THE JOURNAL OF AGRICULTURE
OF THE UNIVERSITY OF PUERTO RICO

Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, for the publication of articles by members of its personnel, or others, dealing with any of the more technical aspects of scientific agriculture in Puerto Rico or the Caribbean Area.

Vol. XLI January 1957 No. 1

A Comparison of Different Leaf-Sampling Techniques Used in the Foliar Diagnosis of Sugarcane in Different Countries

G. Samuels, S. Alers Alers, and P. Landrau, Jr.[1]

INTRODUCTION

Foliar diagnosis is being used in many sugarcane-producing areas of the world as a means of determining the fertilizer needs of the cane. However, the same techniques are not used by all workers in foliar diagnosis. Differences exist in methods of sampling and interpretation of data.

Halais (*4*)[2] in Mauritius utilizes a leaf-punch sampling technique on the whole third leaf of the cane for nitrogen, phosphorus, and potassium analyses. He prefers sampling the cane at from 5 to 7 months of age, using ratoon but not plant canes. Sampling is not advised by this worker unless rainfall exceeds 2 to 3 inches during the preceding fortnight, winds do not exceed 30 to 40 miles per hour, and there is no great damage by pests and diseases.

In Hawaii, the system of crop-logging devised by Clements (*1*) is used commercially. The system makes use of periodic sampling throughout the life of the crop to control fertilizer applications, irrigation, and cane-ripening. Leaf blades Nos. 3, 4, 5, and 6, with their corresponding leaf sheaths are collected. The leaf blade is used for determining nitrogen and the sheath for phosphorus, potassium, moisture, and total sugars.

Innes in Jamaica (*5*) makes use of the lamina of the third fully opened leaf for nitrogen, phosphorus, and potassium analyses. The fertilizer recommendations are based on field experimentation and complementary advisory procedures are based upon the leaf analyses.

In British Guiana, Evans (*3*) utilizes the first cane leaf from the top with a visible dewlap. This top visible-dewlap leaf is used for nitrogen, phosphorus, potassium, calcium, magnesium, manganese, iron, copper, zinc, boron, and molybdenum determinations.

[1] Agronomist, Research Assistant in Agronomy, and Associate Agronomist, respectively, Agricultural Experiment Station of the University of Puerto Rico, Río Piedras, P. R.

[2] Italic numbers in parentheses refer to Literature Cited pp. 9-10.

In Puerto Rico cane-leaf blades Nos. 4, 5, and 6 are utilized for nitrogen, phosphorus, and potassium analyses, and the corresponding leaf sheaths for moisture determination (*7*). The midrib is not removed from the leaf blade before analyses.

The different methods of sampling for foliar diagnosis in sugarcane, plus the differences in manner of reporting the results, have made comparisons of results between various cane-growing areas in the world somewhat difficult. To evaluate these differences for the sake of comparisons, foliar-diagnosis samples of sugarcane were procured by using the procedures adopted by each of the workers mentioned. The results obtained, as evaluated and standardized, are presented in this paper.

PROCEDURES INVESTIGATED

The foliar-diagnosis procedures used for comparison were those of Halais in Mauritius, Clements in Hawaii, Evans in British Guiana, and Samuels, *et al.*, in Puerto Rico. These methods were selected primarily because they are already in semicommercial or commercial practice, and adequate literature is available giving both procedures and standard indexes of nutrient levels. There are, of course, other workers using foliar diagnosis for sugarcane, and also other procedures. But, at present, these unreported workers are new to the field, and very few data are available; or they are following present methods only slightly or not at all modified; or their new procedures are still too undeveloped to be applied on a commercial scale.

First of all, the numbering of the sugarcane leaves and sheaths must be clarified. Such vague indications as, "The first leaf from the top", etc., have caused much confusion. Van Dillewijn (*8*), one of the leading authorities on sugarcane morphology, favors the system of Kuijper for designating the various organs of the cane plant. Basically this system designates the highest visible dewlap as +1, the leaf to which this dewlap belongs as leaf +1, and the sheath and joint on which the leaf is implanted the same. Leaf +1 represents the topmost of the unfolded leaves, any leaves younger than this, or still folded, are consecutively numbered 0, −1, −2, etc. The older leaves are consecutively numbered +2, +3, etc. This order is shown in figure 1.

Unfortunately, no such standard system is used throughout the world where sugarcane is grown. Each foliar-diagnosis system has evolved its own particular rules for cane-leaf numbering, and leaf No. 1 for one system is not necessarily the same as leaf No. 1 for another. It would be a very good idea if some sort of standard leaf-numbering could be adopted. However, for the practical purposes of this article, the leaf number used by the

procedure being discussed will be given, followed immediately, in parentheses, by the Kuijper number as shown in figure 1.

The various leaf-sampling methods used are summarized in table 1, and more complete descriptions are as follows:

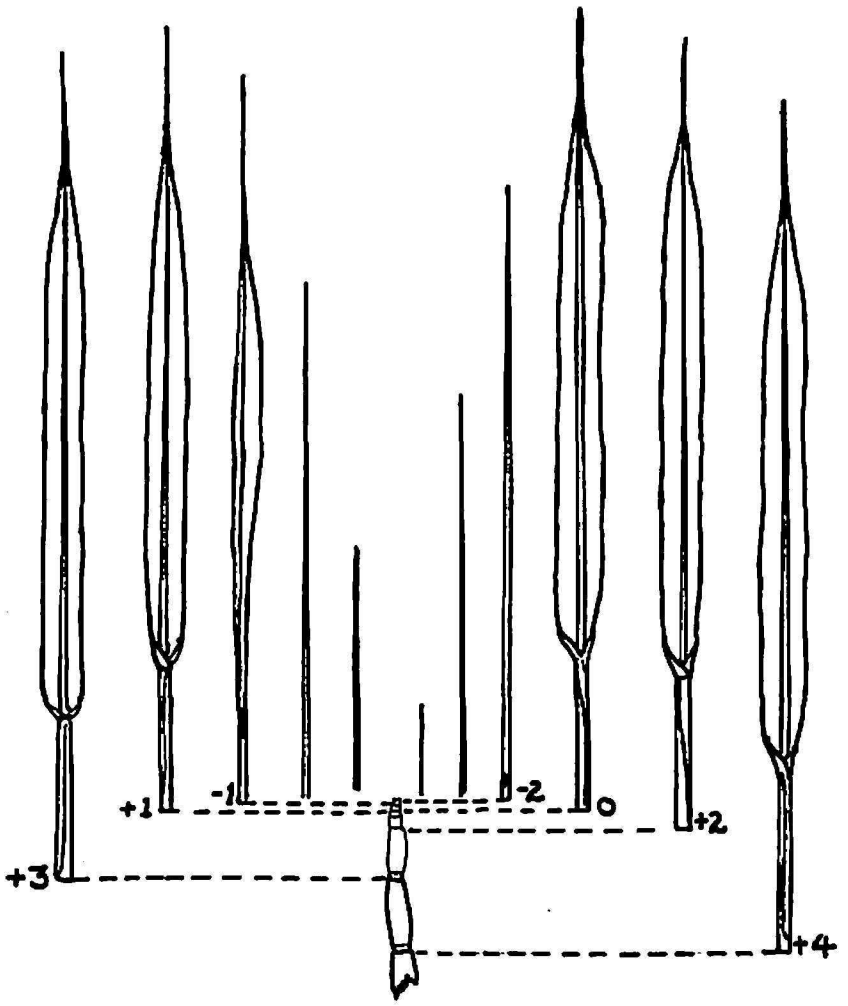

FIG. 1.—The cane top showing the various leaves used in sampling. The leaves are numbered in accordance with the system of Kuijper; after Clements (*8*).

MAURITIUS (*4*)

The leaf-rank rule is to tear off the whole blade of the third leaf (+1) starting from the top, the one partly unfolded counting as the first leaf (−1). The number of leaves constituting a sample should not fall below 60 when regularly spread over the field. The extremities of the collected leaves are removed, keeping just 6 inches of the central portion. The midrib is removed and the laminae are piled one over the other. A leaf-punch is made with a borer fashioned from an empty copper cartridge. The collected punches are placed in a sampling box. Chemical analyses are made of the dry leaf tissue for nitrogen, phosphorus, and potassium.

TABLE 1.—*A summary of leaf-sampling procedures for the foliar diagnosis of sugarcane used in different countries*

Country	Age when sampled	Leaf blades[1]			Leaf sheaths		
		Regular No.	Kuijper No.	Analyzed for—	Regular No.	Kuijper No.	Analyzed for—
	Months						
British Guiana	4½–5	(2)	+1	N, P, K, micro-elements	(3)	(3)	(3)
Hawaii	3–24	3, 4, 5, 6	+1, +2, +3, +4	N	3, 4, 5, 6	+1, +2, +3, +4	P, K, Ca, Mg, moisture, total sugar
Jamaica	4–5	3	+1 or +2	N, P, K	(3)	(3)	(3)
Mauritius	5–7	3	+1 or +2	N, P, K	(3)	(3)	(3)
Puerto Rico	3	4, 5, 6	+2, +3, +4	N, P, K	4, 5, 6	+2, +3, +4	Moisture

[1] Including midrib for all countries except Puerto Rico.
[2] Top dewlap.
[3] Not utilized.

HAWAII (*1*)

Five canes are selected from representative sites in the field. Leaves Nos. 3(+1), 4(+2), 5(+3), and 6(+4), are selected. The middle portion of the leaf blade is used, after removal of the midrib, for nitrogen determination. The corresponding leaf sheaths, when dried and ground, are used for the determination of phosphorus, potassium, moisture, and total sugars.

BRITISH GUIANA (*3*)

From 30 to 50 leaves showing the highest visible dewlap (+1) are used. The middle 8 inches of these leaf blades is separated into chlorophyllous tissue and midrib, the latter being discarded. The fresh tissue is dried rapidly at 80°C. in a forced-draft oven, ground, and stored in airtight bottles until analyzed for nitrogen, phosphorus, and potassium, and certain microelements.

PUERTO RICO (*7*)

Depending upon many factors, a sample consists of five or more canes. Leaf blades Nos. 4(+2), 5(+3), and 6(+4), counting the partly unrolled spindle leaf as No. 1(−1), are removed, together with their corresponding leaf sheaths. The leaf sheaths, severed from the leaf blades at the collar joint or ligule, are placed in special moistureproof bags for use in moisture determinations. The leaf blades are cut into 2- or 3-inch sections with a section taken from the basal, middle, and tip section of the leaf blade. This leaf-blade material containing both laminae and midrib is dried, ground, and analyzed for nitrogen, phosphorus, and potassium.

OTHER TECHNIQUES

Innes, in Jamaica (*5*), utilizes the whole third leaf as used in Mauritius. Du Toit (*2*), in South Africa, takes the whole third leaf blade, including the midrib. Lunin and Aughtry in Santo Domingo (*6*) employ the crop-log technique of Clements.

PROCEDURES AS USED

The methods of foliar diagnosis used in British Guiana, Hawaii, Mauritius, and Puerto Rico were utilized in sampling 10 fields of sugarcane varying from 3 to 5 months in age. The varieties sampled were B. 37161, P.R. 980, M. 336, and P.O.J. 2878. In all cases 10 canes were selected at random for each sampling procedure. The number of leaves and parts utilized for chemical analysis in each method were selected according to the stated procedure of each system. A special study was conducted for determining the variation in nutrient value of various leaves. Three separate fields of

plant cane of P.R. 980 and M. 336 were used at a cane age of 3 months. Ten cane samples were utilized for each leaf.

RESULTS

The comparison of the various sampling methods is given in table 2. From a field standpoint, no appreciable difference was encountered in leaf numbers when the British Guiana method of using the first visible dewlap was compared with the Mauritius method of using the whole third leaf. Therefore, the British Guiana method is given in the work reported in table 2, although similar values were obtained with the Mauritius method.

Very little difference existed in nutrient content of the leaf blades when using the Hawaiian or British Guiana methods, although the British Guiana values were slightly higher than those derived by the Hawaiian system. The leaf-blade values when using the Puerto Rican method were lower in

TABLE 2.—*A comparison of the nutrient composition and moisture content of sugarcane leaves when using different leaf-sampling methods*

Origin of method	Nutrient content of leaf blades on a dry-weight basis for—			Nutrient content of leaf sheaths on a dry weight basis for—			Moisture content of leaf sheath, green-weight basis
	N	P	K	N	P	K	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
British Guiana	2.22	0.23	1.79	0.69	0.08	2.02	83.1
Hawaii	2.16	.22	1.77	.75	.09	2.28	84.7
Puerto Rico	1.74	.20	1.89	.71	.08	1.92	83.6

nitrogen and phosphorus and higher in potassium than when the other two methods were used. The major difference in the Puerto Rican method is the fact that the midrib is not eliminated from the leaf blade for analysis.

A clearer understanding of why certain similarities and differences exist can be obtained when we examine the analysis of the various components of the cane leaf itself. A comparison of the various cane-leaf values is given in table 3. Nitrogen shows little variation in the range of cane leaves normally sampled, leaves Nos. 3(+1) to 6(+4). There is a decrease with increasing leaf number for phosphorus, potassium, and sheath moisture. Thus one would expect that the Hawaiian method, using leaves Nos. 3(+1), 4(+2), 5(+3), and 6(+4), would give somewhat lower phosphorus, potassium, and sheath-moisture values than the British Guiana or Mauritius methods, which use only leaf No. 3(+1).

A comparison of the analyses of various parts of a cane leaf blade is given in table 4. The lamina is much higher in nitrogen and phosphorus, but lower

in potassium, than the midrib. Thus, for the Puerto Rican system, wherein the whole leaf blade is used, midrib included, we would expect lower nitrogen and phosphorus values and higher potash values than for the other methods which use the lamina only.

Table 5 was compiled to serve as a guide in making comparisons between the various methods of foliar diagnosis used on sugarcane in different parts of the world. The optimum values for foliar diagnosis of sugarcane as given by the leading authorities in each area were all standardized to represent

TABLE 3.—*A comparison of the nutrient composition and moisture content of the different sugarcane leaves used for foliar diagnosis*

Leaf No.	Kuijper No.	Nutrient content of leaf blade on a dry weight basis for—[1]			Moisture content of leaf sheath
		N	P	K	
		Percent	*Percent*	*Precent*	
3	+1	1.56	0.19	1.71	84.5
4	+2	1.61	.17	1.61	83.3
5	+3	1.60	.17	1.52	83.0
6	+4	1.58	.15	1.36	82.6

[1] Midrib is included.

TABLE 4.—*A comparison of the nutrient composition of different parts of the sugarcane leaf blade*

Part of blade	Nutrient content of sample on a dry weight basis for—		
	N	P	K
	Percent	*Percent*	*Percent*
Whole	1.62	0.15	1.53
Lamina	2.09	.19	1.47
Midrib	.79	.09	1.62

leaf-blade tissue without midrib. Where midrib tissue was included in the values from Puerto Rico, these were converted by appropriate factors derived from tables 2 and 4. Appropriate factors were used to convert to leaf-blade values of the Hawaiian method where phosphorus and potassium are determined using the sheaths. All values reported are in nitrogen, phosphorus, and potassium and needed changes were made from P_2O_5 and K_2O values used in Mauritius and Jamaica.

It is interesting to note that the general values for optimum levels of nitrogen, phosphorus, and potassium, are quite similar, even though they represent distinctly different geographical areas, soils, climates, and cane

varieties. The greatest variation seems to be in potassium values with a low of 1.1–1.2 for Jamaica and a high of 1.72–1.90 for South Africa. Phosphorus levels show surprisingly little variation for any of the countries or techniques. Nitrogen values did not show too great variation for optimum-yield levels. Mauritius and Puerto Rico had the lowest values and Jamaica the highest.

In general, it speaks well for the practice of foliar diagnosis of sugarcane, that close agreement on leaf-nutrient values are obtained regardless of differences in sampling techniques.

TABLE 5.—*A comparison of foliar-diagnosis values for sugarcane from different countries using different techniques*[1]

Country	Nutrient content of leaf blade for optimum yields on a dry-weight basis for—		
	N	P	K
British Guiana	2.0–2.1	0.21	1.20
Hawaii	2.0	.21[2]	1.75[3]
Jamaica	2.3	.25–.28	1.1–1.2
Mauritius	1.66–1.85	.20–.24	1.12–1.32
Puerto Rico	1.80[4]	.23[5]	1.56[6]
South Africa	1.93–2.18[4]	.24–.29[5]	1.72–1.90[6]
General average	2.00	0.24	1.40

[1] Based on sample age of 4 to 6 months for plant canes. The midrib is excluded in the analyses.

[2] Converted from leaf-sheath P values by use of a factor of 2.6.

[3] Converted from leaf-sheath K values by use of a factor of 0.78.

[4] Converted from leaf N values with midrib by use of a factor of 1.28.

[5] Converted from leaf P values with midrib by use of a factor of 1.25.

[6] Converted from leaf K values with midrib by use of a factor of 0.95.

SUMMARY

Several different methods of sampling sugarcane leaves for foliar diagnosis are used in as many different countries. In order to evaluate the values obtained for nitrogen, phosphorus, potassium, and moisture, four of these were used in an experiment at this Station, and the results compared. The following findings were regarded as significant:

1. The Hawaiian, British Guiana, and Mauritius sampling methods gave closely similar values.

2. The Puerto Rican method, wherein the midrib of the leaf is included, gave lower nitrogen and phosphorus values, and higher potash values.

3. The individual cane leaves from Nos. 3(+1) to 6(+4) showed no

appreciable variation in nitrogen, but a decrease in phosphorus, potassium, and sheath moisture with increasing leaf number.

4. The analysis of the various parts of the cane leaf blade showed that the lamina was higher in nitrogen and phosphorus but lower in potassium than the midrib.

5. The optimum leaf-nutrient values for the various countries and techniques were compared after appropriate adjustments were made to standardize them on a common basis. In general, the leaf values were similar regardless of country, method, or cane variety.

RESUMEN

Cuando se compararon distintas técnicas para tomar las muestras en cuanto al diagnóstico foliar de la caña de azúcar, las diferencias fueron las siguientes:

1. Los métodos que usan en Hawaii, en la Guayana Inglesa y en Mauricio para tomar las muestras indicaron valores similares.

2. El método en uso en Puerto Rico, en el cual se incluye la vena central de la hoja, dió valores más bajos para nitrógeno y fósforo, pero más altos para potasa.

3. Las hojas de caña individuales, desde el número 3(+1) a 6(+4) no demostraron variación apreciables alguna para nitrógeno, pero los valores bajaron para fósforo, potasio y humedad de la vaina, según se aumentaba el número de hojas.

4. El análisis de las distintas partes de la hoja demostraron que la lámina tiene un mayor contenido de nitrógeno y fósforo, pero menor de potasio que la vena central.

5. Los valores óptimos de los nutrimientos en las hojas fueron comparados entre varios países, después que se hicieron los ajustes requeridos para someter estos valores a una norma igual sobre una base común. En términos generales, los valores en cuanto a las hojas fueron similares, sin tener que ver en nada con el país, el método o la variedad de caña.

LITERATURE CITED

1. Clements, H. F., Crop-logging sugarcane in Hawaii, *Better Crops with Plant Food* **32** 11-8 and 45-8, 1948.
2. Du Toit, J. L., Sugarcane nutrition in South Africa, Proc. Eighth Congress Int. Soc. Sugarcane Tech., Barbados, 1953, pp. 40-4, 1954.
3. Evans, H., Studies in mineral nutrition of sugarcane in British Guiana II: The mineral status of sugarcane as revealed by foliar analysis, *Trop. Agr.* **32** (4) 295-322, 1955.
4. Halais, P., Foliar diagnosis, a new guide to fertilization of sugarcane in Mauritius, Proc. Seventh Cong. Int. Soc. Sugarcane Tech., Brisbane, 1950, pp. 218-32, 1951.
5. Innes, R. F., and Chinloy, T., Experiences with crop control in Jamaica, *Hawaiian Planters' Rec.* **55** (1) 149-65, 1955.

6. Lunin, J., and Aughtry, J. D., The effect of soil type and fertilization on the growth and yield of a ratoon cane crop as indicated by crop logging, Eighth Cong. Int. Soc. Sugarcane Tech., Barbados, 1953, pp. 3–16, 1954.
7. Samuels, G., Landrau, P., Jr., and Alers Alers, S., and Riera, A., The method of foliar diagnosis as applied to sugarcane, Agr. Exp. Sta., Univ. P. R., Bul. 123, Feb. 1955.
8. Van Dillewijn, C., Botany of Sugarcane, pp. 103–4, The Chronica Botanica Co., Waltham, Mass., 1952.