Hunt Institute for Botanical Documentation
5th Floor, Hunt Library
Carnegie Mellon University
4909 Frew Street
Pittsburgh, PA 15213-3890
Telephone: 412-268-2434
Email: huntinst@andrew.cmu.edu
Web site: www.huntbotanical.org

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

January 28, 1971

Professor David J. Rogers
Department of Biology
Taximetrics Laboratory
University of Colorado
Boulder, Colorado 80302

Dear Dave:

Thanks for your good letter of January 23rd relative to Manihot. I am delighted that the final piece is now taking form.

We are sending to you a revised copy of the Guide-lines in which you will note that the offer to provide distribution maps has been withdrawn. Since the death of Charlie Hitchcock at the A.G.S., our relationships and cooperation has not been as satisfactory. The outline map arrangement just never worked. Consequently each monographer must provide his own maps to suit his own purposes.

Undoubtedly in Manihot there will be a much greater emphasis on the chemical and nutritional attributes of the genus and I have no doubt that it will be flavored by a taximetric approach. This is fine because the editors will not attempt to determine content so long as the work is in itself a discriptive monograph of the taxon in question and so long as the Guide-lines are followed.

Swartzia should not be used as a model. The editorial procedures are gradually undergoing evolution as they should, so as to bring about a greater coordination in successive monographs. I suggest that you use Cuatrecasas' monograph on Brunelliaceae. This monograph, although prepared by the Director of Phanerogams, is not the ultimate or final either. We shall attempt to make further refinements and improvements. They would largely be editorial and lie in the hands of Clark Rogerson.

One further question - how many manuscript pages will Manihot comprise and how many plates or figures? Estimates of these quantities will help us make an earlier appraisal with the publisher.

New York is in deep freeze this week. Perhaps it is colder in Boulder but you wouldn't feel it so much.

With best personal regards to you and the family,

Sincerely yours,

Bassett

Bassett Maguire
Director of Botany

P.S.
Clark and I feel that we should not categorize kinds of synonyms. Let us retain the format procedure of listing them all in chronological order.

BM:dz

Connie: File in correspondence on this paper.

May 26, 1973.

To: Graduate School

From: David J. Rogers

Subject: Purchase of reprints of paper "A Monograph of *Manihot esculenta* with an Explanation of the Taximetrics Methods USed."

This is to certify that none of my present grants or contracts permit purchase of reprints of this paper. I have asked the responsible contract officer for my current AID contract, and told specifically that I may not use funds in that contract for this purpose.

If purchase price ($162.91) of the 100 reprints exceeds allowable amount by the Graduate School, please charge the excess to EPO Biology, account 1708-01.

David J. Rogers
Professor of Biology

(1)

4483

Mss pages 1-14

29-45

A MONOGRAPH OF MANIHOT ESCULENTA

with an explanation of the Taximetrics methods used.[1]

David J. Rogers and Henry S. Fleming

[1] Taximetrics Laboratory,
Department of Biology,
University of Colorado,
Boulder, Colorado.

Footnote

Submitted for publication November 9, 1970.

Authors; could you give us a footnote on the monograph? Grant number? Etc. where written? Submitted for publication November 9, 1970.

Authors: please identify yourselves as to present status and whereabouts.

TABLE OF CONTENTS

Part I

TABLE OF CONTENTS (continued)

INTRODUCTION

As an economic botanist, the senior author has long felt that one of the basic needs for the improvement of plants useful to man is a knowledge of the kinds of variations that are found within a species, or group of species, and how these variations relate to one another. Recognizing the complexities and problems involved in meeting such needs, development of the necessary tools and procedures began in 1952. Rather than attacking the problem from a general standpoint, it seemed more reasonable to start with one crop (Manihot esculenta Crantz = manioc, cassava, yuca or tapioca) and use that crop as a model to solve problems in other crops. Having been trained as taxonomists, it is natural that we should describe the problem as one of classification wherein the variations within the species are classified on the basis of the gross morphology. Problems of classification of the variation of a cultivated species are qualitatively different from those of wild plant classification, but the basic methods of study in taxonomy should apply for all types of classification problems. Comparative methods, the most powerful means available to produce classifications, could be employed if the information were available. It is at this point that the qualitative differences between wild and cultivated plant taxonomy are most apparent: the large number of variants of cultivated species, differing in some cases only in one biochemical property, maintained only by intercession of man's conscious cultivation, are more difficult to compare (or differentiate) than wild species, in which more apparent differences separate the variants. Natural selection is not as powerful in destroying many variations of cultivated plants (because of man's efforts to keep desirable cultivars) as it is in wild plants. Thus, in the husbanded species, an apparent continuum may be found which causes difficulty in making clean-cut groupings of the cultivated variants.

Yet anyone interested in cultivated plants knows that, within the complex of one crop, there are "constellations" of cultivars by which the individuals may be related, or clustered. Every cultivated group has some informal classification, usually based on one or two evident characters (as for example, red-skinned versus brown-skinned Irish potatoes). The problem, then, is to discover if there might be some correlations between several characters which could be used in the classification of the "constellations" of cultivars.

We record here the results of our efforts to determine the most efficient methods to collect specimens and data of *Manihot esculenta* Crantz (Euphorbiaceae), and to correlate these. Our objectives are two-fold: (1) to provide a classification of the variants or cultivars, and (2) describe in some detail the Taximetric methods (Rogers & Appan, 1969; Rogers, 1963a, etc.) developed for the larger objective of studying the variation in all cultivated plants.

There are few cultivated crops with as many wild species in the same genus as have been recorded for *Manihot*. The latest monograph (Pax and Hoffman, 1910) accounts for about 127 species. Thirty or forty species have been described since 1910. The amount of variation in the genus provides a tremendous amount of genetic diversity and out of this complex has come the heterogeneity of the species we designate as *Manihot esculenta*.

For several reasons, we cannot hope to exhaustively analyze the biological nature of this complex species. As with all cultivated species, the crop has been transported far from its native habitat by both primitive and modern man. The crop was apparently distributed through all the American tropics by the time the first European explorers had reached these shores. As the crop was moved by man, it incorporated new genetic material from wild, related species indigenous to the new localities. There was also the opportunity for the cultivated species to become dispersed among the wild species, for there is no evidence for a one-way distribution of genetic material, and in all probability the wild species became enriched by the addition of new genes from the freshly introduced cultivated species. The involved and intricate biological structure of the species further defies precise analysis here because of the lack of time, interest in, or support for proper and adequate research work to have accumulated the kinds of evidence we now have for the origin and diversity of Indian corn (*Zea mays*), white potatoes (*Solanum tuberosum*) or rice (*Oryza sativa*). There are few comprehensive cultivar collections in the world, and those that do exist are barely maintained and inadequately financed.

Ref II

There are a variety of problems associated with the classification of the cultivars within any one cultivated species. First, since most botanists interested in collection of plant materials have concentrated on wild plants, few guide-lines have been perfected for the adequate collection and sampling of cultivated species. Edgar Anderson (1951) came closer than any other botanist in his attempt to establish an adequate procedure to assemble all of the relevant parts of a cultivated plant on standard-size herbarium paper. In the concept of an "inclusive herbarium" he pointed out that each species had its own unique problems, but by judicious combinations of standard-ized collecting procedures, coupled with photographs taken to scale and precise field data, one could reduce to manageable proportions otherwise bulky plants. Owing to its requirements for rigorous self-discipline, this technique has not been taken up by any large group of botanists. By suitable extension, the Andersonian "inclusive herbarium specimen" can be adopted for population sampling. Indeed, the "mass collection" also established by Anderson (1941) was intended to be a population sample, but the inefficiency of the mass collection technique is such that some modification is required.

Some, though by no means all, of the other problems associated with classification of cultivated plants include (1) the appropriate methods of classification of reticulately related taxa (which we address in the methods section, p. 38ff) and (2) those problems concerned with nomenclature at the subspecific level. Some efforts have been addressed to the nomenclature problem by an international commission (Gilmour, et al., 1969). Formal taxonomic units, such as subspecies, varieties, forms, etc., are clearly difficult to assign in cultivated plants, where recombinations of the genetic materials are constantly being made. Under these conditions, the stability of any nomenclatorially fixed category is of doubtful benefit, where tastes and requirements from a cultivated species change over relatively short periods. This is as true of plants cultivated for their beauty as it is for those producing some product of more immediate concern for human survival. For further discussion, see section on Categories within the Cultivated Species (p. 8).

PART I

HISTORY OF CLASSIFICATION

There have been three major monographic studies of the genus *Manihot*: Pohl (1827), Mueller von Argau (1866), and Pax (1910). Pohl's work was the only one based on extensive field experience, and his observations and classifications provided the framework for most of the later efforts. In his monograph, Pohl erected species to indicate the difference between those cultivars of *Manihot esculenta* with high concentrations of prussic acid and those supposedly free of this poisonous substance. He designated the poisonous variants as *M. utilissima* and the non-poisonous types *M. aipi*. In *M. utilissima*, two varieties, *beta castellana* and *delta sutinga* were recognized. Mueller von Argau maintained Pohl's *M. utilissima*, but included *M. aipi* as a variety of *M. palmata*. Mueller recognized no subspecific taxa of *M. utilissima*.

Pax (1910) also maintained Pohl's designation M. utilissima, without any formal subspecific taxa, but did present a synoptic key of several cultivars grown in West Africa. His treatment placed Pohl's M. aipi as a variety of M. dulcis (J. F. Gmel.) Pax.

Apparently, Pohl was not aware of the publication by Crantz (1766), which first provided the presently recognized epithet M. esculenta, or perhaps he felt no need to employ Crantz's name, as no rules of nomenclature at that time applied the rules of priority.

Crantz, in establishing the name M. esculenta, copied descriptions from several older, pre-Linnaen works, such as those of Tournefort (1700), without giving credit to the earlier workers. He did, however, cite an illustration given by Merian (1726), a naturalist whose interests were as much in insect metamorphosis as in plants, but whose illustrations of the plants clearly indicated that the one cited by Crantz is Manihot esculenta.

Linnaeus (1753) placed M. esculenta, the only species of the genus known at that time, in the genus Jatropha as J. Manihot. Miller (1754) is the first post-Linnaean author to employ the generic epithet Manihot, but he apparently continued to use polynomials for the species names. Actually, Miller and many other pre-Linnaean botanists designated the cultivated species as M. Theveti, an epithet first used by Bauhin (1658) honoring André Thevet, a French monk who travelled in Brazil.

Ciferri (1938) is the first botanist to recognize the priority of Crantz's name, M. esculenta, and he first recognized that there were insufficient reasons to keep those variants with high prussic acid content separate from those with lower concentrations. Ciferri formally designated two subspecies of M. esculenta: ssp. flabellifolia (Pohl), and ssp. grandifolia. Under ssp. flabellifolia, eight varieties are formally established, and under ssp.

grandifolia, eleven varieties. Ciferri's work was confined to the Dominican Republic, and we have failed to ~~find~~ discover any documenting herbarium specimens for the taxa he established.

The foregoing attempts to formally classify the cultivars of *M. esculenta*, while of some historical interest, are of little value because they were based on inadequate samples of the variation or because they were not documented by specimens deposited in any of the world's herbaria. There are several other notable works wherein no effort was made to give formal status to any subspecific categories, but which provide insight into ways ~~in which~~ the cultivars might be classified. The following are ~~the most outstanding~~ worth noting:

Zehntner (1919) divided the Brazilian cultivars into two groups. One group contained the cultivars with high concentrations of the cyanogenic glycoside CN^-[3] and the other supposedly with none. Tests of about 100 Jamaican cultivars by the Agricultural Chemistry Section of the Jamaican Department of Agriculture (Rogers 1965) indicate that such a separation is not taxonomically valid. The CN^- concentrations are present in a continuum from low to high and are not correlated with any other known feature, whether morphological, ecological, or other, and in some known instances, they vary with the maturity of the plant. Although from a *taxonomic* point of view a separation is not justified, from both the *economic* and *health* standpoint the separation is important.

Other workers have made informal classifications of some cultivars restricted to a local area. These are largely useful for the identification of the cultivars growing in these regions, but cannot relate to the plants in other growing regions of the tropics. Such are the papers by Cours (1951) for Malagasy,

---

[3] Since the identity of the sugar in *M. esculenta* is unknown to us, we will hereafter refer to the compound by the symbol CN^-.

Do not type

Chandraratna and Nanayakkara (1944, 1945) for Ceylon, Templeton (1969) for Malaysia and Doku (1966) for Ghana.

BIOCHEMICAL PROPERTIES

There are varying concentrations of disaccharides and polysaccharides, cyanogenic glycoside, vitamins, proteins, minerals and water in the roots of *M. esculenta*. The foliage contains varying concentrations of proteins and amino acids. Precise knowledge of these substances would enhance the value of any classification, but is beyond the scope of this study.

In all cultures of the Western Hemisphere tropics, the farmers divide the locally occurring cultivars into "dulce" and "amarga" types, into "mandioca" and "macacheira", or "sweet" and "bitter." Whether these differences are based strictly on taste, as the names imply, or upon the content of CN^- is a question that has not been settled. Pereira and Pinto (1962), and Pereira, *et al.* (1965) have concluded that CN^- content is the sole basis for these divisions, but Sinha and Nair (1968) indicate that other factors enter into these categories. Presumably the content of CN^- is the farmer's main criterion, because questions to individuals usually indicate that the "bitter" type is poisonous, and requires special processing for food, and thus corresponds to Zehntner's and other classifications. In the Yucatan peninsula, the Indian native farmers usually separate the "dulce" from the "amarga" types in their fields, the sweet ones grown interspersed with maize, while the bitter (amarga) are kept some distance away, never interspersed with other crops. This is not commonly the practice in other parts of the Western Hemisphere agricultural areas.

Considerable research is needed to determine the relevant factors influencing the concentration of CN^- to be found in an individual cultivar, both during the ontogeny of the root and under different environmental conditions.

Considerable variation in sugar and starch content is found between cultivars. While genetic differences clearly play the most significant role in this variation, cultural practices are influential as well. For example, the usual length of time for growth to maturity in some parts of Brazil is considered to be 18 months, but in many other areas roots are considered mature after nine or ten months. The same careful experimental work is needed to determine these variations and influences as is needed for variable CN^- concentrations.

Protein content of the foliage of M. esculenta has been the subject of some research (Rogers, 1959; Rogers and Milner, 1963). Amino acid analyses of ten cultivars from Jamaica and ten from Belem, (Pará, Brazil) indicate a good balance of amino acids essential for human nutrition, but in some rat-feeding trials, other undetermined factors adversely affected the animals fed on the dehydrated foliage (Rogers and Milner 1963). Tabulations of each of the cultivar amino acid analyses are given in Part Two, describing the groups of cultivars.

Protein content of the root is (as for most root crops) of minimal significance. Efforts have been made in the past to raise the concentration of proteins in the roots by interbreeding M. esculenta with M. saxicola (Lanjouw, 1939), but little apparent success was achieved.

CATEGORIES WITHIN THE CULTIVATED SPECIES

We have not segregated Manihot esculenta into the formal subspecific categories customarily used for uncultivated plants. First of all, the category, subspecies, has a geographical restraint which renders the category unsatisfactory for a cultivated species such as M. esculenta which has a pan-tropical distribution because of dispersal by man. Since the plant has not been found in a state that could with any confidence be called natural, even restricting the criterion to the taxon's native range, the neotropics, the species does not meet the necessary conditions for proper subspecies designation. The designation "variety" also has geographic implications, although a smaller and more local geographical area limitation is implied (Du Rietz, 1930; Rothmaler, 1944). "Variety" may also entail ecological or cytological considerations (cytodemes) and is consequently as unsatisfactory a term as subspecies. The term "forma" is used for those variants of wild species that are sporadic and usually involve a single feature (Davis and Heywood, 1963) and though we might postulate that many of the plants of M. esculenta cultivated by man originated in a random and adventitious manner, the fact that they have been perpetuated by man, and thus exist as persistent recognizable entities, makes the term inappropriate.

We have used only two terms for aggregations of cultivars. The first term, division, is hierarchical and divides all the cultivars of M. esculenta into two principal parts. The second term, "group", is not hierarchical except in the sense that a group will be in one or the other division. A group (see Figs. 6-24) is a sequence of cultivars with the greatest similarity between pairs of cultivars. These sequences of cultivars form morphological clines which we have called gradients. The latter term does not have the geographical connotation that is associated with the word "cline."

TAXONOMIC CHARACTERS: general considerations

It is appropriate at this point to emphasize that the primary taxonomic purpose of this classification is to assemble the cultivars into groups with the greatest overall similarity. (Since many individuals have little understanding of the definition of a taxonomic character, we recommend that the readers review them in Estabrook and Rogers, 1966.) While the states of each single character will partition the plants into non-overlapping groups, employment of a single character classification is likely to produce groups containing members whose relationships are heterogeneous except for the single character. The principle of overall similarity (see definition p. 00), besides giving a better reflection of the overall gene content of the cultivar, also minimizes the effect of a character that may not properly reflect the natural affinity of the cultivars. The power of this type of similarity measure has been demonstrated in several applications: Wirth *et al.* (1966), Orchidaceae; Irwin & Rogers (1967), *Cassia*, Leguminosae; Prance *et al.* (1969), Chrysobalanaceae; Hawksworth *et al.* (1968), *Arceuthobium*, Viscaceae.

For any single character, the character states we have selected serve to divide the study into parts (or, in other words, will make a single-level classification). A character that has a large number of states carries more information than one with few states, and will partition the study into more discrete parts. On the other hand, if the states do not reflect a valid gene expression, or if the states are so finely delimited that it is difficult or impossible to assign a specimen with confidence to one particular state, very little useful information will be represented. In this study, cultivars rather than specimens are being compared and classified. For instance individual specimens within a cultivar might have distinguishable but very fine differences in the color of the petiole of the leaf. But the circumscription of the state assumed by the cultivar must be expressed in a manner that contains or subsumes these more exact and particulate color refinements.

The characters chosen to group and classify the cultivars of *M. esculenta* had to be comparable over the whole of the species and to be at least relatively stable, the latter being the most difficult restriction in regard to a collection of cultivars. The subsequent characters have been observed in sufficient frequency to recognize that they are stable within and between cultivars and the only ones consistently observable in a species whose cultivars may not produce flower, fruit or seed. Most frequently, even if the cultivar has this capability, it is harvested before flowering.

The characters are also selected to represent the cultivars in various stages of maturity and development. Since it was not possible to observe the plants in a single cultivated plot, an attempt had to be made to make common observations in many areas of the geographical range of the plants such that the age differences were eliminated or at least minimized.

Vegetative characters are sometimes not as reliable for classification as are floral and fruit characters. It must be recalled, however, that we are classifying populations within one highly variable species, and that even in taxonomy of natural species, vegetative structures play a considerable role in the definition of taxa, particularly at the subspecific level. Furthermore, in the Euphorbiaceae generally, characters of the vegetative portions of the plant have considerable taxonomic significance. Essentially, by conscious or unconscious processes, selections of the cultivars have been made by growers with the quantity or quality of the root as the consideration, the adaptability of the plant to various soils and climatic conditions and the length of time for the root to mature. The flower- or fruit-producing capacity has not been a factor in selection.

The form of the flower and fruit, and the leaves associated with the inflorescence in _M. esculenta_ are very uniform between cultivars. Unfortunately, the bulk of herbarium specimens representing the species deposited in most herbaria of the world are but samples of the inflorescence and do not give any indication of the variations ~~which~~ that exist in other parts of the plants. However, information about the reproductive structures provides good characters for interspecific differentiation in the genus _Manihot_.

Some of the information used in this classification concerns pigmentation

X
nf. 3

of various parts — roots, stems, petioles and immature leaves at the stem apex. This type of information is subject to some environmental and age influences. By the use of various techniques (see p. [illegible]) we have been able to structure the statements of coloration in such a way as to allow any implications of significant similarity to be included in a single state of a color character and allow only very obvious and different pigment systems to show any contrast. In the early stages of the work the senior author's private designation was used, but later a color chart[4] was adopted. While this chart does not match the exact color of the plants, it has the advantage of being portable, standardized and sufficiently accurate for the purpose.

Since the types of pigments of the flowers are similar to those in other parts of the vegetative structures, one gains little by describing pigmentation of the flower parts when selecting characters for cultivar classification.

There is no doubt that interesting and useful information for classification may be found in variations in biochemical substances in the cultivars. A reliable difference in the CN^- content of the plants would be one of the most valuable of characters, were the information uniformly available. Unfortunately, the test for CN^- in the field is not precise enough about the CN^- variations from plant to plant. Much research is needed on the sites of CN^- production, the process of formation, and variation in concentration with age. Further knowledge is needed concerning the influence upon CN^- concentration of a variety of environmental factors, such as soil pH, nitrate concentration in soils, moisture content, etc. Variations in starch seem to have some ill-defined relationship to the CN^- concentration, if one may use the information from growers who state that for starch production, they prefer

---

[4] Nickerson Color Fan, American Horticultural Society, 2401 Calvert St., NW, Washington, D. C. 20008.

cultivars with high CN concentration; and for eating as a fresh vegetable those with lower CN and starch concentrations. These rather crude observations are worth investigating since one may put some trust in those who use the plants most intensively. However, several questions remain, are the farmers basing their selections on plants of the same age, or are they merely harvesting plants earlier for eating as a vegetable, and would the same cultivar, if left in the ground, later produce a higher concentration of starch? Most users of the crop say that there are variations in the age at which different cultivars "mature." It is not known whether it is the size of roots that is the measure of maturity, or whether some other property is the deciding factor. Since other aspects of the plants vary with age, we can expect variation in the time needed for the maturation of the roots for different cultivars.

All the characters employed represent the information derived from a number of plants in the same field or plot. Before a decision was made concerning the branching pattern, the storey length[3], the pigmentation of a part, etc. at least 20 plants were examined. Most frequently as many as 50 plants of the same cultivar formed the basis of a statement. This procedure allows a sampling test to be made concerning the occurrence of some character state for a cultivar. Anyone familiar with the classification of cultivated plants recognizes that it is often difficult to make a completely unambiguous statement about some character for all the plants representing that cultivar.

Field observations of characteristics of plants are frequently made with more precise difinition than can easily be employed in constructing a classification. Day-to-day observations vary slightly, and those from year to year may vary considerably. For these reasons, some standardization of the observations were made by using reference plants to compare the observations from

---

[3] See definition, p. 17

one year to the next. The reliability test was based on observations over four separate years on plants grown in experimental gardens in Jamaica. Each year's observations were accompanied by a separate collection of the same cultivars, and each specimen, with the recorded data, was given a separate collection number. When computer runs were made, the cultivars were indistinguishable from one another on the basis of the characters used. In a few instances some differences were indicated which involved juxtaposed states of some character, but the cultivars involved were, nonetheless, in each case, closest mutual neighbors. In no case were the disagreements significant. Individual observations could indicate different intensities of pigments, but only about 5% of the observations of bud color asserted a complete shift from one pigment state to another over the four years.

SPECIFIC CHARACTERS USED

The philosophy used in selecting information for classification was that the most important group of workers for whom the classification should be useful is that group who might wish to do breeding work or agronomic studies, and not those who would merely use the work for the purposes of naming the plant.

A. Root Characters (characters 1 to 3)

The enlarged roots of *M. esculenta* arise from the nodes and callus area of the stem cuttings, which are universally used as the propagule by cultivators. When seeds of the cultivated species are planted, a tap-root system develops with little enlargement of the secondary roots. Since no detailed anatomical or developmental studies of the storage roots of *M. esculenta* have been made, the following terms are descriptive only (but see Holleman & Aten, 1956).

The roots are fusiform, long and slender, turbinate, or in a very small number of cultivars, globose. The roots are attached to the cuttings by slender and/or very short connections giving the appearance, as indicated by the name of one cultivar in Jamaica, of a "Bunch of Keys." Most of the roots are disposed horizontally in the soil, seldom penetrating deeply into the lower horizons.

Three distinct portions of the enlarged roots are discernible: (1) an outer layer, referred to as the phelloderm, which is generally composed of an outer epidermis, a sub-epidermis and a thicker inner layer. The phelloderm (commonly called "peel") is generally 1-3 mm. thick, and easily separated from the next inner layer; (2) a layer of parenchymatous cells (probably secondary xylem parenchyma) ~~which~~ that constitutes the bulk of the root and is the carbohydrate storage region. Most cultivars at the age of harvesting have few, if any, fibers in this region; older roots, however, may develop a number of hardened fibers, an undesirable condition for use as an edible vegetable. This portion is called either cortex or flesh; (3) at the center of the root is a well-defined central vascular core.

The root has three characters applicable to the classification. The first, Surface of the Root (Table 1, character 1), has two states, smooth or rough. In most parts of the range of cultivars, one has little difficulty in distinguishing between the two states, but in some cases, particularly very immature roots, it is difficult. Apparently in the rough-surfaced groups, the outer layer of the root cracks longitudinally and transversely, and the edges curl outward, giving the roughened appearance. In the smooth-surfaced groups, the outer layer remains intact.

External Color of the Root (Table 1, character 2) is divided into five usually easily distinguishable states. Internal Flesh Color (Table 1, character 3) is essentially a character with two states, whitish or yellowish. However, in a few cultivars a pinkish color may be superimposed on the base color of white or yellow.

B. Stem Characters (characters 4 to 7)

Stems of the cultivars of M. esculenta are woody and usually rather brittle. The ultimate diameter of the stem is dependent on the age of the plant, but under cultivation, one seldom finds stems of more than 10 to 12 cm, diameter at the base of the plant. Average stem diameter of the cultivars is 3 to 6 cm. Stems may be tall and unbranched, frequently more than three meters high, or branched in varying degrees.

A striking character of the living plants is the pigmentation of the mature stem. Stems just below the growing point are usually some shade of green, and the pigmentation of the stem referred to below is that of the more mature, lower regions. Stems may be silver or light grey, or may contain some reddish, yellowish or brown pigment. The silver stems owe this character, apparently, to the absence of the darker pigments, and the silver cast is the result of a waxy bloom on the surface overlying the next lower (epidermal) layer. The more darkly pigmented stems, red, yellow, or brown, are fairly easily detectable in both fresh and dried herbarium specimens. Some difficulty arises in distinguishing some of the lighter shades of brown from the silver stems, and this difficulty is reflected in the field-coding of the specimens. Part of this problem is due to the waxy surface of the stems. Rather than to force the coding to either brown or silver, the combination, silver-brown, was designated for some of the cultivars (Table 1, character 4).[6] ~~See page 30, Section B. Ordered Characters for discussion of the void states.~~ Usually, after the stems have been dried for herbarium specimens, one may readily assign the stems to either of the states, silver or brown.

The leaves of M. esculenta usually drop off the lower portions of the stem, and as the stems mature, more or less prominent scars develop. Apparently, the stipular scars are included in the protruding areas. There are periods of rapid growth, with apparently less distance between nodes than in periods

[6] See discussion of the void states in Section B, page 00.

of slower growth. While the cultivars generally have these differences on all the plants, it is also evident that differences in scar locations are useful differentiating characteristics. In order to use the information, the "storey" length is employed. A storey is defined as the distance from one leaf scar to the next one directly above it, no matter how many nodes occurred between the two. The phyllotaxy of the species is apparently stable and constant. For each population sample, as for all other characters in this study, a number of different plants of the same cultivar were examined, and a "typical" sample chosen. A stem cutting, long enough to include several storeys, was a component of each herbarium specimen.. The three states of the stem character Storey Length (Table 1, character 5) cover a sufficient range to allow for the variations caused by changes from a growth flush to a period of relatively inactive growth for any cultivar. The second state, 9-20 cm, is the most commonly encountered, and only extremes of variation exist in states one or three.

Nature of Scars on Stem (Table 1, character 6) is a measure of the size of the leaf scars on the mature stem. This character is not as easy to standardize as the previous character, for which it was convenient to use actual millimeter ruler measurements. Ruler measurement would be possible, but it is very inconvenient and time-consuming to measure the size of the leaf scars, and these data add nothing to the accuracy of the character states established. The character as constructed is qualitative and is dependent on the perceived estimates of the conspicuousness or distinctness of the appearance of the leaf scars. Since the states of this character, and the attributes of the cultivars take the form of a continuum, it was considered desirable to have cultivars with properties that placed them in adjoining or juxtaposed states in order that this relationship be expressed when the plants are compared. Thus, Nature of Scars on Stem was established as an ordered character (Estabrook

~~and~~ & Rogers, 1966) for which plants scored in neighboring states are regarded as half similar. The ordering of the states of a character is a facility of the Graph Theory Clustering Program that is employed when the states are considered as interrelated or interdependent in some sense as opposed to discrete states whose relatedness is only subject to their pertinence and relevancy to the substance or purpose of the character. This ordering facility allows the investigator the use of an equation within the program by inserting an instruction specifying the number of states that are to be considered as related. It is useful in cases such as the Nature of Scars on Stem where the states reflect a continuous gradation from state to state along the sequence of sizes. As we instructed the program for this character to consider neighboring states as related, the effect has been to assign, for example, a similarity of identity for two plants coded as moderately raised, and .4 similar if one of the plants is coded either as slightly raised or very large, and the other as moderately raised. This allows some freedom in scoring the character, either from dried or from fresh material. Because each specimen is accompanied by a photograph of the fresh plant, judgments were made both in the field and on herbarium material and checked each time by separate, independent judgments of at least two workers. The states of the character are indicative of our intention: a smooth state indicated no, or very little, enlargement of the leaf scar, etc.

Branching of Plant (Table 1, character 7) was one of the most difficult to develop into a meaningful differentiating character. In the field the plants were arbitrarily divided into four sectors of height, and counts of branches at each height were made: branching 1/4 way up the stem, 1/2 way up, 3/4 way up, at top, or unbranched, and various combinations of these features. This type of scoring did not reflect the branching patterns accurately and was discarded in favor of that adopted.

Manihot esculenta most frequently has a trichotomous branching habit. However, branching is frequently dichotomous and infrequently quadrifid. Each point of branching is initiated by the appearance of a terminal inflorescence. Therefore, the frequency of branching is also a measure of the frequency of flowering of a cultivar.

The final choice of three states for branching patterns is satisfactory both to reflect relationships and to differentiate the cultivars into groups. As noted in the discussion under Group 3 (p.00), some indication of the putative origins of the cultivars may be obtained from the types of branching patterns. In our statements about the three states of the branching pattern, the first (one branch at top or no branches) might indicate an ancestral form with very few branches, the second state (one or two branches, but not one branch if at top) indicates the preponderance of the cultivars and possibly the center of a hybrid swarm, and the third state (more than two branches) indicates the possibility of a wild ancestry from a low, very frequently branched ancestor. In an earlier publication (Rogers, 1965) the senior author postulated an ancestral form of *M. esculenta* from the lowlands of Mesoamerica. The most likely ancestral species is *M. aesculifolia* (HBK) Pohl, a tall, slender species with relatively infrequent branching (Plate 2, 3).

C. Leaf Characters (characters 8 to 15)

Leaves of M. esculenta can be of two forms, generally, depending on the point of attachment. The mature vegetative leaves are deeply 3- to 9-lobed, palmately veined, supported by a heavy petiole, subtended by hairlike caducous stipules. The leaves near the inflorescence are generally reduced in size and lobe number, most frequently 3-lobed, but the leaf inserted closest to the base of the inflorescence is frequently simple and unlobed. If the leaves near the inflorescence have more than three lobes, they are most frequently much smaller than those not associated with the inflorescence. The number of lobes of the mature vegetative leaves is relatively constant for individual cultivars though some variation in number may occur (the senior author measured leaves of over 2,000 plants before making this statement). It is fairly common to find leaves associated with the inflorescence with three, or two lobes as well as simple on a single plant. Only a few cultivars are characterized by having 3-lobed mature vegetative leaves, the same as those associated with the inflorescence (this, again, may represent a primitive or ancestral form). The leaves are attached to the petiole at the base of the lamina, not peltate. Most of the petioles are slightly S-shaped, holding the lamina on a nearly horizontal plane.

The stipules are variously slender and hairlike, or sometimes laciniate. In the fresh condition, the stipules are maintained on the plants for varying lengths of time, some lasting until the leaf falls, others are early caducous. Stipular scars are more or less prominent, and are fused with the leaf scars. Other authors (particularly Cours, 1951) have placed considerable emphasis on the stipules for classificatory purposes. We have not, because one must make frequent observations of the plants over long periods to get accurate data.

The leaf lamina are variously pubescent, but the number of hairs apparently varies with the age of the leaf. The under surfaces of the leaves are frequently glaucous, but the variation in this character is such that no clear-cut differentiations may be made. There is a waxy indument on the abaxial leaf surface characteristic for all members of the species. This indument is characteristically farinose, forming an irregularly hexagonal pattern around the stomata. The margins of the lobes are usually entire, but some are shallowly sinuate. The lobe shape varies from obovate to linear, with a few truly pandurate lobes occurring on the mature vegetative lobes. There are some lobes whose shapes are nearly elliptic, but these are taken to be some modification of those which are obviously obovate, and are included as such in the scoring of the character, Leaf Lobe Shape.

Number of Lobes of Leaf (Table 1, character 8) refers only to the mature vegetative leaf. Great care is needed in scoring this character, to be certain that one has an adequate sample of the mature leaves, and not those from or near the inflorescence. The leaves associated with the inflorescence are not taxonomically useful. In character 8, the six states employed allow an expression of the variations found in the cultivars. Herbarium specimens were collected to indicate the kinds of leaf-lobe number variation exhibited by several plants representing a cultivar. State 1-4 have overlapping lobe number counts, to accommodate the variation found in a few cultivars. By far the predominant number of cultivars have 7-lobed leaves, and all the other states of the character are represented by a far fewer number of cultivars. No significant valuable statement can be made concerning the relation of lobe-number to any wild species of the genus, inasmuch as the wild species so far examined seem to have as much variability in the lobe number as do the cultivars.

Leaf Lobe Shape (Table 1, character 9) is a simple 2-state character, but it is modified by the two characters, 10 and 11. We assume that the basic shapes exhibited by the lobes are either obovate or linear, but through various processes of either intraspecific or interspecific hybridization, or perhaps even by environmental influences, these two shapes may be modified as indicated in characters 10 and 11. These characters may be interpreted to read as follows: (state 1 of character 9, obovate, is modified by the states of character 11) an obovate-lobed leaf may exhibit deep indentations on the margin (pandurate character 11, state 1), may have only slight indentations (sinuate character 11, state 2), may not exhibit any indentation (simple character 11, state 3), or the statement is not logically associated with the leaf-lobes because the specimen to be coded has linear-lobed leaves; (state 2 of character 9, linear, is modified by the states of character 10) a linear-lobed leaf may be sufficiently modified to be designated pandurate (state 1 of character 10), sinuous, simple, or not logically applicable. Discussion of the coding procedures are found under "Methods" and further discussion on structuring of characters and character states is found in Estabrook ~~and~~ & Rogers (1966).

Characters 12 and 13 (Table 1), Length and Width of Median Lobe, respectively, were established after many trials with cultivars in Jamaica, Costa Rica and other countries. As anticipated, there is some arbitrariness to the divisions into states, but the great majority of leaves measured are easily placed within the states. The attempt here was to allow only the extremes of variation to be differentiated in states 1 and 3 of both characters. Any finer differentiation of the states would have introduced environmental and developmental variations rather than inherited differences. The exact measurement of the length and width is not considered significant, but the relative length and width, with respect to other cultivars, are considered important.

Characters 14 and 15 (Table 1), both pigmentation characters, provide

Tape 4 starts here

some of the most striking field characters available. The color of the petiole varies between the limits established, with some additional yellowish pigments occasionally exhibited, but those that have the yellowish pigments are variations of green, and all plants with green pigments are placed together, whether light green, yellowish green, or dark green. The use of a matrix character (see character 3, p. 8) for the petiole colors allows the most flexible method of indicating a relationship between the different colors. Note that some relationship is allowed between red and greenish red, between greenish red and reddish green, and between reddish green and green, but no overlap is allowed between states 1 and 4.

Character 15 (Table 1), Color of Young Foliage, refers to the vegetative apices of the cultivars, with the young leaves actually containing the colors indicated in the three different states. As the leaves mature, the lamina become uniformly green and the colors exhibited by the young leaves, if reddish blue or bluish green, are no longer visible. In this character, each of the states includes a broad range of variability, such that any expressions of color may be clearly placed.

MATERIALS

Specimen and sampling techniques. The senior author's collection of 228 population samples is employed in this classification. This was necessary because an initial examination of herbarium materials from several herbaria in the United States and abroad indicated that specimens collected for a typical botanical collection do not contain sufficient information to permit the differentiation and description of the cultivars in *M. esculenta*. Typically, and with rare exception, a normal herbarium collection contains dried material from the inflorescence of the plant, and none of the other parts are represented. For general plant classification purposes, such specimens are satisfactory. The reproductive structures and the foliage associated with the inflorescence of *M. esculenta* are remarkably uniform in morphological structure in all the cultivars.

The general condition of herbarium specimens for studies of cultivated plants is deplorable. The typical herbarium specimen, in addition to its paucity of plant material represented, more seriously lacks detailed descriptive information on the labels, and so few specimens contain comparable label data that it is impossible to get more than a sketchy description of uses, pigmentation, height, or branching pattern, etc. Few collectors have been properly instructed to gather material and information necessary for cultivated plant taxonomy. Anderson (1951) has given the only good instructions for collecting materials for cultivated plant taxonomy, in his study *Inclusive Herbaria*, and in *Mass Collections* (Anderson *et al.*, 1941).

The classification does not include information about the flowers or fruits of the cultivars. In many cases, cultivars do not come to the flowering stage before the plants are ready for harvest. In other cases, there are numbers of flowers or fruits, but because the information to be used in a classification must be comparable over a large percentage of the collection, we have chosen to exclude flowering and fruit characters. In any case, as noted above, the morphology of the flower and fruit is almost identical. Hsu & Valerio (1966) reported various degrees of male sterility amongst the cultivars. Again, unless a sufficient number of the cultivars have been studied, we cannot use this type of information in deriving the classification of the group.

In this study, the specimens that were used to represent the cultivars were selected in the following manner. When a row, plot or field of a cultivar was found, a survey and appraisal were made of the range of morphological variation present. The adventitious or trivial features of the plants such as those caused by insect damage, cultivation practices, light and shade conditions, etc., could then be determined, as well as the characteristics that were of genetic origin and distinctive of the cultivar. A plant that best corresponded to the typical condition of the cultivar was selected for the herbarium specimen.

The herbarium specimens for all collections used in this study consist of the following plant material: a longitudinal section of the root, a representative section of the stem, at least one mature vegetative leaf, a portion of the vegetative apex, and where available, portions of the inflorescence. Accompanying the specimen is a habit photograph against a backboard marked in metric dimensions and a full set of field notes, standardized, to insure consistent data gathering. Color variations were measured with a Nickerson color chart based on the Munsell Hues. The data associated with each specimen were compiled in the field along with any notes about any interesting or unusual features. There was no practical method of making a proper soil analysis at the plant site. However, often a general comment was made about the soil. No chemotaxonomic data were gathered.

DKD

Flush → Geography and Ecology of Specimens

The specimens used in this study were collected in Jamaica, Costa Rica and Nicaragua; the states of Amazonas, Pará, Pernambuco, Minas Geraes and São Paulo, Brazil; and on the eastern slopes of the Andes in Bolivia and Peru. Most of the material was collected by the senior author either from a plot maintained by an experiment station, or from a farmer's field. Because much previous survey and collecting work have been done at several of the experiment stations, an excellent cross section of the types of variation to be

The specimens used in this study are to be deposited in the herbarium of the United States National Arboretum, Washington, D.C. 20002.

found in *M. esculenta* in most of its native range in the Western Hemisphere has been sampled. For example, 107 different cultivars were collected on the island of Jamaica, and many represent earlier imports from other West Indian islands and from the South American mainland as well as from the Far East. The 200 cultivars maintained at the Federal Agronomic Experiment Station near Belem represent samplings of the Amazon basin. The cultivars maintained at the Tambe Experiment Station in the northeastern part of the state of Pernambuco represent the coastal and near coastal sections of northeastern Brazil, while those maintained at the Araripina Experiment Station in extreme western Pernambuco represent the cultivars of the very dry regions of the Caatinga. Another large collection of cultivars was sampled at Campinas, and at the Sao Paulo State Experiment Station.

Correlation between cultivar and geography is difficult to make, but just as clearly there is great need to attempt geographic, climatic and particularly edaphic correlation if we are to derive the most information about the potentialities of any one cultivar. The studies do, however, give some indication of a tenuous relationship between distribution and morphological characteristics. Some small aggregations of morphological combinations tend to be found in the same region, but no large segment of genetically controlled variation can yet be so attributed.

In the Western Hemisphere, plantings are known to occur in the Florida Everglades on lands of the Seminole Indians, who regularly cultivate several cultivars in a region where occasional freezing temperatures are recorded. A more regular cultivation of *Manihot* cultivars is reported from Rio Grande do Sul, Brazil, where frequent frosts occur, and during this period, the plants die back to the ground level. When warmer weather returns, the plants sprout again, and six months later the roots are harvested. Regular production seldom occurs above 6,000 feet altitude. Within the vast area remaining, almost all regions support some cultivar of *M. esculenta*. Since the species is a heliophile, it grows in dry, arid, xerophytic regions as well as in areas of high rainfall such as tropical rain forests. In the latter case the only requirement is a cleared area to let in the light.

THE TAXIMETRICS PROCEDURES EMPLOYED

Taximetrics procedures include all the steps necessary to complete a classification. We feel that it is important to expose the methods employed, from initial specimen selection to the final classification. This section is organized as a step-by-step set of procedures, including the application of computer programs. Further descriptions of taximetrics are found in Rogers, 1963b; Wirth, et al., 1966; Estabrook and Rogers, 1966; Rogers, Fleming and Estabrook, 1967; Rogers and Appan, 1969.

1. Selection of specimens to be used in classification.

In this study we chose those specimens representing cultivars for which the senior author had assembled the most complete documentation. Thus, of the total of 330 collections of *M. esculenta* made by Rogers approximately 100 specimens and/or cultivars were excluded because of the inadequacy of the herbarium specimens or field notes.

2. Selection and coding of information to be used in the classification.

The purpose of the classification determines to a great extent what characters will be selected. A selection of characters for an ecological, geographical, etc. classification will be different than one using morphological information for a taxonomic classification. In the present instance, since we are classifying cultivars quasi-taxonomically, a special set of characters has been chosen (see p. 14 ff) that differs in some respects from those characters commonly selected in natural populations. The guiding rule simply stated is select those characters that (1) serve the purpose of the classification and (2) are comparable for the objects (in this instance, cultivars) in the study. For each of the chosen characters a number of states (2 to *n*) are determined that (1) collectively cover the range of variation in the study respective to the character, (2) can be determined by a yes or no answer for each of the cultivars in the study, and (3) are valid attributes of the cultivar and not simply variations in individual plants. Table 1 lists Characters and Character States that have been selected for the cultivars of *M. esculenta*.

Since the measure of similarity applied in the Graph Theory Clustering Program (Wirth *et al*., 1966; Estabrook and Rogers, 1966) is the sum of the number of matches (states possessed in common by the cultivars when compared with one another) divided by the number of characters used to compare the respective cultivars, the facility and accuracy with which each character reflects the observations and judgments of the classifier are critical. The following paragraphs explain how the various options available in the program were used in the study of *M. esculenta*. For a more detailed and complete discussion, see Estabrook and Rogers (1966).

The Graph Theory Clustering Program is particularly appropriate because both quantitative and qualitative characters can be used. Character 8[4], Number of Lobes of Leaf, or Character 12, Length of Median Lobe, are quantitative characters. Character 8 is a quantitative character with the states using cardinal, or simple counting numbers, and Character 12 is a character having states using numbers to represent linear measurements. Characters 1 and 2 have qualitative states.

Sometimes a character, while suitable for the classification intended, is not applicable to every member in the study. This occurs when we do not have information or knowledge of a character state pertaining to a particular

---

4. Table 1 lists the characters and attributes (states) used and should be used in conjunction with the text whenever characters are discussed.

object for reasons that are not inherent or intrinsic to the object. For instance, a herbarium specimen may lack flowers because someone carelessly lost them, or the specimen may have been collected at a time of year during which the plant simply did not flower. In either instance, the researcher must contend with missing information. In Table 17, morphological and other descriptive information for Group 10, in the column for Character 3, cultivars 436, 482 and 485 are coded in state 0. The color of the root-flesh was not recorded for some reason when these cultivars were collected. The Graph Theory Clustering Program will not compare any object with any other object in the study for a character or characters in which either of the objects is coded in state 0. Thus, the above-mentioned cultivars of Group 10 have not been compared with any other cultivars of the study (not only cultivars of Group 10) in respect to the flesh color of the root. These cultivars have been compared with other cultivars for 14 rather than the complete number of characters, 15.

Tape 100 ref 1

A character whose attributes describe only a portion of the specimens under study must have one attribute, "not-logical," to accommodate those specimens which the other attributes of that character cannot define. Those objects whose properties cannot reasonably be ascribed to an actual or essential state are coded in the "not-logical" state. For instance, when classifying dioecious plants, some characters will only be appropriate for the morphology of pistillate specimens, in which case the staminate specimens will be coded in the "not-logical" state of the respective characters. In turn, the staminate plants will have their appropriate characters with the inclusion of a "not-logical" state to accommodate the pistillate plants. In this study, characters 10 and 11 (see Table 1) have logical (equivalent to the "not-logical" statements above) states. We consider that the genetic control of the sinuosity of the

appropriate start here.

leaf-lobe margins is different for linear lobed leaves than for obovate lobed leaves. If this assumption is correct, then the shapes of the leaf margins of the obovate lobed leaves must be described by a different character than that for linear shaped leaves, and each contains a logical state for the coding of those cultivars to which the respective character does not logically apply.

An additional feature of the Graph Theory Clustering Program is the ability to reflect different relationships that attributes, or states, of a character may have to one another. For example, in a character, "numbers of flower parts," a 4-parted flower state must show a much closer relationship to a 5-parted flower state than to a 3-parted flower state (dicots with 4 or 5-parted flowers vs. monocots with 3-parted flowers), though we may mistakenly think of juxtaposed numbered sequences as reflecting equivalent biological relationships. The procedures to deal with this significant problem in a computing program are given below, in both the "ordered" character and the "matrix" character.

A. Simple Characters. The majority of the characters in this study are simple characters. Characters 1, 2, 4, 5, 7, 8, 9, 10, 11, 12, 13 and 15 are simple characters in which the included states are considered to be equally related. Cultivars that are coded in the same state for each of these characters will be considered as identical in respect to the character in question (similarity = 1), dissimilar if in different states (similarity = 0).

B. Ordered Characters. The states of some characters are in an orderable sequence, and the relative physical position of one state to another can be used to indicate a relationship. The Graph Theory Clustering Program provides an equation which, when the number of states that have an orderable relationship and the desired range of relationship are given to the program, will compute the similarity between the compared objects on the basis of the physical position of the states within the character (for detailed information, see Estabrook & Rogers, 1966). This equation has been used to assign similarities between the cultivars for Character 6, Nature of Scars on Stem. Cultivars in identical states are computed as similar (S=1.0); in juxtaposed states as 0.4 similar (S=0.4); cultivars separated by one state, dissimilar (S=0.0). Note that Character 4 has two states, 3 and 4, with no color designation. These two states, which have no cultivars assigned to them, were created because we considered early in the study that this character was orderable. Silver and Silver-brown on the one hand, and Brown and Yellow on the other, are to be considered related, and the null states 3 and 4 (0 states in which no cultivars were coded) prevented any similarity to be shared by cultivars coded in 2, Silver-brown, and 5, Brown.

C. *Matrix Characters*. The last of the three types of characters employed in this program has states that are not linearly orderable, but in which the worker judges that some states are more similar to each other than to other states of the same character. To indicate this type of relationship, a matrix is made in which the degree or percentage of similarity between each of the states is indicated. Character 3, Root Flesh Color, and Character 14, Petiole Color, of the present study are matrix characters (Table 1). In Character 3, the matrix accomplishes the same end as the null states of Character 4. States 1 and 2, and 3 and 4 are respectively related, but not 2 and 3, etc., with the additional facility that any desired degree of affinity from 0 to 1 may be reflected. In Character 3 we think that the fundamental color of the flesh of the root is either white or yellow, and the pinkish coloration a modification of these two states; those cultivars with pink imposed on white are considered as being more closely related to the white-fleshed cultivars (75%) than those cultivars with pink associated with yellow-fleshed cultivars, and vice versa.

3. Data Input to the Computer

The details of the assembling of the program deck and the associated input data along with flow-charts, listings and other documentation are available through the SHARE Library[8]. Instructions and information to the program such as number of studies, what part or parts of the Graph Theory Clustering Program are to be printed, the names and descriptions of the studies, and the character type designation (simple, ordered, or matrix), are assembled along with the descriptive data for each of the objects, in this instance, cultivars of *M. esculenta*. The mathematical model and taxonomic rationale of the Graph Theory Clustering Program have been described by Estabrook (1966) and Wirth *et al.* (1966).

4. The print-out of the Graph Theory Clustering Program

After running the clustering program, the following information is given in the printed results:

A. Data Table. This table lists the data for each of the cultivars. The specimen or cultivar number is on the left of the page, and following in line to the right, in groups of ten (to facilitate reading), the states of each character in order. This table is useful for verifying the original data and for determining the morphological features of the clusters at different levels of similarity.

B. List of Identicals. Following the data table is a list of any of the cultivars that are identical for the information on the data card. In the event of identical cultivars, the lower-numbered cultivar is retained in the analysis.

C. Table of Similarities S(a,b). The similarity of each of the cultivars to all of the other cultivars in the study is in tabular form. The two compared

---

[8] Program Information Department, I.B.M., 40 Saw Mill River Road, Hawthorne, New York 10532. Library #3501.

cultivars are printed first followed by the similarity figure and last by the number of characters that were used in deriving the similarity measure. This latter figure is important in assessing the significance of a comparison when some of the information on which the comparison between the cultivars is based is missing. The table is ranked in the order that the cultivars were processed by the program. In some studies this facility of the program may not be required, but if desired, is so specified when the program deck is assembled.

The main output of the Graph Theory Clustering Program has been described in several publications (Estabrook, 1966; Irwin and Rogers, 1967; Prance, et al. 1969; Wirth, et al. 1966). In the following section we give details which are necessary to make the various printed results useful to taxonomists interested in employing this program. The parts to be considered are: D. The main output of the Graph Theory Clustering Program E. Sequence of object similarities for nearest ten objects, and F. Histogram. As a matter of convenience to workers using these methods, the computer program is designed so that any of the three parts may be omitted from the printed results.

D. The Main Output of the Graph Theory Clustering Program (Fig. 1)

The print-out is a continuous, rouletted, folded sheet. The partitions[8] (levels L1 to Ln) are printed consecutively until the last partition in which the similarity (c-value) has been sufficiently relaxed (low similarity) to admit all the cultivars into one cluster.

Besides the title of study at the top of each page, the following kinds of information are given at each level (partition): Fig. 1 (a) **the level** number in sequence; (b) the c-value of the respective level which is equivalent to the degree of similarity at which at least one new cluster was formed; (c) the cultivars in each of the clusters; (d) the c-value at which each of the clusters formed (some clusters in practice persist through many partitions); (e) connectedness (or homogeneity) expressed as 2 figures, the first of which gives the number of pairs of cultivars in the cluster that are at least as similar as the c-value of the particular level, but may be as similar as some similarity ratio greater than the c-value of the next subsequent level (see g in L=2, level 2); the second figure is the total number of pair connections possible for the number of members in the cluster; (f) an R set contains those members of the study that, at the particular amount of similarity indicated

[8] A partition for a collection of objects is a dividing of the collection into lesser collections such that each object in the first collection is in one and only one of the lesser collections.

by the c-value of the partition, change the membership of an existent cluster; (g) a list of the internal connections between pairs at the c-value for the particular level, followed by another list of the connections that will be made before the c-value of the next succeeding level; (h) a figure, moat, which is the amount of drop in similarity value necessary before the membership of the cluster will be changed by the addition of other cultivars (one or many); (i) next pairs to join, following the moat value and enclosed in parentheses, is the identification number of the cultivar that is a member of the respective cluster that will change the membership at some subsequent partition (c-value of respective partition minus moat value equals c-value of subsequent partition at which cluster membership changes). More than one pair of cultivars may change a cluster's membership at a particular level. (j) Last, a list of the cultivars that are single member clusters, or, in other words, those cultivars at the respective level of similarity that are so dissimilar that they are not allied to any other cultivar at the specified c-value.

E. Sequence of Object Similarities for Nearest Ten Objects. This is a list of each of the cultivars with the ten others most closely related to it ranked in order of their similarity values. This list is informative for conventional taxonomic work in detecting discontinuities in variation pattern between populations correlated with geography, ecology, etc., as well as in enabling the researcher to see the relationship of a specimen or taxon with related forms at a glance. In groups of organisms exhibiting reticulate relationship it is important to be able to determine the specimens (cultivars) that show the highest similarity to each other, and the sequence of object similarity print-out is very helpful.

F. Histogram. A computer-produced plot (called SKYLINE) shows the amount of dissimilarities (moat) between clusters. The similarity values are ordered on the vertical axis and the cultivars are ranked on the horizontal axis in order of their affinities by clusters.

G. Review of Graph Theory Clustering Program

The Graph Theory Clustering Program assembles and organizes information about specimens, etc., on the basis of certain assumptions (Wirth *et al.*, 1966; Estabrook, 1966) that clarify and expedite taxonomic decisions. As the interpretation of taxonomic data varies in different groups of organisms, so also will the emphasis and interpretation given to different aspects of the information printed out by the Graph Theory Clustering Program change correspondingly.

The computer print-out of the Graph Theory Clustering Program provides at least four primary ways by which a taxonomist can be aided in making choices of the taxa to be recognized in his classification.

i. "Moat" is a measure of the discreteness (or relative lack of difference) between two clusters whether single or multiple membered clusters. Large moats between clusters usually indicate distinct entities (taxa). The histogram, SKYLINE, is a graphic summary of moat for the whole study.

ii. "Interconnectedness" is a measure of the relatedness or affinity of the members within a cluster. It is an indication of the homogeneity or variability of a cluster or taxon.

iii. "Prime Connections" are the maximum similarity values between pairs of objects (cultivars in this study) whose relationship(s) is such as to alter cluster membership.

iv. "Sequence of Object Similarities" shows, in descending order of relatedness, the amount or percentage of similarity of particular cultivars to other cultivars in this study, regardless of the cluster or group membership. This information has frequently been useful for discovering ecological or geographical clines in conventional taxonomic studies.

The first three of these facilities are specifically given at each level in the main computer print-out, but in practice a graphic display of this information as "subgraphs" (according to the mathematics of graph theory, each cluster is a connected subgraph) along with the other available print-out data renders the information more comprehensible and explicit. The subgraphs have a dynamic aspect which helps in the analysis and synthesis of the various elements of the study.

5. Graphic exposition of computer print-out (subgraphs).

Figure 1 is an example of the computer print-out as it could appear for a small study of 10 specimens. The information in this print-out is explained in the section titled the "Graph Theory Clustering Program", Part 4, D, the main output of the Graph Theory Clustering Program (p. 33). Fig. 2 is a graphic, hand-produced representation of the information contained in Fig. 1.

To prepare the subgraphs a sheet of paper of sufficient size is selected to list in a column on the left vertical edge all of the specimens contained in the study. These are arranged in the order in which they appear on the computer-produced histogram (SKYLINE). This list is ordered so that cultivars and clusters of cultivars are associated with the other most similar cultivars and clusters of cultivars. The level number and the c-value are written on the upper horizontal edge of the sheet. The cultivars that are affiliated at the first level are indicated by the R-sets and as indicated in Fig. 2, are written near the ordered cultivar numbers in the left column. Their affinity is shown by connecting them with a line. At the particular level at which the cultivars are R-sets, we have adapted the convention of either writing the line very heavily or using a red pencil. As the study progresses from one level to another, this rule enables one to see at a glance which cultivars have formed new clusters or have altered clusters that have formed at a previous level. After each cluster, a line is drawn which will not be interrupted until the cluster is altered by the addition of a new cultivar(s), or the homogeneity of the cluster is changed. The moat (Fig. 1 (h)) is written on top of the line. If we subtract this figure from the c-value for the respective level, the resulting number will be the c-value of the level at which the cluster will be changed by the incorporation of a new member(s). Below the line is entered the connectedness of the particular cluster expressed as a fraction. This figure is obtained from the print-out (Fig. 1 (e)). The numerator is the actual number of connections that have been made, and the denominator is the total number of connections possible. If the numerator does not agree with the number of connections drawn, a mistake has been made in the drawing. A convenient convention to follow is to draw all connections made at a particular level with wavy red lines. When copying a cluster formed at a previous level, all connections, whether former R-sets or internal connections, are indicated by ordinary ink or pencil lines. The actual arrangement of the cultivars within the clusters is subservient to the facility of drawing the connections between the cultivars, as may be noted in Fig. 2 for the cluster containing object 3 as the cluster altered in level 2. A convention that saves time in copying clusters from one level to another has been adopted for maximally connected cultivars within clusters. These maximally connected cultivars are enclosed by a red line. In copying cluster 3 from level 2 to level 3 we would reproduce the cluster as shown in Fig. 2, level 3, before adding any of the information contained in the print-out of level 3. The diagramming of the computer print-out is continued until the last level is drawn and all the cultivars are contained in one cluster, or else, to some level at which satisfactory understanding of the structure has been attained.

INTERPRETATIONS OF THE SUBGRAPHS OF *MANIHOT ESCULENTA*

The following section is given for those interested in the detailed processes of decision on cultivar classification. The discussion contains much information about the very basic problems involved in classification of taxa whose relationships are known to be, or are thought to be, reticulate. While problems of reticulate relationships may be slightly different from one taxon to another, this discussion should clarify some of the methodological problems faced by taxonomists interested in the studies of such complexes. We do not know of any previous published discussion of the type given here, and feel that this one is of such significance that it must be included to interpret the results.

Since the print-out of the Graph Theory Clustering Program assembles and orders the information in progressive steps as the c-values (similarity measures between pairs of cultivars) decrease, it is possible to follow the interactions of each specimen in all the steps from beginning to end, so that the substantive knowledge of the taxonomist can be applied in continuously recurrent question-and-answer mode. At each level the membership of at least one cluster has altered, the similarity relationship (moat) to the subsequent cluster has changed, and homogeneity of some of the clusters may have increased or decreased significantly.

In *Manihot esculenta* the problem is the classification of a highly complex cultivated species in which the relationships are reticulate, with multiple referrable associations or relationships. To indicate these, we have used the computer print-out in several ways as follows:

1. *To Discover the Properties (Attributes) of the Species that are Correlated.* The relevancy of the properties of the organisms making up natural taxa have been measured by the amount of correlation or association of the attributes employed. Since so little biological information is available for

M. esculenta, we have had to depend on the assumption that the morphological correlations amongst the characters employed indicate a significant genetic foundation. Large disjunctions (moats, gaps) between clusters usually indicate significant taxonomic structure.

2. *To Discover the Homogeneity of a Cluster of Cultivars.* Internal connections approaching the ratio of one are considered as indications of homogeneity within the limitations imposed by the similarity value. For instance, a high ratio of internal connectedness at a low similarity value may have little significance, whereas at a high similarity value, it usually indicated a group whose membership is only slightly variable. Conversely a low connectedness value is considered as indicating a heterogeneous assemblage of objects, whether because they are very different kinds of things or because they are reticulately related.

3. *To Discover Different Gradients of Morphological Relationship.* Refer, for example, to Figure 6 for group 1. Starting with 487, a gradient goes to 486, to 377 or to 330 in one morphological set of relationships, in another, starting again with 487, to 264, to 90, or to 268, 260, etc. In this study, nodes indicate small clusters (or even pairs) of highest similarity value within a larger cluster (corresponding to all members of a group). It is tempting to consider these nodes as the type of the group, but to do so is erroneous if only because a slight shift in coding could easily cause two other specimens to become the nodes.

When the initial computer print-out was diagrammed as subgraphs, two principal clusters formed that remained distinct until the lower 80% similarity values. When the data table was inspected for the properties or attributes for the two large clusters, it was discovered that the smaller of the two clusters contained cultivars with smooth-surfaced, light tan to light brown roots and silver colored stems. The larger cluster was made up of cultivars with rough-surfaced roots, light brown-yellow or red-brown colored roots and either yellow or brown colored stems. Of the 230 cultivars in the study, only 14 (6%) of the cultivars were found to contain combinations of these characters different from the majority (Tables 2, 3).

Of the 72 cultivars (32%) with smooth-surfaced roots, two cultivars, 286 and 294, have a silver-brown stem rather than the usual silver stem. Another smooth-rooted cultivar, 493, has the unique external root color of dark orange-yellow. We may have coded this color incorrectly as we assigned it to the state, light brown-yellow, and this state is usually associated with rough-surfaced roots. Of the 158 cultivars with rough-surfaced roots, 11 cultivars did not conform to the prevalent correlation noted above (Table 3). Four of the cultivars have light brown or tan roots, nine cultivars have silver-brown stems, and two cultivars silver stems. The last two cultivars with the silver stems also have light brown or tan roots. One of the silver-stemmed cultivars has roots that are decidedly less rugose than usual, though still beyond the limits of smooth-surfaced roots. The distribution of the smooth- and rough-surfaced root cultivars over the states of root and stem color is shown in Table 3.

In the subgraph diagrams, several of these intermediate cultivars joined in the lower 80% similarity ratio levels. The internal connectedness (homogeneity) of the original two clusters was very low. This was interpreted as indicating a reticulate relationship. The internal connectedness ratio decreased sharply when the two main clusters, one made up of the cultivars with roots having smooth surfaces and the other larger cluster with rough-surfaced roots, merged as one. The internal connectedness ratio did not increase even with the progressively decreasing similarity ratio (c-values). This was interpreted as indicating the amalgamation of two disparate and discrete collections of cultivars. Therefore, the cultivars that had roots with smooth surfaces were separated from the cultivars with rough-surfaced roots and each considered as a division (see page 9). Each of the divisions was processed separately in the Graph Theory Clustering Program.

The confusing and obscuring effect of the intermediate cultivars was removed when each of the divisions was run independently. The atypical combination of the states of three characters of the intermediate cultivars, while serving to bring these cultivars to our notice, also acted to decrease the moat or distinctness of the two divisions. In other Graph Theory Clustering studies with naturally-occurring populations of species, these intermediates or "articulators" between clusters have frequently been hybrids between the species. We are not certain what the "articulators" represent in M. esculenta, but that the condition exists is now well established and we should be able to address ourselves to the biological solution.

Since the subgraphs of the first computer run had discovered and compared the two divisions and we were to run each of the divisions independently, we had the option of selecting a new set of characters for each of the divisions, if warranted. The original set of characters was found to be a valid comparison of the cultivars in each of the divisions.

When each of the divisions was processed separately on the Graph Theory Clustering Program, the subgraphs of each of the divisions had a significant moat between the cultivars with obovate leaf-lobes and the linear leaf-lobes. Linear lobed leaves are more prevalent in the division with smooth-surfaced roots (17 cultivars out of 72) than in the rough-surfaced division (18 cultivars out of 156). The smooth-surfaced division is more disjunct (75% similarity as opposed to 80%), and the internal connectedness ratio slightly higher (30 and 25% respectively) before amalgamation with the cluster made up of cultivars with obovate leaf-lobes. However, since no discoverable correlation appears to exist between either the obovate or linear shaped leaf-lobes and any other character, there does not seem to be any justification for considering the linear lobed clusters as divisions. The logical states in characters 10 and 11 (Table 1) may perhaps overemphasize the condition of linearity or obovateness. These characters were structured in this fashion because of a belief that the pandurosity and sinuousness are under different genetic control when the leaf lobes are linear rather than obovate. However, even if this stress is removed, an appreciable disjunction or moat exists within both divisions to maintain the distinction and separateness of the cultivars with linear lobed leaves as distinct from those with obovate lobed leaves.

In this study, the moat, to some extent the measure of connectedness, the subgraphs, and tables of coded states and characters, enabled us to determine two divisions, and within each of the divisions that group with linear lobed leaves. Within the clusters composed of cultivars with the lobes of the leaves obovate, the relationships of the member cultivars were reticulate and no significant or taxonomically meaningful moats or internal connectedness were shown in the subgraphs. The subgraphs did indicate that the relationships of the cultivars of the study formed patterns of taxonomic value. Certain states (attributes of the cultivars were not randomly or independently distributed over the species but were integrated, however loosely, and provided a basis for assemblages of cultivars. These assemblages were associated with cultivars that are related to two or more (in this study, three) other cultivars by R sets at high values of similarity. These latter cultivars are considered as nodes from which several sequential series of other cultivars radiate. These gradients or morphological clines of cultivars, called groups in this study, are not composed of cultivars with evenly graduated morphological differences. The cultivars within each group exhibit a predominance of certain morphological attributes and combinations of these attributes. In most cases each cultivar is associated with its other most closely related cultivar. In some instances, however, a cultivar is equally related to more than one other cultivar which may be a member of a different group though for a different combination of morphological attributes (see cultivar 136, Table 33 appendix).

Since homogeneity is only of very limited interest in gradients or clines, only the R sets (those cultivars that formed or altered clusters) were of significance. Figs. 6-24 inclusive show only the connections between cultivars that were formed in the Graph Theory Clustering Program as R sets.

As the cultivars that are nodes initiate several different gradients, each nodal cultivar could be considered as a member of more than one group. The nodal cultivars were assigned to the group having the highest c-value connection to another cultivar. While on most occasions we accept the numerical indications from the subgraph, there are a very few occasions when the biological relations indicate another placement (because of some characteristic of the cultivars involved), and we relate these cultivars to another group, even though the numerical indications say otherwise. In no circumstances are the numerical indications very greatly significant when such changes are made. One must recall the philosophy employed with respect to the methods--the computer only gives suggestions about relationships, not decisions. This same decision process was also used when the assignment of a cultivar to a group was in question because of an equal arithmetic similarity ratio S(a,b) to cultivars in more than one group or gradient. When multiple relationships are of interest, Tables 33 and 34, Sequence of Object Similarities, show the ten most similar cultivars to any particular cultivar. Figures 4 and 5 are a diagrammatic representation of the closest two cultivars in different groups. Only one pair of cultivars is shown even though more than one pair might qualify as connectors between the groups (more than one pair with the same similarity value in different groups).

As noted before, we modified or restricted the selection of nodal cultivars to those cultivars that were classified at the early levels (higher c-values or similarity ratios). Logically, any of the cultivars that satisfied the criterion for being a node, regardless of the level or amount of similarity, could have been selected. The hierarchical arrangement could have been continued and groups based on nodal cultivars with lower c-values could have been designated as subgroups. However, since the understanding of the biology of the species and genus is very limited at the present time, in spite of its importance as a world crop, it has not been considered either wise or productive of a better understanding of the complex to divide the groups of cultivars any further. There would also have been good taxonomic justification for establishing a dozen or so single membered groups of cultivars having low similarity values because of the unusual attributes or attribute combinations present in these cultivars. We have placed them in the group with which they show the greatest affinity [S(a,b) value]. Additional relationships for these distinctive cultivars can easily be found in Tables 33 and ~~or~~ 34 or in the respective group figures.

At the same time, the groups established satisfy the taxonomist's need to have some method of indicating relationships in groups that ~~which~~ have mosaic or reticulate interrelationships. The groups will disappoint him to the extent that seldom can one expect an invariant set of exclusive descriptions that will encompass all included cultivars. Previous attempts ~~that have been made~~ to resolve reticulate relationships have consisted of ~~been:~~ (1) selecting those characters that are the most easily determined and dividing the population on a ranking of these characters, and (2) selecting characters on the basis of their phylogenetic or ancestral importance. The first method almost invariably results in placing together quite unrelated elements, and the second is at best difficult if done before a valid classification is formed. At all events, our ignorance of the necessary biological aspects of M. esculenta excludes the latter method.

SUMMARY OF METHODS

1. Select descriptors of the objects, specimens, taxa (in this instance, cultivars) pertinent to a classification of the objects in the study.

2. From the print-out of the Graph Theory Clustering Program draw subgraphs, noting the following:

   a. Partitions (L values)

   b. Similarity ratios (c-values)

   c. Cluster membership

   d. Moats

   e. Homogeneity (internal connectedness)

   f. Objects changing cluster membership and classification (R sets)

   g. Nodal points and clinal configurations

3. Use Histogram (SKYLINE), Sequence of Object Similarities, and Table of Object Attributes to supply additional data.

4. Determine structure of study using biological, ecological, etc., information to give validity and purpose to the classification.

PART II

SPECIES DESCRIPTION

1. General

Tropical shrubs, one to four meters tall, native to the Western Hemisphere tropics, but generally cultivated in all lowland tropical areas of the world; ~~in lowland areas;~~ all parts of plant with varying concentrations of a cyanogenic glycoside. Roots from seed a tap root, with secondary roots generally slender; adventitious roots arising from stem cuttings tuberous, variously shaped, from long and slender to globose. Stems woody, glabrous, or sparsely pubescent, except at the heavily pubescent apex, variously branched, from low, many-branched plants to tall and essentially unbranched; pith usually massive; leaf and stipule scars usually raised, sometimes not raised; predominantly brown, but sometimes yellow or silver. Vegetative leaves simple, palmately lobed, the lobes from three to ten, linear, obovate or pandurate, the upper and lower lamina surfaces slightly pubescent between the veins, slightly to heavily pubescent on major veins; abaxial surface of lamina with a farinose layer, generally in a hexagonal pattern about the stomata; margins entire or slightly sinuate; stipules caducous, linear or laciniate; petioles from 5 to 25 cm. long, frequently slightly S-shaped, attached basally to the lamina or slightly peltate, glabrous or slightly pubescent at base, and frequently a tuft of hairs at apex; leaves associated with inflorescence generally smaller, frequently 3-lobed, or sometimes simple, entire; lamina generally dark green, sometimes with red veins; petioles green, yellow-green, red or mixed red and green; young foliage at stem apices green, bluish green to dark red, very heavily pubescent. Inflorescence a panicle, generally from 2 to 10 cm. long, glabrous; bracts and bracteoles strap-shaped, generally inconspicuous and caducous. Flowers monoecious, the pistillate basal, opening first, the staminate apical, opening later. Pistillate flower hypogynous; perianth of 5 separate, strap-shaped tepals, red, green, or purplish, pubescent along margins, and frequently with a tuft of hairs at the interior apex; ovary subtended by a non-lobed disc, 3 carpellate, glabrous, style short, with 3 finely dissected stigmas. Staminate flower with a 5-lobed perianth of tepals united about half the length, glabrous externally, pubescent internally; stamens usually 10 (infrequently 8) in 2 whorls, 5 short, and 5 longer, the filaments slender, glabrous, arising between the lobes of the basal disc, supporting versatile anthers; pollen 3-colpate, large, sticky, with spine-covered exine, in some cultivars sterile. Fruit a schizocarp, usually winged, but sometimes smooth-surfaced; dehiscence septicidal and loculicidal, leaving a central stalk. Seeds carunculate, elongate or rounded, variously marked, mottled brown and light brown, or plain.

2. Detailed Cultivar Description

Surface of tuberous roots most frequently rough (156)[6] but often smooth (72). External root color most frequently brown, dark brown or reddish brown (138) but often light brown, tan or light tan (65), seldom light brown yellow (10), pinkish white, light pink or pink (7) or pinkish brown or pinkish tan (5). Root flesh usually white to cream (174), sometimes cream yellow or yellow (42), rarely with some pink intermixed (3).

Stems commonly brown (109), but often silver (72), sometimes yellow (36), seldom silver-brown (11). Storey length usually 9 to 20 cm (171), but sometimes short, 4-8 cm (35) or long, 21-28 cm (22). Scars on stem usually either slightly raised (105) or moderately raised (72), sometimes very large (34), seldom not raised (or smooth) (17). Stems most frequently more than

---

[6] Numbers given in parentheses indicate the number of specimens in each category.

two branched (92), but commonly with one or two branches (excluding any branches at the top) (79), less frequently unbranched or a single branch at top (57).

Leaves with basic number of lobes odd, but occasionally with an even number of lobes; most frequently 7- or 8-lobed (148), sometimes 9- or 10-lobed (42), occasionally 5- or 6-lobed (23), rarely 3- or 4-lobed (4) or variable, 3-, 4- and 5-lobed (9) or 4-, 5-, or 6-lobed (2). Leaf-lobe shape prevalently obovate (193) but sometimes linear (35). Leaf margins of obovate leaves usually simple (176), sometimes sinuous (15) and rarely pandurate (2); of linear-shaped lobes, margins commonly sinuous (26), occasionally simple (8), rarely pandurate (1). Length of median lobe most frequently long, greater than 17 cm. (105), often of moderate length, 14 to 17 cm. (86) and occasionally short, less than 14 cm. (37). Width of median lobe predominantly moderate, 2.6 cm. to 4.8 cm. (160), sometimes narrow, 1.5 cm. to 2.4 cm. (36), or wide, 5 cm. or more (32). Petioles mostly green (115), frequently red (73), occasionally reddish green (29), seldom greenish red (11). Young foliage most frequently green (142), often reddish blue (57), sometimes bluish green (29).

AIDS TO IDENTIFY AN UNKNOWN CULTIVAR

Fig. 3 gives the major categories we have used in the classification of the cultivars. Since this classification shows the relationships of the cultivars for their gross morphological characters, it is not always a simple matter to identify an individual cultivar. To use this classification, we suggest that the investigator describe the cultivar on the basis of as many of the characters given in Table 1 as are available. Having described the plant with the characters given, proceed to Fig. 3, which gives the major categories. Following discovery of the major subdivision to which a cultivar belongs. (i.e. rough-rooted, obovate lobed leaves), one then recognizes that the unknown plant belongs to one of twelve groups (Fig. 3). Within the groups

1-12, three groups (Nos. 8, 9, 10) have roots whose flesh color is yellow. The remaining nine groups have white-fleshed roots. Inspection of the descriptions of the nine groups is now required to give most accurate relationship of an unknown. We must add a word of caution: in the species with the large number of variations contained in it, and by the nature of the recombination of characters, there is no guarantee that any new cultivar cannot be assigned to more than one group. The major relationships will remain relatively constant, but below these, there is a good chance that there will be difficulty of assignment to one specific group.

In addition to the above methods of group assignment, the investigator will be aided by examination of the data given in Tables 2 and 3. These tables relate the stem colors to the root colors. Generally, plants with brown, dark brown, or reddish-brown stems are rough-rooted, and plants with light brown, tan or light tan stems have smooth-surfaced roots. Those plants whose stem color vary from these states are indicated in Tables 2 and 3, so that these can be assigned to the major categories given in Fig. 3.

Since the objectives of this classification are to show relationships ~~which~~ that might be useful for plant-breeders and others working with this species as a crop-plant, the classification may not serve the needs of those interested in the identification of herbarium specimens.

Acknowledgments

We are indebted to many people and organizations who have supported our efforts. First, the senior author wishes to acknowledge the fundamental importance to the whole concept and development given by the late Dr. Edgar Anderson, former Curator of Useful Plants at the Missouri Botanical Garden. He not only encouraged the study, but also provided the basic ideas for the methods that we have developed in the course of this work.

Secondly, numerous individuals and organizations in the countries of Latin America and the West Indies, where *Manihot esculenta* is a primary source of food, have, by their friendly cooperation, made this work a reality. In Jamaica, the Department of Agriculture provided personnel, facilities, and considerable resources to the work. In Brazil, we wish to thank the Director of the Federal Agronomic Experiment Station at Belém, Pará, and Sr. Milton de Albuquerque and Dr. Murça Pires. The assistance of Dr. Mario Coelho, and of Mr. Alberto Sarmento in Pernambuco are gratefully acknowledged. Dr. and Mrs. Alcides Texiera, Director of the São Paulo Botanical Garden in São Paulo, extended much appreciated hospitality and assistance. Dr. Edgard Normanha and his assistant, Sr. A. S. Pereira, in Campinas, gave permission to study their extensive collections. In Peru and in Costa Rica Dr. Jorge Leon, of the Inter-American Institute of Agricultural Science has been a constant source of information, aid and hospitality. In Venezuela, Mexico, Peru, Bolivia, and Costa Rica I have been given the most courteous and willing assistance, from a number of individuals, too numerous to enumerate.

Dr. Taffee Tanimoto, Department of Mathematics, University of Massachusetts, Boston, helped us to see various problems in applying mathematics to classification.

Grants for travel and collection of materials from the following are gratefully acknowledged: Allegheny College, Meadville, Pennsylvania; the American Philosophical Society, Philadelphia, Pennsylvania; the National Science Foundation, (Grant G 14129). Support for the development of the computer programs has come from the Office of Naval Research, [contract NON R 3640 (00)]; from the National Institute of General Medicine (GM 11208); and from International Business Machines Corporation, New York.

We wish to note that many workers have investigated problems of classification employing methods widely known as numerical taxonomy, to which taximetrics is clearly related. The standard reference on numerical taxonomy, Principals of Numerical Taxonomy, by Robert Sokal and Peter Sneath, was published in 1963 by W. H. Freeman and Company (San Francisco). Our work is no doubt influenced by these studies, but our purpose is to describe and employ one method well, and demonstrate its application to a pressing problem in Economic Botany.

Sept. 5, 1973

Dear Mr. Sutton:

I was certainly glad to see my paper on Manihot finally appear. It looks good.

I think I ordered 100 reprints of the Manihot paper, and wonder if you have any idea about the time of delivery of the reprints. I received 25 copies of EB containing the paper directly from the press, but I don't yet have the 100 reprints. Can you look into this for me?

Sincerely,

David J. Rogers
Professor of Biology

Mr. Joe Sutton
Publications,
The New York Botanical Garden
Bronx, New Yor 10458

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

July 13, 1973

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

Dear Dave:

This is to congratulate you on your excellent study of Manihot and the attractiveness of the book which it produced. We are much pleased to have it as a monograph for Flora Neotropica.

Because of its extraordinary economic significance, I have proposed to UNESCO and FAO that this and the companion piece, your review of Manihot esculentum which is coming out in the Botanical Review, be widely distributed by one or the other of these two organizations. I feel very strongly that they should be.

Thanks for your nice comments re Manihot maguireana.

Again, with congratulations and all best wishes,

Sincerely,

Bassett

Bassett Maguire
Executive Director
Organization for Flora Neotropica

BM:ckm

PLEASE FURNISH SERVICE(S) INDICATED BY CHECKED BLOCK(S). REQUIRED FEE(S) PAID.

☐ Show to whom, date and address where delivered

☐ Deliver ONLY to addressee

RECEIPT

Received the numbered article described below.

REGISTERED NO.

SIGNATURE OR NAME OF ADDRESSEE (*Must always be filled in*)

1

CERTIFIED NO.
058766

2

SIGNATURE OF ADDRESSEE'S AGENT, IF ANY

INSURED NO.

DATE DELIVERED

3

SHOW WHERE DELIVERED (*only if requested*)

c50—16—71548-11 247-198 GPO

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

January 31, 1973

Dr. David Rogers
Department of Environmental Population
and Organismic Biology
Univesity of Colorado
Boulder, Colorado 80302

Dear Dave:

Enclosed are corrected galley-proofs and page-proofs for Flora Neotropica No. 13. Please indicate where figure 28, a two part foldout, is to be inserted. Also please insert page numbers in the Index.

Sincerely,

Clark

Clark T. Rogerson
Editor
Flora Neotropica

CTR:JT
Enc.

author corrections red?

all my corrections in galley included in the master set of galleys?

how about index — no. of times of name is cited?

Index <u>only</u> systematic section? or include the introduction?

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

June 28, 1972

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

Dear Dave:

We very promptlyreceived the five packages containing your most impressive monograph of Manihot and Manihotioides. All of the text and illustrations have been turned over to Clark Rogerson for the usual processing.

Later this week or early next week, after we have had time to enjoy our review of your work, there may be some bit of editorial comment that Clark will pass on to you. Without having given critical attention to it, the text looks to me to be in excellent form and most appropriate for Flora Neotropica.

I am sure that you will have set a precedence in supporting a taxonomic study by such clearcut and exacting methodology. We are indeed happy to have this landmark paper for Flora Neotropica.

You will be hearing from Clark off and on. We will try to move it along to its publication as rapidly as possible, and let me thank you for giving it to us.

With all best regards to you, Connie and the kids,

Sincerely,

Bassett

Bassett Maguire, Executive Director
Organization for Flora Neotropica

BM:ckm

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

June 28, 1972

Dr. David J. Rogers
Gulf Universities Research Consortium
GURC Field Office
NASA/Mississippi Test Facility
Bay St. Louis, Mississippi 39520

Dear Dave:

The manuscript on Manihot and Manihotoides, 545 pages (3 copies) plus 124 plates, for Flora Neotropica arrived safely on 26 June 1972. Bassett has promised to check through one of the copies and make a decision on its acceptability; meanwhile I will look through it to see if any format queries need to be referred to you.

Best wishes to you and to Mary and Henry.

Sincerely,

Clark

Clark T. Rogerson
Editor
Flora Neotropica

CTR:JT

G U
R C

Gulf Universities Research Consortium

GURC Field Office • NASA/Mississippi Test Facility
Bay St. Louis, Mississippi 39520 • (601) 688-3760

June 22, 1972

Dr. Bassett Maguire
The New York Botanical Garden
Bronx, New York 10458

Dear Bassett:

At long last, I am sending our monograph of Manihot and Manihotoides gen nov, for Flora Neotropica. There are five separate packages, three of text, and two of illustrations.

Althought the appearance of the monograph is little different from any other in the series, we believe this to be an historic first in the sense that the work was done with the aid of computer programs. We know of no other monographic work of this complexity which has so thoroughly employed computer programs. Such a development has, as you know, been a long-sought objective of mine. With appropriate application, the computer programs developed under my guidance can be of tremendous assistance to others in systematic biology, by removing much of the drudgery and inaccuracies inherent in record keeping of the many different data necessary for the monograph. One of our frustrations was, for example, that we had produced an index to exsiccate with the computer program TAXIR in less than two minutes time with the computer, and then spent days copying from the printout into a format suitable for inclusion in Flora Neotropica. But still, the work is probably more accurate than we could have made it in the absence of the computer, considering the fact that we examined over 6,000 specimens. I trust you will understand if I seem proud of this accomplishment--I think this powerful set of tools is now demonstrably available for the taxonomist.

Production of the manuscript has been a very major task, considering the various problems we have had to face at the various institutions where we did the work. First, we never had a typist who had ever seen a botanical treatise before, particularly one who recognized the need for meticulous accuracy and consistency (even though each typist had the guidelines before them). Second, there are no typewriters on this huge NASA facility which have the capacity to make 3 spacings between lines. Third, we could not afford to have our illustrations done by a competent botanical artist, and that accounts for the use of photography throughout. Even so, I think our illustrations are useful to the readers of the monograph, and demonstrate the appropriate characteristics employed in the study.

Please send any communications to me at the Dept. of Biology, Univ. of Colorado, Boulder, Colo., 80302, where I will be after July 12. (I leave here next weekend, and return to Boulder via Birmingham, England). In the meantime, would you please notify Dr. Appan, the junior author, of the arrival of the various parcels at the address given on this letterhead.

Thank you for the opportunity to place this work in Flora Neotropica. I consider it a great honor to publish under your guidance.

Sincerely yours,

Dave

David J. Rogers

July 28, 1972

Dr. Clark Rogerson
The New York Botanical Garden
Bronx, New York 10458

Dear Clarkk

Thanks for the speedy work on the Manihot monograph. As a former editor, I blush for my sins of ommission and commission.

I have corrected the Lit Cit, and enclose 3 corrected copies, with appropriate manuscript pagination.

For the footnote of positions and addresses, use the following:

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

S. G. Appan, Research Associate
Gulf Universities Research Consortium
Mississippi Test Facility
Bay St. Louis, Mississippi 39520

I enclose three new numerical list of taxa, with corrections removing "Rogers & Appan" behind the name-bringing subspecific taxa according to Article 26. I send this corrected list because it is the best way to tell you where the corrections according to Article 26 should be made. The enclosed numperical list of taxa has been marked with the pages in the manuscript where deletions of "Rogers & Appan" are to be made. I completely overlooked the provisions of the article.

Figures 5-A and 28-A are enclosed. Complete oversight on my part.

A photograph of the authors, and the biographies, are enclosed.

I am sure that you have already picked up the transposition of letters in "BARSIL" (on page 299), 4th line from top.

Thanks again for your attention to the manuscript. Address all mail, galleys, etc., to me at the letterhead address.

Sincerely,

David J. Rogers
Professor of Biology

Encl.

July 28, 1972

Dr. Clark Rogerson
The New York Botanical Garden
Bronx, New York 10458

Dear Clarkk

Thanks for the speedy work on the Manihot monograph. As a former editor, I blush for my sins of ommission and commission.

I have corrected the Lit Cit, and enclose 3 corrected copies, with appropriate manuscript pagination.

For the footnote of positions and addresses, use the following:

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

S. G. Appan, Research Associate
Gulf Universities Research Consortium
Mississippi Test Facility
Bay St. Louis, Mississippi 39520

I enclose three new numerical list of taxa, with corrections removing "Rogers & Appan" behind the name-bringing subspecific taxa according to Article 26. I send this corrected list because it is the best way to tell you where the corrections according to Article 26 should be made. The enclosed numberical list of taxa has been marked with the pages in the manuscript where deletions of "Rogers & Appan" are to be made. I completely overlooked the provisions of the article.

Figures 5-A and 28-A are enclosed. Complete oversight on my part.

A photograph of the authors, and the biographies, are enclosed.

I am sure that you have already picked up the transposition of letters in "BARSIL" (on page 299), 4th line from top.

Thanks again for your attention to the manuscript. Address all mail, galleys, etc., to me at the letterhead address.

Sincerely,

David J. Rogers
Professor of Biology

Encl.

May 29, 1973

Mr. Harry Lubrecht
Hafner Publishing Company
31 East 10th St.
New York, N.Y. 10003

Dear Harry:

I enclose my personal check for $160.00, according to our recent telephone conversation, in which you kindly offered to supply 30 copies at this price for the forthcoming monograph on Manihot and Manihotoides. These 30, plus the 20 free copies, will supply my needs for complementary copies to those who aided in preparing this work.

I recently learned that the Agency for International Development wanted to purchase copies for distribution. If you can notify: Dr. Sam Litzenberger
Technical Aid/Agriculture
Agency for International Development
Department of State
Washington, D.C. 20523

I feel certain that he will arrange for purchase of a number of copies--I have no idea how many. I think I have already written that Dr. Barry Nestel, IDRC, University of Guelph, Guelph, Ontario, is also interested in being notified of publication, and wanted, if possible, an advanced copy, before purchasing a number of copies.

I agree to write an introduction to McMillan's book, justifying its reprinting, and will do so on my return from 6 weeks abroad. I should be back here by July 15. In the meantime, could you find a copy which I could borrow for a while? I do not have my own copy, and the University Library does not own a copy. It would speed things along if there were one available when I return.

Thank you for your kind offers above. I really appreciate them.

Sincerely,

David J. Rogers
Professor of Biology

HAFNER PRESS
A DIVISION OF MACMILLAN PUBLISHING CO., INC.
866 Third Avenue, New York, N. Y. 10022

March 9, 1973

Mr. David J. Rogers
Univ. of Colorado
Dept. of Environmental,
Population, and Organismic Biology
Boulder, Col. 80302

Dear Dave

I was happy to hear from you again. A note has been made to send a compliment-ary copy to Dr. Jimenez.

As to Dr. Nestel, I shall see that he gets page proofs on the blues. We appreciate your interest, and are only too glad to get suggestions from you. Welcome in the Series, and I am happy that we finally got a book from you indirectly which we can publish.

I am sending a copy of this letter to Clark, so that he is informed also.

With kind regards,

Sincerely

Harry Lubrecht

Harry Lubrecht
Vice-President

HL:lms
cc: Clark T. Rogerson

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

March 7, 1973

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

Dear Dave:

The package containing Fig. 28 and your letter of 24 Feb arrived last week. The larger package containing proofs arrived on 4 March. All of this will be delivered to Hafner today.

In checking through your corrections I discovered your note that for 34. Manihot anisophylla the paragraph on Distribution goes with species 35a, Manihot guaranitica and that the paragraph for species 34 was apparently dropped when breaking from galley. However, if the galley-proofs are correct only the first line is wrong. The galleys for 34 give "Distribution. (Fig. 44A). Argentina, in the provinces Salta, Catamarca, Tucuman," (first line) instead of the page-proof "44D). BOLIVIA. Tarija: Pflanz 4035 (US) Villamontes. PARAGUAY." The remainder of the paragraph is identical to that in the galley-proof for 34. The galley-proof and page-proof for 35a agree.

All of the remaining changes and corrections and your suggestions for Fig. 28 have been passed on to Hafner.

Apparently your copy of page-proof did not have the biographies. I enclose a copy.

I have informed Mr. Lubrecht of Dr. Nestel's interest in seeing a final page-proof.

I will keep you informed of progress.

Sincerely,

Clark

Clark T. Rogerson
Editor
Flora Neotropica

CTR:JT
Enc.

Biography for Subramaniam G. Appan

Dr. Subramanium G. Appan, a native of Trivandrum, India, was born in 1937. He received his undergraduate training at the University of Kerala in 1958, his M.Sc. at the University of Osmania in 1960, and his Ph.D. in Population Biology at the University of Colorado, Boulder, in 1969. His doctoral dissertation, The North American Species of the Genus *Manihot*, will soon be published by the University of Colorado Press.

Dr. Appan has a long term interest in the improvement of *Manihot esculenta* as a crop, both in south India and in the United States. In India, he was the farm manager of the Indian Tropical Root Crop Experiment Station at Trivandrum, where he participated in many cytological, plant breeding and agronomic studies of *Manihot esculenta*, with several publications on these subjects.

In his present position, he continues his systematic studies of biology, applying computer-aided programs (which he helped develop at the Taximetrics Laboratory at the University of Colorado) to problems of biology and the environment.

Biography for David J. Rogers

Dr. David J. Rogers was born in Florida in 1918. He received his bachelor's degree in botany at the University of Florida, Gainesville, in 1941. After 4.5 years of military service in the United States Army in World War II, he continued his graduate education at Washington University, St. Louis, receiving the M.A. degree in 1949 and Ph.D. in 1951. His major studies were in taxonomic botany, with emphasis on monographic studies in the Euphorbiaceae.

He has held teaching and research positions at Allegheny College, Meadville, Pa., at The New York Botanical Garden (editor of ECONOMIC BOTANY), as Professor of Botany at Colorado State University, Ft. Collins, and at the University of Colorado, Department of Biology. He has been a consultant to the Rockefeller and Ford Foundations, the Agency for International Development and the Food and Agricultural Organization of the United Nations.

Dr. Rogers' major interest has been in economic botany, with strong emphasis on systematic development of computer programs to aid in the analysis of complex problems in biology. Under grants from ONR, NSF, NIH, and others, he (and a staff of ten interdisciplinary personnel) developed taximetric procedures as powerful aids to the biologist in understanding of complex phenomena. His concern for application of research findings to problems of humanity are indicated by his numerous endeavors to aid in the improvement of the cultigen, *Manihot esculenta*, and by recent interdisciplinary environmental analyses.

Dec. 5, 1972

Dr. B. L. Nestel
International Development Research Center
2192 Riverside Drive
Ottawa, Ontario
Canada

Dear Barry:

I write to inform you of my forthcoming monograph of the genus Manihot, which is to be published as monograph number 13, in the series, Flora Neotropica, by Hafner Publishing Company, Inc. I believe that there will be quite a demand for this publication among tropical people who would not ordinarily have a chance either to get an announcement of the publication, or having the announcement, sufficient budget to purchase it. The retail price is $23.75 (it is a fairly hefty publication, with lots of illustrations), which unfortunately, will be beyond the means of many of our cassava colleagues.

Do you think there is a possibility that, through yours, and the IDRC, some subsidisation of the publication would be forthcoming? I am not asking to be the distributing agent, nor even the supplier of names of people. Perhaps through the librarian at CIAT there could be developed a list of people in the tropical areas who might benefit from receiving a copy. Actually, I am not asking for subsidization of the work itself--that has already been taken care of. Perhaps that wasn't clear from the statements above.

I suspect that, if you so desired, you could get a special price from the publisher, if you were to order some considerable number. If you do decide to purchase a number of copies, I would appreciate it if you did not mention to the publisher that I made this recommendation to you.

I only get ten copies of the monograph free, and have to purchase some extra to pay back obligations to many people who helped in one way or another with the monograph. I don't suppose you could help me out with the purchase of extra copies for this purpose, or could ~~I~~ you?

I will be pleased to hear from you on the above, and about any other developments of interest concerning cassava.

Sincerely,

David J. Rogers
Professor of Biology.

Feb. 24, 1973

Dr. Clark Rogerson
The New York Botanical Garden
Bronx, New York 10458

Dear Clark:

Yesterday I mailed two packages, one containing the re-worked figure 28, and the other both the marked page proof and the copy of the galley.

The reworked figure 28 is all right. Too bad that they lost the original, because they could have used it, in the event that it is a reasonable solution to place that figure in an envelope in the back. I can't see how that placement can cause any problems, since that method is frequently employed for publications with maps in them.

If the printer does employ the envelope idea, we definitely must indicate at several points in the text where to look for the figure.

I told you over the phone of my sin of omission of several dubious names, nomina nuda, and incorrectly-authored names. I have included manuscript of two and a half triple-spaced pages of these and appended them to the page proof at page 251, where they should be placed. I don't know how I could have overlooked these at an earlier stage, but am glad that I caught them now, before final printing. The only came to my attention as I was adding page numbers to the index of scientific names.

The proof of the Index of Scientific Names was so badly marked up with corrections and additions of page numbers that I thought it necessary to retype the whole index, and send it to you because otherwise I fear there will be more confusion caused by attempts to correct the present Index that just to reset the whole thing using the typescript as a guide. That typescript is appended to the page proof at the proper location in the page proof.

There will still be a few names in the Index which have not been paged, caused by the omission of the dubious names or excluded nomina nuda. When the new list of these names has been added to the page proof, either you or I can then add the names, and their page numbers, to the Index. I will do it, if you want, but thought that one step might be saved if either you or the printer added the page numbers.

You will note that I have had to change a citation for Rogers and Fleming at several points. This refers to the paper which should have been out long ago in Economic Botany. I have asked Joe Sutton to supply the correct citation and pagination to you as soon as he has it (which he promises should be fairly soon.). That paper has been nothing but a headache to me because of the continuing delay of EB publication.

One final thing: Dr. Barry L. Nestel, Associate Director, Canadian International Development Research Centre, 265, Arts Building, University of Guelph, Guelph, Ontario, has indicated that his organization might be interested in purchasing a number of copies of this monograph to be distributed to workers in underdeveloped countries, whose budgets could not allow them to purchase copies themselves. Dr. Nestel would like to see a late proof of the monograph before making up his mind. I don't know how Stechert works such things, or whether it is appropriate to send page proofs as advertising (which this sort of is) but would you relay to Stechert the above?

Thanks for your continuing efforts with this monster.

Sincerely,

David J. Rogers
Professor of Biology

February 24, 1973

Mr. Joe Sutton
The New York Botanical Garden
Bronx, New York 10458

Dear Joe:

Earlier today, I mailed off my copy of the galley and the tables which I had. All the tables except 33, 34, are included. As I suspected, I had sent you the tabular material earlier, so what is sent to you know constituted my set of galleys. I should like to have them back when you next return the next proof.

I will ask you to make one correction on galley one, which I forgot to change. In the second column of the galley, I ask for insertion of a new sentence. In that insertion is a reference, "Rogers & Appan, 1972" which you should read "Rogers & Appan, 1973". Please make that change for me.

As soon as you have full pagination in page proof, will you please inform Dr. Rogerson, so that he may make the required changes in a monograph he is doing for me. Give him full bibliographic reference, if you please.

Sincerely yours,

David J. Rogers

Jan. 23, 1973

Dear Mr. Sutton:

Enclosed are the remaining tabular proof in my hands. Please note that you sent me an incomplete proof of Table 33. It is most confusing to receive proof in bits and dribbles, without any indication just what proof you have sent. It takes some time to identify the proof you send, when it comes as it has been. At the moment, I have no idea how much of the total manuscript I have seen and proofed.

In answer to your question about the legends for the Tables, I merely sent the legends separately, because this is commonly done to give the editor and thex printer a guide. Usually, also the two are set separately, and need to be proofed. As in the case of Table 23, (and for that matter, all tabular material I have seen) you did not have the legend on the proof with the table, so I assumed that it was necessary to do as I did, that is, to send you a separate listing for the legends.

I agree that the legends are superfluous and do not need to be included, again, as long as you place the title of the table as it was given in the manuscript. Do not duplicate, nor use the legend, if you are certain that the title of the Table is given.

You called Sunday morning to ask about the placement of Plate I. As I indicated, that is indeed a frontspiece, to be set as such. In this long paper, it would seem to me reasonable to set a separate title page, and have the frontspiece facing it, if possible.

Please do not delay printing this paper beyond where you have just said you would put it, namely, in #1 for 1973. I have had to change the citation of this work in other publications which refer to it at least three times now, and it is becoming very confusing xxx in the literature, because of this extremely long delay, and the different decisions made as to its time of appearance.

Please give me some advanced indication about the cost of reprints of this paper. I must start very soon to find enough money to buy reprints.

Sincerely yours,

David J. Rogers
Professor of Biology

P.S. Please note my correct address, given on this letterhead. Your last correspondence was addressed to a nonexistent laboratory in a nonexistent department!2

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

January 19, 1973

Dear Dr. Rogers:

I enclose here a copy of the Appendix material for you to read proof by.

I enclose also a copy of the "Legends for Tables," which I wish you would take a look at. These captions have bothered me since the first time I looked at them. Tables have headlines, as your tables already have. They can also have explanatory footnotes, as some of yours now do. But I don't recall ever seeing tables with captions in addition.

I you want these printed as they stand, would you indicate to me where you want them to go? At the bottom of the tables, just as if the tables were figures?

Or do you think that some of them, at least, might be redundant? Or do you want to re-write your headlines?

Whatever you tell me to do, I shall do.

And if you will now return your corrections to me for the tabular material, I shall make all corrections, and you will see them in page proof.

Sincerely yours,

Joe

Joe Sutton

JGS:jgs

Check citation of this paper in monograph.

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

December 11, 1972

Dr. David Rogers
Department of Biology
Taximetrice Laboratory
Boulder, Colorado 80302

Dear Dr. Rogers:

Two requests:

1. Can you give me a footnote of the usual kind indicating the whereabouts of the two authors, as is customary in Economic Botany?

2. I have two figures which puzzle me. Neither figure 1 nor figure 2 as they now stand is appropriate for the camera. I don't dare to undertake to set this material in type because I don't understand your intention. Are these items something an artist should set up for you?

Sincerely yours,

Joseph G. Sutton
Manager of Publications

JGS/bp
enc.

Figure 1

FACSIMILE OF COMPUTER PRINT-OUT

TITLE: ______________________

(a) L=1 (b) C (1)=.9500

CLUSTER MEMBERSHIP	(d) C-VALUE	(e) CONNECTEDNESS		(f) R (1)
(c) 1 2	.9500	1	1	(1,2)

MOAT = .1132 NEXT PAIRS TO JOIN (2,6)

CLUSTER MEMBERSHIP	C-VALUE	CONNECTEDNESS		R (1)
3 5 7 9	.9500	3	6	(3,5) (5,7) (7,9)

(h) MOAT = .0500 (i) NEXT PAIRS TO JOIN (3,4) (7,8)

(j) SINGLE MEMBER CLUSTERS (4)

4, 6, 8, 10

TITLE: ______________________

L=2 C (2)=.9000

CLUSTER MEMBERSHIP	C-VALUE	CONNECTEDNESS		R (2)
1 2	.9500	1	1	
CLUSTER MEMBERSHIP	**C-VALUE**	**CONNECTEDNESS**		**R (2)**
3 4 5 7 8 9	.9000	8	15	(3,4) (7,8)

→ (g) INTERNAL CONNECTIONS AT .9000 INTERNAL CONNECTIONS AFTER .9000

(3,7) (3,9) (5,9)

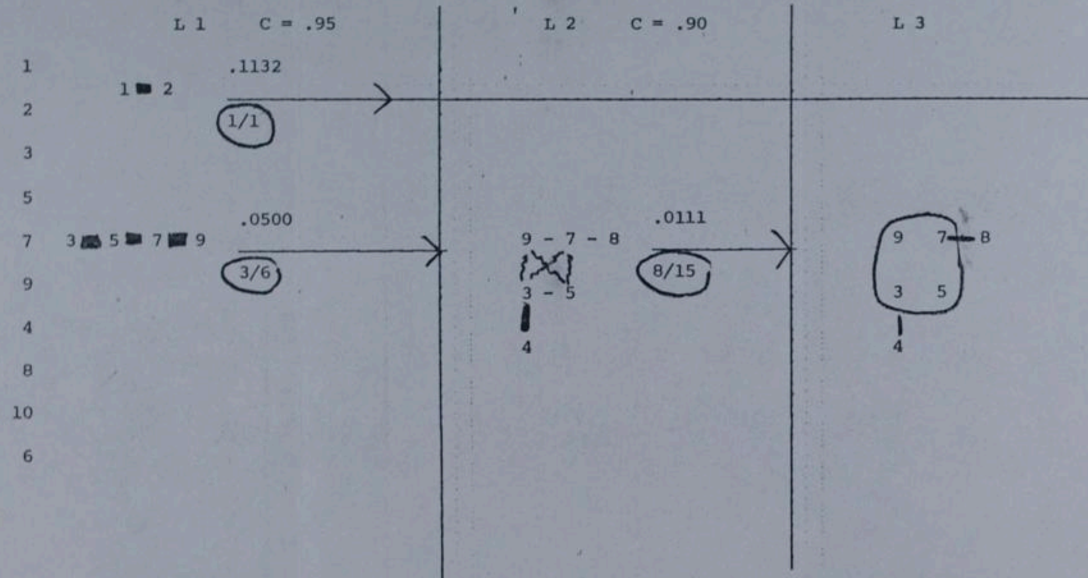
MOAT=.0111 NEXT PAIRS TO JOIN (9,10)

SINGLE MEMBER CLUSTERS

6,10

Figure 2

GRAPHIC EXPOSITION OF COMPUTER PRINT-OUT (SUBGRAPH)



SENDER: Be sure to follow instructions on other side

PLEASE FURNISH SERVICE(S) INDICATED BY CHECKED BLOCK(S)
(Additional charges required for these services)

☐ Show to whom, date and address where delivered
☐ Deliver ONLY to addressee

RECEIPT
Received the numbered article described below

REGISTERED NO. 17474

SIGNATURE OR NAME OF ADDRESSEE (Must always be filled in)
① Botanical Garden
Nicholas Master #77

CERTIFIED NO.

② SIGNATURE OF ADDRESSEE'S AGENT, IF ANY

INSURED NO.

DATE DELIVERED
③ 12.2.72

SHOW WHERE DELIVERED (Only if requested, and include ZIP Code)

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

June 12, 1972

Dr. David J. Rogers
GURK
Mississippi Test Facility
Bay St. Louis, Mississippi 39520

Dear Dave:

As you should have now received at least the initial galleys of your Manihot opus, I trust your question last week is sufficiently answered.

I've enjoyed reading the galleys that Joe Sutton has sent my way, the rather uncharitable reference to a presumed lack of "rigorous self-discipline" on the part of "any large group of botanists" notwithstanding, this with regard to the collecting procedures required for the Andersonian "inclusive herbarium." In my own humble opinion, you've pinned the wrong tail on the donkey: ignorance and other priorities are the real culprits.

Also, in the first paragraph there is reference to "wild and cultivated plant taxonomy"; hyphens would transfer the distinction to plants rather than to plant taxonomy!

And why Taximetric (is the name patented?) in preference to taximetric? This appears in paragraph four of Galley 1.

Anyway, I'm not your proofreader and am not trying to be a nit-picker either, but I do take a great deal of interest in your paper, Dave, and hope it will soon be out.

Sincerely,

Howard

Howard S. Irwin
Executive Director

HSI:cr

November 22, 1972

Mr. Harry Lubrecht
Hafner Publishing Company
866 Third Avenue
New York, New York 10022

Dear Harry:

Clark Rogerson tells me that I should ask you the cost of copies of my forthcoming work in Flora Neotropica, Monograph #13, Manihot and Manihotoides. Clark tells me also that I will receive about 10 free copies. I will need many more than that to send to people who helped me in development of the work, and will need to know how much they will cost.

Perhaps you cannot give a precise dollar figure at this time, although the whole work is now in galley. If you could give me at least an estimate of costs, I will be pleased. After I hear from you, I will have to find some source of funds to buy the extra copies.

I would guess that there will be more of a demand for this particularly monograph than for some of the others in the same series because this study includes a crop species, Manihot esculenta, which is widely grown around the tropics.

Thanks for you help.

Sincerely,

David J. Rogers
Professor of Biology

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

November 17, 1972

Dr. David J. Rogers
Department of Environmental
Population and Organismic Biology
University of Colorado
Boulder, Colorado 80302

Dear Dave:

Here is the address that you requested:

Mr. Harry Lubrecht
Hafner Publishing Company
866 Third Avenue
New York, New York 10022

The corrected proofs arrived safely and I will get them transferred to the masters within a few days. My contact at Hafner promised to find out about proofs for the illustrations but as yet I have not heard from her.

Sincerely,

Clark

Clark T. Rogerson
Editor
Flora Neotropica

CTR:JT

Nov. 14, 1972

Rogerson
N.Y. Bot. Garden

Dear Clark:

Your recent letter told me that I had to contact Harry Lubrecht to find information about additional reprints of the Manihot monograph. However, you did not tell me Lubrecht's address. Could you please let me have it? It will take some arranging for me to finance the additional copies, which will take some time. So, the sooner you tell me, the sooner I can get started on finding the necessary support.

Thanks for your help.

Sincerely,

David J. Rogers
Professor of Biology

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

October 10, 1972

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

Dear Dave:

Under separate cover galleys 1-61 and manuscript pages 1-368 for FLORA NEOTROPICA MONOGRAPH NUMBER 13 are being forwarded to you. I will rely on you to catch all of the printer's errors (as well as any goofs made by the editor). Please use one color for printer's errors and another color for editor's (or author's) errors. Also indicate on the galley approximate position for illustrations. You need not return the manuscript pages unless some serious problem develops.

Sincerely,

Clark

Clark T. Rogerson
Editor
Flora Neotropica

CTR:JT

THE NEW YORK BOTANICAL GARDEN

BRONX • NEW YORK 10458 212/933-9400

November 3, 1972

Dr. David J. Rogers
Department of Environmental
Population and Organismic Biology
University of Colorado
Boulder, Colorado 80302

Dear Dave:

I forgot to answer some questions in your last letter. Bassett tells me that in the agreement with Hafner Publishing Co. authors are allowed 10 free copies. I believe that you should contact Harry Lubrecht directly about additional copies and the cost of them. I know that Utrecht made arrangements with Harry for additional copies of the Maas and the Berg monographs but I do not know the details.

I believe that you should see the page-proof so that you can complete the Index.

Best wishes.

Sincerely,

Clark

Clark T. Rogerson
Editor
Flora Neotropica

CTR:JT

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

October 30, 1972

Dr. David J. Rogers
Department of Environmental
Population and Organismic Biology
University of Colorado
Boulder, Colorado 80302

Dear Dave:

Your letter arrived on Saturday. Today, additional galley-proofs (p 62-88) arrived. I suspect that this includes all of the remainder of the text.

Gally-proofs and the marked manuscript are enclosed. I will check with the printers about the illustrations.

Sincerely,

Clark

Clark T. Rogerson
Editor
Flora Neotropica

CTR:JT
Enc.

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

July 17, 1972

Dr. David J. Rogers
Gulf Universities Research Consortium
GURC Field Office
NASA/Mississippi Test Facility
Bay St. Louis, Mississippi 39520

Dear Dave:

Bassett said to go ahead with the scheduling of your paper in Flora Neotropica Monograph Number 13; the printer indicates that it can be handled promptly. I got the paper copy-edited without too much difficulty. A few things mostly in the cited literature needs clarification:

p 2 Rogers 1970 not in Lit Cit.
p 4 Miller 1754 not in Lit. Cit.
p 5 Bauhin 1658 but in Lit. Cit. only Bauhin 1651 is given.
p 5 Sloan but in Lit. Cit. only Sloanne is given; spelled Sloane fide Barnhart
p 5 Linnaeus 1771 not in Lit. Cit.
p 5 Merian 1726 not in Lit. Cit.
p 6 Pohl 1827 not in Lit. Cit.
p 6 Pax 1910 not in Lit. Cit.
p 8 Steudel 1841 not in Lit. Cit.
p ~~24~~ 43 Melchior 1964 not in Lit. Cit.
p 73 Linnaeus 1753 not in Lit. Cit.
p 73 Crantz 1776 not in Lit. Cit.
p 74 Loueiro 1793 not in Lit. Cit.
p 76 De Bruijon 1972 but is 1971 in Lit. Cit.
p 189 Gmelin 1772-1778 not in Lit. Cit.
p 193 Cruz 1965 but only 1968 is in Lit. Cit.
p 212 Humbolt, Bonpland and Kunth 1817 not in Lit. Cit.
p 212 Loefling 1758 not in Lit. Cit.
p 212 de Candolle 1866 not in Lit. Cit.

We are placing footnotes on page one giving position and address for each author. Please let me know what these should be.

I note that you cite Rogers & Appan after the infraspecific epithet which repeats the specific epithet. Please reread the first sentence of Article 26 and see if your method of citation is allowable under the Rules.

I can not find figures 5A or 28A. Captions are included for them but a search through the copies of the manuscript, the package of plates and the long package containing figure 28 fails to reveal either of these. Did you send them?

Mr. Sutton is on vacation and I have not been able to determine the status of the paper in Econ. Bot. You will have to modify the galleys.

THE NEW YORK BOTANICAL GARDEN
BRONX • NEW YORK 10458 212/933-9400

When you get the galleys, be alert for Sessé & Mociño. Accents are present in some cases, absent in others.

I am sending the copy as I have it to the printer today. Answer as much of the above as you can now and send it to me. Don't forget the two biographies and photos of authors.

Galley-proof might be ready in 4 to 6 weeks. Let me know where you will be.

Sincerely,

Clark

Clark T. Rogerson
Editor
Flora Neotropica

CTR:JT

Clark Rogerson N.Y.B.G.

Oct. 24, 1972

Dear Clark:

I've just finished up the first batch of galleys that you sent, and am ready for the next set. Could please encourage the printer to send me clearer galleys? It is extremely difficult to read the 6 point type, even at best (age is creeping up), and when I get photocopies of the galley, it frequently only partially prints such things as hyphens, semicolons, commas, etc., and the boldface doesn't always appear to be boldface.

I must say the printers have done a very good job, and most of the corrections are those that I should have made in the original ms. Do I get a second set of galleys or page proof?

What are the rules for reprints, or free copies of the finished product? I will need quite a few, just to distribute to those organizations that I am indebted to. For example, each of the loaning herbaria should get a free copy. Aside from obligatory free copies, I want to send out a few more that I feel I owe something, either for service or suggestions. Let me know as soon as possible, because I want to make financial arrangements, and suspect that there will be pretty steep charges for reprints.

Thanks for getting the manuscript going with such dispatch, and with such careful attention to the editting.

Sincerely,

David J. Rogers
Professor of Biology

January 3, 1973

Dr. S. G. Appan
Gulf Universities Research Consortium
Mississippi Test Facility
Bay St. Louis, Mississippi 39520

Dear Dr. Appan:

The new copy for Figure 28 of Flora Neotropica Monograph number 13 arrived on 27 December and has been turned over to the printer. Thank you very much for your prompt attention to the request. The original still has not been found by the printer.

Sincerely,

Clark T. Rogerson
Editor
Flora Neotropica

CTR:JT

cc: Dr. David J. Rogers ✓