THE CHEMICAL COMPOSITION OF GREEN COFFEE BEANS AND COFFEE LEAVES AS RELATED TO SOIL AND FOLIAR APPLICATIONS OF SECONDARY AND MINOR ELEMENTS

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Saulo J. Rodriguez

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presented by

SAULO JOSÉ RODRIGUEZ

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Major professor

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AN ABSTRACT OF A THESIS

Submitted to
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ABSTRACT

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By Saulo J. Rodríguez

Samples of green beans and leaves of coffee trees (*Coffea arabica* L. var. *bourbon* Choussy) were collected in 1959 from an experiment located at the Coffee Experiment Substation in Puerto Rico. The substation is located at an elevation of 2,000 feet; mean monthly temperatures of 70 to 80 degrees Fahrenheit, and 70 inches of rainfall annually. The soil is lateritic with 30 to 45% slope, and has a low exchange capacity and a pH of 4.72.

The experimental plants were nursery seedlings and were planted in sun-hedges. The experimental design was a 5 x 4 triple rectangular lattice with six replications and six trees per plot.

The treatments consisted of applying the minor elements (iron, manganese, zinc, boron and molybdenum) and magnesium, as a complete nutrient treatment to the soil and to the foliage. Lime was applied to the soil at 3.5 tons per acre. Two complete nutrient treatments were applied to the soil without lime or with an equivalent amount of gypsum. One treatment was used in which the minor elements were supplied as FTE (fritted trace elements) to the soil in the presence of lime. The balance of the treatments consisted in omitting one of the minor elements from the soil or foliar application.

All treatments including the check plots received an application of nitrogen, phosphorus and potash with lime either spread or incorporated with the soil.

The green coffee bean samples were analyzed for total, reducing and non-reducing sugars, caffeine, protein and ether soluble substances.

The samples of green coffee beans and leaves were analyzed for nitrogen, potassium, phosphorus, calcium, magnesium, iron, manganese, zinc, copper, boron, molybdenum and aluminum. Nitrogen and potassium were analyzed by the Kjeldahl method and flame photometer, respectively. The remaining nutrient elements were determined spectrographically.

Coffee Beans

Analyses of variance and test of significance at the one percent level showed that the organic constituents of the green coffee bean samples were affected by the treatments. The percentages of total and non-reducing sugars were depressed by the omission of molybdenum from the foliar application. The omission of boron from the soil application increased the percentages of total and non-reducing sugars. The percentage of reducing sugars was depressed by lime when any one of the elements was omitted. The FTE application increased reducing sugar.

The omission of zinc increased the protein content in green coffee beans as well as the ether soluble substances. The same was true of the caffeine content.

The total nitrogen content of the coffee samples was depressed by the omission of magnesium from the foliar treatment while it was increased by the omission of boron.

Lime reduced the potassium and magnesium content of green coffee beans while phosphorus was increased by the omission of boron and molybdenum.

Calcium content was increased by the omission of magnesium from the soil application.

FTE increased the manganese and boron contents of green coffee beans while lime reduced the zinc content.

The aluminum content was increased by the omission of manganese and boron.

Coffee Leaves

The leaf analyses showed no significant differences in the nitrogen, phosphorus and iron content. Leaf potassium was increased by the omission of iron while it was not affected by lime.

Leaf-calcium increased with lime application and depressed by magnesium.

Leaf-magnesium increased with the application of magnesium to the soil, but not to the foliage.

Leaf manganese decreased with the omission of manganese from the soil or to the foliar application. The FTE application increased leaf manganese.

Leaf-boron was depressed by the lime or by the omission of boron. The same was true of the leaf-zinc.

Leaf-molybdenum was positively related to lime application, while leaf-aluminum was negatively related.

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INTRODUCTION

Coffee (*Coffea arabica* L-var, *typica* Cramer) has been under cultivation in Puerto Rico since 1736 (58). Originally, coffee was cultivated on good arable land and yields were high. Until the end of the nineteenth century, coffee was the best source of income in Puerto Rico.

During that period, yields were high and cost of production was low. There was a great demand for Puerto Rican coffee in Europe. Since the end of the 19th century, however, sugar cane cultivation has become more and more important, and coffee growing has been moved from the good arable soils to submarginal soils of the mountainous region of the Island. The yields per unit area decreased constantly and cost of production increased; thus coffee has become the second crop, as to value, in Puerto Rico. Tropical hurricanes have caused heavy damage to the crop and resulted in periodic depressions in production.

During the last twenty years, the production per acre has averaged about 200 pounds of market coffee. Nevertheless, most of the farmers and the government economists believe that its cultivation is part of the Island life. Moreover, the possibility of a substitute crop for the mountainous region is very dim.

The government is deeply interested in improving the crop since approximately 300,000 persons depend directly or indirectly upon coffee for their subsistence. Emphasis is being placed on improving its yield per unit area through intensive cultivation.

Among the cultural practices being tested in the Island, are the following: reduced shading or complete elimination of shade; systems of planting; insect and disease control; introduction, selection and testing of new varieties and cultivars; heavy fertilization, use of minor elements; use of mulch in non-shade conditions; and weed control.

The Agricultural Experiment Station initiated in 1953 a series of tests to demonstrate the feasibility of planting coffee without shade. High yields are obtained with non-shade coffee, but apparent nutritional disorders appeared in the plantation.

In 1956, and experiment was initiated to determine the effect of secondary and minor elements on coffee growth and yield. Little information has been available as to the effect of nutrient application on the composition of the green beans and the leaf.

The purpose of this work was: first, to determine the effects of secondary and minor elements on the composition of the green coffee beans[1]; and second, to determine the effects of the same nutrients on the leaf composition.

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[1] The terms "green coffee beans" and "unroasted coffee seeds" are used interchangeably throughout the work.

REVIEW OF LITERATURE

Chemistry of Coffee

The chemistry of coffee has interested research workers in coffee-producing as well as in coffee-consuming countries. Most of the research has centered around the organic components that may affect the flavor and aroma, and the changes occurring in them during the roasting process.

Among the reports, Prescott (43) has presented very interesting information of the components in different types of coffee, as well as chemical procedures used in the analysis. According to Prescott, "coffee varies greatly in analysis depending upon the type of coffee, the region from which it comes, altitude, soil and many other factors."

According to his report, the following would be a representative analysis of four types of coffee in percentage dry weight:

	Type of Green Coffee Beans			
Component	Santos	Padang	Guatemala	Mocha
Ash	4.71	4.23	3.93	4.20
Oil	12.96	12.96	12.28	14.04
Caffeine	1.87	1.56	1.26	1.31
Crude fiber	20.70	21.92	22.92	22.46
Protein	9.50	12.92	10.43	8.56
Water Extract	31.11	30.83	31.04	31.27

The mineral constituents listed by Prescott were potassium, sodium, calcium, magnesium, iron, tin, aluminum, manganese, lead, copper, and vanadium. The organic constituents were carbohydrates, proteins, fats, oils and waxes. The most characteristic organic component was caffeine or trimethyl xanthin.

Recently, Thorold (53) presented a complete quantitative spectrographic analysis of the coffee bean. He mentioned the fact that any effect of fertilizer on coffee quality would be an indirect rather than direct physiological factor.

Researchers have given a new push to the study of the constituents of coffee and their changes during processing. This increased research has resulted from the advances in paper and gas chromatography and an increase in the use of soluble coffee in recent years. Since most of the work on the chemistry of coffee has been associated with the quality, it is interesting to mention here, two works done in Central America. Swain (51) found that the applications of gamma BHC[1] in combination with DDT[2] to coffee will give a "muddy" taste to the coffee beans. De Gialluly (18) made a summary of all the factors involved in the cup quality of coffee. He divided them into genetic and environmental. He has been working in such cultural practices as nutrition, irrigation and diseases and their

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[1] Benzene hexachloride

[2] Dichloro-diphenyl-trichloro-ethane

effect on the cup quality. No conclusive results have been reported.

A review of the coffee chemistry will not be complete without mentioning the work done by Kremers (33) on the two nitrogenous compounds present in the coffee bean: caffeine and trigonelline. He speculated on the synthesis of the two compounds from DPN by hydrolysis, diammonification, oxidation and methylation of two nitrogen bases: pyridine and adenine.

Coffee Mineral Nutrition

Basic studies of the coffee mineral nutrition have been reported by Tanada (52), Mayne (36), S'Jacob (50), Franco and Mendez (21), Schweizer (49), Cibes and Samuels (13) and Lott et al. (29).

Müller (41) presented a review of the work on the mineral deficiencies of major and minor elements. The apparent levels of deficiencies and toxicity were reported in his review.

Response to Major Nutrients

Coffee response to applications of major nutrients has been reported by several workers in the coffee producing areas of the world (1, 5, 15, 17, 23, 37, 42).

McClelland (37) working in Puerto Rico in an alluvial fan soil found a favorable response in yield of coffee trees to applications of potash if accompanied by nitrogen. Significant responses in yield from applications of potash were observed by Dean and Beaumont (17), Beaumont and Fukunaga (5), Cooil and Fukunaga (15), on high yielding coffee trees in Hawaii.

In the same report, McClelland mentioned an adverse effect of nitrogen when applied at high levels and not accompanied by potash. No response to phosphorus application was observed in that trial.

Gomez _et al._ (23) working in a lateritic soil found a significant response in yield to phosphorus in coffee grown under shade. No response to either nitrogen or potash was observed in that trial.

Other workers like Anstead (2), Anstead and Pittock (3), Beckley (7), and Borel (9) have recommended the use of a high content of potassium and nitrogen in the fertilizer. Their works were based on the high content of the two elements in the coffee cherries. Lucy (30) found a favorable response in yield to rock phosphate application. Pereira (42) could not find any correlation of citric acid soluble phosphorus with coffee yields.

Abruna _et al._ (1) found that coffee grown without shade gave a significant response to potassium especially when accompanied by nitrogen, in a fertilizer test conducted on a lateritic soil in Puerto Rico. Yields over 1800 pounds per acre were obtained in this test, although biennial bearing was not overcome.

Response to Secondary and Minor Elements

As to secondary and minor elements, Müller (41) in his review of mineral nutrition mentioned that a deficiency of calcium in the field has been reported in Costa Rica and Colombia. Beneficial effects of applying calcium containing fertilizers have not been obtained, although in certain areas in Costa Rica it has been obtained with liming.

Müller, in the same work, reported no sulfur deficiency under field conditions. However, Lott *et al.* (29) reported that they were able to induce sulfur deficiencies in coffee under greenhouse conditions in a sulfur deficient soil in Brazil. In field plots receiving a low sulfur-containing fertilizer, deficiencies were liable to appear. They corrected the deficiency with the application of 20-40 pounds of sulfur per acre.

Iron and boron deficiencies seem to be widespread in coffee-producing countries. Mayne (36) reported a high boron requirement for coffee. He pointed out a possible response to borax application at a rate of 1-2 pounds per acre. In the same report, he mentioned the possible antagonistic effects of manganese on iron, producing a deficiency similar to the one in pineapple grown on manganiferous soils in Puerto Rico and Hawaii.

Probably the most interesting report is that by Medcalf and Lott (39) in which they obtained an increase in yield of coffee of over 200 percent by the application of 16 grams of metal chelated minor elements.

Müller (41) mentioned the fact that, in certain areas in Costa Rica, boron shortage may curtail coffee production. Corrections may be obtained with soil or spray applications of boron-containing compounds.

Zinc has been reported deficient according to Müller (41) in various coffee-producing countries. In Hawaii, Kanehiro (31) reported zinc deficiency in new shoots coming from the main stump of the trees after pruning. Deficiency of the element was correlated with available zinc in the soil.

Leaf Analysis in Coffee Nutrition

Leaf analysis either for diagnostic technique or as a research tool in coffee nutrition has been used since 1940 (1, 11, 13, 14, 20, 28, 29, 38, 39, 41, 44, 49). During the past five years, its use has spread over the different coffee-producing countries.

In 1940, Roelofsen and Coolhaas (44) presented data in regard to composition of leaves, branches and berries of fruit-bearing and non-bearing Robusta trees. Nitrogen, phosphorus and potassium decreased in the course of the season. In the case of potassium, the authors observed a minimum during the ripening of the berry.

The leaf may take up nitrogen and potassium until it has reached maturity, afterwards losing again part of these elements. Phosphorus decreased continually, whereas calcium, magnesium, iron and manganese accumulated in the leaf.

In a well planned experiment, Schweitzer (49) studied the changes in composition of the coffee leaves as related to seasonal cycles. He selected leaves of the same age, color and position on the branch. Samples were collected at the same hour of the day (11:00 a. m.) to prevent fluctuations. He reported that cuticular excretion played an important role in the leaf content of calcium and magnesium. During the dry season, calcium and magnesium increased in the leaves independent of the crop until leaf fall. During the rainy period, the amount of calcium and magnesium decreased before leaf fall. During the leaf development a negative correlation was observed between calcium and potassium.

Phosphorus, nitrogen and potassium in the leaves of bearing trees were at their maximum at the beginning of the adult leaf.

Schweitzer emphasized the relation of yield and dieback. In a heavy crop, phosphorous may decrease up to 60 percent of the original amount. Starch disappeared completely and total sugars decreased up to 4 percent of the control samples. Carbohydrate consumption was enormous during the ripening period.

The same relation of carbohydrate content of the leaves and dieback have been pointed out by Clements (11) and Cooil (14) in Hawaii, for coffee cultivated without shade. They related the condition to potassium level in the leaves.

Cibes and Samuels (13), in a controlled conditions experiment for the display of mineral deficiencies, reported the lowest leaf contents for nitrogen, phosphorus, calcium and magnesium in the plants from which the respective element was omitted from the nutrient solution. In the case of the iron and manganese, the lowest leaf contents were not associated with the omission of the two respective elements from the nutrient solution except in the case of iron in the old leaves. Low values of iron were associated in young leaves with minus-boron and minus-potassium treatments. The minus-boron, minus-iron, and minus-sulfur treatments produced lower leaf-manganese than the minus-manganese treatment. A Fe:Mn 1.0: 2.9 in young leaves and 1.0: 2.0 in old leaves were obtained in the complete solution treatment.

High leaf-iron values were obtained in the young leaves of the minus-nitrogen and minus-manganese plant as well as in the old leaves of minus-calcium plants. The highest manganese of young leaves was observed in the complete solution. In the old leaves the highest values were found in the minus-iron treatment. With minus-iron, the manganese content was more than double the quantity found in young leaves of plants grown in the complete solution.

The highest nitrogen content was obtained in the minus-phosphorus treatments; while for the potassium, the highest values were obtained in the minus-calcium treatment.

Lott et al. (28) reported on some interesting work done in Brazil. They had in mind the application of leaf analysis in interpreting the response in field plot experiments and for diagnostic purposes in making fertilizer recommendations. Most of the work dealt with procedures and techniques and time of sampling with the intentions of processing a good number of samples without losing reliability.

They found the most reliable results when using the more recently matured pair of leaves. For their experimental plots, the third pair of leaves starting from the tip of the lateral was the least variable.

The following ranges in composition were found by Lott et al. (28) in the analysis of coffee leaves in Brazil:

Nitrogen	1.9%	----------------4.00%
Phosphorus	0.03%	----------------0.20%
Potassium	0.33%	----------------4.00%
Calcium	0.50%	----------------2.00%
Magnesium	0.08%	----------------1.30%

In all cases, except for calcium, the leaves giving the lowest values exhibited appropriate deficiency symptoms.

The techniques and procedures of Lott et al. (28) have been applied by Medcalf (38), Medcalf and Lott (39), Franco (20), and Lott, McClung and Medcalf (29) in reporting a series of studies in Brazil.

Medcalf (38) reported from the leaf analysis that mulch plots have higher levels of phosphorus and potassium than the control plots. Heavy mulch applications tend to depress the leaf-nitrogen and the leaf-manganese.

Medcalf and Lott (39) reported a reduction in level of leaf-manganese from 1113 ppm to 522 ppm when metal chelates were applied to coffee trees. There was an increase of iron level at certain times of the year.

In a temperature study for coffee growing, Franco (20) reported that a leaf analysis showed a reduced absorption of N, P, K, Ca and Mg at root temperatures of 33° C. and 38° C. Absorption of potassium increased at root temperatures of 13° C. and 18° C. Calcium and magnesium were greatly reduced at temperatures of 13° C.

Abruna _et al._ (1) in an experiment carried on in Puerto Rico on coffee without shade, reported leaf-nitrogen levels of 2. 3, 2. 8 and 3. 0 percent when nitrogen applications to the soil were 0, 150 and 300 pounds per acre, respectively. Potassium levels were 0. 98, 1. 67 and 2. 18 percent when potassium was applied at the same previous rates. Magnesium was depressed from 0. 85 to 0. 59 and 0. 45 percent with the increase in the potassium levels. No appreciable effects of treatments were observed for phosphorus and calcium. They observed a high level of calcium and phosphorus in the treatment to which no nitrogen was applied.

Müller (41), in a summary of most of the literature available on detection and control of deficiencies in coffee, gave the various levels of leaf nutrients reported by research workers in coffee. The following values were obtained from his report as being either suitable, critical or toxic for the coffee plant:

	Critical	Suitable	Toxic
Nitrogen	-	2-3%	-
Phosphorus	0.1%	0.12-0.18%	-
Potassium	1.5%	2%	-
Calcium	-	-	-
Magnesium	0.1%	0.2-0.3%	-
Sulfur	-	-	-
Iron	0.007%		-
Manganese	0.0025-0.001%	0.02%	0.1%
Boron	0.002%	0.006-0.012%	0.01-0.015%
Zinc	0.001%		-

Müller further stated that light intensity was a factor in determining the suitable levels of nitrogen in the leaf for better growth. Phosphorus values as low as 0.03% have been found in the field. Phosphorus has been reported to be correlated with magnesium and nitrogen in the leaf. Potassium values as low as 0.1% have been reported in the coffee literature, as stated by

Müller. Calcium had been found in relatively low concentrations in the coffee fruit as compared to the leaves. In the iron deficient leaves a ration P/Fe of 30 or over was found, while in normal leaves the ratio was below 25. In manganese deficient leaves, there was an accumulation of nitrogen and potassium. The deficiency is seasonal, being more severe during the rainy season.

Lott, McClung and Medcalf (29) reported that sulfur deficiencies could be induced in coffee grown in the field and in the greenhouse. They grew coffee in a sulfur deficient soil. Through leaf analysis, they obtained values of sulfate-sulfur of 60 ppm for extremely deficient plants, 93 ppm for moderately deficient, and 221 ppm for normal plants. The total sulfur values were 720, 800 and 1330 ppm respectively.

Sulfate-sulfur values of 126, 381, 724 and 784 ppm were obtained in untreated plants and plants treated at the rate of 10, 20, and 40 pounds of sulfur per acre as gypsum. According to them, the values for sulfate-sulfur were a better criterion by which to diagnose the deficiency than the percentage of total sulfur.

A survey failed to show any sulfur deficiency at the low rate of fertilizer application used in the commercial orchard.

MATERIALS AND METHODS

Field Experiment

Description of Site and System of Planting

The field test was established in the Coffee Substation of the Agricultural Experiment Station of the University of Puerto Rico.

The Substation is located in the heart of the coffee area of the Island at an elevation of about 2000 feet, with mean monthly temperature varying from 70 to 80 degrees Fahrenheit, and 70 inches of rainfall annually.

The soil is a lateritic soil locally known as Alonso clay with a 30 to 45 percent slope. The exchange capacity was 22 me/100 gm of soil. The original pH was 4.72 and the soil required an application of 3.5 tons of $CaCO_3$ to increase the pH to 6.5.

The tract of land was cleared of weeds and trees. The holes were marked following the Cowgill system of sun hedge plantings (16). Distance between hedges was 12 feet, and the trees were planted 4 feet apart in a double row.

Planting Material

The Bourbon variety of coffee (Coffea arabica L-var, bourbon Choussy) was used for the test. Uniform one-year nursery seedlings were selected for the test and transplanted with the earth ball. Transplanting was done during the month of December 1956.

Pretreatment Procedure

During the first year, uniform treatments of a fertilizer mixture (9-10-5) and sulfate of ammonia were applied to the trees. The complete fertilizer was applied at the rate of 1.5 pounds per tree per year in three applications. Between applications, approximately four ounces of sulfate of ammonia were applied to each tree.

Experimental Design

A 5 x 4 triple rectangular lattice design was used in the test (see Table 1 for list of treatments). The experiment consisted of twenty treatments and six replications, i.e., a total of 120 plots. Each plot consisted of six trees plus two trees left as buffer between plots.

Application of Treatment

The treatments were started in April 1958 and are described in Tables 1 and 2. Lime was applied to the treatments as required at a rate of 3.5 tons to the acre. Depending on the treatment, the lime was either spread on the top or incorporated in the first six inches of soil covering the whole plot. In treatments 12 and 20 the lime was applied on the soil surface instead of being incorporated, as in the other treatments.

For treatment 2, gypsum equivalent to 3.5 tons of lime, was applied to the plot mixing it with the top soil.

Table 1.--Coffee Minor Elements Experiment - Castaner Substation.

List of Treatments

Treatments	Description			
	Mg	$CaCO_3$	Minor Elements	Type of Application
1	x	x	Complete	Soil
2	x	-[1]	Complete	Soil
3	x	-	Complete	Soil
4	-	x	Complete[2]	Soil
5	-	x	Complete	Soil
6	x	x	-Fe	Soil
7	x	x	-Mn	Soil
8	x	x	-B	Soil
9	x	x	-Zn	Soil
10	x	x	-Mo	Soil
11	-	x	None	Soil
12	-	x	None[3]	Soil
13	x	x	Complete	Foliar
14	-	x	Complete	Foliar
15	x	x	-Fe	Foliar
16	x	x	-Mn	Foliar
17	x	x	-B	Foliar
18	x	x	-Zn	Foliar
19	x	x	-Mo	Foliar
20	-	x	None[3]	Soil

[1] Equivalent amount of $CaSO_4$ was used instead of $CaCO_3$.

[2] FTE was used as source of minor elements.

[3] Treatments 12 and 20 are identical. The lime was spread on top of the soil instead of incorporated as in the other treatments.

Table 2.--Sources and Rates of Application of Secondary and Minor Elements.

Elements	Sources[1]	Rates of Application	
		Soil	Spray
Mg	Epsom salt	8 ounces per tree	26 pounds/100 gallons
Fe	Fe EDTA	20 grams per tree	2 pounds/100 gallons
Mn	Manganese-sulfate	10 grams per tree	2 pounds/100 gallons
B	Sodium Borate	14 grams per tree	2 pounds/100 gallons
Zn	Zinc sulfate	14 grams per tree	3 pounds/100 gallons
Mo	Sodium molybdate	1 gram per tree	2 pounds/100 gallons

[1] Treatment 4, FTE was used as the source of minor elements at 4 ounces per plot.

In treatment 4, four ounces of the fritted trace elements (FTE)[1] mixed with fine sand was applied per plot. Holes were dug around the canopy area of the tree and the material was placed in each hole.

In the magnesium and minor elements, either in soil or spray application, the quantity per tree per year was distributed in two applications.

The soil applications were made by spreading the material in the canopy area of each tree. In the spray applications, the proportional amount corresponding to a 4-gallon knapsack sprayer was prepared for each treatment. Hydrated lime (8 lbs/100 gal.) and sticker (Nu-Film)[2] 250 cc/100 gal. were used in the preparation of the sprays.

In all cases, the major elements were supplied in a fertilizer mixture. At the beginning a 9-10-5 fertilizer was applied to the whole plantation. The rates started at 1.5 pounds per tree, distributed in three applications for the year with the idea of increasing the amount if needed. The first application was made directly after the end of the picking season, and every four months thereafter.

Insects and diseases were controlled with a mixture of Copper A compound (2.0 lbs.), Parathion (1.5 lbs.) and Dieldrin (2 quarts) in 100 gallons of water, applied to the foliage every 3 to 4 months.

Weeding was done by hand to keep the area in the hedge free of weeds.

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[1] A product of the Ferro Corporation, Cleveland, Ohio.

[2] A product of the Miller Chemical and Fertilizer Corp'n, Baltimore, Md.

Sampling and Preparation

Sampling and Preparation of Coffee Samples

The ripened berries of each tree were picked by hand and yield recorded. The berries were mixed thoroughly and a composite sample of one-half pound was taken.

The berry pulp was removed by hand and the mucilage was removed by washing after overnight fermentation. The samples were sun-dried and stored in paper bags as parchment coffee in open shelves.

To prepare the sample for analytical procedures, the parchment was removed in a Spex-mixer mill (Spex Industries Incorporated, Scotch Plain, New Jersey). The samples were shaken for four minutes in small, hard plastic bottles with plastic pestles. The triturated parchment was removed by hand, leaving the green coffee beans clean.

The green coffee beans were ground in a Wiley mill to pass through a 20-mesh sieve. The ground material was stored in two-ounce capped bottles for further analytical determinations.

Sampling and Preparation of Coffee Leaves

The coffee leaves were samples following the instructions outlined by Lott *et al.* (28).

The samples consisted of 24 leaves from each plot. Four leaves of similar physiological age were picked drom the median lateral branches of each tree. The third pair of leaves starting from the tip of the lateral branches, were selected for sampling.

After the samples were gathered, the leaves were washed in a 0.3 N HCL solution plus detergent. The detergent used was Sparkleen[1] at a rate of 70 grams in 6 liters of water. The dorsal and ventral sides of each leaf were rubbed in the solution for one minute.

After rinsing the leaves in tap water, they were passed through four beakers containing distilled water.

The leaves were dried at a temperature of 65 to 70 degrees C. After grinding, they were stored in two-ounce capped bottles for further analytical determinations.

Chemical Analyses

Caffeine

The caffeine was determined spectrophotometrically as outlined by Ishler *et al.* (25) with certain modifications in the digestion and the actual determination.

The digestion was carried on in fiber digestion flask instead of the 1-liter Erlenmeyer flask. The concentration of caffeine was determined by a standard curve prepared with pure caffeine instead of using the factor

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[1] A product of Calgon Inc., Pittsburgh, Pennsylvania.

previously determined from the crude caffeine as suggested by them.

A 2.0 gram sample was transferred to a tared fiber digestor. Fifty ml of 0.1 N sulfuric acid solution and 450 ml of distilled water were added to the sample and digested for 30 minutes. After cooling to room temperature, the sample was made to weight (tare plus 502.0 grams) and filtered.

A 50 ml aliquot was pipetted into a 100-ml volumetric flask. To the aliquot sample in the volumetric flask, 7.0 ml of a 1.0 M buffered zinc acetate solution was added and swirled vigorously and 6.0 ml of a 0.25 M potassium ferrocyanide was added with a constant swirling of the flask. Distilled water was added to make up to volume and filtered through No. 41 Whatman filter paper. The first 10 ml were discarded.

A 50 ml aliquot of filtrate was transferred to a tared 250 ml Erlenmeyer flask containing 5.0 grams of magnesium oxide. Distilled water (50 ml) was added and boiled for 20 minutes. The Erlenmeyer flask was cooled to room temperature and made to weight (tare plus 105 grams).

After filtering and discarding the first 10 ml portion, the filtrate was read in the D. U. Beckman Spectrophotometer at a wave-length of 272 mu. The reading was compared to a standard curve of pure caffeine previously prepared. Results were expressed as percent caffeine.

Petroleum Ether Extract

For the petroleum ether extract a soak procedure used by Dr. Bedford (6), Food Science Department, Michigan State University, was employed.

A 5-gram sample of the dried material was weighed and placed in 4-ounce bottles and capped. To the samples, 50 ml of petroleum ether was added. The bottles were left overnight in a shaker moving at medium speed.

The samples were filtered through No. 2 Whatman filter paper and thoroughly washed three times with petroleum ether. Excess ether was removed by drying in an over for one hour. Loss in weight was considered as petroleum ether extract and expressed as percent of the sample.

Total and Reducing Sugars

The extraction for reducing and total sugars was done by the official A. O. A. C. method (4). The actual determination of reducing sugars was done with the Lane-Eynon method, using a 0.5% standard dextrose solution for the comparison.

The inversion of the non-reducing sugars was carried on at room temperature. A 50 ml aliquot of the extracted material was transferred to a 100 ml volumetric flask. To the volumetric flask 25 ml of water and 10 ml of concentrated hydrochloric acid were added. After 24 hours, the total sugars were determined titremetrically with the Lane-Eynon method.

The results for total sugars were reported as inverted sugar.

Nitrogen and Potassium

The nitrogen and potassium were determined by the Kjeldahl method and flame photometer, respectively.

Other Components

The balance of the mineral components (P, Ca, Mg, Mn, Fe, Zn, Cu, B, Mo, Al) in both the green coffee beand and the leaves were determined spectrographically.

All the mineral components were determined in the Plant Analysis laboratory of the Horticulture Department, Michigan State University, using their standard procedures.

Statistical Analyses

Analysis of variance was calculated for each of the organic and mineral components using the procedure outlined by Robinson and Watson (46), and Harshbarger (24), for a rectangular triple lattice design.

For the comparison of the results, Duncans Multiple range test and the variance for all comparisons were used in each case.

Table 3.--Analysis of Variance.

Source		DF
Total		119
Replications		5
Block		24
Components (a)	12	
Components (b)	12	
Treatment		19
Intrablock error		71

RESULTS AND DISCUSSION

The chemical analyses of the unroasted coffee beans were divided into three groups to facilitate the presentation of the data. The organic components are presented in Tables 4 and 5, while the inorganic components are presented in separate tables for each element.

The leaf analyses were separated from the green coffee analyses and each individual element is presented separately. Each treatment was identified by the first letter of the nutrient applied or omitted. The foliar applied treatments (magnesium and minor elements) were identified with the letter (F) designating the method of application. The balance of the treatments were applied to the soil. Lime was also applied to the soil in all cases.

Treatments 12 and 20 were combined in a single mean and identified as check B for the purpose of the experiment. Treatment 11 was identified as check A in the data table. In all cases, the adjusted mean represents six replications except check B with twelve replications. Means with the same letter or set of letters were not significant at the 1% level.

The results were compared in the following way: to determine the effect of any one of the elements, all treatments containing the element were compared to the treatment in which it was omitted. In the same way gypsum and lime were tested by comparing the lime containing treatments to the gypsum treatment.

Composition of Green Coffee Beans

Organic Components

Total Sugar:--The application of lime alone in the presence of magnesium and all the minor elements did not affect significantly the total sugar content of green coffee (Table 4). The results did not show any significant effect by the application of lime in the presence of FTE or in the way lime alone was applied to the soil. On the other hand, in the absence of boron from the soil application, lime increased the total sugar content, while in the absence of molybdenum from the spray application, lime depressed significantly the total sugar content. No effect of gypsum was observed when it was compared to lime alone, or lime and all the nutrient elements, but significant differences were observed between lime and gypsum in the absence of molybdenum and boron from the spray and soil applications, respectively.

The following decreasing order as to total sugar content was observed from the soil application of minor and secondary elements: -B, -Mg, -Mn, complete, check A, -Zn, -Mo, check B. In the foliar spray the following decreasing order was observed: complete, -Mn, -Fe, check A, -Mg, -Zn, check B, -B, -Mo.

The omission of any one of the elements from the soil application did not affect the total sugar content of green coffee when they were compared

Table 4.--The Effects of Secondary and Minor Elements on Total, Reducing and Non-reducing Sugars of Green Coffee Beans.

Treatments	Total Sugar as Inverted Sugar		Reducing Sugar		Non-reducing Sugar	
	%	Rating	%	Rating	%	Rating
Mg, L, ME	8.03	abc[2]	0.90	abcd	7.13	bcde
Mg, G, ME	7.74	abc	0.92	abc	6.82	cde
Mg, -L, ME	7.63	bc	1.00	ab	6.63	cde
-Mg, L, FTE	8.00	abc	1.12	a	6.88	cde
-Mg, L, ME	8.38	ab	0.06	h	8.32	ab
Mg, L, -Fe	7.50	bc	0.00	h	7.50	abcd
Mg, L, -Mn	8.06	abc	0.14	gh	7.92	abc
Mg, L, -B	9.10	a	0.31	fgh	8.79	a
Mg, L, -Zn	7.59	bc	0.48	efg	7.11	bcde
Mg, L, -Mo	7.38	bc	0.58	cdef	6.80	cde
Mg, L, ME(F)	7.93	abc	0.06	h	7.87	abc
-Mg, L, ME(F)	7.22	bc	0.56	def	6.66	cde
Mg, L, -Fe (F)	7.85	abc	0.62	cdef	7.23	bcde
Mg, L, -Mn (F)	7.88	abc	0.62	cdef	7.26	bcde
Mg, L, -B (F)	6.65	c	0.08	h	6.57	cde
Mg, L, -Zn (F)	6.74	c	0.44	efg	6.30	de
Mg, L, -Mo (F)	5.16	d	0.48	efg	4.78	f
Check A	7.74	abc	0.75	bcde	7.00	bcde
Check B	6.65	c	0.66	bcde	5.94	ef

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with same letter or set of letters are not significant at the 1% level.

to the complete treatment. The same was true when they were compared to check A (lime incorporated to the soil). However, the -B and -Mg treatments showed a higher accumulation of total sugars when they were compared to check B. The same -B treatment showed a higher total sugar content than the -Fe or -Mo treatments.

The foliar treatments among themselves did not show any effect on the total sugar content except a reduction by the omission of molybdenum. The same foliar treatments, when compared to the soil treatments showed that the -B and -Mo soil applied treatments had a higher total sugar content than the respective foliar applied treatments.

The FTE treatment did not show any effect on the total sugar content when it was compared to the complete treatments and check plots, but it had a higher content of total sugar when it was compared to the -Mo spray treatment.

Reducing Sugar:-- The reducing sugar content varied from undetectable amounts to 1.12% (Table 4).

Liming did not affect the reducing sugar content when in the presence and absence of magnesium and all the minor elements supplied to the soil or as FTE. On the other hand, the reducing sugar content was markedly reduced by liming in the complete foliar spray.

Lime, when any one of the elements was omitted from the soil or spray application, decreased the reducing sugar content when it was compared to the unlimed treatment. No difference in method of lime application was observed.

No difference between lime and gypsum was observed in the presence of magnesium and all the minor elements. The same was true when magnesium or iron was omitted from the spray application and molybdenum from the soil application. When any other of the elements was omitted from the soil or spray application, lime showed a depression of reducing sugar over gypsum.

The following decreasing order was observed in the reducing sugar content as affected by the soil treatments: complete, check A, check B, -Mo, -Zn, -B, -Mn, -Mg, -Fe. In the spray application, the decreasing order was as follows: check A, check B, -Mn, -Fe, -Mg, -Mo, -Zn, -B, complete.

There was a decrease in reducing sugars due to the omission of boron, manganese, magnesium or iron when they were compared to the complete soil treatment and to the check plots. The -Mo treatment contained more reducing sugar than the -Mn, -Mg or -Fe treatments. The -Zn treatment contained a higher quantity of reducing sugar than the -Mg or -Fe treatments.

The order in the reducing sugar content as it was affected by the foliar application was different from that in the soil application. The complete and the -B treatment decreased the quantity of reducing sugar in the green coffee when they were compared to the check plots and to the -Mn, - Fe, -Mg, -Mo, or -Zn treatments.

The complete treatment as foliar spray contained less reducing sugar than the complete treatment as soil application. On the other hand, the foliar applied -Mg, -Fe or -Mn treatments showed a higher accumulation of reducing sugar when they were compared to the soil applied comparable treatments.

The FTE treatment showed the highest quantity of reducing sugar and was significantly higher than the complete foliar treatment, and any of the incomplete treatments, either soil or foliar applied.

Non-reducing Sugar:-- The correction of the soil pH by lime application in the presence of magnesium and all the minor elements did not affect the non-reducing sugar content of green coffee. On the other hand, the correction of the soil pH by lime application in the absence of boron or magnesium from the soil application increased the non-reducing sugar content. Lime in the absence of foliar applied molybdenum decreased markedly the non-reducing sugar content.

No difference between lime and gypsum was observed in the presence of magnesium and all the minor elements either soil or foliar applied. On the other hand, when boron or magnesium was omitted from the soil treatment, an increase in non-reducing sugar was observed due to lime. In the foliar applied treatments, lime in the absence of molybdenum decreased the non-reducing sugar when it was compared to gypsum.

The non-reducing sugar content may or may not be affected by the minor elements (Table 4). The following decreasing order of the soil treatments was observed: -B, -Mg, -Mn, -Fe, complete, -Zn, check A, -Mo, check B. In the foliar applied nutrients the decreasing order was as follows: complete, -Mn, -Fe, check A, -Mg, -B, -Zn, check B, -Mo.

It was observed from the two orders that the omission of molybdenum reduced in both cases the quantity of non-reducing sugars, but significantly only in the foliar application. The omission of boron from the soil application increased the non-reducing sugar content when it was compared to the complete soil treatment or to either one of the checks.

The omission of magnesium resulted in a higher non-reducing sugar content than check B, but not different than the complete treatments and check A.

In the foliar treatments, the complete treatment had a greater accumulation of non-reducing sugar than the incomplete treatments. No further differences were observed in the group except the low accumulation of non-reducing sugar of the -Mo treatment.

The -B, -Mg, -Mn, or -Mo soil treatments showed a greater accumulation of non-reducing sugar than the comparable foliar treatments.

The FTE treatment did not show any difference as compared with the complete treatment or to the checks. However, when it was compared to the -B and -Mg treatments, FTE caused less accumulation of non-reducing sugar. The -Mo foliar treatment showed a lesser accumulation than the FTE treatment.

Protein:-- The check plots (lime only, applied on top of the soil or incorporated to the top soil) showed the lowest values for protein, but not significantly different than the complete soil treatment. The same was true when they were compared to the uncorrected pH treatment with magnesium and all the minor elements applied to the soil (Table 5). Gypsum or FTE did not affect the protein content.

The following decreasing order of the soil treatments was observed: -Mo, -Zn, -B, -Fe, -Mn, -Mg, complete, check A, check B. The decreasing order of the foliar applications was as follows: -Zn, -Mn, -Fe, complete, -Mo, -B, -Mg, check A, check B.

No differences were observed in the soil treatments, but in the foliar treatments, the -Zn had a higher protein content than the -Mg foliar treatment and the two check treatments.

Caffeine:-- The caffeine content was relatively uniform varying from a high value of 1.48% to a low of 1.22% (Table 5). No effect attributable to lime

Table 5.--The Effects of Secondary and Minor Elements on Total Proteins, Caffeine and Petroleum Ether Extract of Green Coffee Beans[1].

Treatments	Protein (Nx6.25)		Caffeine		Petroleum Ether Extract	
	%	Rating	%	Rating	%	Rating
Mg, L, ME	13.94	b[2]	1.33	abc	11.75	bc
Mg, G, ME	14.25	ab	1.42	ab	12.22	ab
Mg, -L, ME	14.31	ab	1.36	abc	11.69	bc
-Mg, L, FTE	14.44	ab	1.37	abc	11.30	bcd
-Mg, L, ME	14.12	ab	1.33	abc	11.72	bc
Mg, L, -Fe	14.25	ab	1.30	abc	11.57	bcd
Mg, L, -Mn	14.12	ab	1.25	bc	12.20	ab
Mg, L, -B	14.62	ab	1.40	abc	11.43	bcd
Mg, L, -Zn	14.62	ab	1.42	ab	13.33	a
Mg, L, -Mo	14.62	ab	1.33	abc	11.20	bcd
Mg, L, ME(F)	14.44	ab	1.26	bc	10.76	cde
-Mg, L, ME(F)	13.94	b	1.22	c	10.71	cde
Mg, L, -Fe (F)	14.62	ab	1.30	abc	10.65	cde
Mg, L, -Mn (F)	14.75	ab	1.35	abc	10.76	cde
Mg, L, -B (F)	14.31	ab	1.37	abc	11.87	bc
Mg, L, -Zn (F)	14.88	a	1.48	a	9.88	ef
Mg, L, -Mo(F)	14.38	ab	1.41	ab	9.41	f
Check A	13.88	b	1.35	abc	10.39	def
Check B	13.90	b	1.41	ab	9.44	f

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with same letters or set of letters are not significant at the 1% level.

application was observed from the comparisons of those treatments receiving lime to the treatments without it. The same was true when gypsum and lime containing treatments were compared, except the -Mg foliar treatment, which contained less caffeine than the gypsum treatment.

The decreasing order of the soil treatments was as follows: -Zn, check B, -B, check A, -Mg, complete, -Mo, -Fe, -Mn. In the sprays, the decreasing order was as follows: -Zn, -Mo, check B, -B, -Mn, check A, -Fe, complete, -Mg.

The highest values were obtained with the -Zn treatments in both cases. However, they were not significantly different from the check treatments. The -Zn spray treatment was significantly higher than the complete foliar treatment or the -Mg foliar treatment. No differences between the soil and the comparable foliar treatment was observed. The same was true of the FTE treatment.

Petroleum Ether Extract:-- The petroleium ether extract of the green coffee beans varied considerably (Table 5). Lime alone decreased the petroleum ether extract of the green coffee bean when it was compared to the complete soil treatment, or to the complete soil treatment without lime. Lime alone, when applied in the top soil, decreased the petroleum ether extract if compared to the complete spray treatment and lime. On the other hand, no difference was observed in the two methods of lime application. No effect of lime in the presence of FTE was obtained.

The omission of lime appeared to decrease or increase the petroleum ether extract depending on the omitted element in the presence of lime. The application of lime in the absence of zinc in the soil application increased the petroleum ether extract, while the omission of magnesium and all the minor elements resulted in a decrease. The same was true when zinc and molybdenum were omitted from the spray treatments.

Gypsum and lime did not show any difference in the presence of all the nutrients as a soil application. On the other hand, when the complete nutrients were supplied as a spray, there was a decrease in the petroleum ether extract resulting from the lime application. The same was true when all the nutrients (checks), iron, magnesium, manganese, zinc or molybdenum were omitted from the spray.

The following decreasing order in the soil applied nutrient treatments was observed: -Zn, -Mn, complete, -Mg, -Fe, -B, -Mo, check A, check B. In the foliar applications the decreasing order was as follows: -B, -Mn, complete, -Mg, -Fe, check A, -Zn, check B, - Mo.

The omission of zinc brought about an increase in petroleum ether extract when it was compared to the complete and incomplete soil treatments. The same was true when it was compared to the two check plots. The -Mn sil treatment was not significantly greater than the complete soil treatment, but it was significant over the two checks. The same was true of the complete and the -Mg soil treatment. The -B and -Mo soil treatments were only significant over the check plot to which lime was applied on top of the soil.

In the spray treatments, the -Mo treatment showed less petroleum ether extract than the complete, -Fe, -Mg, -Mn or -B treatments. The -B treatment contained more petroleum ether extract than the two checks and -Zn treatment. Also, -Mn, -Mg, or -Fe were significant over check B.

No difference between the soil and foliar complete treatments was observed. However, differences between soil and foliar applications were observed for some of the incomplete treatments. The -Zn soil applied treatment contained more petroleum ether extract than the foliar applied -Zn treatment. The same was true of the -Mn and -Mo treatments.

FTE did not show any difference when it was compared to the complete treatments, but contained more petroleum ether extract than the checks and the -Zn and -Mo spray treatments. On the other hand, the -B soil treatment contained more petroleum ether extract than the FTE treatment.

<u>Nutrient-element Composition</u>

<u>Nitrogen</u>:-- The nitrogen content was fairly uniform in the green coffee (Table 6). Only the -Zn spray treatment showed a significantly higher content of nitrogen as compared to the checks, complete soil treatment or -Mg spray treatment. No further differences due to treatments were observed in the nitrogen content of green coffee.

<u>Potassium</u>:-- The potassium content was affected by the application of the secondary and minor elements (Table 7). Lime alone reduced the potassium content significantly when it was applied in the top soil. Lime in the presence of magnesium and all the minor elements as soil application did not affect the potassium content. Lime in the presence of all the elements as spray contained less potassium than the complete soil treatment without lime. The same depression by lime occurred when molybdenum, manganese or boron were omitted from the soil application.

Gypsum did not affect the potassium content when it was compared to lime in the presence of all the nutrient elements. In the absence of molybdenum from the soil application, green coffee beans from gypsum treated plots contained more potassium than green coffee beans from lime treated plots.

The following decreasing order was observed in the potassium content as affected by the soil treatments: -Fe, -Mg, complete, -Zn, check A, check B, -B, -Mn, -Mo. In the spray treatments, the decreasing order was as

Table 6. --The Effects of Secondary and Minor Elements on Nitrogen Content of Green Coffee Beans[1].

Treatments	Nitrogen (%)	Rating
Mg, L, ME	2.23	b[2]
Mg, G, ME	2.28	ab
Mg, -L, ME	2.29	ab
-Mg, L, FTE	2.31	ab
-Mg, L, ME	2.26	ab
Mg, L, -Fe	2.28	ab
Mg, L, -Mn	2.26	ab
Mg, L, -B	2.34	ab
Mg, L, -Zn	2.34	ab
Mg, L, -Mo	2.34	ab
Mg, L, ME (F)	2.31	ab
-Mg, L, ME (F)	2.23	b
Mg, L, -Fe (F)	2.34	ab
Mg, L, -Mn (F)	2.36	ab
Mg, L, -B (F)	2.29	ab
Mg, L, -Zn (F)	2.38	a
Mg, L, -Mo (F)	2.30	ab
Check A	2.22	b
Check B	2.22	b

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with the same letter or set of letters are not significant at the 1% level.

Table 7.--The Effects of Secondary and Minor Elements on Potassium Content of Green Coffee Beans[1].

Treatments	Potassium (%)	Rating
Mg, L, ME	1.81	abcd[2]
Mg, G, ME	1.87	abc
Mg, -L, ME	1.87	ab
-Mg, L, FTE	1.86	abc
-Mg, L, ME	1.86	abcd
Mg, L, -Fe	1.87	abc
Mg, L, -Mn	1.68	cd
Mg, L, -B	1.68	cd
Mg, L, -Zn	1.76	bcd
Mg, L, -Mo	1.65	d
Mg, L, ME (F)	1.66	d
-Mg, L, ME (F)	1.84	abcd
Mg, L, -Fe (F)	1.95	a
Mg, L, -Mn (F)	1.80	abcd
Mg, L, -B (F)	1.73	bcd
Mg, L, -Zn (F)	1.81	abcd
Mg, L, -Mo (F)	1.74	bcd
Check A	1.71	bcd
Check B	1.69	cd

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with same letter or set of letters are not significant at 1% level.

follows: -Fe, -Mg, -Zn, -Mn, -Mo, -B, check A, check B, complete.

The omission of iron from the soil applied treatments did not affect the potassium content when it was compared to the complete soil treatment or to the checks. The same treatment showed a significantly higher potassium content than the -Mo soil treatment.

The only difference observed in the foliar treatments was obtained by the omission of iron in comparison to the complete foliar treatment, but not in comparison to the checks.

No differences between similar spray and soil applications were observed.

The FTE treatment did not affect the potassium content when it was compared to the complete soil treatment, but it contained a significantly higher potassium content than the complete spray treatment and the -Mo soil treatment.

Phosphorus:-- Lime alone or in the presence or absence of any one of the minor elements or magnesium did not affect the phosphorus content (Table 8).

The omission of magnesium from the foliar spray depressed the phosphorus content as compared to the check plots. No difference in the effects of comparable soil and foliar treatments was observed. FTE application depressed the phosphorus content when it was compared to the -B or -Mo

Table 8.--The Effects of Secondary and Minor Elements on Phosphorus Content of Green Coffee Beans[1].

Treatments	Phosphorus (%)	Rating
Mg, L, ME	0.135	abcd[2]
Mg, G, ME	0.126	cd
Mg, -L, ME	0.130	bcd
-Mg, L, FTE	0.129	bcd
-Mg, L, ME	0.132	abcd
Mg, L, -Fe	0.134	abcd
Mg, L, -Mn	0.133	abcd
Mg, L, -B	0.138	abc
Mg, L, -Zn	0.135	abcd
Mg, L, -Mo	0.136	abcd
Mg, L, ME (F)	0.127	cd
-Mg, L, ME (F)	0.124	d
Mg, L, -Fe (F)	0.140	abc
Mg, L, -Mn (F)	0.137	abcd
Mg, L, -B (F)	0.146	a
Mg, L, -Zn (F)	0.141	abc
Mg, L, -Mo (F)	0.142	ab
Check A	0.140	abc
Check B	0.140	abc

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with same letter or set of letters are not significant at the 1% level.

foliar treatments. The -B and -Mo spray treatments showed a greater accumulation of phosphorus than the complete spray treatment.

Calcium:-- There were no large differences in the calcium content of green coffee beans (Table 9). Lime alone or in the presence or absence of magnesium as any one of the minor elements did not affect the calcium content. Minor elements and magnesium did not affect the calcium content. No difference was observed in the comparison of foliar and soil treatments. The -Mg soil treatment showed a higher accumulation of calcium than the -Zn, -Mo, -Fe, or -B foliar treatments. The same was true with the -Mo soil treatment.

Magnesium:-- Lime in the absence of boron from the spray treatment tended to depress the magnesium content of the green coffee beans. No other differences were observed that could be attributed to lime. Lime in the absence of boron from the foliar application depressed the magnesium content when it was compared to the gypsum treatment (Table 10).

The following decreasing order in the soil treatment was observed: complete, check A, -Mo, -B, -Zn, -Mn, check A, -Mg, -Fe. The decreasing order in the foliar treatments was as follows: check A, -Mo, -Zn, -Mg, check B, -Mn, -Fe, complete, -B.

No differences in the soil treatments were observed. In the foliar treatments, the -B treatment showed a depression of magnesium when

Table 9.--The Effects of Secondary and Minor Elements on Calcium Content of Green Coffee Beans[1].

Treatments	Calcium (%)	Rating
Mg, L, ME	0.166	ab[2]
Mg, G, ME	0.170	ab
Mg, -L, ME	0.154	ab
-Mg, L, FTE	0.170	ab
-Mg, L, ME	0.186	a
Mg, L, -Fe	0.180	ab
Mg, L, -Mn	0.180	ab
Mg, L, -B	0.155	ab
Mg, L, -Zn	0.154	ab
Mg, L, -Mo	0.138	b
Mg, L, ME (F)	0.175	ab
-Mg, L, ME (F)	0.160	ab
Mg, L, -Fe (F)	0.136	b
Mg, L, -Mn (F)	0.162	ab
Mg, L, -B (F)	0.135	b
Mg, L, -Zn (F)	0.140	b
Mg, L, -Mo (F)	0.137	b
Check A	0.149	ab
Check B	0.152	ab

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with same letter or set of letters are not significant at the 1% level.

Table 10. --The Effects of Secondary and Minor Elements on Magnesium Content of Green Coffee Beans[1].

Treatments	Magnesium (%)	Rating
Mg, L, ME	0.226	a[2]
Mg, G, ME	0.220	ab
Mg, -L, ME	0.219	ab
-Mg, L, FTE	0.214	abc
-Mg, L, ME	0.210	abc
Mg, L, -Fe	0.210	abc
Mg, L, -Mn	0.212	abc
Mg, L, -B	0.220	ab
Mg, L, -Zn	0.220	ab
Mg, L, -Mo	0.223	a
Mg, L, ME (F)	0.195	bc
-Mg, L, ME (F)	0.212	abc
Mg, L, -Fe (F)	0.205	abc
Mg, L, -Mn (F)	0.210	abc
Mg, L, -B (F)	0.192	c
Mg, L, -Zn (F)	0.217	abc
Mg, L, -Mo (F)	0.219	ab
Check A	0.225	a
Check B	0.211	abc

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with the same letter or set of letters are not significant at the 1% level.

compared to check A and to the -Mo treatment. The complete foliar treatment contained less magnesium than check A.

In the comparison of the soil and similar foliar treatments, the only differences were observed in the complete and -B treatments, which showed a depression of magnesium.

Iron:-- No differences in the iron content was observed. The content varied from 31 ppm to 103 ppm.

Manganese:-- Lime alone did not affect the manganese content except in the absence of iron, manganese, zinc, boron, or molybdenum as foliar treatments, where the manganese content was increased. Lime and gypsum did not show any differences except when iron, manganese, boron, zinc or molybdenum were omitted from the foliar treatments. All the previous treatments showed a higher manganese content than the gypsum treatment. The same was true when lime and FTE were compared to the gypsum treatment (Table 11).

The following decreasing order was observed in the soil applications: -Mg, check A, -Zn, complete, -B, -Fe, -Mo, check B, -Mn. In the foliar applications the decreasing order was as follows: -Zn, -Mn, -B, -Fe, -Mo, complete, check A, check B.

There were no differences in the soil applied treatments. The -Zn, -Mn, -B, and -Fe foliar treatments showed a significantly higher accumulation

Table 11. --The Effect of Secondary and Minor Elements on Manganese Content of Green Coffee Beans[1].

Treatments	Manganese (Ppm)	Rating
Mg, L, ME	36.5	de[2]
Mg, G, ME	39.2	cde
Mg, -L, ME	43.2	bcde
-Mg, L, FTE	49.7	bc
-Mg, L, ME	42.3	bcde
Mg, L, -Fe	36.3	de
Mg, L, -Mn	34.0	e
Mg, L, -B	36.5	de
Mg, L, -Zn	36.6	de
Mg, L, -Mo	35.3	de
Mg, L, ME (F)	45.0	bcde
-Mg, L, ME (F)	47.6	bcd
Mg, L, -Fe (F)	61.0	a
Mg, L, -Mn (F)	62.0	a
Mg, L, -B (F)	61.7	a
Mg, L, -Zn (F)	62.2	a
Mg, L, -Mo (F)	52.0	ab
Check A	41.4	bcde
Check B	34.4	e

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with the same letter or set of letters are not significant at the 1% level.

of manganese than the complete foliar treatment and the checks. The -Mo and -Mg foliar treatments had a higher accumulation of manganese than check B (lime applied on top of the soil). In all cases, except in the complete treatments, the foliar spray showed a greater accumulation than the comparable soil applied treatments.

The FTE showed a greater accumulation of manganese than all the soil applied treatments and check B, but it was lower than the -Zn, -Mn, -B and -Fe foliar treatments.

Copper:-- The copper content was fairly uniform. There was no difference attributable to lime or gypsum. The foliar complete treatment tended to accumulate more copper than the checks and the -Fe, -Mn or -B foliar treatments. The same was true when it was compared to the -Mo and -Zn soil supplied treatments (Table 12).

Zinc:- The zinc content was very variable (Table 13). Applications of lime alone decreased the zinc content. The same was true when lime, in the absence of zinc or molybdenum, was applied to the soil. Gypsum did not produce any different effects than lime in the presence of the complete nutrient elements. However, it was significantly different than the checks (lime alone). The same significant differences of gypsum over lime were observed when lime was applied in the absence of iron or zinc from the spray application or in the absence of zinc or molybdenum from the soil application.

Table 12. --The Effects of Secondary and Minor Elements on Copper Content of Green Coffee Beans[1].

Treatments	Copper (Ppm)	Rating
Mg, L, ME	14.8	ab[2]
Mg, G, ME	15.6	ab
Mg, -L, ME	16.1	ab
-Mg, L, FTE	15.5	ab
-Mg, L, ME	15.2	ab
Mg, L, -Fe	16.6	ab
Mg, L, -Mn	16.4	ab
Mg, L, -B	15.6	ab
Mg, L, -Zn	14.6	b
Mg, L, -Mo	14.5	b
Mg, L, ME (F)	17.7	a
-Mg, L, ME (F)	15.9	ab
Mg, L, -Fe (F)	14.2	b
Mg, L, -Mn (F)	14.5	b
Mg, L, -B (F)	14.2	b
Mg, L, -Zn (F)	14.9	ab
Mg, L, -Mo (F)	14.9	ab
Check A	14.2	b
Check B	14.1	b

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with the same letter or set of letters are not significant at the 1% level.

Table 13. --The Effects of Secondary and Minor Elements on Zinc Content of Green Coffee Beans[1].

Treatments	Zinc (Ppm)	Rating
Mg, L, ME	15.0	a[2]
Mg, G, ME	15.0	a
Mg, -L, ME	13.0	abc
-Mg, L, FTE	13.6	ab
-Mg, L, ME	14.3	a
Mg, L, -Fe	14.0	a
Mg, L, -Mn	14.0	a
Mg, L, -B	11.6	abcde
Mg, L, -Zn	8.0	def
Mg, L, -Mo	7.6	ef
Mg, L, ME (F)	15.3	a
-Mg, L, ME (F)	12.0	abcd
Mg, L, -Fe (F)	9.3	bcdef
Mg, L, -Mn (F)	10.6	abcde
Mg, L, -B (F)	13.3	abc
Mg, L, -Zn (F)	9.3	bcdef
Mg, L, -Mo (F)	12.6	abc
Check A	6.0	f
Check B	8.9	cdef

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with the same letter or set of letters are not significant at the 1% level.

The following decreasing order from the soil treatments was observed: complete, -Mg, -Fe, -Mn, -B, check B, -Zn, -Mo, check A. In the spray treatments, the decreasing order was as follows: complete, -B, -Mo, -Mg, -Mn, -Fe, -Zn, check B, check A.

The complete soil treatment showed a higher accumulation of zinc than the checks, -Zn or -Mo soil treatments. The -Mg, -Fe or -Mn soil treatments had a significantly higher zinc content than the two checks. However, the -B soil treatment showed a significantly higher zinc content only to check A.

The complete spray treatments showed a significantly higher zinc content than the two checks, -Fe or -Zn foliar treatments. The -B and -Mo treatments of the same group contained more zinc than the checks.

The FTE treatment resulted in a higher zinc content than the checks, -Zn or -Mo soil treatment, but not different than the complete.

Boron:-- Lime alone mixed with the soil depressed the boron content compared to the gypsum treatment. The same was true of lime in the absence of boron from the soil application, and in the absence of iron, boron and magnesium from the spray application (Table 14). No further differences were observed in the boron content.

Molybdenum:-- Any apparent effect of lime on molybdenum accumulation was not visible from the results. The application of gypsum did not

Table 14.--The Effects of Secondary and Minor Elements on Boron Content of Green Coffee Beans[1].

Treatments	Boron (Ppm)	Rating
Mg, L, ME	8.75	ab[2]
Mg, G, ME	10.92	a
Mg, -L, ME	8.19	ab
-Mg, L, FTE	7.73	ab
-Mg, L, ME	8.26	ab
Mg, L, Fe	8.50	ab
Mg, L, -Mn	7.31	ab
Mg, L, -B	6.01	b
Mg, L, -Zn	9.43	ab
Mg, L, -Mo	8.38	ab
Mg, L, ME (F)	9.46	ab
-Mg, L, ME (F)	5.79	b
Mg, L, -Fe (F)	6.78	b
Mg, L, -Mn (F)	7.04	ab
Mg, L, -B (F)	6.37	b
Mg, L, -Zn (F)	8.02	ab
Mg, L, -Mo (F)	8.36	ab
Check A	6.31	b
Check B	7.28	ab

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with the same letter or set of letters are not significant at the 1% level.

show any effect in the presence of all the minor elements and magnesium, but in the absence of zinc, gypsum showed more accumulation of molybdenum than lime (Table 15).

The following decreasing order was observed in the soil treatments: -Mg, -Fe, -Mn, complete, -B, check A, -Zn, -Mo, check B. The decreasing order in the spray treatments was as follows: -Mn, complete, check A, -Mg, check B, -Fe, -Mo, -Zn.

The -Mg soil treatment contained more molybdenum than check B. There were no further differences in the soil treatments.

The spray treatments did not show any differences among themselves or when they were compared to similar soil treatments.

The FTE treatment showed no difference to the complete plots, but contained a significantly higher accumulation of molybdenum than the -Zn foliar treatment.

Aluminum:-- No apparent effect on aluminum by lime alone or in the presence or absence of the minor elements and magnesium was observed from the results. Gypsum did not show any difference from lime in the presence of all the minor elements and magnesium. However, it showed less aluminum content than lime in the absence of magnesium from the spray treatment. The same was true in the absence of boron and manganese from the soil treatments (Table 16).

Table 15. --The Effects of Secondary and Minor Elements on Molybdenum Content of Green Coffee Beans[1].

Treatments	Molybdenum (Ppm)	Rating
Mg, L, ME	1.23	abc[2]
Mg, G, ME	1.30	ab
Mg, -L, ME	1.15	abc
-Mg, L, FTE	1.39	ab
-Mg, L, ME	1.53	a
Mg, L, -Fe	1.34	ab
Mg, L, -Mn	1.26	abc
Mg, L, -B	1.17	abc
Mg, L, -Zn	1.03	abc
Mg, L, -Mo	0.83	abc
Mg, L, ME (F)	1.13	abc
-Mg, L, ME (F)	0.93	abc
Mg, L, -Fe (F)	0.76	bc
Mg, L, -Mn (F)	1.17	abc
Mg, L, -B (F)	0.78	bc
Mg, L, -Zn (F)	0.56	c
Mg, L, -Mo (F)	0.75	bc
Check A	1.12	abc
Check B	0.78	bc

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with the same letter or set of letters are not significant at the 1% level.

Table 16.--The Effects of Secondary and Minor Elements on Aluminum Content of Green Coffee Beans[1].

Treatments	Aluminum (Ppm)	Rating
Mg, L, ME	22.3	de[2]
Mg, G, ME	27.2	cde
Mg, -L, ME	41.3	abcde
-Mg, L, FTE	40.6	abcde
-Mg, L, ME	32.0	bcde
Mg, L, -Fe	41.8	abcde
Mg, L, -Mn	70.0	ab
Mg, L, -B	73.7	ab
Mg, L, -Zn	64.3	abcd
Mg, L, -Mo	35.6	bcde
Mg, L, ME (F)	66.5	abc
-Mg, L, ME (F)	79.0	a
Mg, L, -Fe (F)	58.8	abcde
Mg, L, -Mn (F)	17.3	e
Mg, L, -B (F)	30.4	cde
Mg, L, -Zn (F)	58.1	abcde
Mg, L, -Mo (F)	53.7	abcde
Check A	66.9	abc
Check B	48.9	abcde

[1]Adjusted means of six replications except check B, with twelve replications.

[2]Means with the same letter or set of letters are not significant at the 1% level.

The decreasing order in the soil treatments was as follows: -B, -Mn, check A, -Zn, check B, -Fe, -Mo, -Mg, complete. The decreasing order in the foliar treatments was as follows: -Mg, check A, complete, -Fe, -Mo, -Zn, check B, -B, -Mn.

The omission of boron and manganese from the soil application showed a higher aluminum content than the complete soil treatment. The omission of magnesium from the spray treatment showed a significantly higher aluminum content than the -B or -Mn spray treatments. The complete spray treatment contained more aluminum than the -Mn spray treatment.

The foliar complete treatment contained more aluminum than the soil applied complete treatment. The same was true of the -Mg treatment, but it was the contrary in the -B or -Mn treatments.

There was no difference in the aluminum content by the application of FTE.

Discussion

Organic components:-- The composition of coffee has interested many workers. The interest has centered on changes occurring during the processing (26, 33, 44, 54, 55, 56, 58).

Fruits and seeds, as pointed out by Loehwing (27), are relatively uniform. The results previously presented do not follow the above pattern.

In this work, not only the nutrient composition was affected by the secondary and minor elements treatments, but, also, all six organic components were influenced.

Although several workers have theorized on the relationship between the chemical composition of the green coffee bean and its mineral nutrition, such information has not been reported.

The results showed that all the elements studied affected the composition of green coffee beans either in a positive or negative way. All of the organic components studied were affected by the application of the nutrient treatments. Any possible explanation through plant metabolism, complicates the picture. A very good example is the results obtained for total sugar. The omission of boron from the soil application brought about the highest percentage of total sugar, while the omission of molybdenum from the foliar application brought about the lowest.

Boron is supposedly involved in the transportation of sugars through membranes, while molybdenum is involved in nitrogen utilization. If the plants were deficient in the two elements, the results would have been the reverse.

The results report only the influence on the percentage of various constituents and not the total content in the whole crop. The total content may not have been affected in a similar manner because of differences in yield.

DeGialluly (18) reported changes in cup quality of coffee as related to nutrition, but he did not study changes in the organic components. It appears that the two factors are closely related, but would require further study to demonstrate the relationship. The results presented accentuate the neef for that study.

Nutrient-element Constituents:-- The treatments, undoubtedly, have a marked influence on the accumulation of the different elements by the green coffee beans. The interrelationship of the different elements in the green beans has not been reported.

Most of all the relationship found in the results have been well established in cultivated crops through leaf analysis, but not in the fruits.

The nitrogen content of the green coffee is associated with boron nutrition of the plant. The potassium content was related negatively to lime application, especially with the omission of molybdenum, manganese or boron. The negative relation of lime and potassium has been established by soil and plant scientists.

Molybdenum and potassium were positively related, a fact not previously established.

A positive relation of magnesium nutrition and phosphorus content was established by the fact of a low accumulation of phosphorus in the -Mg spray treatment. This relationship has been already established in coffee through leaf analyses (41).

The calcium content was negatively related to magnesium nutrition while it was positively related to zinc, molybdenum, iron and boron spray application. The same positive relationship was seen with the molybdenum soil treatment. The negative relationship of magnesium and calcium has been well established by soil and plant scientists (39). It is more clearly seen in the magnesium analyses.

A positive relationship of boron nutrition and magnesium content of the green bean was clearly shown in the results. Also, a negative relationship between lime and manganese was clearly shown. With lime application, the pH may have increased causing a reduction in the manganese activity with a possible reduction in the absorption and accumulation by the plant. The relationship of pH and manganese is a well known fact in plant nutrition. The same negative relationship was observed between zinc, boron, or iron to manganese, a well known fact in plant nutrition.

Zinc accumulation was negatively related to lime, boron and molybdenum applications. The reduction of zinc by lime can be seen by the changes occurring in the pH of the soil. The same negative relationship in zinc accumulation was obtained by magnesium, iron and manganese. A positive relationship between boron and molybdenum was observed.

Lime was negatively related to boron accumulation, while there was a positive relationship by iron and magnesium. Magnesium was negatively related to molybdenum.

Boron, manganese and magnesium were negatively related to aluminum accumulation in the soil treatments, while magnesium was negatively related as a spray treatment.

Composition of Leaves

Nutrient-element Composition

Nitrogen, Phosphorus, Iron:-- No differences in the leaf-nitrogen were observed (Table 17). The same was true with the leaf-phosphorus and leaf-iron (Table 17).

Potassium:-- Lime alone did not affect the leaf-potassium, but in the absence of iron from the spray treatments the potassium content was increased. Gypsum did not show any effect when compared to lime treatments (Table 18).

The decreasing order of leaf-potassium as affected by soil applied nutrients was as follows: -Zn, check A, check B, -Mg, -Fe, -B, -Mn, -Mo, complete, -Mg, check A, check B. No differences were observed in either of the groups, but the foliar sprays showed a higher leaf-potassium than their respective comparable soil applied treatments. Only the complete foliar spray was highly significant over the complete soil application.

The FTE treatment contained less potassium than the -Fe or -Mn spray treatments.

Calcium:-- Lime application undoubtedly brought a higher calcium content since the lowest value of calcium was obtained with the omission of lime from the soil application (Treatment 3). Gypsum did not show any depression on leaf-calcium when compared to the complete treatment.

Table 17.--The Effects of Secondary and Minor Elements on Nitrogen, Phosphorus and Iron Content of the leaf.[1]

Treatments	Nitrogen (%)		Phosphorus (%)		Iron (Ppm)	
Mg, L, ME	3.05	a[2]	0.145	a[2]	115.0	a[2]
Mg, G, ME	3.14	a	0.153	a	101.2	a
Mg, -L, ME	3.24	a	0.152	a	107.2	a
-Mg, L, FTE	3.17	a	0.164	a	110.9	a
-Mg, L, ME	3.18	a	0.153	a	108.2	a
Mg, L, -Fe	3.17	a	0.141	a	103.4	a
Mg, L, -Mn	3.10	a	0.142	a	92.4	a
Mg, L, -B	3.10	a	0.139	a	91.1	a
Mg, L, -Zn	3.17	a	0.146	a	99.2	a
Mg, L, -Mo	3.06	a	0.140	a	91.8	a
Mg, L, ME (F)	3.15	a	0.142	a	116.8	a
-Mg, L, ME (F)	3.14	a	0.144	a	115.6	a
Mg, L, -Fe (F)	3.15	a	0.144	a	94.8	a
Mg, L, -Mn (F)	3.13	a	0.137	a	96.4	a
Mg, L, -B (F)	3.09	a	0.138	a	98.6	a
Mg, L, -Zn (F)	3.14	a	0.138	a	96.9	a
Mg, L, -Mo (F)	3.06	a	0.145	a	108.1	a
Check A	3.14	a	0.144	a	96.3	a
Check B	3.16	a	0.144	a	89.0	a

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with same letters or set of letters are not significant at the 1% level.

Table 18. --The Effects of Secondary and Minor Elements on Leaf-Potassium.[1]

Treatments	Potassium (%)	Rating
Mg, L, ME	1.34	e[2]
Mg, G, ME	1.67	abcde
Mg, -L, ME	1.58	bcde
-Mg, L, FTE	1.54	cde
-Mg, L, ME	1.70	abcde
Mg, L, -Fe	1.68	abcde
Mg, L, -Mn	1.57	bcde
Mg, L, -B	1.63	abcde
Mg, L, -Zn	1.84	abcde
Mg, L, -Mo	1.40	de
Mg, L, ME (F)	1.93	abcd
-Mg, L, ME (F)	1.89	abcde
Mg, L, -Fe (F)	2.16	a
Mg, L, -Mn (F)	2.14	ab
Mg, L, -B (F)	1.93	abcd
Mg, L, -Zn (F)	2.07	abc
Mg, L, -Mo (F)	1.94	abcd
Check A	1.83	abcde
Check B	1.78	abcde

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with the same letter or set of letters are not significant at the 1% level.

Lime in the absence of iron, zinc, manganese, boron or molybdenum from the foliar application brought a significantly higher quantity of leaf-calcium than the gypsum treatment. The same was true when all the elements (checks) or magnesium were omitted from the soil application (Table 19).

The decreasing order of leaf-calcium according to soil nutrient treatments was as follows: -Zn, check A, -Mg, check B, -Mo, complete, -Mn, -B, -Fe. The decreasing order in the foliar treatments was as follows: -Fe, check A, -Zn, -Mn, -B, check B, -Mo, complete, -Mg.

No differences were observed in leaf-calcium for the spray or soil applied nutrients or in the foliar versus the soil treatments. The application of FTE did not show any difference as compared to the complete treatment. However, when compared to the -Zn soil treatment and -Fe, -Zn or -Mn treatments, there was a depression of leaf-calcium due to FTE. Leaf calcium was also depressed when FTE was compared to lime alone (check A).

Magnesium:-- Lime alone depressed the leaf-magnesium but not significantly higher than the unlimed treatment. On the other hand, lime in the absence of iron and manganese or in the presence of all nutrients as foliar spray depressed the leaf-magnesium. Gypsum treated plots did not show any difference compared to lime treated plots in the complete soil

Table 19.--The Effects of Secondary and Minor Elements on Leaf-Calcium.[1]

Treatments	Calcium (%)	Rating
Mg, L, ME	.780	abc[2]
Mg, G, ME	.632	cd
Mg, -L, ME	.541	d
-Mg, L, FTE	.652	bcd
-Mg, L, ME	.817	ab
Mg, L, -Fe	.702	abc
Mg, L, -Mn	.750	abc
Mg, L, -B	.716	abc
Mg, L, -Zn	.855	a
Mg, L, -Mo	.787	abc
Mg, L, ME (F)	.802	ab
-Mg, L, ME (F)	.787	abc
Mg, L, -Fe (F)	.869	a
Mg, L, -Mn (F)	.826	a
Mg, L, -B (F)	.816	ab
Mg, L, -Zn (F)	.834	a
Mg, L, -Mo (F)	.803	ab
Check A	.835	a
Check B	.814	ab

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with the same letter or set of letters are not significant at the 1% level.

treatment. However, if compared to the complete spray treatment, there was a significantly higher leaf-magnesium in the gypsum treatment (Table 20).

The following decreasing order of magnesium content was obtained with the soil treatments: complete, -Mn, -Mo, -Fe, -B, -Zn, -Mg, check A, check B. The decreasing order in the foliar sprays was as follows: -Zn, -B, -Mg, check A, check B, -Mn, -Fe, complete.

The complete soil treatment brought more leaf-magnesium than the -Mg soil treatment and both checks. The complete foliar spray depressed the leaf-magnesium, as compared to the -Mo spray treatment. The soil treatments brought a higher leaf-magnesium than similar foliar treatments, but only the complete, -Fe or -Mn soil treatments were significantly higher than similar foliar treatments.

The FTE treated plants contained less leaf-magnesium than the complete soil treated plants, but was not significantly different than the rest of the treatments weither soil or foliar applied.

Manganese:-- Lime alone did not affect the leaf-manganese, but lime in the presence of FTE increased leaf-manganese. Leaf-manganese was significantly higher for the FTE treatment than for the balance of the treatments. The omission of manganese from the soil treatment showed significantly less leaf-manganese than the -Zn soil treatment (Table 21).

Table 20. --The Effects of Secondary and Minor Elements on Leaf-Magnesium.[1]

Treatments	Magnesium (%)	Rating
Mg, L, ME	0.527	a[2]
Mg, G, ME	0.449	abcd
Mg, -L, ME	0.474	abc
-Mg, L, FTE	0.413	bcde
-Mg, L, ME	0.403	bcde
Mg, L, -Fe	0.466	abc
Mg, L, -Mn	0.495	ab
Mg, L, -B	0.443	abcd
Mg, L, -Zn	0.435	abcd
Mg, L, -Mo	0.484	abc
Mg, L, ME (F)	0.316	e
-Mg, L, ME (F)	0.393	bcde
Mg, L, -Fe (F)	0.352	de
Mg, L, -Mn (F)	0.359	de
Mg, L, -B (F)	0.401	bcde
Mg, L, -Zn (F)	0.380	cde
Mg, L, -Mo (F)	0.440	abcd
Check A	0.392	bcde
Check B	0.379	cde

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with the same letter or set of letters are not significant at the 1% level.

Table 21. --The Effects of Secondary and Minor Elements on Leaf-Manganese.[1]

Treatments	Manganese (Ppm)	Rating
Mg, L, ME	252.6	bc[2]
Mg, G, ME	314.4	bc
Mg, -L, ME	308.5	bc
-Mg, L, FTE	435.6	a
-Mg, L, ME	285.6	bc
Mg, L, -Fe	243.8	bc
Mg, L, -Mn	196.6	c
Mg, L, -B	237.9	bc
Mg, L, -Zn	320.5	bc
Mg, L, -Mo	256.3	bc
Mg, L, ME (F)	256.9	bc
-Mg, L, ME (F)	260.6	bc
Mg, L, -Fe (F)	273.3	bc
Mg, L, -Mn (F)	229.5	bc
Mg, L, -B (F)	289.2	bc
Mg, L, -Zn (F)	270.0	bc
Mg, L, -Mo (F)	299.6	bc
Check A	277.2	bc
Check B	255.6	bc

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with the same letter or set of letters are not significant at the 1% level.

Copper:-- The leaf-copper was not affected by lime application, but was depressed by the application of gypsum (Table 22). On the other hand, the omission of zinc from the spray application increased significantly the leaf-copper content.

Boron:-- Lime alone depressed leaf-boron. The same was true of lime in the absence of boron, manganese, magnesium or iron from the foliar spray and in the absence of boron or zinc from the soil application (Table 23).

The gypsum treatment showed an increase in leaf-boron if compared to lime alone or lime in the absence of molybdenum, zinc or boron from the soil treatments.

The decreasing order in leaf-boron as affected by the soil treatment was as follows: -Mg, complete, -Fe, -Mn, -Mo, -Zn, -B, check B, check A. The decreasing order for the spray treatment was as follows: -Mo, -Zn, complete, -Fe, -Mg, -Mn, check B, check A, -B.

The omission of boron either in the spray or soil treatment resulted in less leaf-boron. The omission of magnesium from the soil application brought a significantly higher leaf-boron than the omission of all the elements, molybdenum, zinc or boron from the soil application. The application of the complete soil treatment brought a significantly higher leaf-boron than the checks, -Mo, -Zn, or -B soil treatments.

No differences were observed for the foliar spray treatments. They

Table 22. --The Effects of Secondary and Minor Elements on Leaf-Copper.[1]

Treatments	Copper (Ppm)	Rating
Mg, L, ME	13.3	bc[2]
Mg, G, ME	11.9	c
Mg, -L, ME	13.6	abc
-Mg, L, FTE	13.2	bc
-Mg, L, ME	15.0	ab
Mg, L, -Fe	15.4	ab
Mg, L, -Mn	15.4	ab
Mg, L, -B	13.3	bc
Mg, L, -Zn	15.5	ab
Mg, L, -Mo	13.4	bc
Mg, L, ME (F)	12.6	bc
-Mg, L, ME (F)	13.4	bc
Mg, L, -Fe (F)	12.7	bc
Mg, L, -Mn (F)	13.4	bc
Mg, L, -B (F)	13.6	abc
Mg, L, -Zn (F)	16.3	a
Mg, L, -Mo (F)	14.9	ab
Check A	14.8	ab
Check B	14.8	ab

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with the same letter or set of letters are not significant at the 1% level.

Table 23.--The Effects of Secondary and Minor Elements on Leaf-Boron.[1]

Treatments	Boron (Ppm)	Rating
Mg, L, ME	112.1	ab[2]
Mg, G, ME	119.6	a
Mg, -L, ME	107.8	abc
-Mg, L, FTE	111.8	ab
-Mg, L, ME	112.6	ab
Mg, L, -Fe	110.1	abc
Mg, L, -Mn	95.6	abcd
Mg, L, -B	72.8	d
Mg, L, -Zn	79.7	d
Mg, L, -Mo	83.0	cd
Mg, L, ME (F)	83.2	cd
-Mg, L, ME (F)	74.2	d
Mg, L, -Fe (F)	79.7	d
Mg, L, -Mn (F)	72.7	d
Mg, L, -B (F)	67.0	d
Mg, L, -Zn (F)	87.6	bcd
Mg, L, -Mo (F)	92.2	abcd
Check A	68.0	d
Check B	67.0	d

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with the same letter or set of letters are not significant at the 1% level.

contained less leaf-boron than the respective similar soil treatments with the exception of the -Mo treatments. The complete, -Mg or -Fe soil treatments were significantly higher than the similar spray treatments.

The FTE treatment proved to be a good supplier of boron giving the fourth highest leaf-boron value and being as good as the complete soil treatment.

Zinc:-- Lime alone did not affect the leaf-zinc. It increased leaf-zinc in the complete foliar spray and in the absence of iron, manganese, boron or molybdenum from the foliar treatment. Gypsum did not affect the zinc content when compared to lime in the presence of all the elements as soil application (Table 24). Lime in the presence of all elements as a spray or in the absence of iron, manganese, boron or molybdenum contained more leaf-zinc than gypsum.

The decreasing order of the soil treatments was as follows: complete, -Mg, -Fe, -Mn, check A, -B, check B, -Mo, -Zn. The foliar treatments showed the following decreasing order: -Fe, complete, -Mn, -B, -Mo, -Mg, check A, check B, -Zn (Table 24).

No differences in the soil treatments were observed, but in the foliar treatments, all treatments except -Mg were significantly higher than the checks. The omission of zinc from the spray significantly depressed the leaf-zinc. The foliar treatments except the -Zn, were better than the corresponding soil treatments.

Table 24. --The Effects of Secondary and Minor Elements on Leaf Zinc.[1]

Treatments	Zinc (Ppm)	Rating
Mg, L, ME	18.5	cde[2]
Mg, G, ME	17.3	de
Mg, -L, ME	17.2	de
-Mg, L, FTE	18.5	cde
-Mg, L, ME	17.3	de
Mg, L, -Fe	16.8	de
Mg, L, -Mn	16.4	de
Mg, L, -B	15.3	de
Mg, L, -Zn	14.0	e
Mg, L, -Mo	14.4	e
Mg, L, ME (F)	28.7	ab
-Mg, L, ME (F)	20.1	cd
Mg, L, -Fe (F)	29.3	a
Mg, L, -Mn (F)	26.0	ab
Mg, L, -B (F)	23.3	bc
Mg, L, -Zn (F)	14.0	e
Mg, L, -Mo (F)	22.8	bc
Check A	16.0	de
Check B	15.2	de

[1]Adjusted means of six replications except check B with twelve replications.

[2]Means with the same letter or set of letters are not significant at the 1% level.

The FTE treatment was not different from the soil treatments. However, the complete, -Fe or -Mn foliar treatments contained more leaf-zinc than the FTE treatment (Table 24).

Molybdenum:-- The omission of lime in the presence of magnesium and all the minor elements depressed leaf-molybdenum. Lime and gypsum did not show any difference in the presence of magnesium and all the minor elements as soil applications. The same was true when iron was omitted in the presence of lime or FTE was applied with lime. However, lime in the presence of magnesium and all the minor elements as foliar applications contained significantly higher leaf-zinc than the gypsum treatment. The same was true of the checks and the rest of the incomplete treatment either soil or foliar applied.

The decreasing order of leaf-molybdenum as affected by soil treatments was as follows: check A, -Mn, -Zn, check B, -Mg, -Mo, -B, complete, -Fe. The decreasing order for the spray treatments was as follows: -Mn, -Fe, complete, -B, check A, -Zn, check B, -Mo, -Mg.

The complete soil and -Fe treatments depressed leaf-molybdenum when compared to the rest of the soil treatments and to the checks.

No differences in the spray treatments were observed. The foliar treatments brought about more leaf-molybdenum than the corresponding soil treatments, but the increase was not significant.

Table 25.--The Effects of Secondary and Minor Elements on Leaf-Molybdenum.[1]

Treatments	Molybdenum (Ppm)	Rating
Mg, L, ME	3.52	bc[2]
Mg, G, ME	2.65	cd
Mg, -L, ME	2.22	d
-Mg, L, FTE	2.55	cd
-Mg, L, ME	4.01	ab
Mg, L, -Fe	3.48	bc
Mg, L, -Mn	4.15	ab
Mg, L, -B	3.86	ab
Mg, L, -Zn	4.10	ab
Mg, L, -Mo	3.92	ab
Mg, L, ME (F)	4.60	ab
-Mg, L, ME (F)	4.04	ab
Mg, L, -Fe (F)	4.66	ab
Mg, L, -Mn (F)	4.92	a
Mg, L, -B (F)	4.56	ab
Mg, L, -Zn (F)	4.33	ab
Mg, L, -Mo (F)	4.08	ab
Check A	4.38	ab
Check B	4.09	ab

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with the same letter or set of letters are not significant at the 1% level.

Table 26.--The Effects of Secondary and Minor Elements on Leaf-Aluminum.[1]

Treatments	Aluminum (Ppm)	Rating
Mg, L, ME	86.1	cdef[2]
Mg, G, ME	162.1	abcd
Mg, -L, ME	173.4	abc
-Mg, L, FTE	137.0	abcdef
-Mg, L, ME	101.4	bcdef
Mg, L, -Fe	165.6	abcd
Mg, L, -Mn	180.0	abc
Mg, L, -B	111.6	bcdef
Mg, L, -Zn	137.9	abcdef
Mg, L, -Mo	72.7	def
Mg, L, ME (F)	222.6	a
-Mg, L, ME (F)	152.1	abcde
Mg, L, -Fe (F)	54.4	f
Mg, L, -Mn (F)	56.9	ef
Mg, L, -B (F)	94.4	bcdef
Mg, L, -Zn (F)	123.6	bcdef
Mg, L, -Mo (F)	180.5	abc
Check A	189.4	ab
Check B	71.6	def

[1] Adjusted means of six replications except check B with twelve replications.

[2] Means with the same letter or set of letters are not significant at the 1% level.

The FTE treatment proved not to be a good source of molybdenum since only the -Fe and complete soil treatments were not significant to it. The rest of the treatments either foliar or soil supplied were significantly higher than the FTE treatment.

Aluminum:-- Lime spread in the soil depressed leaf-aluminum. The same was true when lime was applied in the absence of molybdenum from the soil application, and manganese or iron from the foliar application. Gypsum did not affect leaf-aluminum as compared to lime except when iron or manganese were omitted from the spray treatments.

The following decreasing order in the soil treatments was observed: check A, -Mn, -Fe, -Zn, -B, -Mg, complete, -Mo, check B. The decreasing order in the spray treatments was as follows: complete, check A, -Mo, -Mg, -Zn, -B, check B, -Mn, -Fe.

The complete and -Mo soil treatments depressed leaf-aluminum when they were compared to the -Mn soil treatment and check A. The same depression was seen when manganese or iron were omitted from the spray if they were compared to the complete foliar treatment. The omission of molybdenum from the foliar treatment brought a significantly higher leaf-aluminum than check B, -Fe and -Mn foliar treatments. The omission of magnesium from the foliar treatments brought about a significantly higher leaf-aluminum than the -Fe foliar treatment.

The complete, -Mo and -Mg treatments contained more leaf-aluminum than the corresponding soil treatments. The contrary was observed for the -Fe, -Mn, -B or -Zn treatments.

The FTE did not show any influence on leaf-aluminum.

Discussion

The leaf analyses showed a very clear relationship between the different elements. Some of these relationships, like that of magnesium to potassium, calcium to potassium, calcium to magnesium, iron to manganese, have been established already, not only for coffee but for many of the cultivated crops.

The leaf-potassium varied from a low value of 1.34% to a highest value of 2.16%. These values, according to several workers (28, 35, 41) would be low. Although potassium levels appeared to be low, the plants were performing without apparent shortage of potassium supply.

The omission of a particular element from the soil or foliar application did not always bring about the lowest value of the element omitted. This suggested that a number of inter-relationships can be established. Some of the inter-relationships have been reviewed by Müller (41) and Cibes and Samuels (13). Only those relationships not previously established for coffee will be discussed.

Molybdenum nutrition has not been studied in coffee and in many other plants. The leaf analyses suggested a positive relationship of liming with leaf-molybdenum. The solubility and availability of molybdenum increases as the pH rises, a fact already established by soil scientists.

Boron was depressed by lime application. The changes in pH may reduce the solubility of boron and may become a major factor in a low boron supply. The coffee plant appears to accumulate more boron than many other crops (Müller, 41). Values over 100 ppm were found in the analysis of the samples used in the study. Such levels of boron are considered toxic to many crops.

Leaf-aluminum was depressed by lime application especially when iron and manganese were omitted from the foliar spray. Aluminum is more soluble than iron and manganese at a low pH. When lime was applied to the soil, the absorption of aluminum should be more affected than both the manganese and iron. This suggests that the soil was not deficient in iron and manganese and any possible shortage would be due to competition of other elements.

The comparison of the leaf-nutrients to the green coffee nutrients suggests that the seed composition may not be affected in the same way as the leaf composition. This suggests that there is a greater selectivity of the nutrients by the seed than by the leaf.

General Discussion

The results previously presented prove that the secondary and minor elements not only affected the nutrient composition of the green coffee beans and the leaves, but also the organic composition of green coffee. The leaf and seed samples used in this study were from the first year after the treatments were started. Production was not at its maximum and no symptoms of malnutrition were yet visible. Moreover, the inter-relationship of the nutrients may change, due to changes in availability in the soil.

Although coffee is considered to be uniform and breed true to type, yet the material shows a lack of uniformity in growth and general appearance in the same plots. Such differences, if due to seed reproduction, could have a marked influence on the results obtained. In the future, experiments should be conducted with asexually propagated material under more controlled conditions. Further studies are needed to determine the effect of mineral nutrition and coffee composition on cup quality.

SUMMARY AND CONCLUSIONS

Green coffee beans (Coffea arabica var. bourbon) obtained from an experiment located in the Coffee Substation in Puerto Rico were analyzed for total, reducing and non-reducing sugars, caffeine, protein, petroleum ether extract and nutrient constituents. Leaf samples were analyzed for different nutrient content.

Experimental evidence obtained by the chemical analyses of green coffee beans points to the fact of a possible relation of composition and nutrition of the coffee plant. The following conclusive results were observed:

1. Lime did not affect the total, reducing and non-reducing sugar content of green coffee beans, but it markedly increased the total sugar content in the absence of boron as foliar spray. Lime in the absence of molybdenum depressed the total sugar content in green coffee beans. The omission of boron in the presence of magnesium and lime increased the percent total and non-reducing sugar. Molybdenum in the presence of lime and magnesium depressed the total and non-reducing sugar content.

2. The reducing sugar content was decreased by liming in the absence of any one of the elements tested. The omission of boron, manganese, magnesium or iron as soil application in the presence of lime

depressed the reducing sugar content while molybdenum increased it. The complete foliar and the -B treatment depressed the reducing sugar.

3. FTE application increased the reducing sugar of green coffee beans.

4. The omission of all the minor elements and magnesium depressed the percent protein content of green coffee beans while the omission of zinc increased the protein content.

5. Zinc as soil application brought about an increase in petroleum ether extract while as foliar spray, depressed it. Lime depressed the petroleum ether extract. The omission of molybdenum from the spray treatment in the presence of lime depressed the petroleum ether extract.

6. The omission of zinc increased the caffeine content, while the omission of magnesium brought about a depression.

7. The different nutrient components were affected by the absence of the nutrient treatments. Different inter-relationships were visible, among them:

(a) The coffee nitrogen was depressed by the omission of magnesium from the foliar treatment, while it was increased by the omission of boron.

(b) Lime reduced the potassium content of green coffee either alone or in the absence of boron, manganese or molybdenum from the soil applications. The potassium content was increased by the absence of iron from the spray in the presence of lime, while it was depressed in the absence of molybdenum.

(c) Phosphorus was increased by the omission of boron and molybdenum, and depressed by the omission of magnesium as a foliar spray.

(d) The calcium content was increased by the omission of magnesium from the soil application.

(e) Lime depressed the magnesium content in the coffee bean, while the omission of boron from the foliar spray depressed it.

(f) No differences in the iron content were observed although the values varied from 31 ppm to 103 ppm.

(g) Lime increased the manganese content in the absence of iron, manganese, zinc, boron or molybdenum from the foliar application, while lime in the absence of all the nutrient elements applied, depressed the manganese content.

(h) FTE proved to be a good supplier of manganese to the coffee plant.

(i) Foliar applied complete treatment increased the copper content of green coffee.

(j) Lime application reduced the accumulation of zinc in green coffee beans. The omission of zinc and molybdenum decreased the zinc content.

(k) The omission of boron reduced boron accumulation in the bean.

(l) The omission of magnesium from the soil application increased the molybdenum content of green coffee beans.

(m) The omission of boron and manganese from the soil application increased the aluminum content of green coffee beans, while it was depressed by the same treatments as foliar application. Foliar applied treatments may increase or decrease the aluminum content depending on the nutrients present in the spray.

Leaf analyses proved to be avery valuable tool in determining the response of the coffee plant to differential treatments. Several nutrient interrelationships were observed from the analyses. The leaf samples were the first taken after the initial treatments were started and not too many conclusions can be drawn. Some trends were apparent from the results:

1. No differences in nitrogen, phosphorus and iron content were observed from the results.

2. Lime did not affect the leaf potassium except in the absence of iron from the spray treatment. In fact, there was an increase in leaf potassium in the absence of iron.

3. Lime application, whether alone or in the absence of the different elements studied, increased leaf-calcium.

4. Leaf-magnesium was depressed by lime application. Application of magnesium to the soil brought about an increase of leaf-magnesium.

5. FTE increased the leaf-manganese content of coffee leaves. The omission of manganese from the soil application in the presence of lime decreased leaf-manganese.

6. Coffee plants accumulate relatively high quantities of boron. Leaf-boron was greatly depressed by lime application. The omission of boron either from the soil or spray application depressed the boron content in the leaf.

7. Leaf copper was increased by the omission of zinc from the spray application.

8. Lime and the omission of zinc depressed the sinz content of the leaves. Foliar application of zinc containing sprays increased the zinc content of the leaves. The omission of magnesium from the spray increased the leaf-zinc.

9. Leaf-molybdenum was positively related to lime applications.

10. Lime alone depressed leaf-aluminum. The omission of

iron and manganese in the presence of lime from the spray depressed the leaf-aluminum. The omission of iron and manganese from the soil application increased leaf-aluminum.

More research is needed to determine the relationship between mineral nutrition and coffee cup quality and any changes occurring in the composition. Further studies on the use of leaf analysis for diagnostic purposes and responses to fertilizer treatments are a must in coffee research. Those studies should be conducted under controlled conditions and using asexually propagated material. Yield response should be determined since that is the main interest of the coffee producers.

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Table A1.--Organic Components in Green Coffee Beans.

Sample	Total Sugars (%)	Reducing Sugars (%)	Non-reducing Sugars (%)	Proteins (%)	Caffeine (%)	Petroleum Ether Extract
XA1	7.75	.75	7.00	13.56	1.29	11.4
XB1	8.00	.88	7.12	14.06	1.32	11.8
YA1	8.75	.75	8.00	14.19	1.35	10.8
YB1	8.00	.88	7.12	14.00	1.29	12.7
ZA1	7.75	1.25	6.50	14.12	1.38	11.8
ZB1	7.75	.88	6.87	13.56	1.34	11.9
XA2	8.00	.75	7.25	13.81	1.47	13.1
XB2	7.50	1.12	6.38	14.19	1.29	13.1
YA2	7.75	.88	6.88	15.19	1.38	11.9
YB2	7.75	.88	6.88	13.62	1.39	12.1
ZA2	7.25	.62	6.63	14.88	1.57	11.5
ZB2	8.00	1.25	6.75	13.88	1.47	11.6
XA3	7.50	.88	6.62	13.69	1.19	10.8
XB3	7.50	1.00	6.50	14.50	1.40	13.4
YA3	7.75	1.12	6.62	15.56	1.24	11.2
YB3	7.25	1.12	7.12	13.62	1.48	12.2
ZA3	7.50	1.00	6.50	14.50	1.34	11.3
ZB3	8.25	1.00	7.25	14.19	1.47	11.1
XA4	8.25	1.12	7.13	14.75	1.32	11.8
XB4	7.75	1.25	6.50	14.38	1.38	11.4
YA4	7.50	1.12	6.38	14.56	1.15	10.3
YB4	7.75	1.25	6.50	14.38	1.38	11.4
ZA4	8.50	1.00	7.50	14.50	1.35	10.7
ZB4	8.25	1.12	7.12	13.88	1.43	11.7
XA5	7.75	.25	7.50	13.62	1.29	11.4
XB5	8.50	.12	8.38	14.38	1.32	12.7
YA5	8.75	0	8.75	14.38	1.32	9.9
YB5	8.50	0	8.50	14.19	1.44	12.3
ZA5	9.00	0	9.00	14.38	1.43	11.5
ZB5	7.50	0	7.50	13.62	1.22	12.4
XA6	7.75	0	7.75	14.38	1.35	11.6
XB6	6.75	0	6.75	14.19	1.28	11.5
YA6	7.50	0	7.50	14.75	1.17	11.0
YB6	8.25	0	8.25	14.25	1.24	10.5
ZA6	7.75	0	7.75	13.88	1.37	12.0
ZB6	7.00	0	7.00	14.12	1.37	12.9
XA7	7.75	0	7.75	14.06	1.13	10.8
XB7	9.25	0	9.25	14.88	1.22	13.7
YA7	7.75	0	7.75	13.92	1.08	12.6
YB7	6.25	.12	6.13	14.06	1.32	12.4

Table A1 Cont'd.--Organic Components in Green Coffee Beans.

Sample	Total Sugars (%)	Reducing Sugars (%)	Non-reducing Sugars (%)	Proteins (%)	Caffeine (%)	Petroleum Ether Extract
ZA7	9.50	.25	9.25	14.19	1.36	12.3
ZB7	7.75	.50	7.25	13.88	1.37	11.4
XA8	9.00	.25	8.75	13.81	1.35	11.4
XB8	8.25	.38	7.87	14.38	1.42	12.0
YA8	8.25	.25	8.00	15.00	1.40	11.7
YB8	10.00	.25	9.75	15.31	1.30	11.3
ZA8	9.00	.50	8.50	14.81	1.53	11.6
ZB8	10.00	.25	9.75	14.62	1.40	10.5
XA9	7.25	.88	6.38	14.56	1.27	13.2
XB9	7.75	.38	7.38	14.69	1.55	13.6
YA9	7.50	.38	7.12	14.62	1.52	12.0
YB9	7.50	.25	7.25	14.56	1.28	13.8
ZA9	7.75	.75	7.00	14.62	1.50	13.8
ZB9	7.50	.25	7.25	14.56	1.50	13.5
XA10	6.50	.50	6.00	13.88	1.40	10.5
XB10	8.00	.25	7.75	14.25	1.40	11.7
YA10	6.75	.50	6.25	14.81	1.28	11.6
YB10	8.00	1.12	6.88	15.19	1.23	12.8
ZA10	6.50	.88	5.62	15.00	1.40	10.4
ZB10	8.50	.25	8.25	14.44	1.27	10.2
XA11	8.50	.88	7.62	14.50	1.35	10.6
XB11	7.50	.88	6.62	14.69	1.45	9.1
YA11	6.25	.38	5.87	14.56	1.23	10.2
YB11	7.75	.62	7.13	14.75	1.30	11.0
ZA11	7.75	.75	7.00	14.44	1.55	10.1
ZB11	8.50	1.00	7.50	13.88	1.23	11.3
XA12	6.00	.75	5.25	14.69	1.37	11.5
XB12	7.25	.88	6.37	14.81	1.32	11.1
YA12	7.75	.62	7.13	14.19	1.26	11.6
YB12	7.50	.50	7.00	13.50	1.10	12.1
ZA12	6.50	.62	5.88	13.56	1.50	9.5
ZB12	7.00	.88	6.12	13.31	1.32	11.1
XA13	7.50	0	7.50	13.69	1.25	11.1
XB13	8.88	0	8.88	14.38	1.13	11.6
YA13	6.88	0	6.88	14.94	1.27	9.7
YB13	7.50	.38	7.12	14.69	1.40	9.9
ZA13	8.50	0	8.50	13.88	1.10	10.6
ZB13	8.50	0	8.50	14.94	1.44	11.7
XA14	7.00	.25	6.75	13.37	1.20	10.9
XB14	7.00	.50	6.50	13.56	1.25	11.0

Table 1A Cont'd. --Organic Components in Green Coffee Beans.

Sample	Total Sugars (%)	Reducing Sugars (%)	Non-reducing Sugars (%)	Proteins (%)	Caffeine (%)	Petroleum Ether Extract
YA14	7.50	.75	6.75	14.25	1.25	10.6
YB14	7.50	.75	6.75	13.50	1.11	10.5
ZA14	7.50	.50	7.00	14.38	1.25	9.2
ZB14	7.00	.62	7.38	14.31	1.25	11.2
XA15	9.00	.75	8.25	14.25	1.25	10.0
XB15	9.25	.50	8.75	14.50	1.20	10.0
YA15	7.50	.38	7.12	14.56	1.50	10.9
YB15	7.50	.38	7.12	13.06	1.50	10.6
ZA15	7.00	1.00	6.00	16.38	1.20	11.6
ZB15	7.00	.75	6.25	14.88	1.32	10.8
XA16	9.25	.62	8.63	14.75	1.32	10.5
XB16	9.00	.75	8.25	14.44	1.23	11.2
YA16	7.50	.50	7.00	15.00	1.35	10.4
YB16	7.88	.62	7.26	14.12	1.32	11.0
ZA16	7.25	.75	6.50	14.56	1.55	10.9
ZB16	6.50	.50	6.00	15.50	1.32	10.5
XA17	8.88	.25	8.63	14.50	1.18	11.2
XB17	7.25	0	7.25	15.75	1.45	12.0
YA17	6.88	0	6.88	14.25	1.25	12.1
YB17	4.88	.12	4.76	14.06	1.50	11.8
ZA17	5.25	.12	5.13	13.75	1.45	12.4
ZB17	6.88	0	6.88	13.56	1.45	11.6
XA18	6.88	.50	6.38	14.38	1.50	11.1
XB18	7.50	.38	7.12	15.19	1.59	9.1
YA18	7.00	.38	6.62	15.31	1.45	9.3
YB18	6.88	.50	6.38	14.94	1.30	10.5
ZA18	5.00	.62	4.38	15.12	1.57	9.3
ZB18	7.20	.25	7.00	14.81	1.45	9.9
XA19	6.00	.25	5.75	14.50	1.30	9.2
XB19	5.25	.62	4.63	13.81	1.50	10.0
YA19	5.25	.62	4.63	14.56	1.37	9.2
YB19	4.88	.25	4.63	15.00	1.45	9.6
ZA19	5.25	.25	5.00	13.56	1.33	9.1
ZB19	4.50	.88	3.62	14.81	1.55	8.9
XA20	5.25	.75	4.50	13.75	1.60	9.6
XB20	7.25	.50	6.75	13.38	1.54	9.4
YA20	5.88	.25	5.63	14.44	1.45	8.9
YB20	7.88	.62	7.25	13.81	1.45	10.4
ZA20	4.88	.75	4.12	14.31	1.60	10.0
ZB20	5.88	.88	5.00	13.00	1.45	10.1

Table A 2.--Nutrient-Elements Content of Green Coffee Beans.

Sample	N %	K %	P %	Ca %	Mg %	Mn Ppm	Fe Ppm	Cu Ppm	B Ppm	Zn Ppm	Mo Ppm	Al Ppm
XA1	2.17	1.67	.128	.16	.22	34	28	14.7	6.6	15	1.00	12
XB1	2.25	1.88	.136	.16	.22	34	34	14.7	11.5	15	1.30	19
YA1	2.27	1.74	.136	.19	.23	34	37	15.6	7.8	17	1.20	26
YB1	2.24	2.03	.136	.19	.22	38	28	15.6	7.8	15	1.80	44
ZA1	2.26	1.84	.136	.16	.22	38	31	13.7	7.8	17	1.20	19
ZB1	2.17	1.74	.136	.13	.22	34	28	14.7	10.5	11	.90	30
XA2	2.21	2.00	.128	.19	.23	46	31	14.7	7.8	15	1.80	23
XB2	2.27	1.93	.128	.16	.22	38	34	15.6	8.5	15	1.30	49
YA2	2.43	1.86	.120	.16	.22	38	34	16.6	13.5	19	1.00	19
YB2	2.18	2.01	.128	.16	.23	34	25	14.7	16.8	13	1.40	23
ZA2	2.38	1.83	.128	.19	.21	38	41	16.6	12.5	15	1.40	30
ZB2	2.22	1.60	.128	.16	.21	42	34	15.6	6.6	13	.90	19
XA3	2.19	2.13	.142	.19	.21	46	62	16.6	7.8	15	1.20	40
XB3	2.32	1.98	.120	.13	.22	30	28	15.6	7.8	11	1.60	35
YA3	2.49	1.81	.128	.13	.23	46	44	17.6	12.5	15	.50	23
YB3	2.18	1.82	.128	.16	.22	38	31	16.6	5.6	13	1.00	40
ZA3	2.32	1.76	.136	.16	.22	42	37	16.6	7.8	13	1.40	76
ZB3	2.27	1.81	.128	.16	.22	46	31	13.7	6.6	11	1.30	26
XA4	2.36	1.84	.128	.22	.21	67	37	17.6	9.5	17	1.90	19
XB4	2.30	1.83	.128	.13	.21	30	37	13.7	6.6	13	1.20	30
YA4	2.33	2.00	.136	.16	.22	50	25	15.6	6.6	11	1.20	72
YB4	2.30	1.77	.136	.19	.21	54	41	16.6	8.5	15	1.80	76
ZA4	2.32	1.90	.120	.19	.21	50	47	16.6	8.5	15	1.30	23
ZB4	2.22	1.84	.128	.13	.22	50	18	13.7	5.6	11	1.00	26
XA5	2.18	1.72	.136	.19	.21	38	28	15.6	6.6	15	1.90	40
XB5	2.30	1.71	.120	.16	.21	34	28	13.7	6.6	11	1.20	40
YA5	2.30	2.02	.138	.22	.21	50	37	15.6	9.5	17	2.40	19
YB5	2.27	1.86	.142	.19	.22	38	44	15.6	9.5	15	1.30	19
ZA5	2.30	1.88	.128	.16	.20	38	78	14.7	11.5	13	1.20	62
ZB5	2.18	1.88	.128	.19	.21	46	34	15.6	5.6	15	1.20	23
XA6	2.30	1.93	.136	.16	.21	34	62	17.6	9.5	13	1.60	72
XB6	2.27	1.88	.136	.16	.22	38	44	16.6	7.8	15	1.20	49
YA6	2.36	1.73	.128	.19	.23	34	118	17.6	12.5	15	1.26	62
YB6	2.28	1.92	.142	.19	.23	38	34	16.6	7.8	13	1.60	19
ZA6	2.22	1.84	.136	.19	.22	42	41	16.6	7.8	15	1.60	44
ZB6	2.26	1.87	.128	.19	.22	30	37	14.7	6.6	13	1.60	23
XA7	2.25	1.78	.136	.19	.22	38	25	15.6	6.6	13	1.20	66
XB7	2.38	1.78	.136	.19	.23	26	31	17.6	8.5	13	1.60	102
YA7	2.23	1.62	.136	.16	.22	30	28	15.6	6.6	13	1.30	62
YB7	2.25	1.60	.128	.16	.22	30	31	16.6	6.6	13	.90	30

Table A 2 Cont'd. --Nutrient-Elements Content of Green Coffee Beans.

Sample	N %	K %	P %	Ca %	Mg %	Mn Ppm	Fe Ppm	Cu Ppm	B Ppm	Zn Ppm	Mo Ppm	Al Ppm
ZA7	2.27	1.74	.128	.19	.22	34	118	17.6	8.5	17	1.60	66
ZB7	2.22	1.57	.136	.19	.23	42	37	16.6	6.6	15	1.00	86
XA8	2.21	1.62	.136	.19	.21	34	34	15.6	6.6	17	1.80	30
XB8	2.30	1.73	.128	.16	.21	30	31	17.6	6.6	13	1.60	120
YA8	2.40	1.71	.142	.16	.22	34	37	15.6	5.6	11	1.30	76
YB8	2.45	1.60	.136	.10	.25	30	22	15.6	4.0	3	6.05	96
ZA8	2.37	1.75	.136	.16	.21	42	31	15.6	5.6	9	.90	49
ZB8	2.34	1.67	.151	.16	.22	42	50	13.7	6.6	7	1.40	72
XA9	2.33	1.66	.136	.16	.22	42	28	13.7	6.6	5	.50	44
XB9	2.35	1.88	.151	.16	.22	42	75	14.7	15.7	7	1.20	72
YA9	2.34	1.84	.128	.22	.22	34	53	16.6	10.5	15	1.90	58
YB9	2.33	1.76	.128	.13	.23	34	56	13.7	7.8	5	.50	54
ZA9	2.34	1.68	.136	.13	.22	38	37	15.6	7.8	9	1.30	125
ZB9	2.33	1.78	.128	.13	.21	38	46	13.7	7.8	7	.70	40
XA10	2.22	1.71	.136	.13	.23	38	41	12.9	6.6	7	.60	15
XB10	2.28	1.73	.142	.16	.23	34	34	14.7	10.5	7	1.20	44
YA10	2.37	1.61	.136	.13	.23	34	37	14.7	8.5	7	.50	30
YB10	2.43	1.72	.136	.13	.22	30	34	14.7	6.6	5	.70	44
ZA10	2.40	1.72	.136	.16	.22	42	111	17.6	10.5	13	1.20	96
ZB10	2.31	1.39	.128	.13	.21	34	53	12.9	7.8	7	.90	15
XA11	2.32	1.83	.142	.13	.21	42	31	12.9	5.6	3	.90	15
XB11	2.35	1.82	.142	.16	.25	71	442	19.5	10.5	13	1.20	245
YA11	2.33	1.76	.142	.19	.22	34	53	12.9	6.6	7	1.80	30
YB11	2.36	1.73	.142	.16	.23	34	37	13.7	4.8	5	1.00	30
ZA11	2.31	1.61	.136	.13	.23	38	28	12.9	5.6	5	.70	19
ZB11	2.22	1.52	.136	.13	.21	34	31	12.0	4.8	3	1.00	40
XA12	2.35	1.66	.120	.24	/18	34	31	14.7	4.8	13	1.20	35
XB12	2.37	1.74	.136	.16	.22	30	31	15.6	6.6	11	.70	44
YA12	2.27	1.72	.136	.16	.22	34	41	15.6	4.8	7	.60	49
YB12	2.16	1.58	.120	.16	.22	30	20	16.6	4.0	11	.90	44
ZA12	2.17	1.76	.142	.13	.23	30	53	12.0	5.6	5	1.00	62
ZB12	2.13	1.62	.136	.16	.23	38	41	15.6	6.6	5	.50	92
XA13	2.19	1.63	.120	.16	.22	50	31	15.6	7.8	15	1.20	23
XB13	2.30	1.63	.120	.19	.18	42	41	18.5	14.6	17	1.30	40
YA13	2.39	1.76	.142	.19	.21	42	66	16.6	9.5	15	1.00	96
YB13	2.35	1.76	.112	.16	.22	34	111	17.6	5.6	15	.70	49
ZA13	2.22	1.56	.120	.19	.17	50	66	19.5	8.5	19	1.30	136
ZB13	2.39	1.63	.151	.16	.18	54	44	17.6	10.5	11	1.20	54
XA14	2.14	1.63	.142	.13	.20	58	37	14.7	6.6	12	.70	82
XB14	2.17	1.94	.112	.16	.21	38	22	14.7	5.6	13	.70	40

Table 2 A Cont'd. --Nutrient-Elements Content of Green Coffee Beans.

Sample	N %	K %	P %	Ca %	Mg %	Mn Ppm	Fe Ppm	Cu Ppm	B Ppm	Zn Ppm	Mo Ppm	Al Ppm
YA14	2.28	1.74	.112	.13	.21	42	25	14.7	4.8	11	.60	58
YB14	2.16	1.88	.120	.19	.22	38	72	18.5	5.6	13	1.20	170
ZA14	2.30	2.00	.120	.22	.21	50	41	18.5	6.6	17	1.80	62
ZB14	2.29	1.86	.142	.13	.21	63	37	14.7	5.6	7	.50	66
XA15	2.28	2.00	.136	.13	.20	58	31	14.7	5.6	9	.50	66
XB15	2.32	1.83	.142	.10	.22	67	59	14.7	7.8	7	.20	96
YA15	2.33	2.00	.142	.16	.20	58	50	14.7	9.5	11	1.00	82
YB15	2.09	1.94	.136	.13	.20	58	34	12.9	4.8	9	.70	19
ZA15	2.62	1.98	.142	.13	.21	63	44	13.7	6.6	9	.60	44
ZB15	2.38	1.93	.142	.16	.20	58	50	14.7	7.8	11	1.40	23
XA16	2.36	1.62	.136	.16	.20	58	31	12.9	7.8	7	.90	15
XB16	2.31	1.93	.136	.13	.21	63	31	12.9	5.6	7	.90	19
YA16	2.48	1.87	.136	.22	.22	67	47	16.6	7.8	15	1.90	19
YB16	2.26	1.65	.120	.13	.20	58	34	14.7	5.6	7	.70	19
ZA16	2.33	1.77	.151	.19	.22	67	44	16.6	8.5	17	1.80	23
ZB16	2.48	1.92	.142	.13	.21	63	25	13.7	7.8	11	.60	15
XA17	2.35	1.73	.151	.13	.21	63	37	12.9	6.6	13	.90	19
XB17	2.52	1.74	.151	.16	.20	58	37	14.7	7.8	19	1.30	15
YA17	2.28	1.87	.142	.13	.21	63	28	13.7	5.6	13	.40	19
YB17	2.25	1.68	.136	.10	.21	63	34	12.9	5.6	9	.50	26
ZA17	2.20	1.67	.142	.16	.21	63	20	13.7	6.6	13	1.20	23
ZB17	2.17	1.76	.151	.13	.22	67	41	16.6	6.6	13	.50	62
XA18	2.30	1.77	.142	.13	.22	67	28	14.7	7.8	11	.40	35
XB18	2.43	1.99	.142	.13	.21	63	31	15.6	8.5	11	.60	49
YA18	2.45	1.73	.151	.16	.22	67	41	17.6	9.5	9	.90	58
YB18	2.39	1.88	.142	.13	.22	67	47	15.6	8.5	7	.60	86
ZA18	2.42	1.72	.120	.16	.21	42	50	16.6	5.6	9	.50	76
ZB18	2.37	1.77	.151	.13	.22	67	41	12.9	8.5	9	.50	30
XA19	2.32	1.74	.142	.19	.22	67	47	15.6	8.5	17	1.80	58
XB19	2.21	1.84	.142	.13	.22	67	34	12.9	7.8	11	.50	23
YA19	2.33	1.73	.136	.13	.20	58	88	15.6	8.5	11	.60	72
YB19	2.40	1.72	.142	.10	.22	46	34	13.7	11.5	11	.10	62
ZA19	2.17	1.58	.142	.13	.22	34	95	15.6	7.8	13	.60	49
ZB19	2.37	1.87	.151	.13	.23	38	47	14.7	8.5	13	.90	54
XA20	2.20	1.64	.142	.16	.21	34	37	15.6	17.9	11	1.20	30
XB20	2.14	1.62	.151	.13	.18	34	31	4.3	8.5	9	.70	40
YA20	2.31	1.78	.142	.16	.20	30	31	16.6	8.5	11	1.00	30
YB20	2.21	1.63	.151	.10	.21	30	31	14.7	6.6	5	.10	66
ZA20	2.29	1.77	.136	.13	.21	50	34	13.7	5.6	9	.70	44
ZB20	2.08	1.72	.142	.13	.22	42	85	14.7	7.8	11	.60	54

Table A 3. --Nutrient-Element Content of Coffee Leaves.

Sample	N %	K %	P %	Ca %	Mg %	Mn Ppm	Fe Ppm	Cu Ppm	B Ppm	Zn Ppm	Mo Ppm	Al Ppm
XA1	2.95	1.10	.168	1.06	.57	326	104	12.9	119.0	22	5.4	54
XB1	2.89	1.15	.142	.80	.55	225	108	16.6	128.0	19	3.8	120
YA1	3.16	1.92	.142	.70	.42	140	111	12.0	95.8	15	2.4	72
YB1	3.07	1.10	.136	.77	.59	302	108	11.0	109.8	17	4.0	58
ZA1	3.08	1.72	.128	.67	.55	252	104	11.0	102.8	19	2.8	130
ZB1	3.10	1.10	.159	.70	.52	252	121	13.7	132.6	19	2.8	96
XA2	3.00	1.62	.184	.73	.45	354	104	6.8	132.6	17	2.4	200
XB2	2.90	1.55	.159	.70	.43	332	66	12.9	132.6	17	2.8	170
YA2	3.39	1.63	.128	.46	.42	215	104	12.9	132.6	15	2.1	108
YB2	3.12	2.20	.159	.67	.35	360	102	13.7	132.6	19	2.8	190
ZA2	3.20	1.50	.142	.58	.45	291	108	13.7	132.6	19	2.6	66
ZB2	3.18	1.52	.151	.64	.55	348	102	12.9	77.4	17	3.0	200
XA3	3.15	1.26	.151	.58	.53	416	88	12.0	132.6	15	2.4	148
XB3	3.23	1.55	.142	.46	.40	206	95	11.0	132.6	22	9.8	130
YA3	3.16	1.45	.159	.67	.50	320	137	15.6	97.4	19	3.0	300
YB3	3.12	2.00	.142	.64	.42	258	98	13.7	79.8	19	2.8	213
ZA3	3.18	1.52	.168	.52	.46	354	121	12.0	120.4	15	1.8	86
ZB3	3.36	1.63	.151	.49	.50	274	91	14.7	85.6	13	1.3	154
XA4	2.94	1.04	.202	.73	.46	608	75	12.9	132.6	17	2.2	58
XB4	3.17	1.52	.168	.67	.42	251	78	11.0	112.8	19	2.8	102
YA4	3.12	1.62	.175	.58	.42	408	193	17.6	120.4	26	2.1	165
YB4	3.28	1.52	.151	.73	.45	416	111	11.0	90.0	15	3.0	154
ZA4	3.32	1.92	.151	.70	.40	354	98	10.2	103.8	15	1.8	144
ZB4	3.32	1.92	.151	.70	.43	582	104	17.6	120.4	19	3.0	195
XA5	3.22	1.45	.136	1.06	.38	263	104	14.7	94.3	19	5.6	82
XB5	2.91	1.90	.128	.70	.34	215	95	12.9	88.5	15	2.8	160
YA5	3.36	1.72	.159	.87	.57	390	91	14.7	115.8	17	4.2	82
YB5	3.10	2.20	.159	.70	.40	258	98	16.6	132.6	17	3.6	96
ZA5	3.30	1.20	.151	.80	.45	258	121	13.7	132.6	17	3.8	136
ZB5	3.13	1.72	.193	.77	.37	308	130	16.6	119.0	19	4.2	72
XA6	3.10	1.65	.151	.67	.48	332	104	13.7	115.8	17	3.2	184
XB6	3.28	1.50	.128	.61	.52	236	98	13.7	132.6	22	3.4	86
YA6	3.23	1.72	.136	.73	.43	193	72	13.7	95.8	13	3.0	114
YB6	3.05	1.90	.142	.73	.40	280	130	18.5	128.0	19	4.2	195
ZA6	3.21	1.72	.151	.70	.45	231	108	16.6	112.8	15	3.6	176
ZB6	3.13	1.63	.142	.67	.45	171	114	15.6	81.2	15	3.6	252
XA7	3.15	1.20	.159	.70	.55	263	114	16.6	85.6	17	3.8	184
XB7	3.22	1.15	.136	.70	.50	129	95	13.7	132.6	17	3.8	86
YA7	3.11	2.00	.136	.83	.43	198	88	12.9	78.3	15	4.0	200
YB7	2.97	2.00	.151	.83	.42	193	82	17.6	75.3	15	4.2	213

Table A 3 Cont'd--Nutrient-Element Content of Coffee Leaves

Sample	N %	K %	P %	Ca %	Mg %	Mn Ppm	Fe Ppm	Cu Ppm	B Ppm	Zn Ppm	Mo Ppm	Al Ppm
ZA7	3.12	1.84	.120	.70	.46	162	88	14.7	87.0	17	4.0	176
ZB7	2.94	1.26	.151	.87	.62	231	91	17.6	105.5	17	5.0	213
XA8	3.14	2.00	.175	.67	.42	241	85	12.9	58.0	17	3.8	76
XB8	2.99	1.23	.136	.70	.48	204	108	16.6	81.2	17	4.4	86
YA8	3.09	1.50	.136	.67	.52	231	88	13.7	63.8	11	3.4	130
YB8	3.19	1.84	.136	.70	.43	204	98	13.7	63.8	15	4.2	142
ZA8	3.30	1.65	.136	.55	.37	198	104	12.0	45.5	15	3.0	125
ZB8	2.84	1.72	.120	.91	.48	337	178	10.2	106.8	17	4.6	108
XA9	3.05	1.84	.142	.94	.35	545	102	13.7	87.0	13	4.0	114
XB9	3.22	1.52	.159	.83	.46	308	95	17.6	102.6	17	4.2	114
YA9	3.22	2.05	.168	.91	.35	239	108	12.9	78.3	11	3.0	44
YB9	3.12	1.50	.142	.94	.59	297	91	16.6	44.3	15	4.6	175
ZA9	3.12	2.14	.142	.80	.40	308	118	91.3	87.0	13	3.4	328
ZB9	3.19	1.92	.128	.73	.45	263	78	12.9	78.3	15	4.2	62
XA10	2.84	1.20	.159	.87	.37	416	88	12.9	102.0	13	4.0	30
XB10	3.02	1.45	.128	.87	.50	231	98	12.8	78.3	15	4.6	40
YA10	3.21	1.75	.159	.80	.45	280	95	14.7	71.0	13	3.6	82
YB10	3.04	1.65	.128	.73	.45	167	88	10.2	82.6	11	3.2	40
ZA10	3.09	.82	.142	.70	.59	247	91	14.7	81.2	15	3.8	66
ZB10	3.14	1.52	.128	.70	.43	204	85	13.7	72.5	19	4.4	184
XA11	3.13	2.40	.142	.77	.30	384	104	15.6	59.6	15	4.2	200
XB11	3.09	1.84	.136	.80	.33	231	78	14.7	58.0	19	4.8	86
YA11	3.09	1.75	.159	1.06	.35	225	102	13.7	76.8	15	4.6	148
YB11	2.92	1.52	.159	1.02	.42	320	108	14.7	78.3	15	4.6	220
ZA11	3.19	1.45	.142	.70	.46	225	98	12.9	47.0	13	3.4	307
ZB11	3.33	2.00	.128	.73	.37	297	88	15.6	78.3	19	4.6	165
XA12	3.22	1.30	.120	.87	.31	225	95	15.6	52.4	13	4.4	265
XB12	3.09	1.90	.142	.80	.38	343	102	13.7	39.8	17	3.8	245
YA12	3.25	1.84	.151	.73	.38	193	102	19.5	52.4	22	4.2	279
YB12	3.43	1.63	.136	.77	.40	151	88	12.9	48.2	13	3.4	130
ZA12	3.03	1.75	.136	.83	.47	193	75	13.7	59.6	17	5.0	120
ZB12	3.06	1.63	.151	.77	.43	269	78	13.7	72.5	13	3.4	220
XA13	3.16	2.65	.142	.80	.29	343	108	12.9	68.0	24	4.4	232
XB13	3.21	1.75	.151	.70	.31	274	121	12.0	82.6	30	4.0	160
YA13	3.18	1.75	.142	1.02	.37	269	127	13.7	75.3	34	6.5	176
YB13	3.00	2.14	.142	.80	.34	193	95	12.9	79.8	26	3.6	300
ZA13	3.03	1.52	.136	.80	.28	258	130	12.9	106.8	30	5.0	232
ZB13	3.31	1.72	.142	.67	.34	198	127	11.0	69.6	28	4.2	232
XA14	3.17	1.20	.142	.80	.43	231	143	13.7	93.0	24	5.0	165
XB14	3.18	2.20	.142	.87	.38	231	114	11.0	72.5	26	4.2	195
YA14	3.38	1.90	.136	.64	.31	252	108	12.0	72.5	19	3.8	82
YB14	2.98	2.25	.159	.83	.40	209	88	13.7	63.8	17	3.8	206
ZA14	3.27	2.05	.136	.73	.38	274	124	15.6	59.6	15	2.8	170
ZB14	3.01	1.65	.151	.87	.48	378	111	15.6	74.0	19	4.8	86

Table A 3 Cont'd--Nutrient-Element Content of Coffee Leaves

Sample	N %	K %	P %	Ca %	Mg %	Mn Ppm	Fe Ppm	Cu Ppm	B Ppm	Zn Ppm	Mo Ppm	Al Ppm
XA15	3.21	2.32	.136	.70	.31	326	114	15.6	65.2	24	4.0	92
XB15	3.25	2.20	.151	.94	.38	332	114	13.7	84.0	26	4.8	96
YA15	3.34	1.92	.142	.80	.30	220	102	12.0	66.6	30	5.4	30
YB15	3.03	2.86	.168	.94	.28	225	95	11.0	103.8	34	4.8	30
ZA15	3.26	1.84	.142	.87	.38	247	78	12.9	81.2	24	4.6	35
ZB15	2.98	1.75	.128	.87	.37	297	88	11.0	82.6	38	4.6	40
XA16	3.29	1.84	.120	.77	.34	198	111	13.7	63.8	28	4.4	76
XB16	3.08	2.58	.142	.87	.35	236	88	13.7	82.6	28	5.8	26
YA16	3.01	2.32	.142	.83	.37	198	98	15.6	72.5	30	5.6	66
YB16	3.08	1.55	.151	.91	.46	269	124	12.9	65.2	22	5.2	58
ZA16	3.33	2.45	.128	.61	.31	182	85	14.7	63.8	22	3.4	44
ZB16	3.05	2.05	.142	.87	.37	302	104	12.9	81.2	26	5.2	54
XA17	2.92	1.63	.136	.80	.48	366	98	12.9	63.8	22	4.2	102
XB17	3.35	2.25	.136	.64	.35	193	111	12.9	53.8	36	4.2	82
YA17	3.05	2.40	.142	.91	.31	215	85	12.0	68.0	22	4.6	66
YB17	3.06	2.40	.142	.80	.40	332	104	13.7	72.5	17	4.4	44
ZA17	3.08	1.75	.136	.87	.42	366	85	15.6	51.0	19	4.6	154
ZB17	3.02	1.15	.136	.98	.55	274	111	14.7	79.8	24	5.2	120
XA18	2.92	1.55	.136	1.06	.52	332	114	15.6	132.6	15	5.8	108
XB18	3.04	2.65	.136	.67	.29	198	121	13.7	72.5	13	3.8	82
YA18	3.34	1.90	.142	.83	.43	231	88	17.6	75.3	15	4.8	130
YB18	3.25	2.14	.142	.91	.35	286	72	15.6	79.8	13	4.2	125
ZA18	3.29	2.00	.136	.73	.37	291	85	17.6	69.6	13	3.6	130
ZB18	3.05	2.18	.136	.73	.31	274	95	14.7	85.6	15	4.2	165
XA19	2.98	2.14	.151	.83	.43	378	140	15.6	90.0	24	4.0	265
XB19	3.07	1.65	.151	.80	.42	291	114	21.9	90.0	24	3.8	120
YA19	3.26	2.05	.136	.77	.34	274	121	14.7	84.0	24	4.2	136
YB19	2.98	2.00	.159	.73	.40	428	104	16.6	120.4	19	3.6	184
ZA19	3.01	1.52	.136	.73	.60	182	95	13.7	97.4	24	3.8	252
ZB19	3.03	2.05	.142	.91	.43	231	82	14.7	87.0	22	5.0	136
XA20	2.88	1.55	.136	1.02	.50	308	72	15.6	93.0	15	4.6	114
XB20	3.17	1.72	.168	.77	.28	252	104	13.7	75.3	17	4.4	82
YA20	3.19	2.20	.142	.87	.29	182	75	11.0	71.0	13	4.2	44
YB20	3.19	2.14	.159	.73	.30	167	118	14.7	87.0	13	2.6	96
ZA20	3.17	1.75	.142	.83	.40	464	102	25.1	87.0	15	4.6	136
ZB20	3.17	2.00	.151	.80	.42	326	95	12.9	112.8	15	4.2	49