PRELIMINARY WORK ON THE PROBLEM OF CLASSIFYING MANIOC VARIETIES

— *by* —

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Classification of manioc has generally been limited to a distinction between "sweet" and "bitter" varieties. This common method of classification is based entirely on the taste of the roots (cortex or edible part) which in turn depends largely on the hydrocyanic acid (HCN) content. However, since the HCN content of a given plant fluctuates not only with the physiological stage of the plant but also with the region where it is cultivated, the differentiation between "sweet" and "bitter" varieties does not provide a sound basis for classifying manioc.

The problem of classifying the varieties and cultivars of manioc grown in the tropical and sub-tropical areas of Latin America is complicated by the multiple names given to the same variety and/or cultivar in different countries. According to Barnes (1954) the large number of manioc varieties found in northeastern South America suggests that this area is its original center of domestication while Rogers (1963) postulates two major species centers: one in Mexico and Central America, the other in northeastern Brazil as far as Matto Grosso and including parts of Paraguay. Thus, it appears that the varieties and cultivars of manioc found in Latin America today have been introduced into the various countries from only one or two centers of origin and that in the process of diffusion they acquired different names as they spread from one region to another.

Rogers (1963) points to still another difficulty when he observes that there is some evidence that certain cultivars have hybridized with locally occurring natives species in both geographical centers to form a number of complexes.

Previous studies of manioc by Graner (1942) and Rogers (1963) provide the basis for the classification of manioc presented in this paper. Graner found that the form of the leaf and the coloration of the phelloderm of the root segregate independently and that the form of the leaf is largely dependent on environmental conditions. Working with vegetative material from Jamaica, Costa Rica, Nicaragua, Brazil, Bolivia and Peru, Rogers noted the existence of two stable combinations of vegetative characteristics which could serve as the basis of a major classification of the species.

The present study was conducted on a collection of varieties and cultivars maintained by the Instituto Nacional de Investigaciones Agricolas (INIA) in the Centro de Investigaciones Agricolas del Sudeste (CIASE) which is located at the Campo Cotaxtla, a sub-tropical coastal region near Veracruz, Mexico. The plants of this collection were introduced into Mexico from Brazil, Costa Rica and Colombia (Contreras, 1964). Only one previous study of this collection has been

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published. On the basis of characteristics such as resistance to strong winds and the shape, size and uniformity of the roots, Contreras (1964) selected and described the eight varieties of this collection which appeared to be most promising.

The work presented in this paper represents a preliminary attempt to classify the varieties and cultivars of the above mentioned collection on the basis of certain morphological characteristics. In addition, the HCN concentration in the roots was determined in order to see if any relationship exists between the morphological characteristics used in this classification and the HCN content of the roots. The adaptability and productivity of the plants were also observed for the purpose of selecting the best varieties for distribution in the tropical regions of Latin America.

MATERIAL AND METHODS

On February 10, 1966, eleven cuttings of approximately 40 cm each were taken from each variety included in the Campo Cotaxtla observation plots. These cuttings were planted with about 1/3 of their total length under ground and with an inclination of approximately 45°. A distance of 1.50 m. was left between rows and the cuttings were placed 1.00 m. apart. From planting until harvest all the plants were submitted to the same cultural practices.

Ten months after the cuttings were planted, 5 plants of each variety were harvested (December 22-23, 1966) and one month later (January 18, 1967) the remaining 6 plants were harvested. Two harvests were made in order to observe what effect the difference of one month might have on production.

The same procedure was followed in both harvests. When the roots were taken out of the ground, the relative degree of difficulty encountered in extracting them was observed. Immediately after extraction, the colour (dark brown or light pinkish tan) and texture (rought or smooth) of the epidermis as well as the shape of the roots (cylindrical, conical or irregular were recorded). When the roots were separated from the stem, the relative difficulty encountered in separating these two plants parts and the nature of the point of attachment between them was noted. The roots of each variety were then classified into three commercial sizes:

- No. 1 – large roots (for possible industrial use),
- No. 2 – medium roots (for human consumption), and
- No. 3 – small roots (for use as animal feed).

The number of roots and the weight of the roots included in each of these crops were also recorded.

At the second harvest, 5 kilo compound samples of the roots of the six plants of each variety harvested were sent for chemical analysis. The plant samples were analyzed by the Departmento de Bioquimica of the Centro Nacional de Investigaciones Pecuarias, Palo Alto, Mexico, D. F.

The cyanogenetic glucosides were determined as hydrocyanic or prusic acid by the acid titration method (7) and the % of dry weight, nitrogen-free ex-

tract, ether extract, mineral matter, crude protein, crude fibre, Ca, P and K were analyzed. However, the results of the bromatological analysis are not reported at this time.

RESULTS AND DISCUSSION

The source given for each variety in Table I does not refer to the place of origin of the variety but rather to the location of the collection from which the vegetative material was obtained to form the manioc collection of Campo Cotaxtla. The 31 varieties harvested were divided into groups on the basis of skin color and texture. The results of this classification confirm Roger's observation of two stable combinations of morphological characteristics since it was found that the roots that had a dark brown colour had a rough texture while the light tan or pinkish tan roots were invariably smooth. Twenty-one varieties were found to have a dark brown skin and a rough texture, 9 varieties were light tan in color with a smooth skin and 1 variety, Big Yard Marlie Hill, was pinkish tan with a smooth skin. It was also noted that within the group classified as dark brown/rough there was considerable variation in the shade of brown. However, the dark brown roots were clearly distinguishable from the light tan or pinkish tan roots.

In addition to skin color and texture, certain other characteristics of the roots were observed which might be investigated as a possible basis for refinement of the two major divisions already noted by Rogers (1963). The roots classified as dark brown/rough showed some variation in relation to the number and size of the "lenticella", the color found immediately under the epidermis and the tendency to peel. (In this study "flaking" or the presence of small scale-like pieces of skin was considered as a condition inherent to "rough" skin and therefore was not used as a separate characteristic, while "peeling" was distinguished from "flaking" in that the skin actually came off the roots. However, this could have been due to a condition of immaturity).

Most of the dark brown/rough varieties had a light yellowish color under the epidermis. However, the variety Elmo Stick had a purple color while Sin nombre H-56 and Criolla had a pinkish color under the skin. Several other varieties, such as Yucateca, showed signs of peeling. Although the tendency towards peeling may be largely governed by heredity in that it is related to the thickness of the epidermis, the texture of the soil and the method of harvesting may also be important factors.

The roots classified as light tan or pinkish tan and smooth showed less variation in relation to the characteristics mentioned above and less variation in the color of the epidermis. However, it must be noted that about twice as many dark brown/rough varieties as light or pinkish tan/smooth varieties were studied and this may account in part for the smaller degree of variation found among the light or pinkish tan/smooth varieties.

No relation was found between skin color and texture and production since plants of high production as well as plants of medium and low production were found in both major groups (dark brown/rough and light or pinkish tan/smooth). In Table 2 the production of the varieties studied is presented in terms of the average number of roots per plant, the average yield (kilos) per plant and in the estimated value of tons per hectare. Of the 31 varieties, Eye Wather, EPC No. 3 tipo dulce, Sin nombre H-56 and Valluna were found to have either very low production or low quality roots.

Regarding production, it should be mentioned that high yield alone does not constitute a superior variety. The HCN content and size of the roots as well as certain factors that facilitate or obstruct harvesting such as the ease of extraction, which is dependent largely on the distribution of the radical system, and the ease with which the root can be severed from the stock, are also important factors. Among the varieties studied, Yellow Saunders, a variety of average yield, was found to be very difficult to harvest because its roots go deep into the soil.

Separation of manioc varieties into commercial grades according to the size of the root (Table 3) provides a basis for selecting the best varieties for specific uses. However, it should be pointed out that the results of the grading presented in Table 3 are valid only for plants harvested after 10 months of growth since the size of the root attained within a given amount of time depends to some extent on the precocity of the variety.

The following 10 varieties, which are described in some detail, were considered outstanding because they presented a better combination of desirable characteristics than the other varieties studied. The varieties that produced the highest yields are included in this list. However, HCN content was not taken into consideration in this appraisal.

C59 — 6 Light tan/smooth. The roots, which are short and thick, bulge at the point of attachment to the stock and are difficult to sever. This variety produced a good number of roots per plant and had the highest yield (58.9 t/ha) of all the varieties studied.

Elmo Stick Dark brown/rough. A purple color was noted below the epidermis. The roots are long and slender and irregular in shape. The plant had a large number of roots and produced a high yield (51.8 t/ha). 60.9% of the roots were of No. 1 size.

Big Yard Marlie Hill Light tan/smooth. The conical-shaped roots of this variety are difficult to sever because they are thick at the point of attachment to the stock. The roots have a pinkish color under the skin and purple strips on the epidermis. This variety produced a high yield (45.6 t/ha) and had a large number of roots per plant. 74.8% of the roots were of No. 1 size.

C59 — 9 Light tan/smooth. The roots are thick at the point of attachment to the stock. This variety yielded an average of 39.8 t/ha and produced good size roots of No. 2. grade, 74.3% of the roots were of No. 1 size.

Yucateca Dark brown/rough. The roots, which are long, thick and conical-shaped, are easily severed from the stock. The skin of this variety peeled considerably when the roots were harvested; 75.2% of the roots were of No. 1 size and the average yield was 35.5 t/ha.

White Cuban Light tan/smooth. This variety produces a large number of irregular-shaped roots per plant. In percent of the total yield, the proportion of No. 1 and No. 2 size roots was very similar. The yield of this variety was 34.4 t/ha.

Criolla Dark brown/rough. This variety produces many good size roots per plant (75.7% of No. 1 size) that are cylindrical in shape and easily

severed from the stock. The roots have a pinkish color below the epidermis. The average yield was found to be 34.3 t/ha.

Guaxupe — Dark brown/rough. The conical-shaped roots of this variety are long, thick and straight. They are easily separated from the stock and of an excellent external appearance in general. The production was 31.9 t/ha.

Cubana — Dark brown/rough. The roots are irregular in shape and easily separated from the stock; 55.3% of the roots were No. 1 size and the No. 2 size roots had an especially good appearance. This variety yielded 29.4 t/ha.

Smalling — Dark brown/rough. The cylindrical-shaped roots are thick at the point of attachment to the stock and difficult to sever .Although its total production was not high (an average of 22.6 t/ha), this variety produced the highest percentage of roots of No. 1 size (78.1%).

Manioc roots with an HCN content of less than 5 mg. per 100 g of fresh weight are considered "sweet" while roots with an HCN concentration between 5 and 10 mg. per 100 g are classified as being of "medium toxicity" (Casseres, 1966). According to Jones (1959), roots with an HCN content greater than 10 mg./100 g of fresh weight are too toxic for consumption and suitable only for industrial use.

The results of the chemical analysis made of 30 manioc varieties in this study (Table 4) show that none of the varieties of the Campo Cotaxtla collection produce "sweet" roots since the lowest concentration of HCN found in the cortex was 5.8 mg./100 g of fresh weight.

Of the 30 varieties analyzed, 10 had an HCN content between 5 and 10 mg./100 g. Three of these ten varieties, Guaxupé, Cubana and Smalling, were among those singled out as superior varieties. These three varieties, all highly productive, had an HCN content of 8.6, 9.4 and 6.5 mg./100 g of fresh weight respectively.

Sin nombre H-56, the variety that had the lowest concentration of HCN in the cortex (5.8 mg./100 g) had a very low yield (1.9 t/ha) while Zopilota, the variety that had the second lowest content of HCN in the cortex (6.0 mg./100 g) produced a medium yield. Thus, varieties of high (Guaxupé, Cubana and Smalling), medium (Zopilota) and low (Sin nombre H-56) production were included among those that had an HCN concentration of "medium toxicity". It is also interesting to note that all 10 varieties of "medium toxicity" belonged to the dark brown/rough group while 4 of the 9 varieties that had a very high content of HCN (more than 18 mg./100 g. were of the light tan/smooth group. Four of the nine varieties that had a very high HCN concentration were also among those selected as the best varieties of the Campo Cotaxtla collection.

The results of this study agree with the observation of Jones (1959) that there is no good correlation between morphological characteristics and hydrocyanic acid content.

Six of the varieties of the Campo Cotaxtla collection described by Contreras

(1964) were also included in this study. Contreras did not analyze the HCN content of the roots, but he did classify them as ranging between "sweet" and "bitter" on the basis of taste. A comparison of his classification with the results of the analysis of the HCN content made in this study shows that there was discrepancy between the two ratings in many cases. For example, Contreras considered the variety Sra. está en la mesa, whose HCN content was found to be 21.9 mg./100 g, a "sweet" variety, while a variety he described as somewhat "bitter" (Guaxupé) was found to have only 8.6 mg./100 g of fresh weight. These differences may be explained at least in part by the fact that the HCN content may vary in different samples of the same variety and even in different roots of the same plant (Casseres, 1966).

SUMMARY AND CONCLUSIONS

Working with vegetative material from the manioc collection maintained at Campo Cotaxtla near Veracruz, Mexico, an exploratory classification was made on the basis of certain morphological characteristics, the HCN content of the roots was analyzed and a number of varieties selected as outstanding in this collection were described.

The following conclusions may be drawn from this preliminary study:

1. The epidermis of the mature roots of all 31 varieties included in the Campo Cotaxatla collection were either dark brown with a rough texture or light tan with a smooth texture.

2. In addition to skin color and texture which served as the basis for classifying the manioc varieties into two groups, a group of secondary morphological characteristics that might serve as a basis for refining the classification was observed. These secondary characteristics, which will be studied in detail in the future, included the size and number of the "lenticella", the pigmentation found immediately under the epidermis, and the tendency to peel.

3. Varieties of high, medium and low production were found in both major groups of manioc (dark brown/rough and light or pinkish tan/smooth).

4. On the basis of HCN content, none of the varieties included in the Campo Cotaxtla collection can be considered "sweet". Of the 30 varieties studied 10 had an HCN content between 5 and 10 mg./100 g of fresh weight while the other 20 varieties had more than 10 mg. of HCN per 100 g of fresh weight.

5. No apparent correlation was found between morphological characteristics and HCN content.

Table 1. Morphological characteristics of the roots.

Accession number	Name (x)	Source	Epidermis of mature roots	
			Color	Texture
2001	SG 467 C59— 6	Brazil	light tan	smooth
2	SG 435 C59— 9	Brazil	light tan	smooth
3	SG 445 C59—10	Brazil	light tan	smooth
4	SG 596 C59—12	Brazil	dark brown	rough
5	SG 582 C59—13	Brazil	dark brown	rough
6	2070 Sra. está en la mesa	Costa Rica	dark brown	rough
7	2783 Cubana	Costa Rica	dark brown	rough
8	2888 Bayuna No. 3, tipo dulce	Costa Rica	light tan	smooth
9	3056 Bullet tree	Costa Rica	dark brown	rough
10	3028 Elmo Stick	Costa Rica	dark brown	rough
11	3036 Yellow Saunders	Costa Rica	dark brown	rough
12	3040 Eye Wather	Costa Rica	dark brown	rough
13	3049 Smalling	Costa Rica	dark brown	rough
14	3052 White Stick	Costa Rica	light tan	smooth
15	3060 Bunch of Keys	Costa Rica	dark brown	rough
16	2886 EPC No. 3, tipo dulce	Costa Rica	dark brown	rough
17	3044 White Margaret	Costa Rica	light tan	smooth
18	3047 Big Yard, Marlie Hill	Costa Rica	pinkish tan	smooth
19	3050 White Cuban	Costa Rica	light tan	smooth
20	Crema	Costa Rica	light tan	smooth
21	Siete meses	Costa Rica	dark brown	rough
22	Camota	Costa Rica	dark brown	rough
23	Zopilota	Costa Rica	dark brown	rough
24	1144 Sin nombre, H-56	Costa Rica	dark brown	rough
25	1146 Valluna	Colombia	dark brown	rough
26	1148 EPC No. 3	Colombia	light tan	smooth
27	1150 Sin nombre, H-56-1	Colombia	dark brown	rough
28	192 Itu	Colombia	dark brown	rough
29	454 Guaxupe	Colombia	dark brown	rough
30	Yucateca	Mexico	dark brown	rough
31	Criolla	Mexico	dark brown	rough

(x) The numbers included with the names are those given to the varieties in the collections from which they were obtained.

Table 2. Root production of 31 varieties of manioc harvested 10 and 11 months after planting. Average number of roots per plant, average yield per plant and estimated value of tons per hectare.

Variety	Harvest 1			Harvest 2		
	roots /plant	k/plant	t/ha	roots /plant	k/plant	t/ha
C59— 6	16.4	10.62	70.8	13.2	7.37	4.91
C59— 9	9.6	6.70	44.7	11.5	5.37	35.8
C59—10	7.6	3.06	20.4	7.2	3.47	23.1
C59—12	9.2	1.24	8.3	6.2	1.57	10.4
C59—13	5.6	1.20	7.9	5.7	2.23	14.9
Sra. está en la mesa	10.4	2.96	19.7	10.5	4.67	31.1
Cubana	10.8	4.56	30.4	11.2	4.28	28.6
Bayuna No. 3, tipo dulce	9.6	3.28	21.9	6.0	2.13	14.2
Bullet tree	7.8	2.42	16.1	2.8	.97	6.4
Elmo Stick	11.8	5.64	37.6	16.7	9.55	63.7
Yellow Saunders	10.6	3.90	25.9	7.7	3.70	24.7
Eye Wather	3.8	.90	5.9	5.8	1.95	12.9
Smalling	8.8	3.92	26.1	6.5	2.96	19.7
White Stick	6.6	1.04	6.9	4.3	1.01	6.7
Bunch of Keys	5.8	.60	3.9	4.7	.47	3.2
EPC No. 3, tipo dulce	—	—	—	2.0	.13	.9
White Margaret	10.0	3.34	22.3	3.3	.84	5.6
Big Yard, Marlie Hill	16.6	8.96	59.7	13.2	5.08	33.9
White Cuban	14.0	3.50	23.3	21.3	6.55	43.7
Crema	12.4	2.16	14.4	9.0	2.40	15.9
Siete meses	5.2	.52	3.5	7.3	2.49	16.6
Camota	3.2	.58	3.9	2.2	.49	3.3
Zopilota	6.6	1.14	7.6	8.0	1.58	10.6
Sin nombre, H-56	4.0	.20	1.3	4.0	.37	2.5
Valluna	1.8	.46	3.1	—	—	—
EPC No. 3	3.8	.60	3.9	3.3	.50	3.3
Sin nombre, H-56-1	3.2	.66	4.4	3.7	.97	6.4
Itu	6.6	1.20	7.9	8.7	4.22	28.2
Guaxupe	6.8	3.40	22.7	8.0	5.96	39.7
Yucateca	10.6	4.20	27.9	10.2	6.27	41.8
Criolla	12.4	5.84	38.9	10.7	4.57	30.5

Table 3. Classification of the manioc production into commercial grades expressed as percent of the total yield from the 1st. harvest.

Variety	COMMERCIAL GRADES IN PERCENT No. 1 grade	No. 2 grade	No. 3 grade
C59— 6	63.2%	29.2%	7.5%
C59— 9	74.3	17.6	8.1
C59—10	56.9	22.2	20.9
C59—12	35.5	33.9	30.6
C59—13	31.7	26.7	41.7
Sra. está en la mesa	51.4	33.1	15.5
Cubana	55.3	24.6	20.2
Bayuna No. 3, tipo dulce	54.3	29.9	15.9
Bullet tree	52.1	33.9	14.0
Elmo Stick	60.9	25.9	13.1
Yellow Saunders	68.2	23.1	8.7
Eye Wather	66.7	15.6	17.8
Smalling	78.1	18.9	3.1
White Stick	42.3	32.7	25.0
Bunch of Keys	33.3	40.0	26.7
EPC No. 3, tipo dulce	—	—	—
White Margaret	52.7	22.8	24.5
Big Yard Marlie Hill	74.8	18.3	6.9
White Cuban	38.9	37.7	23.4
Crema	42.6	37.9	19.4
Siete meses	—	46.2	53.8
Camota	20.7	41.4	37.9
Zopilota	38.6	26.3	35.1
Sin nombre, H-56	—	—	100.0
Valluna	—	56.5	43.5
EPC No. 3	43.3	20.0	36.7
Sin nombre, H-56-1	48.5	36.4	15.2
Itu	18.3	41.7	40.0
Guaxupé	73.5	20.6	5.9
Yucateca	75.2	19.0	5.7
Criolla	75.7	18.1	6.2

Table 4. Concentration of hydrocyanic acid (HCN) found in the roots of 11 month old manioc plants.

Variety	mg. HCN/100 g fresh weight		
	phelloderm	cortex	total*
C59— 6	19.0	12.6	16.1
C59— 9	49.9	30.0	34.2
C59—10	49.0	21.6	14.2
C59—12	36.2	12.7	11.5
C59—13	69.6	29.8	34.5
Sra. está en la mesa	23.6	21.9	17.8
Cubana	20.7	9.4	8.5
Bayuna No. 3, tipo dulce	51.1	24.7	18.4
Bullet tree	5.0	8.2	11.2
Elmo Stick	27.4	22.0	33.2
Yellow Saunders	64.0	12.9	15.8
Eye Wather	5.7	12.1	13.0
Smalling	2.3	6.5	9.9
White Stick	9.2	12.7	18.4
Bunch of Keys	10.5	9.7	11.4
EPC No. 3, tipo dulce	18.6	7.4	2.3
White Margaret	9.4	10.3	16.3
Big Yard, Marlie Hill	25.2	11.5	15.4
White Cuban	55.0	18.6	22.7
Crema	24.3	12.1	8.7
Siete meses	15.4	20.3	19.5
Camota	8.3	9.3	10.3
Zopilota	2.3	6.0	3.9
Sin nombre, H-56	15.4	5.8	6.5
EPC No. 3	11.2	11.4	16.7
Sin nombre, H-56-1	6.3	12.0	12.4
Itu	35.3	7.7	9.1
Guaxupe	50.8	8.6	10.9
Yucateca	26.4	19.2	20.3
Criolla	18.6	10.7	11.9
Average	25.5	13.9	15.2

*whole root

REFERENCES

1. Barnes Ross, Hubert 1954. The diffusion of manioc plant from South America to Africa: an essay in ethnobotanical culture history. **Dissertation Abstracts** 14 (10): 1496.

2. Casseres H., Ernesto 1966. Produccion de Hortalizas Lima, Peru. Instituto Interramericana de Ciencias Agricolas. **Textos y Materiales de Ensenanza** No. 16 280 p.

3. Contreras G., Juventino 1964. Observacion de las colecciones de yuca en la region tropical de Veracruz. Proceedings of the Caribbean Region, **American Society for Horticultural Science. XI Annual Meeting** 7 : 60-64.

4. Crawford, J. (comp.) & (ed.) Copley, 1961. Cassava report on growing cassava in St. Elizabeth. Kaiser Bauxite in partnership with Jamaica. 24 p.

5. Graner, E.A. 1942. Genetica de manihot. I. Heredi-tariedade da forma da folha e da coloracao da pelicula externa das raizes en **Manihot utilissima** Rohl. **Bragantia** 2 (1) : 13 : 22.

6. Jones, W.O. 1959. **Manioc in Africa.** Stanford; California. Stanford University Press. 315 p.

7. Official Methods of Analysis of the Association of Official Agricultural Chemists 1965. 10th ed. pp: 341.

8. Rogers, J. David 1963. Studies of **Manihot esculenta** Crantz and related species. **Bulletin of the Torrey Botanical Club** 90(1) : 43-54.