NUTRIENT DISTRIBUTION IN BANANA AND ITS RELATIONSHIP TO LEAF SPOT DISEASE

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INTRODUCTION

The edible banana is by far the most important fruit crop cultivated between latitudes 30° North and 30° South of the equator. The crop is adapted to sub-tropical and tropical regions of the world which have an average annual temperature of about 20°C and a well distributed rainfall of around 2032 mm. (80 in.) per year (Wardlaw, 1961). Simmonds (1966) indicated that bananas thrive in soils of diverse origin, physical structure and chemical composition as long as the soils have good internal drainage.

In 1966, Simmonds stated that the world production of bananas for 1955 was about 18 million metric (20 million imperial) tons, and of this figure, Africa produced 50 percent, while Central plus South America and Asia produced 25 percent each. Bananas are grown for either "Local" consumption or for "Trade". Of the total world production, about 15 percent entered various international markets. The popular 'Gros Michel' banana accounted for 63 percent of the trade, 'Dwarf Cavendish' accounted for 23 percent and the remaining 11 percent was made up of other varieties. Central and South America contributed 70 percent of the trade bananas, with Ecuador alone producing 20 percent. The biggest domestic producer is Uganda in Africa with an output amounting to nearly 15 percent of total world production.

The State of Hawaii produces about 3.6 thousand metric tons annually for domestic consumption (Doue, 1968).

Frieberg (1965) reported that approximately 3.6 million metric tons of bananas were marketed in 1961, which represented some 40 percent of the volume of twelve leading fruits sold on the world market. Statistics for the international trade in 1966 showed that the total world export of bananas was nearly 4.9 million metric tons or 5.4 million imperial tons (U.S.D.A., 1968). Central and South America accounted for approximately 84 percent of the 1966 exports. Evidently, this part of the world continues to dominate the international trade on bananas.

Fluctuations in banana yields may be due to soil, climatic and management conditions as well as pests and diseases. The two most important banana diseases, Panama (Vascular Wilt) and Leaf Spot (Sigatoka and Black Leaf Streak), cause serious reductions in banana yield and quality. Wardlaw (1961) noted that Panama disease was first recorded in Honolulu in 1904 by Higgins. Leaf Spot (Sigatoka) disease was reported for the first time in Java in 1902 by Zimmermann. By 1912, the disease became very severe in the Sigatoka valley of Fiji (hence the name of the disease). Leaf Spot disease was found in the Hawaiian Islands as early as 1958 (Trujillo and Goto, 1963), and this has been identified by Meredith and Lawrence (1969) as Black Leaf Streak disease. Both Panama and Leaf Spot

diseases have since spread to nearly all regions where bananas are cultivated.

Studies on leaf analysis of bananas have been conducted mainly on cultivars of 'Cavendish' bananas but the 'Gros Michel' banana has not received the same attention, even though it is one of the most important bananas in world trade. Furthermore, information could not be found regarding the effect of Leaf Spot disease on the distribution of nutrients in bananas. The present investigation was therefore developed to accomplish two objectives:

1. To investigate the distribution of several nutrient elements in the 'Gros Michel' banana grown under Hawaiian conditions.

2. To study the effect of Leaf Spot disease on the uptake and distribution of several nutrient elements in the 'Gros Michel' banana in Hawaii.

LITERATURE REVIEW

A Brief History of Bananas

Simmonds (1966) reported that bananas originated in South-East Asia, with Eastern Malaysia and the Philippine Islands being regarded as the primary place of origin. Several authors have associated bananas with the early history of man's agricultural development. Frieberg (1965) stated that many writers considered the banana to be one of man's earliest food crops. He pointed out that Sauer in 1952 strongly supported the idea that since South-East Asia was the origin of the first organized agricultural communities, bananas might also have been one of the first cultivated crops. Frieberg further observed that Reynolds in 1951 reported that the banana was first recorded in India between 600 and 500 B.C. and that other reporters mentioned that bananas appeared in Chinese references for the first time in about 200 A.D. The historical consensus of opinion seems to be that the banana spread from Eastern Malaysia to India, then to the Island of Madagascar (Malagasy Republic) in about 500 A.D. It reached the Mediterranean in 650 A.D. and Polynesia in 1000 A.D. The banana supposedly reached East Africa from India and it was spread to West Africa. Portuguese traders carried the plant from West Africa to the Canary Islands in the early 15th century. From the Canary Islands, the crop finally reached the New World

in 1516 via Santo Domingo. Thus, before the 19th century, the banana was a food item and it was transported by adventurous traders. Its dispersal also followed the migration of various races. It was only in the latter part of the 19th century that certain tropical countries began to cultivate bananas extensively for export to balance their international trade. The greatest banana trade developed in tropical America to satisfy markets in Europe and North America. Today, Asia, the Pacific, Australia and Africa have become actively involved in the banana industry for trade or domestic purposes.

Taxonomic Position of Bananas

The taxonomic position of bananas has been developed by several workers. The summaries of Champion (1963) and Simmonds (1966) are presented in Tables 1 and 2 which explain the position of the genus Musa in the monocotyledonous plants and the conspectus of bananas within the genus, respectively.

Table 1. The Position of the Genus Musa in the Monocotyledons (After Champion, 1963)

Order	Family	Sub-Family	Genus	Remarks
		Musoideae	Musa Ensete	Edible bananas
Scitaminales	Musaceae	Strelitzoideae	Ravenala Strelitzia	Ornamentals
		Heliconioideae	Heliconia	

The families Lowiaceae (orchids), Zingiberaceae (spices), Marantaceae (arrowroot) and Cannaceae (ornamentals) also belong to the order Scitaminales. In accordance with the International Code of Botanical Nomenclature (Lanjouw et al., 1966), there is provision for 'section' in plant nomenclature (Division II, Article 4). Simmond's distinction of edible from non-edible bananas within the genus Musa by grouping them into sections is thus a convenient procedure. Cultivars in the section Australimusa (Table 2) are known to have erect fruit bunches and a pink juice. They are grown mainly for their fiber. The edible bananas are mainly cultivars of the Eumusa section and members of this section have drooping or horizontal bunches with milky or watery juice. The Eumusa section is geographically the most widely distributed in the genus Musa. Simmonds (1966) and other banana specialists agree that edible bananas originated from the two wild species Musa acuminata Colla and Musa balbisiana Colla, which both fall in the section Eumusa.

Leaf Spot Disease and Its Economic Importance

Leaf Spot Disease

Leaf Spot disease of bananas may be caused by the fungus Mycosphaerella musicola Leach (conidial stage, Cercospora musae Zimm.) or by M. fijiensis (unpublished). Simmonds (1966) states that Leaf Spot disease has remained specific to

Table 2. Conspectus of the Bananas
(After Simmonds, 1966)

Genus	Basic Chromosome Number	Section	No. of Species	Uses[1/]
Ensete	9	-	7- 8	Fiber, vegetable
	10	Australimusa	5- 6	Fiber, fruit
	10	Callimusa	5- 6	Ornamental
Musa	11	Eumusa	9-10	Fruit, fiber, vegetable
	11	Rhodochlamys	5- 6	Ornamental

[1/] Important uses are underlined.

bananas since its discovery. Unlike Panama disease, which is caused by the soil fungus Fusarium oxysporum var. cubense, both forms of Leaf Spot are air-borne and the spores infect banana leaves.

Although Trujillo and Goto (1963) reported the occurrence of Leaf Spot (Sigatoka) disease in the Hawaiian Islands, Meredith and Lawrence (1969) stated that "Surveys of bananas in the Hawaiian Islands failed to reveal typical symptoms of Sigatoka disease and its causal fungus, Mycosphaerella musicola Leach." Instead, the disease symptoms are those of Black Leaf Streak which is a form of Leaf Spot disease first reported in Fiji in 1963 by Rhodes (Rhodes, 1964; Leach, 1964) and is caused by the fungus Mycosphaerella fijiensis. The disease is widespread in Hawaii and is sometimes very severe. The authors stated that valid publications of the names M. fijiensis and M. musicola have yet to be provided. Plate 1 shows symptoms of the second streak-stage of Black Leaf Streak on the lower surface of a leaf and Plate 2 shows streaks and spots on the upper leaf surface of a severely diseased plant.

Economic Importance

Calpouzos (1955) discussed the economic significance of Leaf Spot (Sigatoka) disease. He pointed out that the banana industry greatly influenced the economic activity of the producing

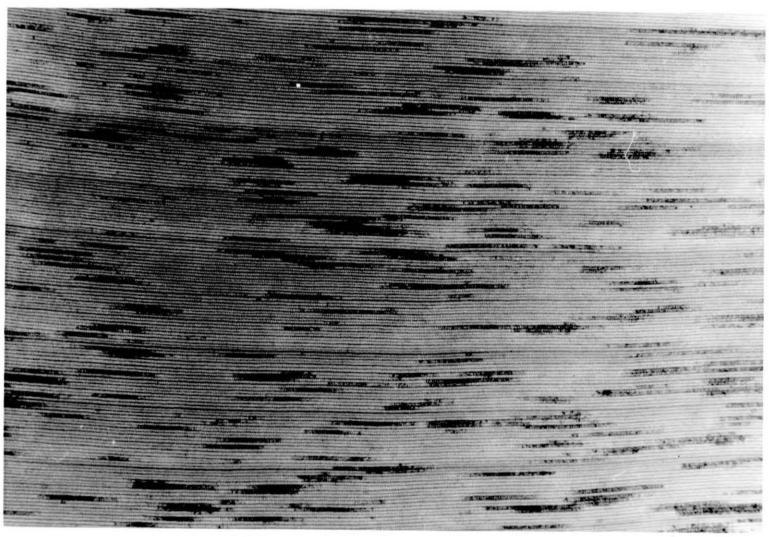

Plate 1. Second-Streak Stage of Black Leaf Streak Disease on the Lower Surface of a Banana Leaf.

(Reproduced with the kind permission of Dr. D. S. Meredith.)

Plate 2. Streaks and Spots of Black Leaf Streak on the Upper Surface of a Severely-Diseased Plant.

(Reproduced with the kind permission of Dr. D. S. Meredith.)

countries, including the development of seaports, railroads, new towns and agricultural lands. He suggested that bananas affected the lives of several million people in the tropics and the threat of a reduction in production due to Leaf Spot disease could have disastrous consequences. He stated that in 1940, banana production in Mexico fell from 23 million to 12 million stems. At about the same time, the disease practically wiped out the banana export trade in Cuba. In Honduras in the 1930's, the disease lowered production from 35 million to 10 million stems. High disease incidence can reduce the number of green leaves from 10 to 14 on a healthy plant to 5 or 6, which would then limit the total photosynthetic area available for carbohydrate production. Consequently, the primary effect of Leaf Spot disease is the reduction of banana yields.

Leaf Spot disease increased the cost of banana production in Central America by as much as $250 per hectare (Wardlaw, 1961). Herrera et al. (1958) remarked that out of 62 million banana bunches produced in Ecuador in 1954, only 19 million bunches were exported and the loss from Cercospora damage was high. The disease reached serious proportions in West Cameroon banana plantations in 1958 and over 800 hectares virtually ceased to produce marketable fruit.

Disease Incidence in Banana Nutrition and Tissue Analyses

Disease Incidence

Butler (1960), Frieberg (1965) and other workers noted that early fertilizer experiments on bananas were designed to observe the effect of improved nutrition on the 'Gros Michel' banana on its resistance to Panama disease. However, no study has been reported relating Leaf Spot disease to the uptake and distribution of nutrients in the 'Gros Michel' banana.

Information concerning the effects of disease on nutrient mobilization in plants other than bananas is also limited. Livne and Daly (1966) studied the translocation patterns in healthy and rust-affected beans (Phaseolus vulgaris). They discussed the classical concept of "source" and "sink" in determining the movements of products of photosynthesis in higher plants. Translocation of photosynthesized products is normally directed from older to younger tissues which are metabolically more active. However, the authors noted that the final distribution of products of photosynthesis in diseased plants was a function of several parameters which in turn depended on the stage of plant development. Losses in yield resulting from disease infection may be due to the diversion of these products of photosynthesis from healthy to diseased tissues.

Johnson et al. (1966) investigated nutrient mobilization in the leaves of wheat plants infected by Puccinia recondita. They

observed that an increase in dry weight of leaves per unit area occurred after infection by this fungus disease and that a metabolically dependent accumulation of organic and inorganic materials at the infection sites was involved in the weight increase.

Yarwood (1965) reported the effects of Powdery Mildew (Erysiphe polygoni DC.) and Rust (Uromyces phaseoli (Pers.) Wint.) on beans. He found that the dry weight of rusted bean leaves was always greater than that of healthy leaves. The author indicated that there was a significant reduction of translocation in diseased tissue which was probably due to selective accumulation of chemicals in the diseased areas.

In his investigation on mobilization of minerals to the roots of tomato plants infected with Root Knot nematodes, Bergeson (1966) concluded that nitrogen, phosphorus and potassium were generally mobilized from non-infected to infected roots.

From these studies, it seems obvious that disease causes mobilization of nutrients from healthy to infected tissues where the nutrients accumulate with little further translocation.

Tissue Analysis as a Guide to Banana Nutrition

Clements et al. (1968) stated that tissue analyses of cultivated crops effectively began in the 1920's with the work of Maume in France and Thomas in the United States of America. Since then, the principle has been extended to nearly every crop.

In the case of bananas, Frieberg (1965) reported that as early as 1807, Fourcroy and Vanquelin found high concentrations of potassium nitrate and potassium oxalate in the juice of the plant. Bailon et al. (1933) presented the first chemical composition of a single mature Cavendish banana plant in the Canary Islands. They determined nitrogen, phosphorus, potassium, calcium, magnesium and iron in a number of tissues and found high potassium in all plant parts Butler (1960) and Twyford and Coulter (1964) indicated that comparatively little research had been done on banana nutrition. This could be due to the fact that 'trade' bananas have usually been grown on rich volcanic soils or alluvial plains. Many scientists have recently investigated the feasibility of using leaf analysis as an indicator of the nutritional status of bananas. Simmonds (1966) stated, "The object of leaf analysis is to provide a guide to economical fertilizer application that is both more accurate and more adaptable than that provided by soil analysis."

The first detailed study of banana leaf analysis was conducted in Jamaica by Hewitt (1955). He determined total nitrogen, phosphorus and potassium in the 1st, 2nd, 3rd, 5th and 7th leaves below the inflorescence in 24 'Lacatan' banana plants at the shooting stage at each of six sites. He found that nitrogen was highest in the 3rd leaf while phosphorus and potassium were highest in the 1st leaf, and he concluded that the 3rd leaf was the best

indicator of banana nutritional status. Other investigators (Murray, 1959; Hewitt and Osborne, 1962; Bhanghoo et al., 1962) followed Hewitt's recommendation and sampled the 3rd leaf for mineral analyses. Brzesowsky and van Biesen (1962) on the other hand, sampled the youngest leaf of 'Lacatan' banana in the Cameroon Republic at 4-week intervals from planting to the shooting stage. The Cameroon has alternating dry and wet seasons and the authors contended that this rainfall pattern caused differences in the physiological age of older leaves which resulted in variable nutrient concentrations. However, the youngest leaf minimized this difference. Boland (1960) also departed from Hewitt's recommendation and analyzed the second fully expanded leaf of 6-8 month old 'Lacatan' bananas in Jamaica.

It is apparent from these investigations that the emphasis has been on the three youngest leaves as possible index tissues of the nutrient status of bananas. Most of the studies on leaf analysis have been carried out on the 'Lacatan' banana in Jamaica. The levels of nutrient adequacy established by various authors are presented in Table 3. The data from these independent investigations in different locations seem to agree quite well. Boland (1961) in Jamaica presented data on nutrient distribution in various tissues of 'Lacatan' bananas sampled in the sixth week of fruiting. Figures for selected tissues from her summary are given in Table 4, which showed high percent nitrogen in the

Table 3. Nutrient Levels of Bananas Considered Adequate by Various Authors[1/]

Research Location	Banana Clone	Leaf Sampled	Plant Stage	Culture	N	P	K	Ca	Mg	Investigators
					Percent[2/]					
Jamaica, W. Indies	Lacatan	3rd	Shooting	Field	2.6	0.20	2.74			Hewitt (1955)
Israel	Dwarf Cavendish	3rd	Shooting	Field	2.5	0.51	2.00	2.71	0.59	Bidner-Barhava and Ravikovitch (1958)
Trinidad, W. Indies	Dwarf Cavendish	3rd	Shooting	Sand	2.6	0.20	2.73	1.00	0.36	Murray (1959)
Jamaica, W. Indies	Lacatan	2nd	6-8 Months	Field	2.9	0.21	3.24	0.72	0.39	Boland (1960)
Jamaica, W. Indies	Lacatan	3rd	Shooting	Field	2.6	0.19	3.65			Hewitt and Osborne (1962)
Windward Islands, W. Indies	Robusta	4th	Before Shooting	Field	2.8	0.17	3.15			Twyford and Coulter (1964)

1/ Drawn in part from Chapman (1966), p. 589; intermediate values.

2/ Converted from oxide to elemental forms (where applicable).

Table 4. Nutrient Distribution in 'Lacatan' Banana Tissues in Sixth-Week Fruiting Stage (After Boland, 1961; converted from oxides to elemental forms)

Plant Tissue	Dry Matter Percentage	Percent of Dry Matter N	P	K	Ca	Mg
Inflorescence	8.74	2.99	0.34	7.30	0.56	0.37
Lamina	15.57	2.87	0.17	3.42	0.62	0.25
Midribs	18.29	0.82	0.10	4.00	0.68	0.18
Dry Leaves	30.03	1.11	0.06	2.66	0.93	0.28
Pseudostem	6.35	1.10	0.11	7.63	0.87	0.32
Corm	13.09	0.97	0.09	4.00	0.97	0.31

inflorescence and the lamina, while the percent potash was high in all parts of the plant.

Micronutrient Status in Bananas

Twyford and Walmsley (1968) reported that little information was available on the micronutrient status of bananas. They sampled several tissues of 'Robusta' bananas in St. Vincent on the Windward Islands of the West Indies at five different stages of growth and determined manganese, iron, boron, zinc and copper. A portion of their data for leaf tissues is presented in Table 5. It can be seen that the content of manganese and copper increased to a maximum at the shooting stage and then decreased with age. The content of boron and zinc dropped after shooting but increased at harvest time. The authors found the order of magnitude for total plant content of these micronutrients to be about 1750 mg. manganese, 1100 mg. iron, 340 mg. boron, 200 mg. zinc and 70 mg. copper, respectively. They also stated that manganese and iron were taken up rapidly in the vegetative phase with manganese moving mostly into the leaves and iron into the pseudostem, leaves and corm. Zinc and copper were taken up mainly in the fruiting phase. Based on their investigation, these workers recommended tentative annual applications of 30.2, 28.0, 12.3, 3.4 and 1.1 kg/ha. of manganese sulfate, iron citrate, borax, zinc sulfate and copper sulfate, respectively, to correct micronutrient deficiencies.

Table 5. Total Micronutrient Content in the Leaf Portion of a 'Robusta' Banana Plant[1/] (After Twyford and Walmsley, 1968)

Stage of Growth	Micronutrient Content (mg)				
	Mn	Fe	B	Zn	Cu
Small (2 1/2 months)	80	45	8	2	2
Large (1-2 mos. before shooting)	737	261	76	25	13
Shooting (flower appearance)	1540	256	83	41	16
Shoot (6 wks. immature fruits)	1316	238	71	36	12
Mature (at harvest)	1011	217	100	44	9

[1/] Analyses were performed on composited samples of 1 inch cross-sections of both lamina and midrib taken from the central part of each leaf. The mean analytical values were multiplied by the weight of the bulked leaf samples to obtain the total micronutrient content of the leaf portion of a banana plant.

MATERIALS AND METHODS

The study reported here was conducted at the Kauai Branch Station of the Hawaii Agricultural Experiment Station of the University of Hawaii, located in the Wailua area of Kauai. The Kapaa soil series on the station was described by De Datta et al. (1963) as a very deep, well-drained aluminous Humic Ferruginous Latosol (Typic Gibbsihumox), developed in saprolitic ferruginous bauxite. The series occurs on lower mountain slopes at elevations between 61 m. and 305 m. The climatic regime indicated by the mean monthly temperature, relative humidity and rainfall is presented in Table 6.

Experimental Treatments

An experiment was started on the Branch Station in 1966 to study methods of controlling Leaf Spot (Sigatoka) disease. Seven spray treatments were imposed in the original experiment, but only five of these treatments were included in the present investigation as described in Table 7. The experiment was laid out in a completely randomized design with each treatment replicated four times. The fungicides were applied as sprays using a knapsack mist blower. Orthol K Oil is 99 percent light-medium petroleum oil with 1 percent inert material, while Volck Oil is 98 percent light-medium petroleum oil with 2 percent inert material. Dithane M-45 is a fine powder and contains 16 percent manganese, 2

Table 6. Mean Monthly Temperature, Relative Humidity and Rainfall Values for Kauai Branch Station

Month	Temperature[1] (°F)		Relative Humidity[1] (Percent)		Rainfall[2]	
	Minimum	Maximum	Low	High	mm.	No. of Rainy Days
January	63	76	66	96	211	18
February	62	75	64	95	134	15
March	64	74	69	96	256	19
April	65	76	63	96	282	21
May	67	78	67	95	196	23
June	69	80	66	96	127	23
July	70	80	66	96	152	27
August	71	80	66	96	144	26
September	70	82	64	96	127	22
October	69	81	66	96	226	22
November	68	78	70	96	277	23
December	65	75	68	95	247	21

[1] 4-year means (1965-1968).

[2] 8-year means (1961-1968).

Table 7. Fungicide Spray Treatments

Treatment	Description	Spray Interval
A	14 liters Orthol K Oil/ha.	10 days
B	The same as treatment A	20 days
C	Control	no spray
D	2.2 Kg. Dithane M-45 + 2.4 liters Volck Oil/ha.	10 days
E	The same as treatment D	20 days

percent zinc, 62 percent ethylene bisdithiocarbamate ($C_4H_6N_2S_4$) and 20 percent inert material. The Dithane M-45 contains about 8 and 38 percent nitrogen and sulfur, respectively, in the 62 percent ethylene bisdithiocarbamate.

Field Operations and Planting

The experimental site was originally cleared, plowed, disced and a blanket application of 1333 kg./ha. of treble superphosphate and 6720 kg./ha. of crushed coral limestone was made. The field was divided into plots 11.1 m. by 12.0 m. Each plot contained three rows spaced 3.7 m. apart from East to West and each row had five hills spaced 2.4 m. apart running from North to South, which gave a total of fifteen hills per plot. Approximately uniform and disease-free 'Gros Michel' banana suckers were obtained from Mr. Edward Shota's[1/] farm isolated in lower Wailua Valley on Kauai. The suckers were trimmed and treated against nematodes by emersing them in hot water at 55°C for 10 to 15 minutes as recommended by Dr. E. E. Trujillo.[2/]

Planting holes were drilled 30-40 cm. deep with a tractor-operated post-hole digger. At planting time, 0.7 kg. of a fertilizer mix was incorporated with soil and packed firmly in the

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[1/] Agricultural Technician and part-time farmer.

[2/] Associate Plant Pathologist at the University of Hawaii and Superintendent of the Kauai Branch Station during the period of this research.

planting hole. The fertilizer consisted of 90 kg./ha. of urea, 168 kg./ha. of treble superphosphate and 168 kg./ha. of potassium sulfate. One-half kilogram of a mixture of 1:1 urea and potassium chloride was applied regularly in a ring around each banana stool every three months from the establishment of the crop. All necessary precautions were taken to prevent the introduction of Panama disease into the experimental area. Herbicides were used to control weeds until the plants closed in, and pruning of suckers was done as necessary to maintain 2-4 plants per hill.

Collection of Samples and Data

Yield and sample data were collected from the three central stools while the other twelve stools served as guard rows to minimize border effects. Procedures for collecting these data are described below.

Soil Samples

Soil samples were collected 1.2 m. away from each of the three central hills at two depths, 0-15 cm. and 15-30 cm. Eight sub-samples for each depth in each plot were composited and mixed thoroughly in a bucket in the field. About 5 kg. of the field-moist soil was immediately placed in a plastic bag and taken to the laboratory for preparation. Soils were partially air-dried in a dust-free, air-conditioned room overnight, after large soil

aggregates had been broken down and all debris removed. The partially air-dried soils were further crushed, then sieved through a 20-mesh screen and stored in tightly closed plastic bags. Soil moisture was later determined by oven-drying small samples of soil overnight at 105-110°F. C

Leaf Samples

The middle portion of the third fully expanded leaf from the top of the plant was sampled at the shooting stage (from flower appearance to 1-3 days after bending of the inflorescence). In this investigation, the length of the leaf was measured from the tip to the junction of the lamina and stalk, and then 30, 45, 60 or 75 cm. length was discarded from each end for leaves measuring 1.8-2.4, 2.4-3.0, 3.0-3.7 and over 3.7 m., respectively. The lamina and midrib were separated, weighed, washed with tap water, rinsed with distilled water and oven-dried at about 70°C. Tissue moisture was recorded on the fresh weight basis. The dry tissue was ground in a Wiley mill through a 20-mesh screen and stored in a plastic vial. The number of leaf samples collected per plot varied because of the irregular shooting (flowering) of plants.

Estimation of Sucker Age

The banana plant is known to unfold one leaf every 7-14 days under conditions of steady growth during warm periods of the

year, but in winter this process may take up to 20 days (Wardlaw, 1961). The rate of leaf expansion was estimated during a period of 75 days from 21 June, 1968, by marking the last fully expanded leaf on a sword sucker of similar circumference in each plot and making daily observations. A summary of the growth rate is shown in Table 8. In order to determine the relationship between plant age and trunk circumference, the total number of leaves (living and dead) was counted on several suckers of various heights and the circumference of the plant trunk was measured at 45 cm above the ground. The estimated age of a sucker was calculated by multiplying the number of leaves by the growth rate found in the leaf expansion study. The age of plants at time of shooting was estimated by Dr. E. Trujillo to be about 300 days, since all leaves were not present at this stage for estimation by the growth rate used for younger plants. The information obtained on age versus circumference (Figure 1) was used to select plants for sampling before the shooting stage. Since the average rate of leaf expansion in treatments A and C was the same (10 days per leaf), the same criterion was used for selecting suckers that were between 150 and 240 days old in both treatments, that is, a trunk circumference of 20-28 cm.

Whole Plant Samples

Two plants were felled at ground level from each replicate of

Table 8. Rate of Leaf Expansion in Bananas on Kauai Branch Station

Treatment	No. of Leaves[1/]	Expansion Rate (days per leaf)
A	8	10
B	9	9
C	8	10
D	8	10
E	8	11

[1/] Means of 4 observations.

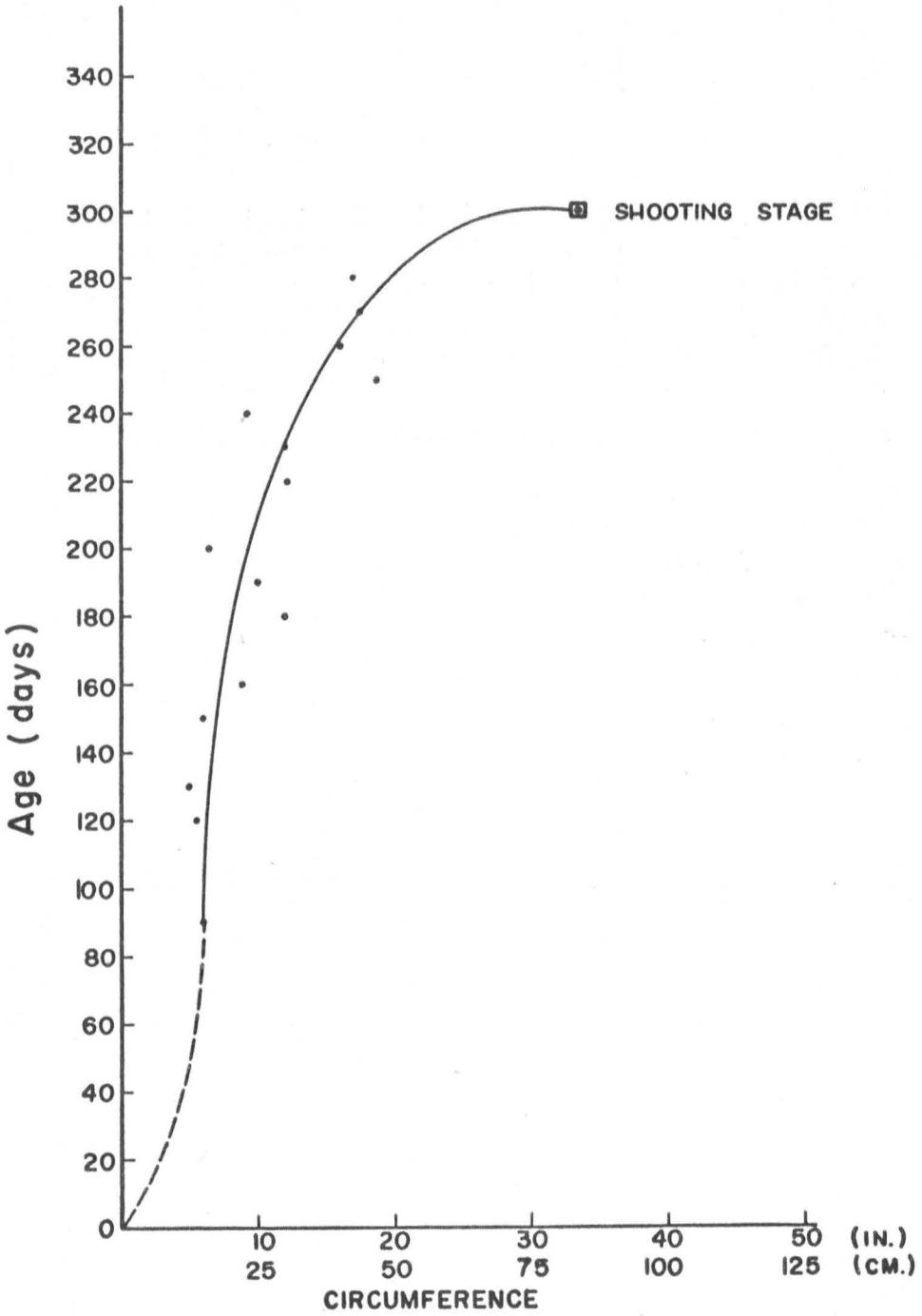

Figure I. Relationship between Sucker Age and Trunk Circumference

treatments A and C, representing moderate and severe disease incidence, respectively, from among the 12 guard row stools. One plant was cut before blooming (5-8 months; 20-28 cm. circumference), and the other after blooming (10 months or older). The seven tissues taken from the immature plants (before blooming) included samples from the third leaf lamina and sheath, composited functional leaf laminae and sheaths, composited dead leaf laminae, composited sheaths of dead leaves, and the corm. Twelve tissues taken from the mature plants (after blooming) included samples from the inflorescence, the true stem, third leaf lamina, midrib and sheath, composited functional leaf laminae, midribs and sheaths, composited dead leaf laminae and midribs, composited sheaths of dead leaves and the corm. All samples were oven-dried and ground as described for the leaf samples. The moisture percentage was recorded on the fresh weight basis.

Yield Record

Plants from which the third leaves were sampled at the shooting stage were appropriately labeled and the banana bunch produced was harvested when it was mature and the weight recorded.

Leaf Spot Disease Rating

A count of leaf spot lesions measuring over 1 mm. in length was made on a 100 square centimeter portion of the lamina of the

fourth leaf of all mature plants from which tissue samples were taken. The 100 square centimeter portion of the leaf blade was removed from the center of the left-hand side of the leaf, looking down from the upper surface, and 5 cm. from the outer edge of the blade in all cases. Counting was done over an illuminated glass table using a tally counter.

Soil and Plant Analyses

Laboratory analyses were carried out on the ten elements, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, silicon, manganese, zinc and aluminum, in both soil and plant samples. Moisture, nitrogen, phosphorus and potassium were analyzed in all plant tissues while the other seven elements were analyzed in the third leaf lamina and third leaf sheath only. The soil samples were composited by treatments into two samples, one for the 0-15 cm. depth and one for the 15-30 cm. depth. All nutrient elements except phosphorus were determined on composited soil samples because fertilizers were applied uniformly to all plots. However, phosphorus was determined on individual plot samples without compositing to assess the variation of this element in the experiment.

Plant Analysis

Total Nitrogen: Total nitrogen was determined by the Kjeldahl method with the pre-treatment to include nitrate. One gram of

dry tissue was pre-digested at low heat for 15 minutes in an 800 ml. Kjeldahl flask containing 35 ml. distilled water, 10 ml. 18 N sulfuric acid and 3.0 g. of reduced iron powder. After cooling, 5.0 g. sodium sulfate, 30 ml. concentrated sulfuric acid, 5 drops of selenium oxychloride ($SeOCl_2$) and a few glass beads were added to the flask. The tissue was digested for 30 minutes after clearing was attained. The flask was cooled, the contents diluted with 300 ml. distilled water and the flask was again cooled to at least 35°C. A 90 ml. volume of 15 N sodium hydroxide was poured slowly down the sides of the flask, a few pieces of mossy zinc were added and the flask was immediately connected to the distillation unit. The flask was shaken and distillation was carried out until about 200 ml. of distillate was collected in a 500 ml. Erlenmeyer flask containing 50 ml. of 4 percent boric acid solution. The distillate was titrated with 0.0714 N sulfuric acid.

Silicon: Total plant silicon was determined with a modification of the lithium tetraborate method of Suhr and Ingamells (1966). A 0.5 g. sample of dry tissue was ashed in a platinum crucible overnight in a muffle furnace at 550°C. The ashed product was transferred from the platinum crucible to a carbon crucible with 0.5 g. anhydrous lithium tetraborate and the mixture was fused at 950°C for 15 minutes. The melt was poured into a 250 ml. beaker containing 100 ml. 0.5 N nitric acid. The beaker was covered with a watch glass and the solution stirred

with a magnetic stirrer until the melt dissolved. Silicon was determined colorimetrically by the silico-molybdate blue method of Kilmer (1965). A 5 ml. aliquot of the extract was pipetted into a 50 ml. volumetric flask, 1 ml. ammonium molybdate[3/] was added and the yellow color was allowed to develop for 30 minutes. Oxalic acid (3 ml.) was added to destroy the phosphomolybdate color and after two minutes, 1 ml. of reducing reagent (1-amino-2-naphthol-4-sulfonic acid)[4/] was added and the blue color allowed to develop for at least 30 minutes before reading the optical density at a wavelength of 660 mμ.

Wet Digestion: The elements phosphorus, potassium, calcium, magnesium, sulfur, manganese, zinc and aluminum were determined in a nitric-perchloric acid digest of the plant tissue. One gram of dry tissue was allowed to pre-digest overnight in 15 ml. 2:1 nitric-perchloric acid solution, then it was digested on a micro-kjeldahl rack until the white fuming stage was reached and the digestion was continued for 15 minutes beyond this stage at low heat. After cooling, the digest was transferred with distilled water by washing into a 50 ml. volumetric flask and made to volume.

3/ Dissolve 7.5 g. ammonium molybdate in 75 ml. water. Add 10 ml. 18 N H_2SO_4 and dilute to 100 ml. with distilled water.

4/ Dissolve 0.7 g. sodium sulfite in 10 ml. water; add 0.15 g. of 1-amino-2-naphthol-4-sulfonic acid; dissolve 9 g. sodium bisulfite in 90 ml. water and add to above solution; remake every 2-3 weeks.

Cations and Micronutrients: The elements calcium, magnesium, potassium, manganese, zinc and aluminum were determined on the Perkin-Elmer atomic absorption spectrophotometer. The determination of calcium and magnesium was made on a 2 ml. aliquot of the nitric-perchloric acid digest which was diluted with distilled water to 50 ml. volume after 5 ml. of 5 percent lanthanum oxide solution had been added. For potassium, a 5 ml. aliquot of the digest was diluted to 50 ml. with distilled water. Manganese, zinc and aluminum were determined in the original solution.

Phosphorus: Total phosphorus was determined colorimetrically using Barton's reagent[5/] (Kitson and Mellon, 1944). A 5 ml. aliquot of the nitric-perchloric acid solution was added to a 50 ml. volumetric flask, about 30 ml. water was added, then 5 ml. Barton's reagent was added and the volume made to 50 ml. with distilled water. After 30 minutes, the optical density was read on a colorimeter at 430 mμ.

Sulfur: Total plant sulfur was determined by the turbidimetric method of Beaton et al. (1968). A 5 ml. aliquot of the nitric-perchloric acid digest was placed in a 25 ml. volumetric flask and diluted to about 20 ml. with distilled water, then 1.0 g. of sized

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5/ Dissolve 22.5 g. of ammonium molybdate in 400 ml. of water; dissolve 1.25 g. of ammonium vanadate in 300 ml. of boiling water; add the vanadate to the molybdate solution and cool to room temperature; add 250 ml. concentrated nitric acid and dilute to 1 liter.

barium chloride crystals (20-30 mesh) was added and the flask was immediately shaken for one minute, followed by the addition of 1 ml. of 0.25 percent gum acacia solution. The contents of the flask were diluted to volume and the optical density was read within 15 minutes at a wavelength of 450 mμ.

Soil Analysis

Total Nitrogen: Total nitrogen was determined by the Kjeldahl method. A 5 g. sample (oven dry basis) of 20-mesh soil was placed in an 800 ml. Kjeldahl flask to which was added 3 glass beads, 10 g. of a salt mixture (10 parts potassium sulfate, 1 part ferrous sulfate and 1 part copper sulfate), and 30 ml. of concentrated sulfuric acid. The soil was digested until the sample cleared (1-2 hours). The flask was cooled, the diluted digest neutralized with 90 ml. 15 N sodium hydroxide, the ammonium distilled off and collected in 50 ml. boric acid solution and then titrated with 0.0714 N sulfuric acid, following the procedure described for plant analysis.

Available Phosphorus: The modified Truog method developed by Ayres and Hagihara (1952) was used to extract soil phosphorus. A 1.5 g. soil sample (oven dry basis) was placed in a 250 ml. flask, 150 ml. of 0.02 N sulfuric acid (containing 3 g. ammonium sulfate per liter) added, and the stoppered flask was shaken on a mechanical shaker for 30 minutes. The extract was

filtered through a No. 42 Whatman filter paper and phosphorus in the extract was determined by the molybdenum blue method of Dickman and Bray (1940). A 10 ml. aliquot of extract was taken and diluted to about 30 ml. with distilled water in a 50 ml. volumetric flask, then 1 ml. ammonium molybdate solution[6/] was added, followed by 5 ml. dilute stannous chloride and the solution made to volume. The optical density was measured at a wavelength of 660 mμ within 10-15 minutes.

Exchangeable Bases: Exchangeable calcium, magnesium and potassium were extracted with 1.0 N ammonium acetate solution adjusted to pH 7.0. A 10 g. soil sample (oven dry basis) was shaken with 100 ml. extracting solution for 30 minutes, allowed to equilibrate overnight, then was shaken for 15 minutes before filtration. The soil residue in the No. 42 Whatman filter paper was washed three times with 30 ml. volumes of ammonium acetate solution and the filtrate plus washings were made to 200 ml. volume with extracting solution. A 3 ml. aliquot of the filtrate was diluted to 50 ml. after the addition of 5 ml. of 5 percent lanthanum oxide solution and calcium and magnesium were determined on the atomic absorption spectrophotometer. Exchangeable potassium was determined on the original extract with the same

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6/ Dissolve 15 g. ammonium molybdate in 300 ml. water; heat to dissolve; cool, add 350 ml. of 10 N hydrochloric acid; cool and dilute to 1 liter.

instrument.

Sulfur: Sulfate-sulfur was extracted by shaking 6.0 g. soil (oven dry basis) with 30 ml. calcium dihydrogen phosphate solution containing 500 ppm P in a 50 ml. centrifuge tube for 30 minutes, following the method of Fox et al. (1954). The extract was centrifuged for 15 minutes at 1500 r.p.m. and a 10 ml. aliquot of the clear supernatant was used for sulfur determination by the turbidimetric method of Beaton et al. (1968) described above for plant sulfur.

Manganese: Extractable soil manganese was determined by the method of Chapman and Pratt (1961). A 10 g. soil sample (oven dry basis) was shaken with 100 ml. 3 N ammonium dihydrogen phosphate ($NH_4H_2PO_4$) in a 250 ml. flask on a reciprocating shaker for one hour and then filtered through Whatman No. 12 filter paper. The manganese in the extract was determined with the atomic absorption spectrophotometer.

Zinc: The procedure of Kanehiro (1954) was used to extract soil zinc. A 10 g. soil sample (oven dry basis) was shaken with 100 ml. 0.1 N hydrochloric acid in a 250 ml. flask for 45 minutes and the extract was filtered through No. 12 Whatman filter paper. The extractable zinc in the filtrate was determined with the atomic absorption spectrophotometer.

Extractable Silicon: The procedure of Fox et al. (1967) was used to extract soil silicon. A 10 g. soil sample (oven dry

basis) was shaken with 100 ml. distilled water in a 250 ml. flask on a mechanical shaker for four hours. The extract was filtered through No. 12 Whatman filter paper. A 5 ml. aliquot of the solution was diluted to about 30 ml. with distilled water in a 50 ml. volumetric flask, 1 ml. acid ammonium molybdate[1] was added and the yellow color allowed to develop for 30 minutes. After adding 3 ml. of 10 percent oxalic acid to destroy the phosphomolybdate complex, 1 ml. of a reducing solution (1-amino-2-naphthol-4-sulfonic acid) was added after two minutes and the blue color allowed to develop for at least 30 minutes before measuring the optical density at 660 mμ.

Exchangeable Aluminum: Exchangeable aluminum was extracted from a 10 g. soil sample (oven dry basis) using a modification of the method employed by McLean et al. (1964). The soil was shaken with 50 ml. 1.0 N potassium chloride for 30 minutes in a 250 ml. flask. The extract was allowed to equilibrate overnight and then filtered through Whatman No. 42 filter paper into a 100 ml. volumetric flask and both the soil residue and filter paper were washed with one 10 ml. volume of the extracting solution. The filtrate was made to volume with the potassium chloride solution.

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[1] The same reagent used for plant silicon determination.

A 5 ml. aliquot of the extract was used for determination of aluminum by the aluminon method of Chenery (1948). The aliquot was transferred to a 50 ml. volumetric flask and 15 ml. distilled water, 2 ml. of 1 percent thioglycolic acid and 10 ml. aluminon reagent were added. The solution in the flask was poured into a 100 ml. beaker and the pH adjusted to 4.2 on a Beckman pH meter by adding a few drops of 1:1 ammonium hydroxide or 1:1 hydrochloric acid. The adjusted solution was returned to the 50 ml. flask and the beaker was washed three times with small volumes of distilled water to quantitatively transfer the solution to the 50 ml. flask. Sufficient distilled water was added to bring the solution level to just below the neck of the flask. The flask was heated in a vigorously boiling water bath for exactly 16 minutes and then allowed to cool for at least two hours before being made to volume with distilled water. The flask was then stoppered and the solution thoroughly mixed by shaking. A set of standards of 0.2 to 1.2 ppm Al was included with each batch of samples heated in the water bath. The color intensity was read on a colorimeter at a wavelength of 537.5 mμ.

RESULTS AND DISCUSSION

The results of this study are discussed in three sections. The first section covers nutrient content of tissues at the shooting stage, the second, the distribution of nutrients in normal (moderate disease) plants before blooming, at shooting and after blooming, and the third, the effect of Leaf Spot disease on nutrient uptake and distribution in bananas.

Nutrient Content of Banana Tissues at the Shooting Stage

The nutrient content of the third leaf lamina for each treatment at the shooting stage is presented in Table 9. Total nitrogen, phosphorus and potassium levels averaged for treatments A through E were 3.07, 0.21 and 3.56 percent, respectively, and were equal to or above the levels considered adequate for 'Cavendish' bananas in other parts of the world (Table 3). When calcium and magnesium levels were compared with comparable values for 'Dwarf Cavendish' bananas (Murray, 1959), they were between adequacy and deficiency levels for calcium and at deficiency levels for magnesium. Other nutrients determined were sulfur, silicon, manganese, zinc and aluminum. Levels of these nutrients in comparable tissues could not be found in the literature.

Treatments varied in their effects on nutrient content, and in general, the mean nitrogen, potassium, calcium, silicon, manganese and zinc values for treatments A and B (Orthol K oil) were

Table 9. Nutrient Content in the Third Leaf Lamina of 'Gros Michel' Bananas at the Shooting Stage

Treatment[1]	Variables[2]														n[3]
	No. of Functional Leaves	Lesions Per 100 cm.^{2}	Yield kg/bunch	H_2O	N	P	K	Ca	Mg	S	Si	Mn	Zn	Al	
				Percent								ppm			
A	10	22	21	76.6	3.04	0.22	3.69	0.68	0.17	0.40	0.20	206	41	36	5
B	10	41	19	78.1	2.91	0.20	3.27	0.72	0.16	0.35	0.15	194	36	30	7
C	8	132	16	77.2	3.05	0.21	3.68	0.76	0.14	0.38	0.15	157	36	28	4
D	9	14	17	77.0	3.14	0.21	3.52	0.78	0.16	0.38	0.22	364	45	33	4
E	8	5	16	77.1	3.22	0.21	3.66	0.83	0.14	0.40	0.17	178	38	22	7
N	6	56	6	74.8	2.14	0.20	3.84	0.41	0.32	0.32	0.57	439	88	32	1

[1] A and B = Orthol K oil sprayed at 10 and 20 days, respectively; C = control; D and E = Dithane M-45 + Volck oil sprayed at 10 and 20 days, respectively; N = not sprayed, not maintained.

[2] Values are averages of n samples.

[3] n = sample size.

lower than the mean values for treatments D and E (Dithane M-45 + Volck oil). Furthermore, the means for A and B were generally higher than the means for D and E for magnesium and aluminum as well as for number of functional leaves, number of disease lesions and yield. The analysis of variance in Table 10 indicated that treatment effects were significant on the nitrogen, calcium, manganese and aluminum levels and also on the number of functional leaves. Treatment effects on the number of disease lesions per 100 cm.^{2} were highly significant. Yield and the other nutrients in the leaf lamina as well as the nutrients in the midrib were not significantly affected by treatments.

Investigation of the individual treatment means with Duncan's multiple range test indicated that the nitrogen value in treatment E was significantly higher than that in treatment B, and that the manganese level in treatment D was significantly higher than those in all other treatments. These high levels were apparently due to the fact that Dithane M-45 applied to treatments D and E contained 8 percent nitrogen and 16 percent manganese, as well as 2 percent zinc and 38 percent sulfur. The plants may have absorbed these elements from the spray, but the quantities of zinc and sulfur absorbed, if any, were not significantly greater than those in the other treatments.

There were also differences in magnesium, silicon, manganese, zinc and aluminum levels between the 10- and 20-day spray

Table 10. Analysis of Variance of Nutrients in the Third Leaf Lamina of 'Gros Michel' Bananas at the Shooting Stage[1/]

Source of Variation	df	Mean Squares					
		% N	% Ca	ppm Mn	ppm Al	Lesions Per 100 $cm.^2$	No. of Functional Leaves
Between Treatments	4	0.0916*	0.0204*	28722.14*	173.10*	11696.19**	3.602*
Within Treatments	22	0.0278	0.0061	8491.35	48.22	214.19	1.257

1/ Only those variables showing significant treatment effects are included.

*Significant at the 5% level.

**Significant at the 1% level.

intervals. The magnesium and aluminum levels of treatments A and D (both 10 days) were significantly higher than those of treatment E (20 days). Treatment D (Dithane M-45, 10 days) had a significantly higher level of manganese than treatment E (Dithane M-45, 20 days). The levels of silicon and zinc were higher for the 10-day spray interval than the 20-day interval, but were not shown to be significantly different. Apparently, these elements were absorbed from the spray mixtures and the more frequent application resulted in greater uptake of these nutrients. The water used for mixing the spray contained about 15 ppm silicon which was supplied with each spray application. Dithane M-45 contained manganese and zinc as mentioned above, as well as very low amounts of magnesium and aluminum. Analyses of Orthol K and Volck oils also showed the presence of very small quantities of magnesium and aluminum. The very low amounts of magnesium and aluminum in these chemicals may possibly be the source of the increased levels of these elements in the spray treatments, but it does not appear likely.

The values in Table 9 for treatment N were from a banana plant which was neither sprayed nor fertilized and presumably reflected growing practices followed by peasants in developing countries. The nitrogen level was deficient and the yield was less than one-fourth of the yield for treatment A (sprayed and fertilized).

The factors affecting yield were studied by simple correlation techniques (Table 11) and the number of functional leaves was found to be the most highly correlated with yield ($r = +0.832$). This relationship is illustrated in Figure 2. Leaf magnesium and calcium were also well correlated with yield and had highly significant correlation coefficients of +0.626 and -0.542, respectively. Nitrogen, calcium and number of disease lesions were negatively correlated with yield. The negative correlation between nitrogen and yield appears to be due to the fact that treatments D and E (Dithane M-45 + Volck oil) had higher nitrogen levels but lower yields than the other treatments. The high nitrogen probably came from the Dithane M-45 which contained 8 percent nitrogen. The lower yields are believed to be due to the phytotoxicity of Volck oil. Simmonds (1966) reports that oils in general are toxic to bananas. However, Orthol K oil apparently had little, if any, toxic effect on bananas, since the highest yields were obtained in treatments A and B which had received this oil.

The coefficients of variation for nutrients in the third leaf lamina and other variables measured are presented in Appendix Table 23. Manganese, number of disease lesions, silicon and aluminum have the highest coefficients of variation ranging from 24 to 44 percent. Moisture, nitrogen and phosphorus on the other hand, have very low coefficients of variation which are between 0.8 and 5.4 percent. The rest of the variables have values

Table 11. Simple Correlation Coefficients Between Yield and Variables Measured

Variable[1/]	Correlation Coefficient (r)
Percent moisture	0.261
Percent nitrogen	-0.194
Percent phosphorus	0.324
Percent potassium	0.293
Percent calcium	-0.542**
Percent magnesium	0.626**
Percent sulfur	0.002
Percent silicon	0.011
ppm manganese	0.108
ppm zinc	0.110
ppm aluminum	0.366
No. of lesions/100 cm.^{2} (4th leaf)	-0.200
No. of functional leaves (at shooting)	0.832**

**Significant at the 1% level.

1/ Nutrients were from the third leaf lamina sampled at the shooting stage.

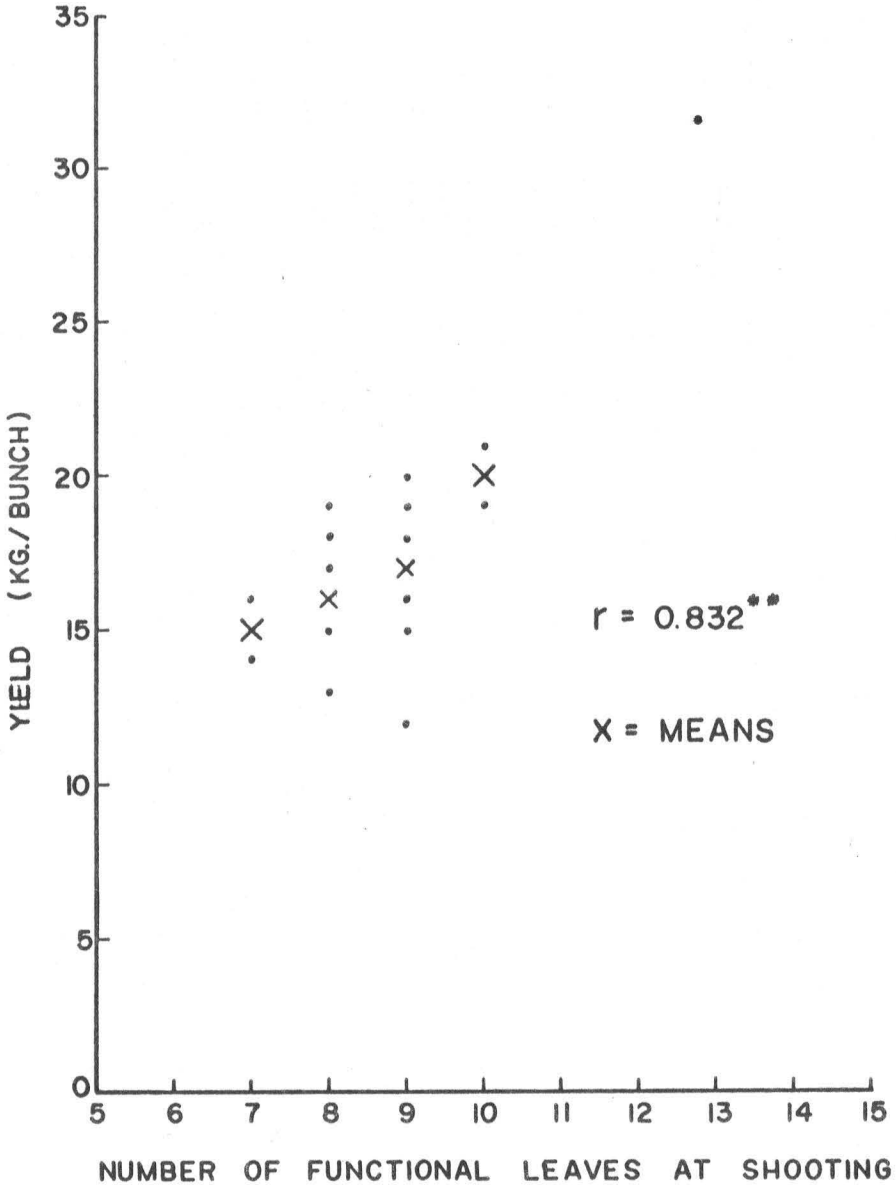

Figure 2. Yield of 'Gros Michel' Banana versus Number of Functional Leaves

between 10.0 and 20.0 percent.

Distribution of Nutrients in Normal (Moderate Disease) Banana Tissues at Three Stages of Growth

Nutrient Distribution in Several Tissues

The distribution of total nitrogen, phosphorus and potassium in tissues sampled before blooming, at shooting and after blooming is shown in Table 12. The values under column "a" are from normal banana plants taken from treatment A (moderate disease, sprayed at 10-day intervals with Orthol K oil), while those under column "b" are from plants which had received no fertilizer in the last three years, and were not maintained.

Moisture levels were highest in sheath tissues at the three growth stages in the fertilized plants, except after blooming when the stem and inflorescence had equally high moisture levels. Total nitrogen concentrations were highest in the third leaf lamina at all three stages of development. Phosphorus was also highest in the third leaf lamina before blooming and at shooting, but was highest in the inflorescence after blooming. Potassium was highest in all sheaths before blooming, but was highest in the third leaf lamina at the shooting stage. After blooming, the inflorescence and the stem had the highest concentrations of potassium. Plants from the unfertilized field followed the same general patterns for moisture, nitrogen and potassium, but differed for phosphorus in that the

Table 12. Distribution of Nitrogen, Phosphorus and Potassium in Banana Tissues at Three Stages of Growth

Tissue	% H_2O		% N		% P		% K	
	a[1]	b[2]	a	b	a	b	a	b
			Before Blooming[3]					
3rd Leaf Lamina	84.8	78.8	3.5	2.3	0.31	0.28	6.7	5.7
CFL Laminae	87.4	82.5	3.1	2.2	0.24	0.29	5.0	6.4
CDL Laminae	25.3	13.9	2.1	1.5	0.14	0.13	2.0	1.3
3rd Leaf Sheath	96.5	94.3	2.3	0.5	0.21	0.27	11.7	7.7
CFL Sheaths	96.1	95.2	2.4	1.0	0.18	0.31	8.6	8.7
CSD Leaves	94.6	94.0	1.9	0.4	0.11	0.20	9.1	5.6
Corm	91.7	83.0	1.7	0.4	0.13	0.14	5.7	2.6
			Shooting[4]					
3rd Leaf Lamina	76.0		3.0		0.18		3.4	
CFL Laminae	75.2		2.7		0.17		2.8	
CDL Laminae	10.4		1.4		0.10		0.5	
3rd Leaf Sheath	95.3		0.4		0.07		3.0	
CFL Sheaths	93.9		0.4		0.06		2.6	
CSD Leaves	91.3		0.4		0.05		2.0	
Corm	86.0		0.5		0.05		1.7	
			After Blooming[3]					
3rd Leaf Lamina	75.1	75.8	3.1	1.7	0.19	0.19	3.4	3.9
CFL Laminae	74.2	76.0	2.9	1.7	0.18	0.17	3.1	3.4
CDL Laminae	11.0	6.3	1.7	1.2	0.10	0.10	1.0	0.3
3rd Leaf Sheath	93.0	90.8	0.4	0.2	0.06	0.10	2.3	3.4
CFL Sheaths	92.4	90.5	0.4	0.2	0.06	0.11	2.3	3.3
CSD Leaves	91.6	89.2	0.5	0.2	0.06	0.10	2.5	2.8
Corm	89.0	84.0	0.6	0.2	0.06	0.06	2.8	2.2
Stem	95.2	95.2	0.7	0.4	0.11	0.12	5.1	5.9
Inflorescence	90.1	91.8	2.4	1.9	0.25	0.32	6.2	9.2
3rd Leaf Midrib	83.3	84.8	0.6	0.3	0.08	0.10	2.2	3.9
CFL Midribs	83.3	83.6	0.6	0.4	0.07	0.10	1.6	3.2
CDL Midribs	13.0	9.1	0.4	0.3	0.02	0.03	0.4	0.2

[1] Fertilized plants.

[2] Unfertilized plants.

[3] Means of 4 samples.

[4] One sample.

NOTE: CFL = composited functional leaf, CDL = composited dead leaf, CSD = composited sheaths of dead

sheaths of functional leaves had the highest phosphorus level before blooming, while the inflorescence had the highest phosphorus concentration after blooming.

A comparison of the levels of nutrients in the fertilized and unfertilized plants indicated that the nitrogen and potassium levels were generally lower before blooming in the unfertilized plants while phosphorus was higher. After blooming, nitrogen was again lower in the unfertilized plants, but both phosphorus and potassium were higher. These high levels of phosphorus and potassium in the unfertilized banana plants may be due to the recycling of nutrients applied in the past.

Concentrations of the three macronutrients in seven tissues before blooming and twelve tissues after blooming for fertilized plants are more clearly shown in Figure 3. It is apparent that before blooming, nitrogen and phosphorus were highest in the functional leaf laminae but potassium was highest in the sheaths. After blooming, the levels of all three nutrients in laminae and sheaths decreased sharply as the nutrients were translocated to the stem and inflorescence. The decreases for nitrogen, phosphorus and potassium in the composited functional leaf laminae amounted to 7, 25 and 38 percent, respectively, and in the composited functional leaf sheaths to 83, 67 and 73 percent, respectively. There was obviously a greater mobilization of nutrients from the sheaths than from the laminae to the stem and

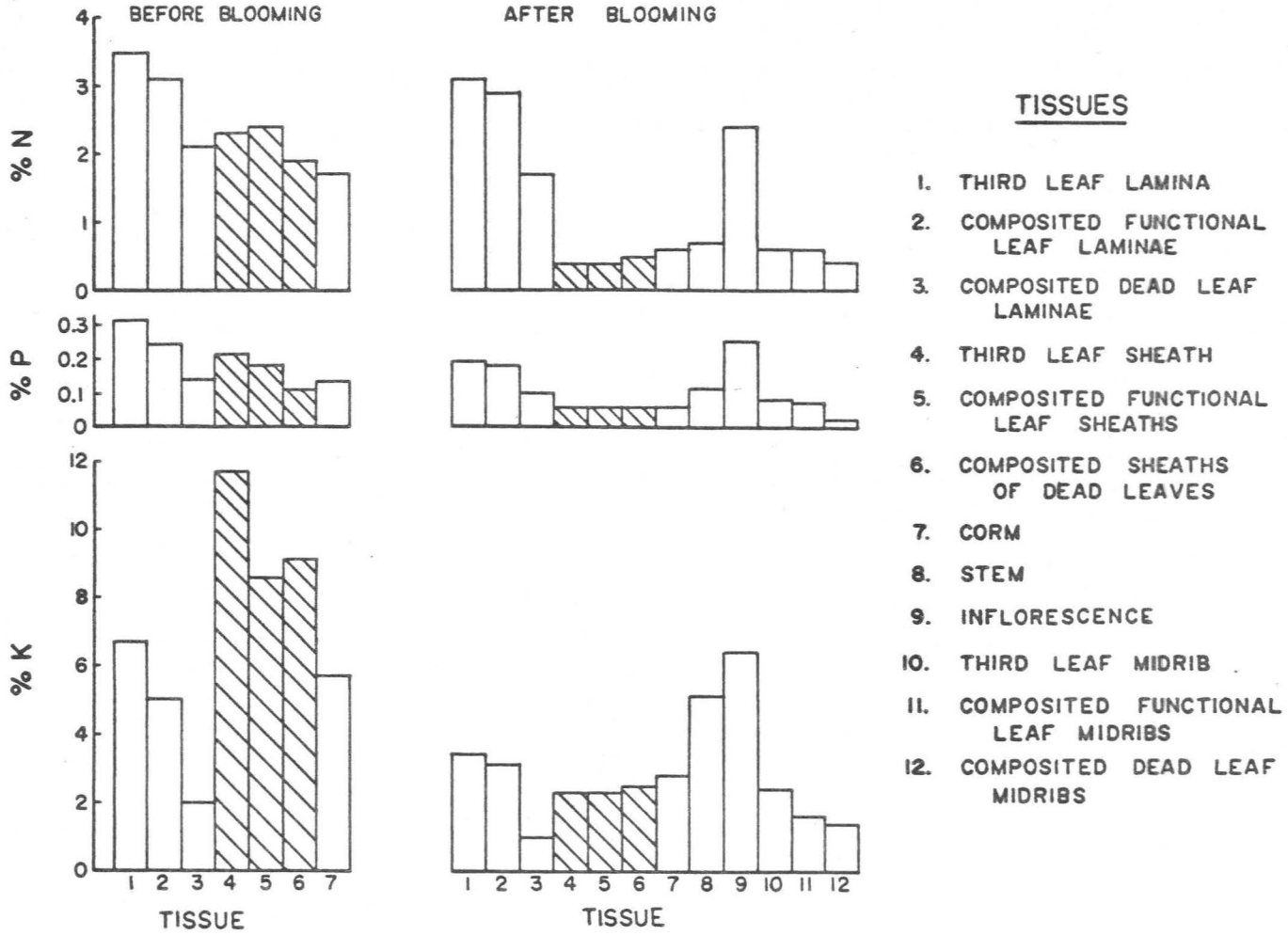

Figure 3. Concentration of Nitrogen, Phosphorus and Potassium in 'Gros Michel' Banana Tissues Before and After Blooming

inflorescence. There was also considerable movement of potassium and phosphorus from the laminae, presumably toward the stem and inflorescence, but there was relatively little movement of nitrogen out of the laminae.

Effect of Age on Nutrient Levels in the Third Leaf Lamina

The concentrations of nutrients in the third fully expanded leaf lamina of normal 'Gros Michel' bananas (from treatment A) at three stages of growth are shown in Figure 4. The values plotted in this figure may be found in Tables 9 and 18. With the exception of calcium, sulfur and aluminum, the levels of the other nutrients generally declined as plant age increased from 6 to 10 months. Calcium and sulfur concentrations, on the other hand, increased for the same period while aluminum remained nearly constant. After blooming, the concentrations of silicon, manganese and zinc increased sharply, while calcium concentration continued to increase at about the same rate, but the concentrations of nitrogen, sulfur and aluminum remained nearly constant. The levels of the other elements decreased after blooming.

These changes in nutrient content of the third leaf lamina with age parallel the changes in the composited functional leaves discussed previously, and thus reflect the translocation of nutrients to the stem and inflorescence after blooming. The causes of the increases in certain nutrients after blooming are not known,

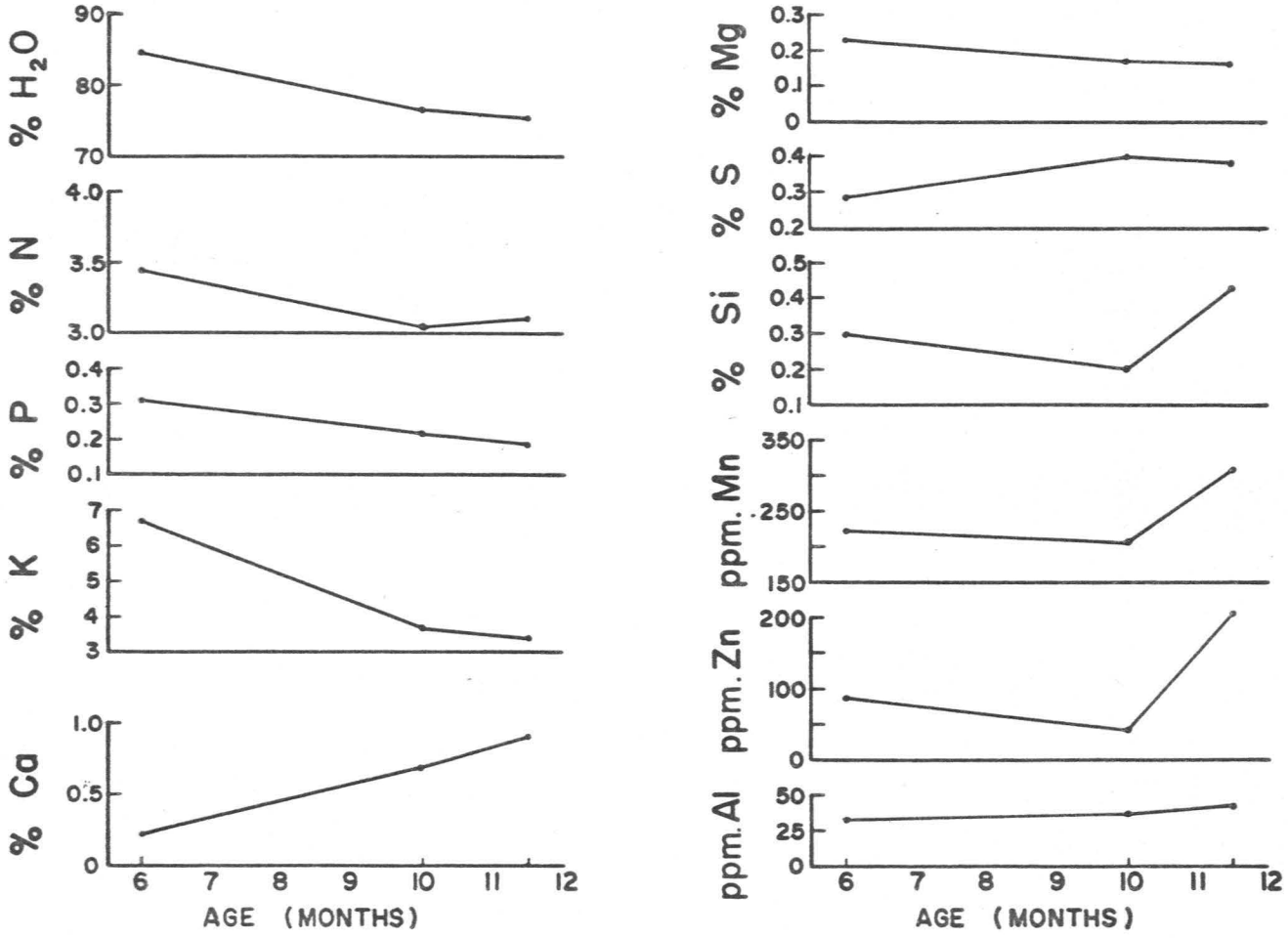

Figure 4. Variation in Nutrient Levels in the third Leaf Lamina of the 'Gros Michel' Banana with Age

except for calcium, which was most probably due to the relatively older leaves analyzed after blooming. This is so because the third leaf at shooting or after blooming is physiologically older than that before blooming, since once the inflorescence emerges, no additional leaves are produced. Thus, calcium, which is deposited in cell walls, increases as the leaf matures. A similar explanation may account for the increases in other nutrients, but this is not definitely known.

Nutrient Ratios

Ratios of individual nutrients to the sum of several nutrient elements were calculated according to the procedure of Boland (1960) to study the nutrient balance in the 'Gros Michel' banana. The sum of the percentages of nitrogen, phosphate and potash was designated as "T" and the ratios N/T, P_2O_5/T and K_2O/T were calculated. Similarly, the sum of the percentages of potash, calcium and magnesium was called "R" and the ratios K_2O/R, CaO/R and MgO/R were also calculated. The values obtained for the effect of stage of growth on nutrient ratios in the third leaf lamina are shown in Table 13.

Boland (1960) obtained nutrient ratios for the lamina of the second leaf of 'Lacatan' bananas at four stages of plant development from 15 areas of good productivity in Jamaica. The ranges of values she obtained were 0.39-0.44, 0.06-0.08 and 0.49-0.55

Table 13. Effect of Stage of Growth on Nutrient Ratios in the Third Leaf Lamina of 'Gros Michel' Bananas

Stage of Plant Growth	N/T[1/]	P_2O_5/T	K_2O/T	K_2O/R[2/]	CaO/R	MgO/R
Before Blooming	0.29	0.06	0.66	0.92	0.04	0.04
Shooting	0.38	0.06	0.56	0.78	0.17	0.05
After Blooming	0.40	0.06	0.54	0.73	0.23	0.05

[1/] T = % N + % P_2O_5 + % K_2O.

[2/] R = % K_2O + % CaO + % MgO.

for nitrogen, phosphate and potash, respectively. Similarly, the ratios for potash, calcium and magnesium were 0.66-0.74, 0.18-0.26 and 0.09-0.13, respectively. The ratios for nitrogen, calcium and magnesium in the 'Gros Michel' banana (Table 13) increased with age of plant, while the potash ratio decreased with age. However, the phosphate ratio was not affected by stage of growth. Comparison of these ratios with those of Boland (1960) indicated that nitrogen was low before blooming and at shooting, but adequate after blooming, while phosphorus and potassium were adequate. Calcium and magnesium were inadequate during the first two stages of growth, but only magnesium was inadequate after blooming. This measure of nutrient balance and adequacy generally agrees with the critical levels of calcium and magnesium in the third leaf lamina discussed earlier.

Total Uptake of Nutrients

The total uptake of nitrogen, phosphorus and potassium in various tissues of banana at the shooting stage is presented in Table 14. These values were obtained by multiplying the nutrient concentration of a particular tissue after blooming by the average dry matter of that tissue taken from plants cut at the shooting stage and separated into the appropriate anatomical tissues. Since plants sampled at the shooting stage in the original study could not be sacrificed because yields were required, this technique was

Table 14. Total Content of Nitrogen, Phosphorus and Potassium in Tissues of Normal 'Gros Michel' Bananas at the Shooting Stage

Tissue[1]	Dry Matter	N	P	K	N+P+K
			(grams)		
3rd Leaf Lamina	141.3	4.4	0.26	4.8	9.5
CFL Laminae	893.2	25.9	1.61	27.5	55.0
CDL Laminae	613.2	10.1	0.63	5.9	16.6
3rd Leaf Sheath	114.4	0.4	0.07	2.6	3.1
CFL Sheaths	1235.3	4.9	0.70	28.2	33.8
CSD Leaves	2419.1	10.9	1.33	61.0	73.2
3rd Leaf Midrib	79.7	0.5	0.07	1.8	2.4
CFL Midribs	594.2	3.3	0.42	9.6	13.3
CDL Midribs	696.1	2.6	0.14	2.9	5.6
Stem	343.4	2.3	0.38	17.6	20.3
Inflorescence	266.7	6.3	0.66	16.4	23.4
Total	7255.3	71.6	6.27	178.3	256.2

[1] CFL = composited functional leaf.
CDL = composited dead leaf.
CSD = composited sheaths of dead.

used to obtain approximate values for total quantities of nitrogen, phosphorus and potassium in the 'Gros Michel' banana. The shooting stage was selected because it is a well-defined stage of growth and it has been used in other studies with bananas.

The data in Table 14 show that potassium is the nutrient taken up in largest total quantity by the banana (178.3 g.), followed by nitrogen (71.6 g.) and then by phosphorus (6.3 g.). These quantities result in an N:P:K ratio of about 11:1:28. Nitrogen was concentrated largely in the lamina of functional leaves and sheaths of dead leaves. Phosphorus was also concentrated in the functional leaf laminae and sheaths of dead leaves. The concentrations of nitrogen and phosphorus were higher in the functional leaf laminae than in the sheaths of dead leaves. However, the higher dry matter of the sheaths of dead leaves (nearly three times greater than that of the composited functional leaf laminae) was responsible for the large quantities of nitrogen and phosphorus in this tissue. The largest amounts of potassium were found in the sheaths of dead and functional leaves and in the functional leaf lamina. The inflorescence and stem also had relatively high quantities of potassium.

The coefficients of variation for chemical determinations in tissues sampled before and after blooming from both moderately and severely diseased plants are presented in Appendix Table 24. These coefficients of variation differ considerably for the various

tissues and the individual determinations. The values for the third leaf lamina are 3.2, 21.3, 26.5 and 35.1 percent for moisture, nitrogen, phosphorus and potassium, respectively. Because the coefficients are relatively high for nitrogen, phosphorus and potassium, a sufficiently large number of the third leaf must be sampled for a reliable determination of these elements in the 'Gros Michel' banana.

Nutrient Composition of Soils

Soil samples were collected from each plot in the experiment at two depths as described earlier and analyzed for ten nutrients. The results are shown in Table 15. Most nutrients were at levels generally considered adequate. However, calcium, magnesium and silicon values were low and at levels generally considered deficient in Hawaiian soils (Fox et al., 1968; Humbert, 1968). This was probably due to the high rainfall in the area (Table 6) which caused extensive leaching of calcium as well as magnesium and silicon. This agrees with findings for tissue data which indicated that calcium and magnesium were at levels considered deficient for other cultivars of bananas.

The pH of the surface soil in the experimental site was about 5.5 which is favorable for nutrient uptake. The relatively low pH of the unfertilized plot may be responsible for the relatively high value of extractable aluminum found in the soil. Attempts to

Table 15. Nutrient Composition of Soils

Treatment[1]	pH[2]		% N		ppm P		% K		% Ca	
	a	b	a	b	a	b	a	b	a	b
Fertilized	5.5	4.8	0.25	0.21	21	12	0.02	0.01	0.10	0.03
Unfertilized	4.6	4.5	0.30	0.24	47	45	0.01	0.01	0.00	0.01

Treatment[1]	ppm Mg		ppm S		ppm Si[3]		ppm Mn		ppm Zn		ppm Al	
	a	b	a	b	a	b	a	b	a	b	a	b
Fertilized	37	12	130	249	0.84	0.68	1.5	1.2	7.1	5.6	2.2	47
Unfertilized	23	12	187	261	0.97	0.78	0.8	0.6	26.0	30.0	97.0	132

a = 0-15 cm., b = 15-30 cm.

[1] Fertilized = means of treatments A through E, unfertilized = one sample only.

[2] Soil to water ratio = 1:2.5.

[3] Silicon concentration on solution basis.

correlate soil values with plant values of nutrients in the third leaf lamina were unsuccessful, except for calcium.

Effect of Leaf Spot Disease on Nutrient Uptake and Distribution in Banana Tissues

The effect of Leaf Spot disease on the nutrient levels in bananas was investigated by sampling plants from treatments A and C (moderate and severe disease incidence). Seven tissues were sampled before blooming and twelve tissues were sampled after blooming.

Nutrient Distribution in Several Tissues

The data in Table 16 are from seven comparable tissues before and after blooming. The other five tissues sampled after blooming are omitted because similar tissues for comparison were not available before blooming. Moisture values before blooming appeared to be unaffected by the severity of disease and varied randomly with disease in the various tissues. Nitrogen levels before blooming were consistently higher in plants with severe disease than in plants with moderate disease incidence, and this difference was significant at the 1 percent level (Table 17). The only significant difference between the nitrogen levels in individual tissues of treatments A and C was in the composited functional leaf laminae as shown by Duncan's multiple range test. Phosphorus levels were quite similar in both groups of plants and

Table 16. Effect of Leaf Spot Disease on Distribution of Moisture, Nitrogen, Phosphorus and Potassium in 'Gros Michel' Banana Tissues

Tissue[1]	% H_2O		% N		% P		% K	
	A[2]	C[3]	A	C	A	C	A	C
Before Blooming[4]								
3rd Leaf Lamina	84.8	87.5	3.5	3.8	0.31	0.29	6.7	5.4
CFL Laminae	87.4	84.1	3.1	4.0	0.24	0.28	5.0	5.4
CDL Laminae	25.3	19.0	2.1	2.6	0.14	0.16	2.0	2.1
3rd Leaf Sheath	96.5	97.2	2.3	2.6	0.21	0.19	11.7	7.7
CFL Sheaths	96.1	96.7	2.4	2.8	0.18	0.20	8.6	7.9
CSD Leaves	94.6	96.0	1.9	2.2	0.11	0.12	9.1	8.3
Corm	91.7	96.6	1.7	2.0	0.13	0.14	5.7	6.9
After Blooming[4]								
3rd Leaf Lamina	75.1	75.2	3.1	3.2	0.19	0.19	3.4	3.1
CFL Laminae	74.2	74.9	2.9	3.0	0.18	0.18	3.1	3.1
CDL Laminae	11.0	10.8	1.7	2.3	0.10	0.14	1.0	1.1
3rd Leaf Sheath	93.0	94.5	0.4	0.4	0.06	0.06	2.3	2.3
CFL Sheaths	92.4	93.4	0.4	0.4	0.06	0.06	2.3	2.2
CSD Leaves	91.6	92.2	0.5	0.4	0.06	0.05	2.5	3.1
Corm	89.0	88.7	0.6	0.6	0.06	0.05	2.8	2.8

[1] CFL = composited functional leaf, CDL = composited dead leaf, CSD = composited sheaths of dead.

[2] A = moderate disease.

[3] C = severe disease.

[4] means of 4 samples.

Table 17. Analysis of Variance in Seven Tissues at Two Levels of Disease Incidence Before and After Blooming

Source of Variation	df	Before Blooming[1/]				After Blooming[1/]			
		% H_2O	% N	% P	% K	% H_2O	% N	% P	% K
Tissues	6	5758.17**	3.946**	0.03526**	53.160**	7014.61**	12.610**	0.030003**	4.45**
Disease	1	2.83	2.658**	0.00111	7.578*	3.06	0.206**	0.000045	0.01
Ts x Di	6	20.21	0.097	0.00103	5.417**	0.85	0.125**	0.000386**	0.13
Error	42	12.61	0.350	0.00288	1.512	2.47	0.013	0.000078	0.40

Ts = tissues, Di = disease.

*Significant at the 5% level.
**Significant at the 1% level.

[1/] Mean squares.

variations appeared to be random. Potassium values were somewhat variable, but were generally lower in the severely diseased plants, and the difference was significant at the 5 percent level (Table 17).

After blooming, moisture levels were similar at the two levels of disease and were generally lower than the values before blooming. The severely diseased plants on the whole had higher nitrogen concentrations. Although the differences were not as great as those before blooming, they were highly significant. Nitrogen levels after blooming were lower than those before blooming. Phosphorus and potassium concentrations were similar in the two groups of plants but the values were lower than those before blooming.

The higher nitrogen concentration in diseased tissues after blooming agrees with the findings of Rangaswami and Natarajan (1966) who reported that leaves of diseased bananas had higher levels of nitrogen. This is believed to be due to the preferential translocation of certain nutrients to diseased tissues which behave as actively growing meristems. The reason for higher nitrogen levels in functional leaf laminae and sheaths of severely diseased plants before blooming is not clear. However, it may be due to an indirect effect of Leaf Spot disease. Walmsley and Twyford (1968) reported that nutrients are translocated from banana parent plants to suckers and vice-versa. It is possible that some of the

nitrogen in the severely diseased mature plants (after blooming) was translocated to the developing suckers.

Nutrient Concentrations in the Third Leaf Lamina and Sheath

Nutrient concentrations in the third leaf lamina and sheath before and after blooming are shown in Table 18 for plants from moderate and severe disease plots. Before blooming, moisture, calcium, sulfur and silicon were higher, but potassium, magnesium, manganese and aluminum were lower in laminae of plants from severe disease plots. The sheaths had higher moisture, nitrogen, calcium, magnesium, sulfur, manganese and zinc, but lower potassium and aluminum in plants from high disease plots. Analysis of variance (Table 19) showed that only potassium, calcium, zinc and aluminum levels were significantly affected by severity of disease. After blooming, levels of all nutrients, except aluminum, were quite similar in both tissues, and none of these nutrients was found to be significantly affected by disease.

Total Nutrient Uptake

The total uptake of nutrients by banana was obtained by multiplying the average dry weight of the various tissues from four plants sampled at the shooting stage by the concentration of the nutrients in the appropriate tissue (Appendix Table 22). The plants sampled were from plots which had been sprayed and thus had relatively low incidence of disease. The assumption made

Table 18. Effect of Leaf Spot Disease on Concentration of Nutrients in 'Gros Michel' Banana Third Leaf Lamina and Sheath Before and After Blooming

Tissue	Disease Level	Nutrient Concentration										
		H_2O	N	P	K	Ca	Mg	S	Si	Mn	Zn	Al
		Percent								ppm		
		Before Blooming[1/]										
Third Leaf Lamina	Moderate	84.8	3.5	0.31	6.7	0.23	0.23	0.29	0.30	224	88	34
	Severe	87.5	3.8	0.29	5.4	0.55	0.20	0.45	0.46	133	86	26
Third Leaf Sheath	Moderate	96.5	2.3	0.21	11.7	0.19	0.10	0.06	0.05	60	69	89
	Severe	97.2	2.6	0.19	7.7	0.69	0.16	0.18	0.06	69	180	39
		After Blooming[1/]										
Third Leaf Lamina	Moderate	75.1	3.1	0.19	3.4	0.91	0.16	0.38	0.43	308	207	42
	Severe	75.2	3.2	0.18	3.1	1.02	0.15	0.39	0.43	174	241	107
Third Leaf Sheath	Moderate	93.0	0.4	0.06	2.3	0.42	0.08	0.01	0.05	73	192	73
	Severe	94.5	0.4	0.06	2.3	0.51	0.10	0.02	0.03	74	256	106

[1/] Means of four samples.

Table 19. Analysis of Variance of Nutrients in 'Gros Michel' Banana Third Leaf Lamina and Sheath at Two Levels of Disease Incidence

Source of Variation	df	% H_2O	% N	% P	% K	% Ca	% Mg
			Before Blooming[1/]				
Tissues (Ts)	1	461.18**	6.003**	0.0410	52.93**	0.0086	0.0289**
Disease (Di)	1	12.08	0.423	0.0018	27.30*	0.6765**	0.0012
Ts x Di	1	4.31	0.003	0.0002	7.16	0.0315	0.0081
Error	12	6.23	0.541	0.0057	3.53	0.0197	0.0026

Source of Variation	df	% S	% Si	ppm Mn	ppm Zn	ppm Al
			Before Blooming[1/]			
Tissues (Ts)	1	0.2475**	0.4389*	51984.0*	5738.1**	4455.6*
Disease (Di)	1	0.0798	0.0298	6889.0	11935.6**	3393.1**
Ts x Di	1	0.0023	0.0218	9900.3	12825.6**	1743.1
Error	12	0.0193	0.0264	10790.0	64.4	692.7

Ts = Tissues, Di = disease incidence.

[1/] Figures are mean squares.

*Significant at the 5% level.
**Significant at the 1% level.

Table 19. Analysis of Variance of Nutrients in 'Gros Michel' Banana Third Leaf Lamina and Sheath at Two Levels of Disease Incidence (Continued)

Source of Variation	df	% H_2O	% N	% P	% K	% Ca	% Mg
			After Blooming[1/]				
Tissues (Ts)	1	1383.84**	30.250**	0.066300**	3.610*	0.9950**	0.0138*
Disease (Di)	1	2.25	0.010	0.000060	0.123	0.0410	0.0001
Ts x Di	1	1.96	0.025	0.000010	0.063	0.0003	0.0008
Error	12	1.79	0.011	0.000073	0.589	0.0646	0.0017

Source of Variation	df	% S	% Si	ppm Mn	ppm Zn	ppm Al
			After Blooming[1/]			
Tissues (Ts)	1	0.5476**	0.6123**	112392.6**	0.0	945.6
Disease (Di)	1	0.0001	0.0003	17622.6	9604.0	9555.1
Ts x Di	1	0.0000	0.0008	18292.6	900.0	976.6
Error	12	0.0005	0.0464	13383.9	3119.2	6368.8

Ts = Tissues, Di = disease incidence.

[1/] Figures are mean squares.

*Significant at the 5% level.
**Significant at the 1% level.

was that the relative weights of tissues in plants with moderate and severe disease were similar and that uptake values would reflect the differences in nutrient concentration between the two types of plants. Visual observations of the two groups of plants in the field appeared to substantiate this assumption.

The uptake data presented in Table 20 are expressed as a percent of the total quantity of each nutrient in the whole plant. The actual weights of nutrients in each tissue are presented in Appendix Table 25. It is obvious that the total quantities of all three nutrients, nitrogen, phosphorus and potassium, were higher in plants with severe disease and the differences were 6.5, 0.08 and 11.49, respectively. The ratios of N:P:K were 11:1:28 for moderately diseased plants and 12:1:30 for severely diseased plants. This suggests that relatively more nitrogen and potassium were taken up by plants with severe disease incidence. Severely diseased plants had relatively higher levels of nitrogen and phosphorus in the dead leaf laminae and lower levels in the sheaths of dead leaves than the moderately diseased plants. The presence of higher amounts of nitrogen in diseased plants agrees with the findings of Rangaswami and Natarajan (1966) that infection by M. musicola resulted in considerable reduction in the amino acid content of banana leaves and a narrowing of the C:N ratio due to an increase in total nitrogen content.

Table 20. The Effect of Leaf Spot Disease on Nitrogen, Phosphorus and Potassium Uptake and Distribution in 'Gros Michel' Bananas at the Shooting Stage

Tissue[1/]	Dry Matter (grams)	Percent of Total Nutrient Content in Dry Matter of Whole Plant							
		Nitrogen		Phosphorus		Potassium		N + P + K	
		Moderate	Severe	Moderate	Severe	Moderate	Severe	Moderate	Severe
Third Leaf Lamina	141.3	6.1	5.7	4.1	4.1	2.7	2.3	3.7	3.3
CFL Laminae	893.2	36.2	34.6	25.7	25.7	15.4	14.6	21.5	20.5
CDL Laminae	613.2	14.1	18.1	10.0	13.1	3.3	3.5	6.5	7.8
Third Leaf Sheath	114.4	0.6	0.6	1.1	0.9	1.5	1.4	1.2	1.2
CFL Sheaths	1235.3	6.8	6.3	11.2	10.7	15.8	14.0	13.2	11.7
CSD Leaves	2419.1	15.2	13.1	21.2	19.1	34.2	38.9	28.6	31.1
Inflorescence	266.7	8.8	9.0	10.5	10.1	9.2	8.3	9.1	8.5
Third Leaf Midrib	79.7	0.7	0.6	1.1	0.9	1.0	0.9	0.9	0.8
CFL Midribs	594.2	4.6	5.1	6.7	6.6	5.4	5.2	5.2	5.2
CDL Midribs	696.1	3.6	3.3	2.2	2.7	1.6	1.5	2.2	2.0
Stem	343.4	3.2	3.5	6.1	6.1	9.9	9.4	7.9	7.7
Totals (grams)	7255.30	71.60	78.10	6.27	6.35	178.30	189.70	256.2	274.2

[1/] CFL = composited functional leaf, CDL = composited dead leaf, CSD = composited sheaths of dead.

The apparent accumulation of nitrogen and phosphorus in the dead leaf laminae was possibly due to the preferential translocation of nutrients to diseased tissues as reported by several workers for plants other than bananas (Johnson et al., 1966, for wheat; Bergeson, 1966, for tomato; Livne and Daly, 1966, for beans). It is also probable that the premature death of these tissues caused by the disease prevented the mobilization of nitrogen and phosphorus to other parts of the plant. The low levels of nitrogen and phosphorus in the sheaths of dead leaves reflect this lack of mobilization.

There was little difference in potassium in the dead leaf laminae of plants with moderate and severe disease, but the sheaths of dead leaves from plants with severe disease had relatively more potassium than those from plants with moderate disease. This may indicate that potassium in the sheaths of severely diseased plants was in a form not easily translocated to the stem and inflorescence because the amounts of potassium in the stem and inflorescence of these plants were relatively low.

SUMMARY AND CONCLUSIONS

A study was conducted on the distribution of several nutrients and the effect of Leaf Spot disease (M. fijiensis) on the uptake and distribution of nutrients in 'Gros Michel' bananas grown in the field under Hawaiian conditions. The experiment consisted of two fungicide treatments (Orthol K oil and Dithane M-45 + Volck oil) sprayed at 10- and 20-day intervals. The lamina and midrib of the third youngest and fully expanded leaf were sampled from each of 27 plants at the shooting stage. In addition, plants with moderate and severe incidence of Leaf Spot disease were sampled at two stages of development (before and after blooming). Seven tissues were collected from plants before blooming (5-8 months) and twelve from plants after blooming (10 months and over).

At the shooting stage, the average levels of total nitrogen, phosphorus and potassium in the third leaf lamina were 3.07, 0.21 and 3.56 percent, respectively, which were within levels considered adequate for normal growth of 'Cavendish' bananas. Calcium, magnesium, sulfur, silicon, manganese, zinc and aluminum were also determined and it appeared that calcium and magnesium levels were at or near deficiency in comparison with levels for 'Cavendish' bananas. Treatment effects on nitrogen, calcium, manganese and the number of functional leaves were significant and these effects on the number of disease lesions were

highly significant. The number of functional leaves was the most highly correlated with yield ($r = +0.832$).

The concentrations of nitrogen, phosphorus, potassium, magnesium, silicon and zinc in the third leaf lamina generally declined as plant age increased from 6 to 10 months, while the concentrations of calcium and sulfur increased with age during the same period, but the level of aluminum remained constant. After 10 months (the shooting stage), concentrations of calcium, silicon, manganese and zinc increased, while those of the other nutrients remained relatively unchanged.

The effect of Leaf Spot disease on nutrient uptake and distribution in individual tissues was variable. However, nitrogen concentration was generally higher in plants with severe disease incidence sampled before and after blooming. Potassium levels, on the other hand, were lower in plants from plots with severe disease before blooming, and about equal to levels in plants with moderate disease after blooming. Phosphorus levels were relatively unaffected by disease incidence. Concentrations of calcium and zinc in the third leaf lamina and sheath before blooming were significantly higher, while concentrations of potassium and aluminum in these tissues were significantly lower in plants from severe disease plots. After blooming, there were no significant differences in the levels of any nutrient between plants with moderate and severe disease.

The quantity of potassium in the whole banana plant (moderate disease) at the shooting stage was highest (178.3 g.), followed by nitrogen (71.6 g.), and then phosphorus (6.3 g.). Total uptake of nitrogen, phosphorus and potassium at this stage was higher with severe disease incidence and the differences in total content of these three nutrients between plants with severe and moderate infection amounted to 6.5, 0.08, and 11.4 grams, respectively. The total uptake ratios of N:P:K were 11:1:28 for moderately diseased plants and 12:1:30 for severely diseased plants.

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Appendix Table 21. Concentrations of Moisture, Nitrogen, Phosphorus and Potassium in 'Gros Michel' Banana Tissues Before Blooming[1/]

Tissues[2/]	% H_2O		% N		% P		% K	
	a	b	a	b	a	b	a	b
Third Leaf Lamina	84.8	87.5	3.45	3.80	0.31	0.29	6.68	5.40
CFL Laminae	87.4	84.0	3.08	4.00	0.24	0.28	5.00	5.40
CDL Laminae	25.3	19.0	2.13	2.57	0.14	0.16	2.03	2.05
Third Leaf Sheath	96.5	97.2	2.25	2.55	0.21	0.19	11.65	7.70
CFL Sheaths	96.1	96.7	2.42	2.75	0.18	0.20	8.62	7.92
CSD Leaves	94.6	96.0	1.85	2.20	0.11	0.12	9.12	8.27
Corm	91.7	92.6	1.65	2.00	0.13	0.14	5.67	6.87

1/ Values are means of four samples; a = moderate disease incidence; b = severe disease incidence.

2/ CFL = composited functional leaf; CDL = composited dead leaf; CSD = composited sheaths of dead.

Appendix Table 22. Concentrations of Moisture, Nitrogen, Phosphorus and Potassium in 'Gros Michel' Banana Tissues After Blooming[1/]

Tissues[2/]	% H_2O		% N		% P		% K	
	a	b	a	b	a	b	a	b
Third Leaf Lamina	75.1	75.2	3.10	3.17	0.19	0.18	3.38	3.07
CFL Laminae	74.2	74.9	2.90	3.02	0.18	0.18	3.08	3.10
CDL Laminae	10.9	10.8	1.65	2.32	0.10	0.14	0.97	1.08
Third Leaf Sheath	93.0	94.5	0.37	0.40	0.06	0.06	2.30	2.25
CFL Sheaths	92.4	93.4	0.40	0.40	0.06	0.06	2.28	2.15
CSD Leaves	91.6	92.2	0.45	0.42	0.06	0.05	2.52	3.05
Corm	89.0	88.7	0.58	0.55	0.06	0.05	2.75	2.80
Inflorescence	90.1	91.9	2.38	2.63	0.25	0.24	6.15	5.90
Third Leaf Midrib	83.3	83.3	0.58	0.62	0.08	0.08	2.20	2.12
CFL Midribs	83.3	84.9	0.55	0.67	0.07	0.07	1.62	1.67
CDL Midribs	13.0	19.7	0.37	0.37	0.02	0.03	0.42	0.40
Stem	95.2	95.7	0.68	0.80	0.11	0.12	5.13	5.23

[1/] Values are means of four samples; a = moderate disease incidence; b = severe disease incidence.

[2/] CFL = composited functional leaf; CDL = composited dead leaf; CSD = composited sheaths of dead.

Appendix Table 23. Coefficients of Variation for Variables Measured in the 'Gros Michel' Banana

Variable[1/]	Means	CV (%)
% H_2O	77.31	0.8
% N	3.07	5.4
% P	0.21	4.8
% K	3.55	11.2
% Ca	0.76	10.3
% Mg	0.15	14.6
% S	0.38	12.8
% Si	0.18	26.5
ppm Mn	211.78	43.5
ppm Zn	38.78	17.7
ppm Al	29.15	23.8
Yield (kg/bunch)	17.82	19.4
No. of Lesions/100 $cm.^2$	37.74	38.7
No. of Functional Leaves	8.81	12.7

[1/] Nutrients were determined in the third leaf lamina at the shooting stage.

Appendix Table 24. Coefficients of Variation for Chemical Determinations in 'Gros Michel' Banana Tissues[1/]

Tissues[2/]	% H_2O		% N		% P		% K	
	Means	CV	Means	CV	Means	CV	Means	CV
Third Leaf Lamina	80.63	3.2	3.38	21.3	0.24	26.5	4.63	35.1
CFL Laminae	80.11	2.6	3.25	18.7	0.22	17.6	4.14	15.1
CDL Laminae	16.52	35.9	2.17	11.7	0.13	9.4	1.53	21.4
Third Leaf Sheath	95.30	1.3	1.39	12.9	0.13	31.9	5.98	20.3
CFL Sheaths	94.64	0.8	1.49	17.5	0.12	34.4	5.24	12.9
CSD Leaves	93.60	1.4	1.23	22.3	0.08	24.9	5.74	12.1
Corm	90.51	1.9	1.19	31.2	0.09	27.7	4.53	23.5
Inflorescence	90.98	2.3	2.50	25.9	0.24	27.6	6.03	30.8
Third Leaf Midrib	83.29	0.7	0.60	15.9	0.08	17.8	2.16	30.0
CFL Midribs	84.10	2.5	0.61	12.9	0.07	20.5	1.65	16.7
CDL Midribs	16.34	46.3	0.38	13.3	0.02	18.1	0.41	45.1
Stem	95.44	0.7	0.74	21.2	0.11	17.4	5.18	13.7

[1/] Includes tissues of plants from moderate and severe disease plots before and after blooming.

[2/] CFL = composited functional leaf; CDL = composited dead leaf; CSD = composited sheaths of dead.

Appendix Table 25. Total Nitrogen, Phosphorus and Potassium Uptake by the 'Gros Michel' Banana at the Shooting Stage[1/]

Tissues[2/]	Dry Matter	N		P		K		Total N + P + K	
		a	b	a	b	a	b	a	b
Third Leaf Lamina	141.3	4.4	4.5	0.26	0.26	4.8	4.3	9.5	9.1
CFL Laminae	893.2	25.9	27.0	1.61	1.63	27.5	27.7	55.0	56.3
CDL Laminae	613.2	10.1	14.2	0.63	0.83	5.9	6.6	16.6	21.6
Third Leaf Sheath	114.4	0.4	0.5	0.07	0.06	2.6	2.6	3.1	3.2
CFL Sheaths	1235.3	4.9	4.9	0.70	0.68	28.2	26.6	33.8	32.2
CSD Leaves	2419.1	10.9	10.2	1.33	1.21	61.0	73.8	73.2	85.2
Inflorescence	266.7	6.3	7.0	0.66	0.64	16.4	15.7	23.4	23.3
Third Leaf Midrib	79.7	0.5	0.5	0.07	0.06	1.8	1.7	2.4	2.3
CFL Midribs	594.2	3.3	4.0	0.42	0.42	9.6	9.9	13.3	14.3
CDL Midribs	696.1	2.6	2.6	0.14	0.17	2.9	2.8	5.6	5.6
Stem	343.4	2.3	2.7	0.38	0.39	17.6	18.0	20.3	21.1
Total	7255.3	71.6	78.1	6.3	6.4	178.3	189.7	256.2	274.2

1/ Uptake figures are in grams; a = moderate disease incidence; b = severe disease incidence.

2/ CFL = composited functional leaf; CDL = composited dead leaf; CSD = composited sheaths of dead.