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Hunt Institute was dedicated in 1961 as the Rachel McMasters Miller Hunt Botanical Library, an international center for bibliographical research and service in the interests of botany and horticulture, as well as a center for the study of all aspects of the history of the plant sciences. By 1971 the Library's activities had so diversified that the name was changed to Hunt Institute for Botanical Documentation. Growth in collections and research projects led to the establishment of four programmatic departments: Archives, Art, Bibliography and the Library.

CU Proposal No. 70.5.164
4/70

A Proposal to the

National Science Foundation

for

A MONOGRAPH OF MANIHOT EMPLOYING COMPUTER-AIDED TAXIMETRIC METHODS

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

Desired Starting Date: 1 September 1970

Amount Requested from NSF: $17,180

Time Period for Which Support is Requested: One Year

Principal Investigator: David J. Rogers, Professor
Department of Biology
University of Colorado
Boulder, Colorado 80302
Telephone: 303-443-2211, Ext. 6712

Askell Löve, Chairman
Department of Biology

David J. Rogers
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

ABSTRACT

Completion of a monograph of Manihot (Euphorbiaceae) is proposed. The work will be done with the aid of three integrated computer programs, developed for this purpose in the Taximetrics Laboratory. Many species of the genus have been described since the last monograph, by F. Pax in the Pflanzenreich (1910), and no integration of the species has been attempted using present-day concepts. There are over 150 accepted species but these are very poorly defined and do not represent biological reality.

I. Objectives

1. To complete the monographic studies of the South American species of Manihot, and integrate previously completed North American species for a total study of the genus.

2. To employ a suite of computer-aided programs (taximetric methods) to demonstrate the utility and facility of these methods for taxonomic work.

II. Expected Significance

One of the long-term needs in biological endeavor is complete and up-to-date monographic work on all organisms. This proposal is in keeping with these needs. The genus Manihot, a medium-sized genus (approximately 150 recognized species) in the family Euphorbiaceae, is an entirely new-world tropical group. One species, M. esculenta Crantz, is a tropical root crop, providing the fifth largest supply of food materials in the world. (FAO Production Yearbook, 1967) Without monographic studies showing the inter-relationships of the species, modern agricultural improvement cannot proceed. With the results of monographic work, the botanist and agriculturist can be provided with information vital to continued efforts. Monographic studies provide the most certain method of developing phylogenetic and evolutionary knowledge. Until the species of a genus are embedded in a monographic work, it is impossible to develop hypotheses of origins of the genus, or of some of its more interesting species. The complex cultivated species has been shown to have derived much of its variability by hybridization with various wild relatives. (Rogers, 1965) Only in monographic work can these inter-relationships be properly evaluated.

Over the past decade, the Principal Investigator has led a team in the development of computer programs to aid the taxonomist in his endeavors.

The programs have been thoroughly tested, and have been successful in a number of applications (see Section III and V). Only by demonstrating the program's validity in actual taxonomic work can these programs be understood and adopted by the taxonomic community. This study will be the first in which all of the programs are used, in proper order.

III. Relation to Present State of Knowledge

A monograph of the North American species of Manihot has been completed (Rogers and Appan, in press), and accepted for publication as a book by the Colorado Associated University Press. The number of species in North America is smaller than the number in South America. However, using the computer methods which were successfully employed for the North American species, and having already done much of the necessary data-gathering, we expect to complete the work within one year from the time the grant is activated.

The South American species of Manihot represent a complex of trees, shrubs, subshrubs, and woody vines, whose distributions are generally given in the maps published in Rogers (1963). I have done considerable field work in the West Indies, and in Central and South America, collecting specimens and field data to give additional information necessary for a modern treatment of the genus. In addition, the expeditions led by Dr. Howard Irwin of the New York Botanical Garden to the ancient uplifted areas of central Brazil have provided a wealth of new specimens in areas which had not been studied for nearly one hundred years. The original monographic work in the genus, done by Pohl in 1827, revised by Mueller von Argau in 1866, and still further revised by Pax for the Pflanzenreich in 1910, depended upon the sporadic and incomplete samples of the early travelers. Consequently, no true knowledge of the interrelationships exists in presently available published work.

There is no modern "species concept" available for the South American members of the genus. All of the present definitions are those developed before the concept of a species as a "closed gene pool." (Figure 4 and 5 indicate procedures to identify various types of modern species concepts.) This proposal intends to provide, within the limitations imposed by information available, such a modern definition.

With respect to the methods used to derive the classification, the Taximetrics Laboratory has developed three powerful integrated computer programs to aid in the analysis and synthesis of information (data). These programs are: TAXIR, an information storage and retrieval system, with routines for extracting data for processing precisely and rapidly, a routine for preparation of keys, for preparation of indices to exsiccate, species descriptions, and preparations of distribution maps; CHARANAL, a program for evaluating (weighting) characters to be used in the classification; and SIMILARITY-GRAPH-CLUSTERING, a program to produce a series of hierarchical clusters, and, for each cluster, information about the specimens contained, the "remoteness" of the cluster, the connecting specimens, and a ranking of the specimen relationships, all based on the characters used in the study. The three programs mentioned above are described in the following papers: TAXIR -- Estabrook and Brill, 1969; CHARANAL -- Estabrook, 1967; SIMILARITY-GRAPH-CLUSTERING -- Wirth, Estabrook and Rogers, 1966. The step-wise employment of these programs is given in flow-chart form in Section VI.

IV. Relation to previous work done on this project and to similar related work

As mentioned earlier, the methods employed in this study have been tested on a number of problems in systematic botany. One of the earliest of these was that of Irwin and Rogers (1967). In this study a section of the

genus Cassia was subjected to the SIMILARITY-GRAPH-CLUSTERING procedures, with the result that an excellent classification of a difficult group of tropical legumes was derived. This paper includes some of the necessary procedures for employing a computing machine in classificatory work. Other studies employing the clustering program have been accomplished, including one by Prance, Rogers, and White (1969). Herein, the genera of the family Chrysobalanaceae were classified satisfactorily, whereas three other models were found to be ineffective. A third study, now in press, was done by Wm. Stearn, of the British Museum (Natural History) on the genus Oplonia (Acanthaceae). In addition, several students of entomological taxonomy have employed these methods successfully in production of their classifications of insects. Also, a student of fish taxonomy used these methods to classify races of fish in the western United States. Several other applications, in various stages of completion, have found the clustering program a powerful ally in solving difficult problems.

The CHARANAL program has been successfully employed by Hawksworth (1968) in studies of the dwarf mistletoe (Arceuthobium). Another application is that made by Mr. Frank Bisby, of the Forestry Herbarium, Oxford University, on a study of the legume genus Crotolaria. Publication of the last work is now in final manuscript stage. CHARANAL is a very powerful aid to the taxonomist in properly evaluating the information content of characters (a form of weighting).

The TAXIR program for information retrieval has been used in earlier parts of the monographic studies of Manihot. The program is especially powerful in handling much of the routine recording of specimen data, in specimen curating, in species descriptions, etc. The program has been used in the

Museum of the University of Colorado on bryophyte specimen data, and by Dr. Askell Löve for retrieval of plant chromosome data.

A monograph of the North American species of Manihot has already been completed, and accepted for publication by the Colorado Associated University Press. In this study, the methods listed earlier have been applied with excellent results, and the ground-work laid for the completion of all the species. While new characteristics and attributes will clearly be needed for the South American species, the general type of characters found useful for the North American species act as a guide for those of the former group. All of the type specimens are now on hand, and loans from most of the pertinent herbaria have been available for the preliminary work for some time.

V. Bibliography

Estabrook, G.F. 1967. An information theory model for character analysis. Taxon 16: 86-97.

Estabrook, G.F. and R.C. Brill. 1969. The theory of the TAXIR accessioner. Math. Biosci. 5(3/4): 327-340.

Hawksworth, F.G., G.F. Estabrook and D.J. Rogers. 1968. Application of an information theory model for character analysis in the genus Arceuthobium (Viscaceae). Taxon 17: 605-619.

Irwin, H.S. and D.J. Rogers. 1967. Monographic studies in Cassia (Leguminosae-Caesalpinioideae). II. A taximetric study of section Apoucouita. Mem. N.Y.B.G. 16: 71-120.

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Pohl, J.E. 1827. Plantae Brasiliensis Icones et descriptiones. I.

Prance, G.T., D.J. Rogers and F. White. 1969. A taximetric study of an angiosperm family: generic delimitation in the Chrysobalanaceae. New Phytol. 68: 1203-1234.

Rogers, D.J. 1963. Studies of Manihot esculenta Crantz and related species. Bull. Torr. Bot. Club 90: 43-54.

Rogers, D.J. 1965. Some botanical and ethnological considerations of Manihot esculenta. Econ. Bot. 19: 369-377.

Rogers, D.J. and S.G. Appan. 1969. Taximetric methods for delimiting biological species. Taxon 18: 609-624.

Rogers, D.J. and S.G. Appan. in press. The North American species of Manihot delimited by taximetric methods. Colorado Associated University Press. Boulder, Colorado.

VI. General Plan of the work

The procedures for this study are given in Figures 1-5. A full explanation of these procedures is given in Rogers and Appan, 1969. We have followed these processes for the North American species, and the work to be done for the South American species has been completed for that portion of the plan represented by Figure 1. Since many of the characters used in this study of the North American species (see Figure 6 for list of characters) are applicable for the South American material, much of the work represented by Figure 2 has already been done. Clearly, there will be additional characters not represented in Figure 6 for the South American species.

By judicious integration of the computer print-outs, following the stepwise processes given, the completion of the monograph can be predicted accurately. The basic studies, including both North and South American species, will be complete within three months of starting date. The integration of information on geographical and ecological data (Figure 3) will require about one month's time, and the final structuring of the integrated data into taxa will require about a month. Figures 4 and 5 illustrate the process of decision to be made with various types of species problems. Writing the monograph will require another two to three months, to be spent integrating information on nomenclature, preparing keys, and various indices. Annotation and return of the specimens will require one month.

The publication of the studies will contain charts and graphs similar to those in Figures 7 and 8, which give the basis for the decision-making process with respect to taxa and their relations. In addition, distribution maps and illustrations of the perinent characters, and of any new taxa, will accompany the finished publication.

VII. Facilities Available

I have already received the herbarium specimens representing the genus from most of the world's larger herbaria. All the available type specimens, or photographs of those not attainable, are also on hand. All the literature describing the taxa of Manihot, and the classification of the genus, have already been brought together.

Sufficient optical equipment is on hand. All specimens are stored in steel herbarium cases, under the general supervision of Dr. Wm. Weber, Curator of Botany, University of Colorado Museum.

The programs for this project are all currently running on the Graduate School Computer, a CDC 6400. Charges for faculty use amount to approximately $300 per hour for core, and $60 per hour for peripheral equipment.

VIII. Personnel

Principal Investigator: David J. Rogers, Professor of Biology
Research Associate: Dr. S.G. Appan, Taximetrics Lab., Department of Biology
Clerk-typist and work-study students: To be named
Consultant Systems Analyst: Robert Brill

Curriculum vitae follow.

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

Date 05/04/70

Prop. Ref. No. B0252h4-000

We are pleased to acknowledge receipt of your proposal which has been referred for review and evaluation to the Biological & Medical Sciences Division.

Would you please advise your institution's business office of the receipt of the proposal by the Foundation. Thank you.

Proposal Services Unit
Associate Director (Research)

F.L. 9A 22 (Jan. 68)

CU Proposal No. 70.5.164
4/70

NATIONAL SCIENCE FOUNDATION

Research Grant Budget

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

Title: A Monograph of Manihot, Employing Computer-Aided Taximetric Methods

Principal Investigator: David J. Rogers

Starting Date & Duration: 1 September 1970 (One Year)

	NSF	CU
A. Salaries & Wages		
Principal Investigator: D.J. Rogers 50% time, 2 mos. Summer 15% time, 9 mos. A.Y.	$ 1,965(1MM)	$ 2,865(1MM)
Research Associate: S.G. Appan 50% time, 12 mos.	5,000(6MM)	
Clerk-typist 15% time, 12 mos.	630(2MM)	
Work-Study Student 540 hrs. @ $1.65/hr. (20% from NSF)	180	
Total Salaries & Wages	$ 7,775	$ 2,865
B. Fringe Benefits		
TIAA: 7% of faculty salaries	$ 135	$ 200
PERA: 8% of staff salaries	50	
Total Fringe Benefits	$ 185	$ 200
C. Permanent Equipment		
None		
D. Expendable Supplies and Equipment		
Film, photography, & graphing supplies	$ 300	
Paper and office supplies	100	
Total Expendable Supplies	$ 400	-0-
E. Travel		
Domestic: two round trips, Boulder-Washington-New York-Boston @ $210/ea.	$ 420	
Per diem, two persons for ten days @ $25/day	500	
Car hire, two days @ $15/day	30	
Total Travel	$ 950	-0-

	NSF	CU
F. Publication Costs		
Reprints	$ 200	
Illustration preparation (figures, maps, charts, graphs, etc.)	250	
Total Publication Costs	$ 450	-0-
G. Other Direct Costs		
Computer Costs: CDC 6400 central processing, 8 1/3 hours @ $300/hr.; 8 1/3 hours peripheral time @ $60/hr.	3,000	
Consultant costs: Systems programmer, R.C. Brill 200 hrs. @ $5/hr.	1,000	
Total Other Direct Costs	$ 4,000	-0-
H. Total Direct Costs	$ 13,760	$ 3,065
I. Indirect Costs		
On campus: 44% of Salaries & Wages	3,420	1,260
J. Total Costs	$ 17,180	$ 4,325

TOTAL REQUESTED FROM NSF FOR ONE YEAR: $17,180

FIG. 1

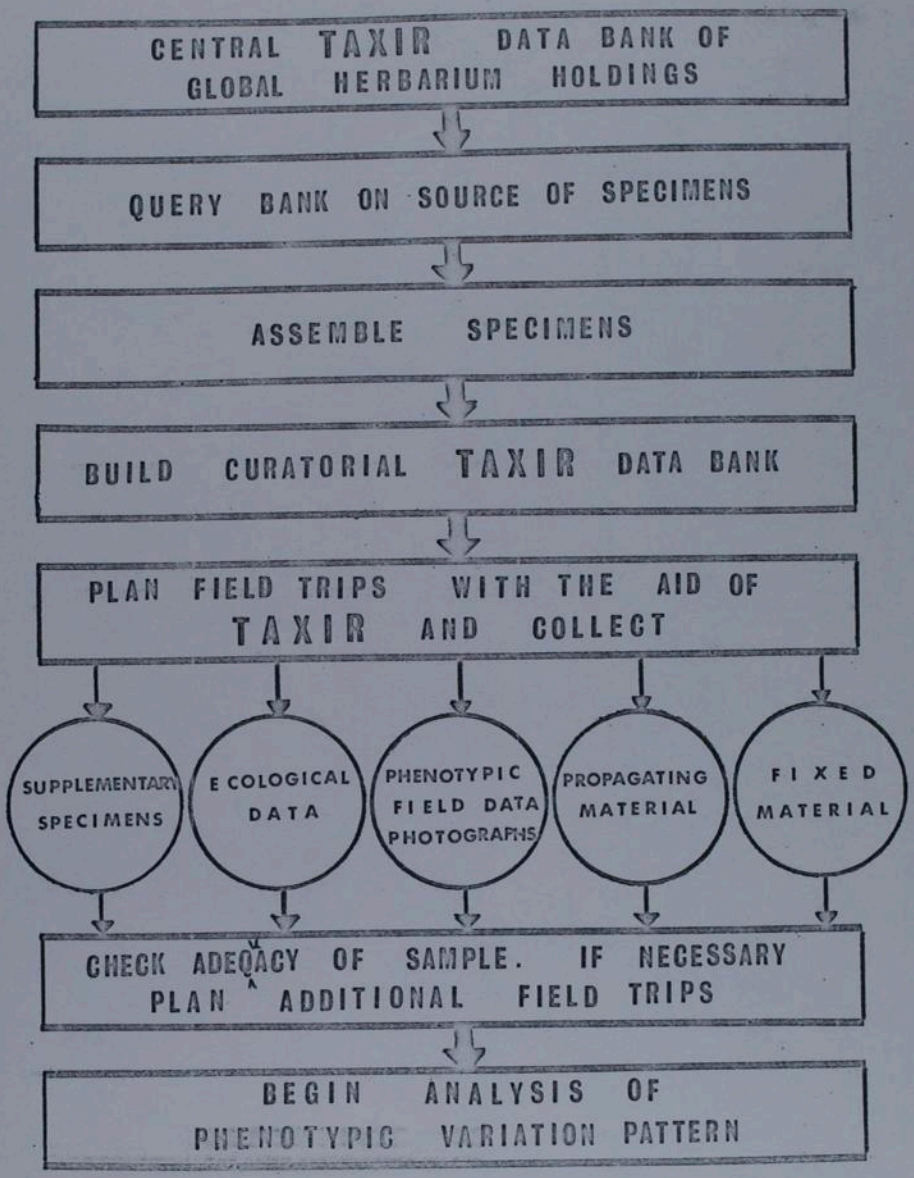


FIG. 2

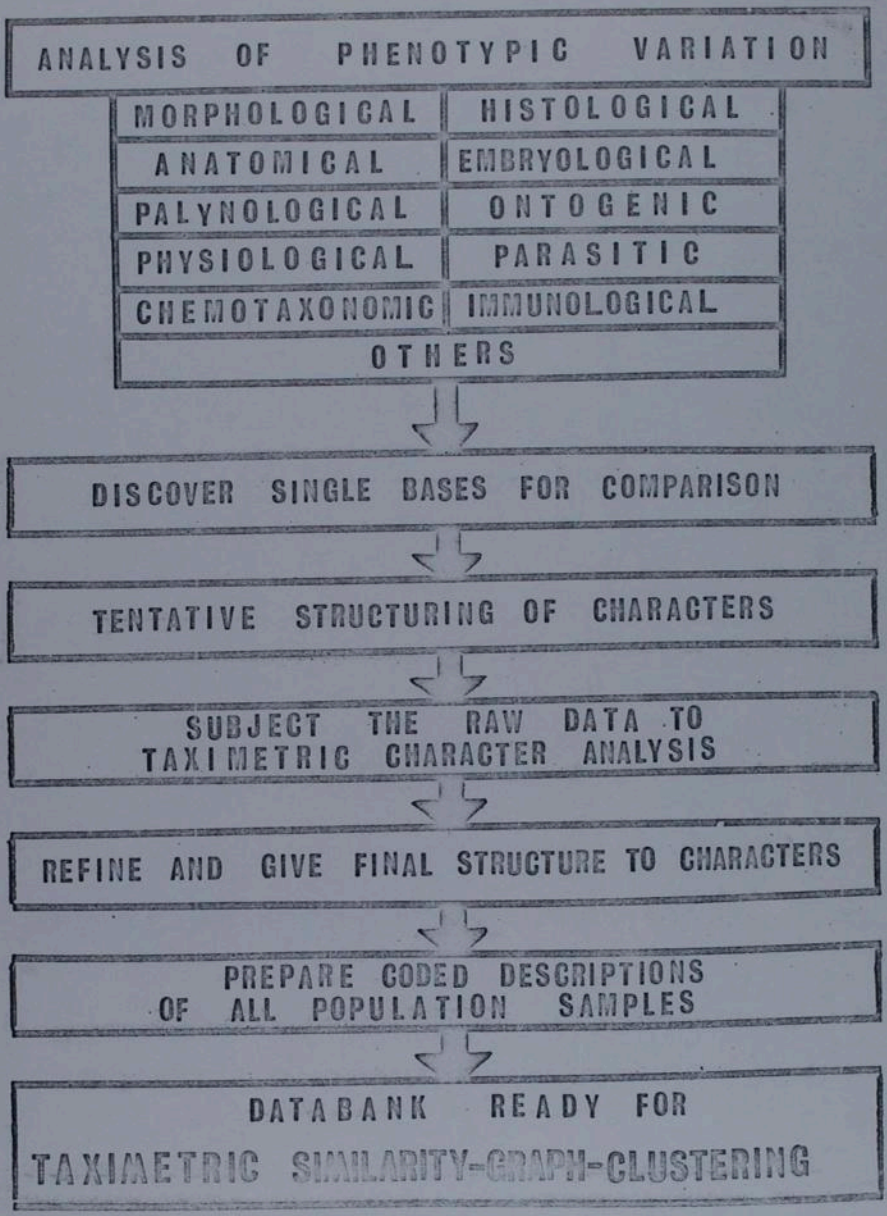


Fig. 3

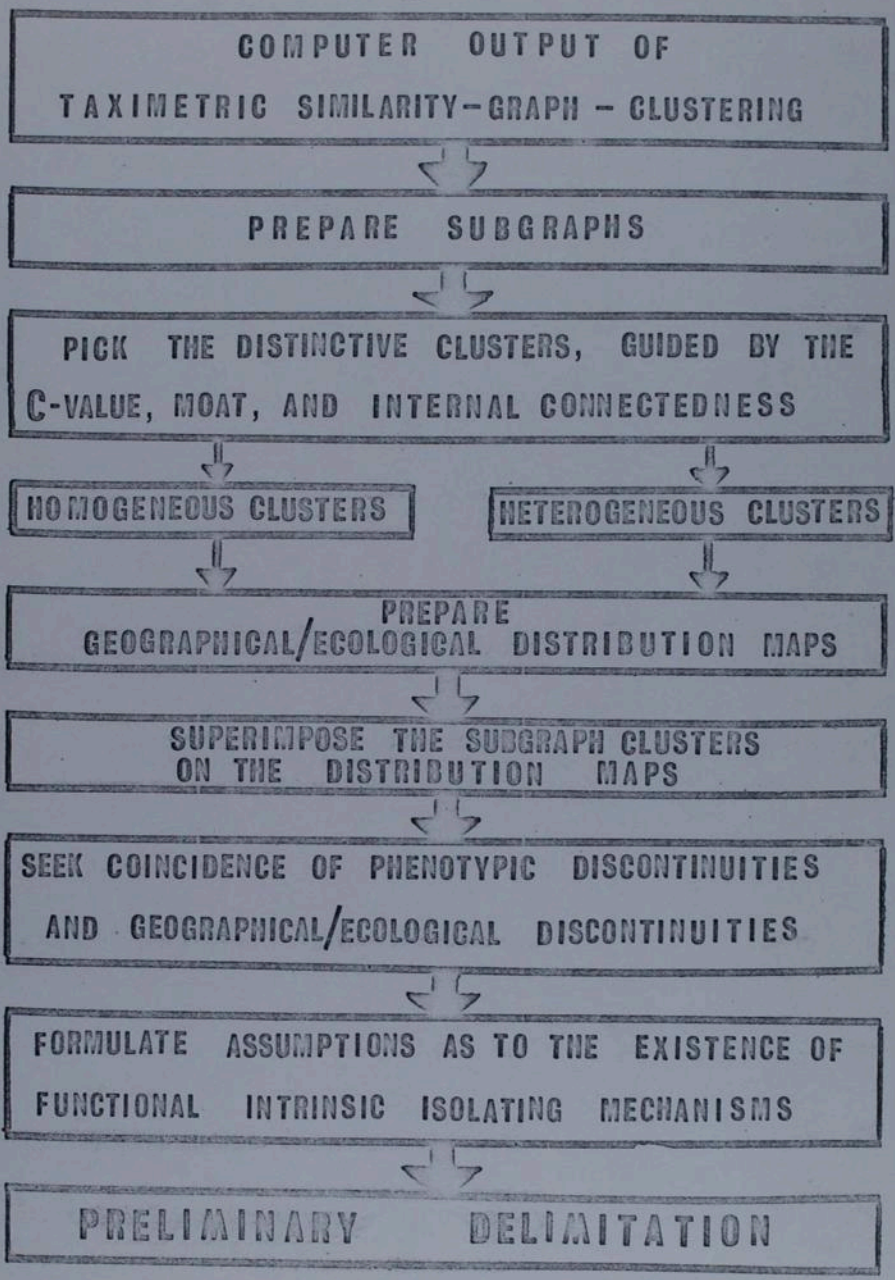


Fig. 4

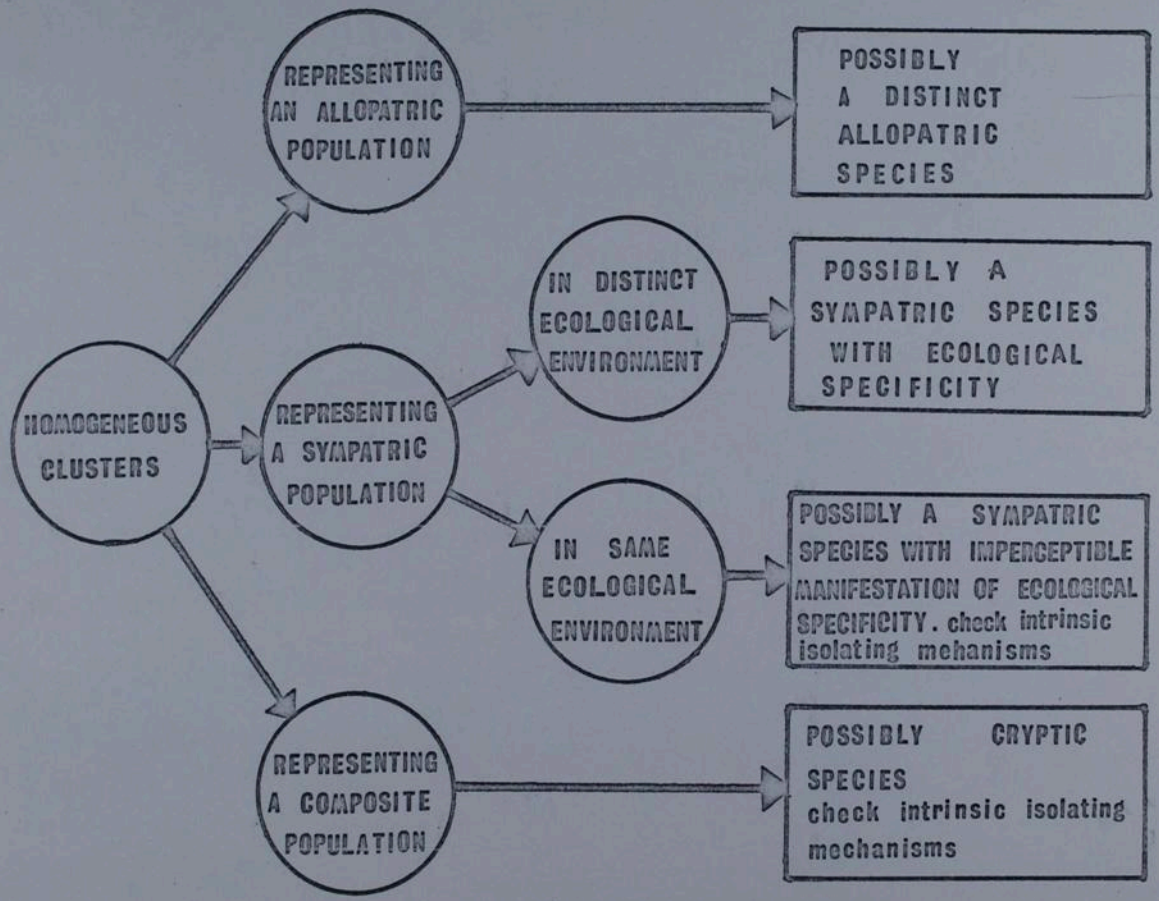


Fig. 5

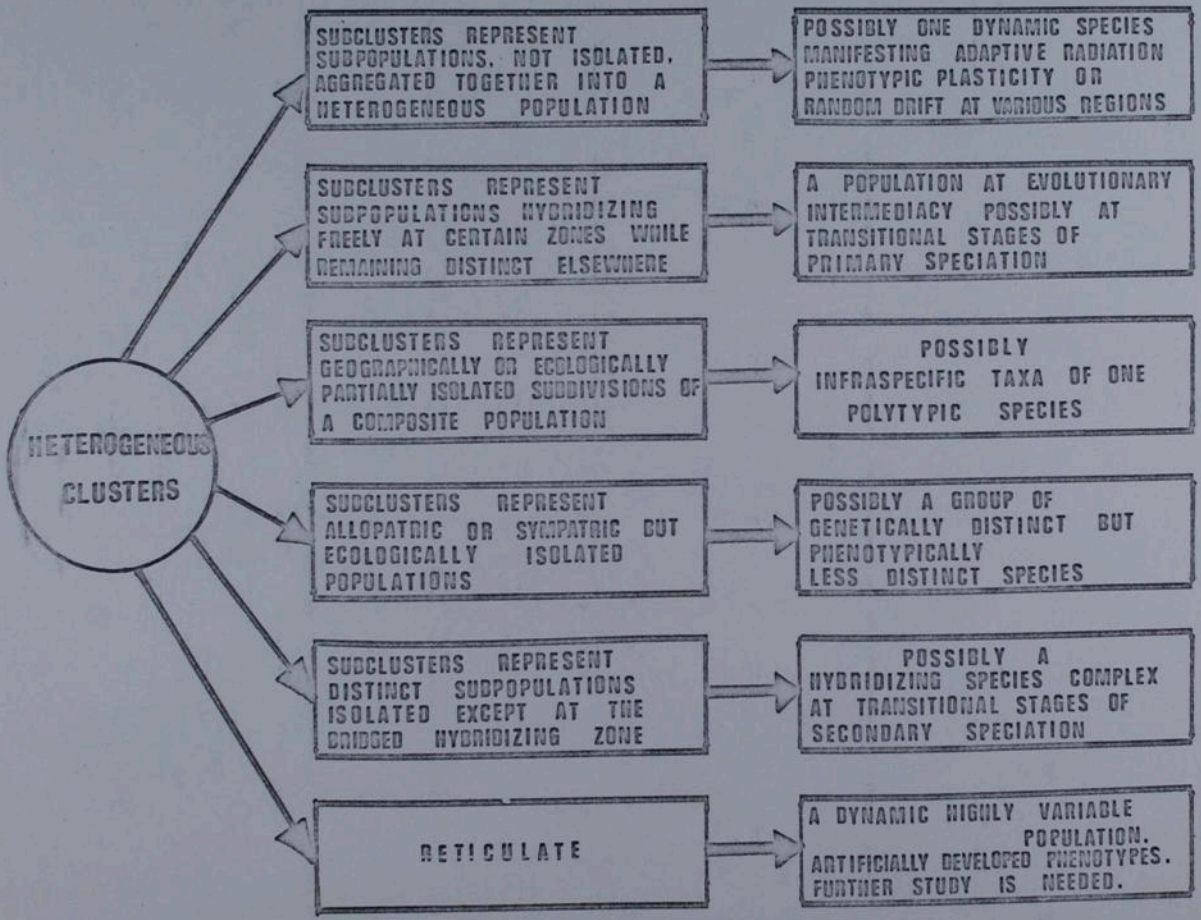


Figure 6

List of characters employed in the North American species of Manihot

01. PLANT GROWTH HABIT
OPTION=CODE NO. OF STATES= 8
1. 01. VINES
2. 02. DECUMBENT SHRUBS
3. 03. SPRAWLING SHRUBS
4. 04. ERECT SHRUBS
5. 05. ERECT TALL SHRUBS TO ERECT LOW TREES
6. 06. ARBORESCENT SHRUBS TO LOW SPREADING TREES
7. 07. LOW SPURRED TREES
8. 08. TALL TREES

02. ROOT ENLARGEMENT
OPTION=CODE NO. OF STATES= 2
1. 01. PROMINENTLY ENLARGED
2. 02. NOT PROMINENTLY ENLARGED

03. PUBESCENCE OF YOUNG STEM
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

04. PUBESCENCE OF MATURE STEM
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

05. COLOR OF MATURE STEM
OPTION=CODE NO. OF STATES= 4
1. 01. GREYISH OR REDDISH BROWN
2. 02. GREY
3. 03. SILVERY GREY
4. 04. DARK GREY

06. NATURE OF VEGETATIVE SHOOTS
OPTION=CODE NO. OF STATES= 2
1. 01. LEAVES BORNE ON SPURS
2. 02. LEAVES NOT BORNE ON SPURS

07. PERSISTENCE OF STIPULES
OPTION=CODE NO. OF STATES= 2
1. 01. PERSISTENT
2. 02. DECIDUOUS

08. PUBESCENCE OF STIPULES
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

09. LENGTH OF PETIOLES
OPTION=CODE NO. OF STATES= 3
1. 01. SHORT < 5.0 CM
2. 02. MEDIUM 5.0 TO 15.0 CM
3. 03. LONG > 15.0 CM

10. PUBESCENCE OF PETIOLES
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

Figure 6 (continued)

List of characters employed in the North American species of Manihot

11. NUMBER / COMPARATIVE SIZE OF LEAF LOBES
OPTION=CODE NO. OF STATES= 6
1. 01. 3 LOBED
2. 02. 5 LOBED: 3 MAJOR 2 SMALLER
3. 03. 5 LOBED: 3 MAJOR 2 SLIGHTLY SMALLER
4. 04. 7 LOBED: 3 MAJOR 2 SMALLER OFTEN 2 MINUTE
5. 05. 7 LOBED: 3 MAJOR 2 SLIGHTLY SMALLER 2 SMALLER
6. 06. 5 TO 9 LOBED: OCCASSIONALLY MORE

12. OUTLINE OF MEDIAN LOBES
OPTION=CODE NO. OF STATES= 13
1. 01. LINEAR
2. 02. TRUNCATE
3. 03. OBOVATE
4. 04. OBOVATE PANDURATE
5. 05. OBLONG
6. 06. OBLONG PANDURATE
7. 07. PARABOLICAL
8. 08. PARABOLICAL INCISED
9. 09. RHOMBOID
10. 10. RHOMBOID PANDURATE
11. 11. HASTATE
12. 12. GLADIATE
13. 13. LOWER HALF HASTATE UPPER HALF RHOMBOID

13. SIZE OF MEDIAN LOBES
OPTION=CODE NO. OF STATES= 12
1. 01. LENGTH < 2.5 CM: WIDTH 1.0 TO 2.5 CM
2. 02. LENGTH 2.5 TO 5.0 CM: WIDTH 1.0 TO 2.5 CM
3. 03. LENGTH 2.5 TO 5.0 CM: WIDTH 1.0 TO 2.5 CM: WITH INDENTATION
4. 04. LENGTH 5.0 TO 12.0 CM: WIDTH < 1.0 CM
5. 05. LENGTH 5.0 TO 12.0 CM: WIDTH 1.0 TO 2.5 CM
6. 06. LENGTH 5.0 TO 12.0 CM: WIDTH 1.0 TO 2.5 CM: WITH INDENTATION
7. 07. LENGTH 5.0 TO 12.0 CM: WIDTH > 2.5 CM
8. 08. LENGTH 5.0 TO 12.0 CM: WIDTH > 2.5 CM: WITH INDENTATION
9. 09. LENGTH > 12.0 CM: WIDTH < 1.0 CM
10. 10. LENGTH > 12.0 CM: WIDTH 1.0 TO 2.5 CM
11. 11. LENGTH > 12.0 CM: WIDTH 1.0 TO 2.5 CM: WITH INDENTATION
12. 12. LENGTH > 12.0 CM: WIDTH > 2.5 CM

14. SHAPE OF PRIMARY CONSTRICTION OF MEDIAN LOBES
OPTION=CODE NO. OF STATES= 9
1. 01. LONG: INCISED
2. 02. LONG: CLEFT
3. 03. SHORT
4. 04. SHORT: OCCASSIONALLY LONG/SINUATE
5. 05. SHORT: OCCASSIONALLY LONG/ENTIRE
6. 06. LONG: REPAND
7. 07. SEVERAL SECONDARY CONSTRICTIONS ONLY
8. 08. NO PRIMARY CONSTRICTION: ENTIRE LOBED
9. 09. NO PRIMARY CONSTRICTION: HASTATE/GLADIATE

15. POSITION / SHAPE OF SECONDARY CONSTRICTIONS OF MEDIAN LOBES
OPTION=CODE NO. OF STATES= 9
1. 01. WITHIN/BELOW PRIMARY CONSTRICTIONS: USUALLY DEEP
2. 02. RARELY PRESENT: WITHIN PRIMARY CONSTRICTIONS ONLY
3. 03. NO SECONDARY CONSTRICTIONS: PRIMARY CONSTRICTIONS ONLY
4. 04. NO CONSTRICTIONS: ENTIRE LOBED
5. 05. SEVERAL SHALLOW TO DEEP CONSTRICTIONS: ABOVE BASAL LOBULES
6. 06. NO SECONDARY CONSTRICTIONS: HASTATE/GLADIATE
7. 07. A VERY SHALLOW APICAL CONSTRICTION
8. 08. SEVERAL SHALLOW TO DEEP SECONDARY CONSTRICTIONS
9. 09. FEW VERY SHALLOW SECONDARY CONSTRICTIONS WITHIN PRIMARY CONSTRICTIONS

16. SHAPE OF APEX OF BASAL LOBULES ON CRASPEDODROMOUS LEAVES
OPTION=CODE NO. OF STATES= 3
1. 01. ACUMINATE
2. 02. CUSPIDATE / DILATED
3. 03. NO BASAL LOBULES: CAMPTODROMOUS LEAVES

Figure 6 (continued)

List of characters employed in the North American species of Manihot

17. BASAL LOBULE TERMINATION
OPTION=CODE NO. OF STATES= 3
1. 01. SPINOUS
2. 02. NOT SPINOUS
3. 03. NO BASAL LOBULES: ENTIRE LOBED

18. SHAPE OF LOWEST LOBES
OPTION=CODE NO. OF STATES= 7
1. 01. SAME AS MEDIAN LOBES
2. 02. SLIGHTLY SMALLER THAN MEDIAN LOBES: NON SYMMETRIC
3. 03. ABOUT HALF AS LONG AS MEDIAN LOBES: APEX CUSPIDATE
4. 04. ABOUT HALF AS LONG AS MEDIAN LOBES: S - SHAPED
5. 05. ABOUT 1/4 AS LONG AS MEDIAN LOBES: APEX ROUNDED
6. 06. ABOUT 1/4 AS LONG AS MEDIAN LOBES: APEX ATTENUATE
7. 07. VARIABLE: USUALLY SAME AS MEDIAN LOBES

19. BASE OF LAMINA
OPTION=CODE NO. OF STATES= 4
1. 01. NON PELTATE
2. 02. NARROWLY PELTATE: 0.2 TO 0.5 CM
3. 03. WIDELY PELTATE: > 0.5 CM
4. 04. VERY NARROWLY PELTATE: < 0.2 CM

20. LAMINA AT BASE OF MEDIAN LOBE SINUS
OPTION=CODE NO. OF STATES= 4
1. 01. LAMINA APPEARS DISJUNCT: LEAF APPEARS COMPOUND
2. 02. LAMINA CONNECTED: NARROW < 0.5 CM
3. 03. LAMINA CONNECTED: VARIABLE NARROW TO WIDE
4. 04. LAMINA CONNECTED: WIDE > 0.5 CM

21. WIDTH OF MEDIAN LOBE BASE
OPTION=CODE NO. OF STATES= 4
1. 01. MIDRIB WITH PRACTICALLY NO LAMINA
2. 02. < 0.25 CM
3. 03. VARIABLE: NARROW TO WIDE
4. 04. > 0.25 CM

22. SHAPE OF SINUS
OPTION=CODE NO. OF STATES= 7
1. 01. FIG. 1
2. 02. FIG. 2
3. 03. FIG. 3
4. 04. FIG. 4
5. 05. FIG. 5
6. 06. FIG. 6
7. 07. FIG. 7

23. SHAPE OF MEDIAN LOBE APEX
OPTION=CODE NO. OF STATES= 14
1. 01. FIG. 1
2. 02. FIG. 2
3. 03. FIG. 3
4. 04. FIG. 4
5. 05. FIG. 5
6. 06. FIG. 6
7. 07. FIG. 7
8. 08. FIG. 8
9. 09. FIG. 9
10. 10. FIG. 10
11. 11. FIG. 11
12. 12. FIG. 12
13. 13. FIG. 13
14. 14. FIG. 14

24. PUBESCENCE OF LAMINA
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

Figure 6 (continued)

List of characters employed in the North American species of Manihot

25. WAX PATTERN OF THE ABAXIAL LEAF SURFACE
OPTION=CODE NO. OF STATES= 4
1. 01. SMOOTH
2. 02. STUBBY
3. 03. FARINOSE
4. 04. FINELY FARINOSE

26. LEAF VENATION
OPTION=CODE NO. OF STATES= 2
1. 01. CAMPTODROMOUS
2. 02. CRASPEDODROMOUS

27. PUBESCENCE OF MIDRIBS
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

28. INFLORESCENCE
OPTION=CODE NO. OF STATES= 7
1. 01. SOLITARY FLOWER: RARELY TWO
2. 02. RACEME: SUBSPICATE/CORYMBOSE
3. 03. RACEME: SUBSPICATE
4. 04. RACEME: SHORT TO MEDIUM IN LENGTH
5. 05. RACEME: LONG
6. 06. PANICLE: MEDIUM IN LENGTH
7. 07. PANICLE: LONG MANY BRANCHED

29. PUBESCENCE OF PEDUNCLES
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

30. PUBESCENCE OF PEDICELS
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

31. NATURE OF BRACTEOLES
OPTION=CODE NO. OF STATES= 4
1. 01. FOLIACEOUS
2. 02. SEMI FOLIACEOUS
3. 03. NON FOLIACEOUS
4. 04. NO BRACTEOLES: FLOWER SOLITARY

32. BRACTEOLE MARGIN
OPTION=CODE NO. OF STATES= 3
1. 01. SMOOTH
2. 02. SERRATE
3. 03. NO BRACTEOLES

33. COLOR OF BRACTEOLES
OPTION=CODE NO. OF STATES= 3
1. 01. PURPLISH
2. 02. GREENISH WHITE
3. 03. NO BRACTEOLES

34. PUBESCENCE OF BRACTEOLES
OPTION=CODE NO. OF STATES= 4
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS
4. 04. NO BRACTEOLES

Figure 6 (continued)

List of characters employed in the North American species of Manihot

35. NATURE OF BRACTLETS
OPTION=CODE NO. OF STATES= 3
1. 01. FOLIACEOUS
2. 02. NON FOLIACEOUS
3. 03. NO BRACTLETS

36. PUBESCENCE OF BRACTLETS
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

37. POSITION OF PISTILLATE FLOWERS IN INFLORESCENCE
OPTION=CODE NO. OF STATES= 4
1. 01. DIVERSE
2. 02. RESTRICTED TO THE UPPER HALF OF RACHIS
3. 03. RESTRICTED TO THE BASE OF INFLORESCENCE
4. 04. FLOWER SOLITARY

38. SHAPE OF MATURE STAMINATE BUDS
OPTION=CODE NO. OF STATES= 6
1. 01. ALMOST TUBULAR
2. 02. SLIGHTLY CONSTRICTED IN THE MIDDLE
3. 03. DISTINCTLY CONSTRICTED IN THE MIDDLE
4. 04. CONICAL
5. 05. CAMPANULATE
6. 06. AURICULATE

39. COLOR OF FLOWER BUDS
OPTION=CODE NO. OF STATES= 2
1. 01. GREENISH YELLOW
2. 02. PURPLISH

40. LENGTH OF STAMINATE TEPALS
OPTION=CODE NO. OF STATES= 2
1. 01. > 2.0 CM
2. 02. < 2.0 CM

41. EXTERNAL COLOR OF FLOWER TEPALS
OPTION=CODE NO. OF STATES= 2
1. 01. GREENISH YELLOW
2. 02. PURPLISH STREAKED

42. PUBESCENCE OF TEPALS
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

43. PUBESCENCE OF OVARY
OPTION=CODE NO. OF STATES= 3
1. 01. PUBESCENT
2. 02. SPARCELY PUBESCENT
3. 03. GLABROUS

44. POSITION OF FRUITS IN INFRUCTESCENCE
OPTION=CODE NO. OF STATES= 4
1. 01. RESTRICTED TO THE BASE
2. 02. RESTRICTED TO THE UPPER HALF OF RACHIS
3. 03. BASE UPTO APEX
4. 04. SINGLE FRUIT CONNECTED TO THE STEM DIRECTLY

Figure 6 (continued)

List of characters employed in the North American species of Manihot

45. NATURE OF FRUIT PEDICELS
OPTION=CODE NO. OF STATES= 4
1. 01. BENT DOWNWARDS ALMOST AT A RIGHT ANGLE
2. 02. SLIGHTLY CURVED DOWNWARDS
3. 03. STRAIGHT ALMOST HORIZONTAL
4. 04. STRAIGHT ASCENDING

46. SIZE OF MATURE FRUITS
OPTION=CODE NO. OF STATES= 5
1. 01. SMALL: LENGTH < 1.25 CM
2. 02. MEDIUM: LENGTH 1.25 TO 1.75 CM
3. 03. LARGE: LENGTH 1.75 TO 2.5 CM
4. 04. VARIABLE: LENGTH 1.25 TO 2.5 CM
5. 05. VERY LARGE: LENGTH > 2.5 CM

47. NATURE OF FRUIT SURFACE
OPTION=CODE NO. OF STATES= 3
1. 01. WITHOUT RIBS
2. 02. PERCEPTIBLY RIBBED
3. 03. PROMINENTLY RIBBED

48. NATURE OF FRUIT APEX
OPTION=CODE NO. OF STATES= 4
1. 01. ROUNDED
2. 02. SLIGHTLY POINTED
3. 03. PROMINENTLY POINTED
4. 04. DEPRESSED

49. FRUIT DEHISCENCE
OPTION=CODE NO. OF STATES= 2
1. 01. SEPTICIDAL
2. 02. LOCULICIDAL

50. SEED SIZE / SHAPE
OPTION=CODE NO. OF STATES= 7
1. 01. SMALL ROUND: < 1.0 CM
2. 02. SMALL OBLONG: < 1.0 CM
3. 03. MEDIUM ROUND: 1.0 TO 1.5 CM
4. 04. MEDIUM OBLONG: 1.0 TO 1.5 CM
5. 05. LARGE ROUND: 1.5 TO 2.0 CM
6. 06. LARGE OBLONG: 1.5 TO 2.0 CM
7. 07. VERY LARGE: > 2.0 CM

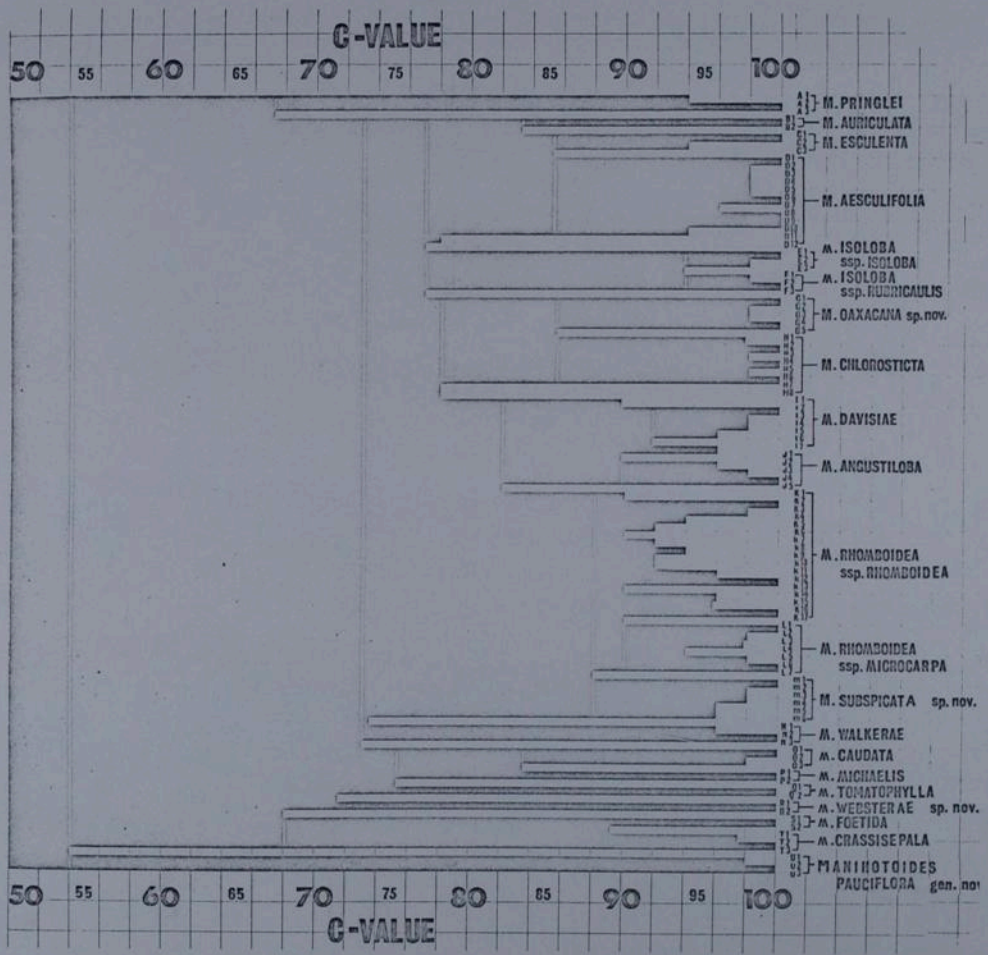
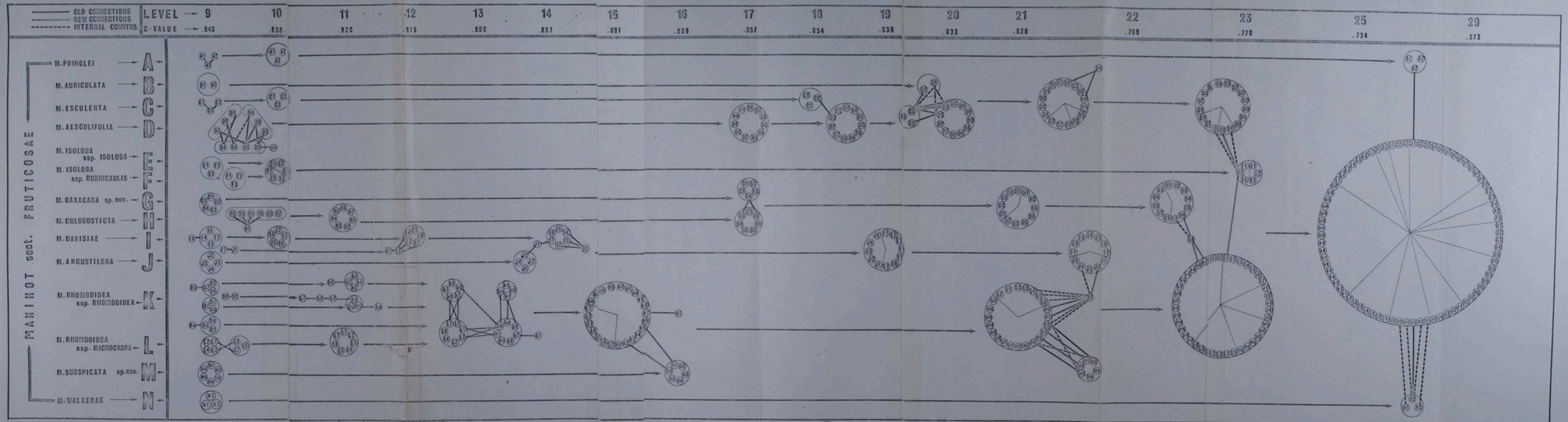


Fig. 7

Fig. 8



HOUSE OF REPRESENTATIVES
WASHINGTON, D. C.

DONALD G. BROTZMAN
COLORADO

December 2, 1970

Mr. David J. Rogers
Department of Biology
University of Colorado
Boulder, Colorado 80302

Dear Mr. Rogers:

I am pleased to note your receipt of a $16,000 National Science Foundation grant for your study. Congratulations!

If I may ever be of service to you as your Congressman, please do not hesitate to contact me.

Sincerely,

Donald G. Brotzman
Member of Congress

DGB/vb

Taximetrics Lab.

December 15, 1970

Mr. Donald G. Brotzman
House of Representatives
Washington, D.C.

Dear Mr. Brotzman:

Thank you for your recent letter of congratulations on the receipt of $16,000.00 from the National Science Foundation. That grant will partially support bothe the completion of 20 years of research on my part, and at the same time lay the necessary foundation for the orderly development of a crop plant which provides the basic food substance for about 200 million people in underdeveloped countries.

In your second paragraph, you are kind enough to offer your services as Congressman. Perhaps the best means of service would be to find ways for the scientists here at the University to continue their important work, particularly with respect to environmental studies. I believe that the best means of this support is through such agencies in Washington as the National Science Foundation, and I encourage your support for their work. As you know, NSF has fundamentally changed its role from disinterested, "pure" science to one of engagement and support of science for our more pressing human problems. I am hoping that my own research is in this vein. As an illustration, I enclose a copy of a grant request to NSF which, although judged to be meritorious scientifically, was not funded because of deep budget cuts in the Office of Scientific Information Services of NSF. Had this request been funded, it would be of fundamental service to the people of Colorado to help keep our environment at a high quality level.

Since it may not be apparent that the request here included is of fundamental importance in the direction of service to people, may I pount out why the enclosed work is of very fundamental importance?

The Museum of the University of Colorado contains within it the most tangible knowledge of our natural resources in this state. The collected specimens of plants, animals and minerals, as well as the artifacts of people, tell us more about what the rich Colorado environment contains than any other single source. We know, from these collections, what plants and animals are found and where, which are rare and need protection, and which can help enrich our human environment. However, without an information retrieval system, much of the information remains burried in the files and storage cabinets. If this grant were funded, we could provide detailed information to city, county and state planners, to the Fish and Wildlife Service, etc. The information system would provide the basic knowledge for a real understanding of Colorado.

To Congressman Brotzman from D. J. Rogers, December 15, 1970

If you could suggest, from your vantage point, how we might be able to attract the funds for the enclosed grant request, we would be most grateful.

Sincerely yours,

David J. Rogers,
Professor of Biology

FINAL TECHNICAL LETTER REPORT ON NSF GRANT GB-25244.

INSTITUTION: University of Colorado, Boulder, Colorado, Department of EPO Biology

PRINCIPAL INVESTIGATOR: David J. Rogers

GRANT: GB-25244

STARTING DATE: November 27, 1970

COMPLETION DATE: November 27, 1971

GRANT TITLE: Monograph of Manihot Employing Computer-Aided Taximetric Methods

BRIEF DESCRIPTION OF RESEARCH AND RESULTS:

The grant permitted the first employment of a series of taximetric procedures developed in this laboratory in a monographic study of the genus Manihot (Euphorbiaceae). The various computer programs employed were: TAXIR, (TAXonomic Information Retrieval), a program to store and retrieve data from the 6000 plus specimens of the genus; program CHARANAL, to test the value of each potential character to be used in the classification; and program GRAPH, a clustering procedure to give an objective classification of the species. The results of this grant are best summarized in the publication: Monograph of Manihot and Manihotoides (Euphorbiaceae). Monograph number 13, in Flora Neotropica, 272 pp., 22 June, 1973, Hafner Press, New York ($23.75). A copy of this publication is being sent under separate cover.*

A separate publication, A Monograph of Manihot esculenta--with an Explanation of the Taximetric Methods Used, by David J. Rogers and H. S. Fleming, in Economic Botany 27: 1-113, 1973, is a companion work which, while not funded in this particular grant, was aided in part by the grant. A copy of this paper will be forwarded when we have received reprints.

THESES AND INVENTIONS:

No theses nor inventions derived from this grant.

SCIENTIFIC COLLABORATORS:

Dr. S. G. Appan, post-doctoral fellow during tenure of the grant.

COMMENTS:

The publication of the papers listed above culminate this phase of the continuing study of the important species, Manihot esculenta. My laboratory is engaged in various types of agricultural development of this root crop in many of the tropical areas where Manihot esculenta

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*Because of the high cost of this publication, I trust that the Foundation will be satisfied with a single copy of the Monograph, rather than the three requested.

forms the major calorie producer. One important result of the generic monograph is that plant breeders and others involved in crop improvement now know which wild species of the genus are most useful in plant improvement programs. Because there is now a sound taxonomic base, other types of studies are better able to proceed in a scientific manner. Our major source of support for continued work is the Agency for International Development of the State Department, specifically in the Nutrition and Agriculture Sections of the Technical Assistance Bureau of AID.

We believe that the work supported by NSF, and the later endeavors supported by AID demonstrate one of the most important means of collaboration between "pure" and "applied" science, with results of the NSF study being rapidly incorporated into the ever-growing need to find means to feed more people in underdeveloped countries. While this is not research applied to national needs (RANN), it is research applied to human needs.

FINAL TECHNICAL LETTER REPORT ON NSF GRANT GB-25244.

INSTITUTION: University of Colorado, Boulder, Colorado, Department of EPO Biology

PRINCIPAL INVESTIGATOR: David J. Rogers

GRANT: GB-25244

STARTING DATE: November 27, 1970

COMPLETION DATE: November 27, 1971

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Dr. S. G. Appan, post-doctoral fellow during tenure of the grant.

COMMENTS:

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We believe that the work supported by NSF, and the later endeavors supported by AID demonstrate one of the most important means of collaboration between "pure" and "applied" science, with results of the NSF study being rapidly incorporated into the ever-growing need to find means to feed more people in underdeveloped countries. While this is not research applied to national needs (RANN), it is research applied to human needs.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

September 28, 1970

Dr. David J. Rogers
Department of Biology
University of Colorado
Boulder, Colorado 80302

Dear Dr. Rogers: Ref: B025244

Regarding your proposal entitled "Monograph of Manihot Employing Computer-Aided Taximetric Methods," ad hoc reviewers have raised several questions that need your consideration. They are:

1. Why does he feel that he can write a monograph for 150 species in two or three months?

2. What do his samples of each species consist of?

3. How many specimens per species will he score for his 50 characters?

4. Why did he choose the characters that he did?

5. At what stage is data accumulation for each of the species? As of September 1970, how many measurements of the expected total are on punched cards?

6. How will intraspecific variation be handled?

7. How will problems of synonymy and nomenclature be handled?

8. The title and preliminary information indicates that the product is to be a monograph of Manihot although the abstract indicates that it is only the South American species which are to be monographed. Will the North and Central American species be included in the publication resulting from a grant even though they are now in press as a separate publication?

May we please have your reply soon? We want the panel members to be able to study your comments before your proposal comes up for final discussion October 16th.

Sincerely yours,

Loran Anderson

Loran C. Anderson
Associate Program Director
Systematic Biology

TAXIMETRICS LAB.
ARMORY 101

September 29, 1970

Dr. Loran C. Anderson
Associate Program Director
Systematic Biology
National Science Foundation
Washington, D.C. 20550

Ref: B025244

Dear Dr. Anderson:

I am pleased to have this opportunity to reply to the questions posed by the ad hoc reviewer on the proposal for monographic studies of Manihot. It is certainly a good idea to allow this type of exchange in advance of the proposal decision-making process.

Thank you for this opportunity. The replies are enclosed, along with copies of the reprint to which I refer.

Sincerely yours,

David J. Rogers
Professor of Biology

Encl.

Reference: BO 25244

Proposal Title: A monograph of Manihot employing computer-aided taximetric methods.

Responses to ad hoc reviewers questions.

1. Why does he feel that he can write a monograph for 150 species in two or three months?

There is no indication anywhere in the proposal that the monograph will be written in two to three months. We expect to take one full year to complete the work. See page 2, paragraph 2 of the proposal.

However, to elaborate to some extent upon the time schedule given, there are several points to be made. During the last 18 years the principal investigator made several expeditions to South America, Central America, Mexico and the West Indies, to collect specimens and information on Manihot species (both wild and cultivated). These expeditions produced a wealth of valuable specimens and allied data. All the data are now in computer banks and can be efficiently manipulated and retrieved.

The Procedures to be employedin this proposal have been outlined in the form of explicit flow charts (figs. 1 to 5 of the proposal). The preliminary steps (fig. 1), such as assembling population samples, ecological data, taxonomic literature, etc. took years of work. All the work of obtaining loans of specimens, discovery of type materials, collating collections from various herbaria, etc., has been done.

Therefore, this proposal is intended as a "capstone." A monograph of ALL the species of Manihot will be produced using gross morphological characters. Many more studies of a chemotaxonomic and biosystematic nature are greatly needed, but these are not a part of this proposal.

2. What do his samples of each species consist of?

Over 6,000 herbarium specimens from most of the important herbaria in this country and abroad, representing the entire genus Manihot have been assembled for this study. Collections made by the principal investigator and by Dr. Howard Irwin and collaborators (from the New York Botanical Garden) augment the information from other collectors in critical geographic areas. In addition to the herbarium specimens, field photographs (black/white and color), pollen slides, root samples, etc. have also been accumulated for this study.

The type specimens for all but two species (presumably unicates destroyed in the Berlin Herbarium during WWII) are on hand.

The size of the sample of each species varies from 1 specimen (in case of 3 species) to over 300 for many of the species.

3. How many specimens per species will he score for his 50 characters?

Because of the slight variation from specimen to specimen, each specimen will be scored. Please see #2 above.

4. Why did he choose the characters that he did?

Because the objectives of the study require that information of the types listed be used. The Characters actually used represent a subset of the total (well over 100) which were first established. By following procedures in Figure 2 of the proposal, the final characters employed will be those which have the most taxonomic significance for the delimitation of the taxa. The choice is objective in that the computer program CHARANAL gives the best source of information about the characters.

Clearly the basis of choice of these characters is the final professional responsibility of the taxonomist, and cannot be entrusted to the dictates of some machine.

5. At what stage is data accumulation for each of the species? As of September, 1970, all the curatorial information for each specimen has been placed on magnetic tape, has been editted and corrected. The gross morphological characters have been partially prepared, and await the procedures listed in #4 above.

6. How will intraspecific variation be handled?

The taxonomic delimitations proposed to be done will be based on the modern biological species concept: a closed gene pool considered as a species. The taximetric program (Graph Theory Clustering) has proved to be a powerful aid in recognizing patterns of the structure of biological populations. The procedure to recognize such patterns, and accordingly designate the taxonomic status of the entities (both at species and infra-specific levels) are discussed at length in pages 618-620 of Rogers and Appan, 1969 (attached).

7. How will problems of synonymy and nomenclature be handled?

The International Rules of Botanical Nomenclature will be followed. To elaborate on the procedures would requir a small book, but in general, the procedures followed in Leenhouts (Regnum Vegetabile 58: 1-58. 1968) are useful guides. The only differences for this study are that the computer system, TAXIR, will be employed to manipulate the literature citations, the specimen data, and the curatorial information, rather than use card indices. These data, as indicated earlier, are already on magnetic tape.

8. (condensation of question)--What differences between publication of Manihot for North America and the results of this proposal?

First, the whole genus including the North American species, will be included in the work of this proposal.

Second, the intent and content of the publication on North American Manihot species is different from that of this proposal. The results of

this proposal, a monograph of all the species, will conform exactly to the style of the FLORA NEOTROPICA, editted by dr. Bassett Maguire. In the North American publication, there was a much more detailed description of the computer methods used, and much more detailed information about the individual species was given. This was done so that anyone interested in the methods could easily refer to an actual example of a botanical taxonomic problem which had been solved with the methods. In addition, the species of the North American Manihot were each illustrated by a color photo made in the natural habitat by the principal investigator. There will be no colored plates in the complete monograph.