evolution can be identified and consequently preserved.

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FOOTNOTE

[1] Contribution to the Rancho Santa Ana Botanic Garden symposium, *Trends in systematic and evolutionary botany,* 25–26 May 1985.