EFFECT OF THREE LEVELS OF NITROGEN ON INORGANIC LEAF COMPOSITION AND GROWTH OF THE BANANA

by

George E. Battikhah

A Thesis Submitted to the Graduate Faculty of

the School of Agriculture in Partial Fulfillment of

the Requirements for the Degree of

MASTER OF SCIENCE IN AGRICULTURE

Split Major: Horticulture-Entomology

Approved:

In Charge of Major Work

Chairman, Graduate Committee

American University of Beirut
1961

NITROGEN INFLUENCE ON BANANA

Battikhah

ACKNOWLEDGEMENTS

The author wishes to extend greatful acknowledgements to:

Dr. R.M. Khalidy for his guidance, advice and suggestions in the laboratory work and in directing the research for this dissertation.

Dean R.A. Nichols, Dr. W.W. Worzella, Dr. A.S. Talhouk and Dr. K. Hanson for their critical study and suggested improvements in this manuscript.

Miss Marie-Louise Davidian who helped me in the statistical analysis of the experimental data.

Miss Adrineh Tanielian and Mr. Vahram Adjemian for their cooperative attitude and patience in typing the final draft, and all those who helped to make this study possible.

ABSTRACT

A short study of eight months duration was conducted in 1961 on the university campus in Beirut to determine the effect of three levels of nitrogen fertilization on leaf inorganic leaf composition and growth of the Cavendish banana. The banana trees were grown in 100 liter asbestos cement barrels which were filled with potting soil to which phosphorous and potassium were added. Nitrogen fertilizer was the only variable and four levels were used namely zero, 100, 200 and 400 grams of ammonium nitrate. Each treatment was replicated five times. The nitrogen fertilizer treatments were divided into three equal parts that were applied at a 45 days interval.

Leaf samples were taken at the end of the study period on July 1961, and analysed for nitrogen, phosphorous, potassium, calcium, magnesium, manganese and iron. Also data involving the indexes of growth such as leaf area, stem weight, stem length and rate of leaf production were taken.

Statistical analysis of the data by the use of analysis of variance and the 't' test revealed that nitrogen in the leaves increases significantly with nitrogen fertilization, also the third leaf had always the maximum nitrogen content. Phosphorous and potassium showed a significant decrease in banana leaves as the leaf advances in age. The other elements calcium, magnesium, manganese, and iron increased significantly with leaf age. A significant increase in stem length, leaf area and rate of leaf production were obtained with nitrogen fertilization. However the high rates of nitrogen fertilizer application did not substantially increase growth and even reduced stem weight.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Though of ancient origin the banana has become a staple food of modern times. It originated most probably in the humid tropical region of South East Asia, where edible diploid strains of *Musa acuminata*, the most primitive edible bananas, persist in large numbers to this day (13). Very early in the development of tropical agriculture the banana existed as a wild plant in the jungles. The plant supplied natives with their main daily food. Shortly after the beginning of civilization the banana was cultivated over an extensive area in the tropic and subtropic regions. The high food value, the prolific yield of nutritious fruit, and its adaptability to a wide range of conditions made the banana belong to the outstanding group of important fruits.

The banana comes second after grapes in total world fruit production with about 20.2 million metric tons annually. The world banana plantations occupy an area of one million hectares (14).

Lebanon which grows only the cavendish type variety is a marginal area for banana production. The banana plantations are mainly found on the coastal plains. According to Khalidy and Piquer (9), the overall area planted to bananas is 2806.83 hectares with an annual production of about 28,500 metric tons of which about 10 to 15 tons are exported.

This study was undertaken to better understand the nitrogen nutrition of banana under local conditions. From a survey conducted on banana cultivation in Lebanon (9), it was found that there is a great difference in the rate of nitrogen fertilizer applied by different growers in the same region. This study also intends to adapt known methods of sampling worked out by other investigators to local conditions and to correlate the effect of different nitrogen levels of fertilization on leaf composition and growth.

The data obtained from these investigations will furnish a basis for future field experiments on the use of leaf analysis as a guide to the nutritional status of the banana plant in Lebanon.

REVIEW OF LITERATURE

Although the banana is an important commercial plant, very little research has been carried out in connection with this plant. This is due to the fact that the banana grows mainly in under-developed countries. The few experiments that were carried out by commercial companies were kept unpublished. Recently a large amount of the experimental data has been released by those companies and a number of experiment stations have been founded in different areas cultivating the crop.

Leaf Sampling in Banana: A major problem in leaf sampling for inorganic constituents is to decide at what age the leaf would provide the most critical data. The work done so far has been on the first seven leaves. The trend among investigators is toward establishing systematic sampling techniques for banana tissue analysis. Efforts are being made to find a particular portion of a particular leaf on a young plant with well defined characteristics, that will give an index of the plants true nutritional status (2).

Hewitt (7) developed the first leaf sampling techniques in 1955 and applied them to the study of banana nutrition in Jamaica. His results showed that sections from the central lamina of the third leaf represents best the whole plant nutritive condition. Murray (11) found out that Hewitt's choice of the third leaf is satisfactory and should be used in all future work. However for those nutrients that tend to accumulate with the age of leaf such as calcium, analysis of an older leaf would give a better indication of the status of the said elements in the plant.

Boland in 1959 (2) found wide variations in nutrient content upon analysing leaves number two and three from plants of similar age growing under uniform conditions. In order to make his work more exact, the age of each leaf in days had to be determined. He used leaves between 16 to 25 days of age in his studies. The said leaves were either leaf number one or two.

According to Boland (2), Brun noted physiological differences between the right and left sides of the leaf lamina. Where an age difference existed between both sides of the lamina this was apparent when the unfurling process of the leaf was observed. On the basis of this latter finding Boland chose the right side of the leaf lamina (Viewing the upper leaf surface from the petiole).

Hasselo (6) in his leaf analysis work on banana took leaf samples by cutting off pieces of leaves about ten cms wide from either side of the mid rib in the middle part of the leaf.

Boland in 1957 (1) investigated the possibility of reducing the size of banana leaf samples necessary for analysis, and after experimentation came to the conclusion that there was no significant difference between concentrations of major elements in the middle two feet portion of the leaf lamina, and the distal or proximal two feet portion of the same leaf.

The time of the year at which to sample leaves was another factor to consider. According to Boland (2), Ulrich in 1943 stated that leaf samples can be usefully taken at regular intervals during the growing season for leaf composition studies. Hewitt (7) investigated on the best time in the life of the tree for taking leaf samples and he came to the conclusion that the best time was as soon as possible after the appearance of the inflorescence due to a higher content of nutrients in the leaf at that time.

Boland (2) suggested monthly leaf sampling as a routine investigation specially in areas showing abnormal symptoms. Also this is helpful in order to have some idea of the monthly variation of nutrients as affected by increased growth rates and by rainfall. According to the said author, Emmert came to the conclusion that the most stable period for leaf sampling was the middle of the growing season when leaf changes are at a minimum. Leaves taken at this time showed greatest sensitivity to changes in the nutrient supply.

The above reviewed work tended to set a certain time or interval of time when sampling is best. According to Boland (2) Broeshart stated that leaf samples can be taken anytime, as far as the comparison of the chemical composition are made on samples collected at similar periods during the year.

Leaf Composition in Banana: The earliest work done on the chemical composition of the banana plant was made primarily with the aim to determine the nutritive value of the fruit, while leaf analysis was made haphazardly.

Hewitt (7) was the first to grasp the potentiality of leaf analysis and its practical use as a nutritional guide in bananas. He worked out the ranges of values, of nitrogen, phosphorous, and potassium for optimal growth in Jamaica. Murray (11) using sand cultures worked out the ranges for calcium and magnesium, the said ranges appear below.

Percent nutrients in third leaf of banana.

	N	P_2O_5	K_2O	CaO	MgO
Adequacy	2.6	0.45	3.30	1.4	0.60
Severe deficiency	<1.5	<0.20	<2.50	<0.75	<0.20

Hewitt (7) found out that the third leaf had a consistently higher content of total nitrogen than did any other leaf. Also phosphorous and potassium bore a direct relation to the age of the leaf, these elements were consistently lower in amounts in the successive leaves starting with the younger leaves from the same plants.

Murray (11) found out that the distribution of nitrogen showed a slight rise from the youngest leaf to the fourth leaf and then a progressive fall with an increase in the age of the leaf. This agrees with the findings of Hewitt (7) which follow the same pattern.

Boland (1) wanted to find out the range of nitrogen in leaves at different stages of plant growth since all the preceeding work was done on "shot" plants (plants that have a fully emerged inflorescence) (14). The stages of growth were divided into three divisions: I. Opening of the first blunt leaf to death of the last pointed leaf. II. From shedding of the last pointed leaf until before initiation of flowering or two third grown. III. Two third grown leaf until plant "shot". The results from analysing leaves in each of the above categories showed the following trends, nitrogen values generally rise to a peak and then fall off gradually in each of the three stages. In stage I plants, the peak is reached in the second leaf, while stage II stage III or "shot" plants the peak is found in the third leaf. Phosphorous and potassium concentrations decrease with leaf age, this is more pronounced in "shot" plants in which there is a steep fall in values between leaf number one and two, followed by a slow, steady decline to leaf number five. In all four categories of plants, calcium and magnesium concentrations increased with leaf age.

Boland (2) states that the inorganic composition of a particular leaf on a plant could be established as a measure for sufficiency. By comparing similar leaves in commercial plantings, the nutritional status of the plant could be established and deficiency corrected before initiation of flowering. Von Loesecke (10) stated that at the time an embryonic bunch of fruit starts to form, the number of hands on the embryonic bunch will depend upon the nutritional status of the rhizome. This further shows the importance of the nutritional status of the whole plant of which the leaves are a good index.

Fertilization and Leaf Composition in Banana:- Hewitt (7) investigated the effect of fertilizers on leaf composition. He applied one fertilizer at a time at different rates to individual plants and detected its effect on leaf composition. Soil application of nitrogen caused an increase in nitrogen in the leaf. However when the third leaf nitrogen content increased over 2.6 percent there was no plant response to nitrogen fertilization. Fertilization with nitrogen tended sometimes to depress the potash content of the leaves. However with increase of phosphorous fertlization there was no corresponding increase in the phosphorous content of the leaves. The increased rates of potassium fertilization caused significant increase of potassium in the leaf.

Murray (11) worked on the deficiency of nutrients and their effect on leaf composition. His results showed that calcium deficiency seemed to depress the nitrogen content of the leaf. This was also true in the case of deficiency of cations other than calcium, and the depression of nitrogen was more pronounced in the older leaves. With phosphorous deficiency some accumulation of nitrogen occurred in the young leaves, while in calcium and magnesium deficient plants the level of said elements in the youngest leaf is not greatly below that of the control. It seemed that there was no accumulation of calcium and magnesium with age, the oldest leaves having much the same content as the youngest leaves. This was rather unexpected and would seem to indicate a greater mobility of calcium and magnesium in the banana than in most other plants.

<u>Effect of Fertilization in Banana on Growth and Yield</u>:- In spite of the fact that the banana plant has been grown commercially for more than half a century, little information has been published regarding its response to fertilizers. According to Butler (4), Croucher and

caused an increase in nitrogen in the leaf. However when the third leaf nitrogen content increased over 2.6 percent there was no plant response to nitrogen fertilization. Fertilization with nitrogen tended sometimes to depress the potash content of the leaves. However with increase of phosphorous fertlization there was no corresponding increase in the phosphorous content of the leaves. The increased rates of potassium fertilization caused significant increase of potassium in the leaf.

Murray (11) worked on the deficiency of nutrients and their effect on leaf composition. His results showed that calcium deficiency seemed to depress the nitrogen content of the leaf. This was also true in the case of deficiency of cations other than calcium, and the depression of nitrogen was more pronounced in the older leaves. With phosphorous deficiency some accumulation of nitrogen occurred in the young leaves, while in calcium and magnesium deficient plants the level of said elements in the youngest leaf is not greatly below that of the control. It seemed that there was no accumulation of calcium and magnesium with age, the oldest leaves having much the same content as the youngest leaves. This was rather unexpected and would seem to indicate a greater mobility of calcium and magnesium in the banana than in most other plants.

Effect of Fertilization in Banana on Growth and Yield:- In spite of the fact that the banana plant has been grown commercially for more than half a century, little information has been published regarding its response to fertilizers. According to Butler (4), Croucher and

Mitchell published in 1940 the results of fertilizer experiments with the Gros Michel variety of banana in several agricultural zones of Jamaica. They found out that nitrogen was always the first element to which bananas responded while the addition of phosphorous fertilizer failed to give a response even when it was apparently deficient. Among the macroelements, potassium was found to be required in greatest amount by the banana crop.

Butler in 1960 (4) reviewed the experiments on banana fertilization carried out in Jamaica between 1933 and 1942 and those from Honduras during 1948 to 1951. In St. Catherine district of Jamaica during 1933 an experiment was initiated on fertilization of banana with nitrogen, phosphorous, and potassium. Results obtained over a four year period showed substantial increase in bunches per acre and total weight per acre as a result of the use of nitrogen. There were further small increases when potassium was included. The weight of the stem also follows the same pattern. In another experiment in the same area the results showed that fruiting or growth responses of an economic nature could not be expected from the use of phosphorous or potassium in addition to nitrogen. This was on soils where the potassium content varied from 150 to 300 ppm and phosphorous content from 100 to 600 ppm. Also according to Butler (4), tests in Honduras on banana fertilization showed that nitrogen caused an increase in growth which ranged from 15 to 37 percent. This increase in growth was parallel to the increase in nitrogen fertilization. The said response was primarily an increase of the plant in height and in earlier shooting.

Also nitrogen fertilization was found to delay the maturing period of the fruit. Little difference in growth could be expected from the addition of either potassium or phosphorous or from the addition of microelements under normal conditions, also the same holds true for mean weight of bunch, total production and shooting heights (4).

MATERIALS AND METHODS

The experiment was conducted on the university campus in Beirut using banana trees of the Cavendish variety Musa, nana. The suckers were secured from the Damour district where the mother plants were used as interplant with citrus trees. Only uniform suckers of three to four month of age were chosen.

The suckers were uprooted on December 2, 1960 and the following data involving weight and length of stem of each plant was recorded. The leaves were removed and the suckers were planted in 100 liter asbestoscement barrels with adequate drainage.

The uniformly mixed soil used in this experiment was analysed and the results appear below:-

Mechanical Analysis

Percent sand	Percent silt	Percent clay	Texture	Percent moisture
42.9	17.3	39.8	Sandy-clay	6.2

Chemical Analysis

PH	$CaCO_3$	Organic matter %	Total % N	C/N	P_2O_5 ppm.	Ca Mg me/100 grm	K_2O me/100 grm	Na me/100 grm	C.E.C. me/100 grm
8.2	13.66	1.83	0.072	14	1.221	33.70	2.18	2.17	38.05

MATERIALS AND METHODS

The experiment was conducted on the university campus in Beirut using banana trees of the Cavendish variety Musa, nana. The suckers were secured from the Damour district where the mother plants were used as interplant with citrus trees. Only uniform suckers of three to four month of age were chosen.

The suckers were uprooted on December 2, 1960 and the following data involving weight and length of stem of each plant was recorded. The leaves were removed and the suckers were planted in 100 liter asbestoscement barrels with adequate drainage.

The uniformly mixed soil used in this experiment was analysed and the results appear below:-

Mechanical Analysis

Percent sand	Percent silt	Percent clay	Texture	Percent moisture
42.9	17.3	39.8	Sandy-clay	6.2

Chemical Analysis

PH	$CaCO_3$	Organic matter %	Total % N	C/N	P_2O_5 ppm.	Ca Mg me/100 grm	K_2O me/100 grm	Na me/100 grm	C.E.C. me/100 grm
8.2	13.66	1.83	0.072	14	1.221	33.70	2.18	2.17	38.05

After planting, the bananas were placed in the glasshouse, and the temperature was kept around 25 C. The trees were sprayed with 0.1 percent "Metain Systox" to control aphids and watered every ten days or when required. During mid April of 1961 the potted trees were moved outside for another three months.

The fertilizer treatments were divided into four groups with five plants in each group. Each plant received the same amounts of potassium and phosphorous namely 400 grams of single superphosphate and 200 grams of potassium sulfate. The superphosphate was applied at the time of planting, while half of the potassium was applied at the time of planting and the other half 45 days later. Nitrogen was the only element that was varied and the said element was applied at three intervals during the experiment as shown below.

Nitrogen Treatment for Potted Plants

Total Nitrogen applied in grms.	Date & Amount of Ammonium Nitrate applied per Plant					
	1st Application		2nd Application		3rd Application	
	Amount grms	Date	Amount grms	Date	Amount grms	Date
0	-	-	-	-	-	-
100	35	Dec. 29, 1960	35	Feb. 9, 1960	30	March 23, 1960
200	75	"	75	"	50	"
400	125	"	150	"	125	"

During July 11 to 14, 1961 the plants were removed from the pots and data involving leaf area, length of stem, and weight of stem were recorded. The area of each leaf was acquired by tracing the boundaries on uniform sheets of paper. The weight of a known area of the same paper sheets was determined and the surface area of each leaf calculated.

Leaf samples for inorganic tissue analysis were taken. The leaves chosen for the said analysis were leaves numbers one, three, five, and seven starting from the last opened leaf as leaf number one. The leaves were normal leaves, free from diseases, malformations, or any other disorder such as adhering foreign material. Every sample consisted of the whole leaf lamina.

The collected leaves were transferred to the laboratory where they were scrubbed with a cheesecloth and detergent on both surfaces (3, 17). Then the leaves were rinsed in water, scrubbed with 0.1 N HCl, rinsed in tap water and twice in distilled water (3).

The washed leaves were placed in tagged cheesecloth bags and dried in a forced-draft oven at 70 C $\pm$ 1 C for at least 48 hours. The bags employed were washed the same way as the leaves.

The dried leaf samples were ground in a Wiley mill using 40 mesh sieve, and stored in screw top sample bottles.

Before weighing out the ground tissue for analysis the samples were dried in an oven at 70$\pm$ 1 C overnight and cooled in a dessicator.

The methods of analysis used for the inorganic leaf composition varied with the elements in question. Nitrogen was determined by the

Kjedahl-method (8). Manganese, Iron, phosphorous and Magnesium were determined colorimetrically with a Beckman Model B. Spectrophotometer, while potassium and calcium were determined spectrographically with a Beckman flame attachement to the Beckman Model D.U. Spectrophotometer, according to the methods described by Toth et al. (16). The results were calculated on the dry weight basis and presented as percentage.

The statistical methods of analysis employed for the different leaf inorganic elements is the analysis of variance for a split-plot design (12), where the tree itself is considered as the main plot and the different leaves as sub-plots. Data other than the inorganic leaf elements were analysed by the method of analysis of variance for randomized blocks (12). The critical difference derived from the 't' test was calculated wherever significant results were obtained.

The discussions in this study for percent leaf composition of the different elements are based on the mean of five replications, while the discussions for growth are based on the mean of four replications. The fifth replication was not used because it was substituted for diseased plants and did not have the same length of time for growth.

RESULTS AND DISCUSSION

I. Effect of Nitrogen Fertilization on Inorganic Leaf Composition:

1. Nitrogen:- The results obtained from the analysis of banana leaf for nitrogen content showed that under all treatments nitrogen increases significantly as we go down the axis of a banana tree, from leaf one to leaf three. This increase was followed by a gradual, but significant decline in nitrogen in leaf five and leaf seven as shown in Table 1. These findings are in agreement with the results of Murray (11), Hewitt (7) and Boland (2). A careful examination of the nitrogen distribution in the four leaves that were analysed showed that there was no significant difference between leaf one and five. However a significant difference in nitrogen content between leaf one or five, and leaf three was obtained. The preceeding results indicated a trend for a normal curve of leaf nitrogen distribution, where the maximum nitrogen content was in the third leaf. Steward and Freiberg (15) suggested an explanation to the accumulation of nitrogen in the third leaf, in that, the soluble nitrogen tend always to move to the more active leaves on the axis of banana plants.

With increase in nitrogen fertilization (in the form of Ammonium nitrate hereafter referred to as nitrogen fertilizer) there was a corresponding increase in nitrogen content of the leaf as seen from Table 1. A significant increase in leaf nitrogen content was obtained between plants receiving the fertilizer and plants that did not receive any nitrogen fertilizer. Also, significant increase in leaf nitrogen

Table 1: Variations in the average content of nitrogen in banana leaves as influenced by leaf number and treatment.

Leaf number	1	3	5	7	
Nitrogen fertilizer grams	Percent		Nitrogen		Mean of Treatments
0	1.82	2.00	1.76	1.57	1.78
100	3.14	3.40	3.25	3.12	3.23
200	3.26	3.59	3.36	3.17	3.34
400	3.45	3.76	3.55	3.30	3.51
Mean of leaves	2.91	3.19	2.98	2.79	

L.S.D. between means at the 1% level

treatment = 0.27

Leaf number = 0.12

Observed F:

treatment = 158.88**

Leaf number = 27.50**

** Statistically significant at the 1% level.

content was obtained from plants receiving 400 grams over those receiving 100 grams nitrogen fertilizer. The same trend was observed between plants treated with 200 and 400 grams nitrogen fertilizer the former having 3.34% while the latter having 3.51%. These results showed that the increase in nitrogen content of the leaf was not of the same magnitude as compared to the increase in nitrogen fertilizer, specially when the treatment exceeds the 100 grams nitrogen fertilizer.

According to Hewitt (7) the critical level of nitrogen in the third leaf is 2.6% above which banana plants grow normally and below which they show deficiency symptoms. From the results obtained in this study it is apparent that the only plants that fall in the nitrogen deficient category were those that were not fertilized, with 2.0% nitrogen in their third leaf. All other treatments induced sufficient nitrogen in their third leaves which ranged from 3.4% to 3.8% and showed normal growth.

2. Phosphorous:- For all treatments the individual leaves were significantly different from each other in phosphorous content as presented in Table 2. The older the leaf is the less the phosphorous content in it, these findings agree with those of Hewitt (7), Boland (2), and Murray (11).

By studying the effect of the nitrogen treatments on leaf phosphorous content, there was no significant difference between plants receiving 100 and 200 grams nitrogen fertilizer in their leaf phosphorous. The same holds true for plants receiving zero and 400 grams

Table 2: Variations in the average content of phosphorous in banana leaves as influenced by leaf number and treatment.

Leaf number	1	3	5	7	
Nitrogen fertilizer grams	Percent		Phosphorous		Mean of Treatments
0	0.259	0.230	0.205	0.148	0.210
100	0.235	0.178	0.165	0.152	0.183
200	0.241	0.182	0.169	0.155	0.187
400	0.275	0.204	0.178	0.163	0.205
Mean of leaves	0.253	0.198	0.179	0.154	

L.S.D. between means at the	1% level	5% level
Treatment =	-	0.022
Leaf number =	0.016	-

Observed F:

Treatment= 3.70 *

Leaf number = 86.75 **

---

* Statistically significant at the 5% level.

** Statistically significant at the 1% level.

nitrogen fertilizer. But there was a significant difference in leaf phosphorous content between plants receiving 100 or 200 grams nitrogen fertilizer and plants receiving zero or 400 grams nitrogen fertilizer. The plants in the former treatments had low values namely 0.183% and 0.187% of leaf phosphorous content, while those in the latter treatments had high values of leaf phosphorous content namely 0.210% to 0.205% as shown in Table 2.

In general the banana plants under this study had lower amounts of phosphorous than the plants studied by Hewitt (7), who has set 0.45% as the level of adequacy of phosphorous in banana leaves. The highest level of leaf phosphorous attained was 0.253%. These findings suggest that bananas under local conditions might be deficient in phosphorous, and it is worthwhile to study the effect of phosphorous in Lebanon on the banana plant performance.

3. Potassium:- The leaf potassium content was found to decrease with leaf age. There was a significant difference in leaf potassium content between leaves one, three, and five. The amounts of potassium found in leaf one was 4.69%, while leaf two had 3.96% and leaf five had 3.48%. There was no significant decrease in potassium leaf content between leaf five and seven, which indicates that in mature leaves the amount of potassium is stable. This could be seen from the data reported in Table 3.

To study if the nitrogen fertilizer treatments had any effect on potassium leaf content, the mean of leaf potassium content for

Table 3: Variations in the average content of potassium in banana leaves as influenced by leaf number and treatment.

Leaf number	1	3	5	7	
Nitrogen fertilizer grams	Percent		Potassium		Mean of Treatments
0	4.48	3.74	3.44	3.48	3.79
100	4.59	3.48	3.12	2.99	3.55
200	4.56	4.07	3.48	3.56	3.91
400	5.14	4.54	3.87	3.73	4.32
Mean of leaves	4.69	3.96	3.48	3.44	

L.S.D. between means at the	1% level	5% level
Treatment =	-	0.46
Leaf number =	0.31	-

Observed F:

Treatment = 4.74 *

Leaf number = 47.01 **

---

* Statistically significant at the 5% level.

** Statistically significant at the 1% level.

each treatment was examined. It is apparent that plants receiving no nitrogen, 100 and 200 grams nitrogen fertilizer contained the same amounts of potassium in their leaves. However the plants receiving the 400 grams nitrogen fertilizer had a significant increase in leaf potassium content namely 4.32% over plants receiving zero and 100 grams nitrogen fertilizer, the latter having 3.79% and 3.55% potassium. This finding suggest that with the increased rate of nitrogen application there might be a greater amount of accumulation of leaf potassium.

4. Calcium:- The data acquired from the analysis for calcium in the leaf tissue of bananas is reported in Table 4. It is seen that the concentration of this element increases significantly with leaf age. This finding agrees with the results obtained by Boland (2) and Murray (11). Murray (11) further established 1.4% as the critical level for sufficiency of calcium in the third leaf. According to the above established critical level only plants receiving no nitrogen fertilizer were calcium deficient and contained 1.2% calcium. The nitrogen fertilizer treatments did not have any significant effect on the calcium content of the leaves.

5. Magnesium:- The results of leaf analysis for magnesium content showed that the said element increases significantly as the leaves become older. This is in accordance with the findings of Boland (2), and Murray (11). By studying Table 5, it is seen that the third leaf had 0.263 mean % magnesium. This is considered to be very low as compared to 0. 60% established by Murray (11), as the

Table 4: Variations in the average content of calcium in banana leaves as influenced by leaf number.

Leaf number	1	3	5	7	
Nitrogen fertilizer grams	Percent		Calcium		Mean of Treatments
0	1.03	1.21	1.73	2.07	1.51
100	1.23	1.41	1.43	1.90	1.49
200	1.02	1.37	1.66	2.00	1.51
400	1.08	1.43	1.77	2.25	1.63
Mean of leaves	1.09	1.36	1.65	2.05	

L.S.D. between means at the 1% level.

Treatment = N.S.

Leaf number = 0.17

Observed F:

Treatment = N.S.

Leaf number = 77.50**

** Statistically significant at the 1% level.

Table 5: Variations in the average content of magnesium in banana leaves as influenced by leaf number.

Leaf number	1	3	5	7	
Nitrogen fertilizer grams	Percent		Magnesium		Mean of Treatments
0	0.238	0.280	0.337	0.359	0.304
100	0.246	0.277	0.337	0.393	0.313
200	0.214	0.254	0.289	0.322	0.270
400	0.221	0.243	0.287	0.352	0.276
Mean of leaves	0.230	0.263	0.312	0.357	

L.S.D. between means at the 1% level

Treatment = N.S.

Leaf number = 0.022

Observed F:

Treatment = N.S.

Leaf number = 84.48**

** Statistically significant at the 1% level.

critical level for sufficiency. Further it could be seen that all the leaves in the different treatments were low in magnesium. This finding may indicate that better plant performance might be expected if magnesium was added to the plant, and such trials are worth experimenting with under local conditions. There was no effect found on magnesium content of leaves from the nitrogen fertilizer treatments.

6. Manganese:- No previous work has been carried on manganese content in banana leaf tissue. The results obtained from this study on leaf analysis, and reported in Table 6 showed that there was a significant increase of this element in the older leaves over younger leaves. The mean manganese content in leaf one was 0.0076%, 0.0172% in leaf three, 0.0297% in leaf five and 0.0408% in leaf seven. This clearly shows significant differences between the successive leaves and a gradual build up of manganese as the leaf advances in age. By further studying the data presented in Table 6, it could be seen that the different rates of nitrogen fertilizer applications did not have any effect on manganese leaf content.

7. Iron:- No work so far has been done on iron in banana leaf tissue. The data collected from this study on iron content of banana leaves is presented in Table 7. There was a significant increase in iron content from leaf one to five with leaf one having a mean of 0.0072%, leaf three 0.0089% and leaf five 0.0100%. Leaf seven having 0.0105% was found not to be significantly different from leaf five. These results show a gradual increase in iron to leaf five after which

critical level for sufficiency. Further it could be seen that all the leaves in the different treatments were low in magnesium. This finding may indicate that better plant performance might be expected if magnesium was added to the plant, and such trials are worth experimenting with under local conditions. There was no effect found on magnesium content of leaves from the nitrogen fertilizer treatments.

6. Manganese:- No previous work has been carried on manganese content in banana leaf tissue. The results obtained from this study on leaf analysis, and reported in Table 6 showed that there was a significant increase of this element in the older leaves over younger leaves. The mean manganese content in leaf one was 0.0076%, 0.0172% in leaf three, 0.0297% in leaf five and 0.0408% in leaf seven. This clearly shows significant differences between the successive leaves and a gradual build up of manganese as the leaf advances in age. By further studying the data presented in Table 6, it could be seen that the different rates of nitrogen fertilizer applications did not have any effect on manganese leaf content.

7. Iron:- No work so far has been done on iron in banana leaf tissue. The data collected from this study on iron content of banana leaves is presented in Table 7. There was a significant increase in iron content from leaf one to five with leaf one having a mean of 0.0072%, leaf three 0.0089% and leaf five 0.0100%. Leaf seven having 0.0105% was found not to be significantly different from leaf five. These results show a gradual increase in iron to leaf five after which

Table 6: Variations in the average content of manganese in banana leaves as influenced by leaf number.

Leaf number	1	3	5	7	
Nitrogen fertilizer grams	Percent		Manganese		Mean of Treatments
0	0.0064	0.0158	0.0311	0.0608	0.0285
100	0.0080	0.0158	0.0250	0.0323	0.0203
200	0.0073	0.0160	0.0297	0.0313	0.0211
400	0.0088	0.0210	0.0331	0.0388	0.0254
Mean of leaves	0.0076	0.0172	0.0297	0.0408	

L.S.D. between means at the 1% level.

Treatment = N.S.

Leaf number = 0.0049

Observed F:

Treatment = N.S.

Leaf number = 104.25**

** Statistically significant at the 1% level.

Table 7: Variations in the average content of iron in banana leaves as influenced by leaf number.

Leaf number	1	3	5	7	
Nitrogen fertilizer grams	Percent		Iron		Mean of Treatments
0	0.0060	0.0082	0.0103	0.0114	0.0090
100	0.0075	0.0096	0.0100	0.0115	0.0097
200	0.0079	0.0087	0.0099	0.0098	0.0091
400	0.0074	0.0091	0.0098	0.0094	0.0089
Mean of leaves	0.0072	0.0089	0.0100	0.0105	

L.S.D. between means at the 1% level

Treatment = N.S.

Leaf number = 0.0008

Observed F:

Treatment = N.S.

Leaf treatment = 54.13**

** Statistically significant at the 1% level.

the supply remain constant in the leaf. It was further established that the different nitrogen fertilizer treatments did not have any effect on iron in banana leaf tissue.

II. Effect of nitrogen fertilization on leaf area, stem weight, stem length and rate of leaf production.

1. Effect on leaf area:- The assimilating capability for nutrients in banana plants depends mostly on the leaf area. Results obtained from this study showed that plants treated with nitrogen fertilizer had their leaf area doubled over plants that did not receive nitrogen fertilizer. The non fertilized plants had a mean leaf area of 14806.3 sq. cm., while those treated with 100 grams nitrogen fertilizer attained a mean leaf area of 31153.1 sq. cm. However it was observed from Table 8, that plants treated with different levels of nitrogen fertilizer did not have significant differences in their leaf area among themselves. Therefore this indicates that, increase in nitrogen fertilizer application does not necessarily imply a similar increase in leaf area of banana plants. No previous work has dealt with leaf area of banana plants as effected by nitrogen fertilizer application.

2. Effect on stem weight:- Butler (4) in his field experiments reported an increase in stem weight as a result of nitrogen fertilizer application. Results from this experiment have shown that with the addition of 100 grams nitrogen fertilizer there was an increase in stem weight over the non fertilized plants. However increasing the fertilizer over 100 grams caused a significant decrease in stem weight

Table 8: Effect of nitrogen fertilizer on leaf area.

	Total leaf area in square centimeters			
	Nitrogen fertilizer (grams)			
Replication	0	100	200	400
I	17287.5	24850.0	27933.6	27712.5
II	12312.5	33075.0	34762.5	29300.0
III	11987.5	33937.5	24600.0	31750.0
IV	17637.5	32750.0	33137.5	32901.8
Mean of treatments	14806.3	31153.1	30108.4	30416.1

L.S.D. between means at the 1% level.

Teatment = 10035.1

Observed F:

Treatment = 15.26 **

Replication = N.S.

** Statistically significant at the 1% level.

over the non fertilized plants. However increasing the fertilizer over 100 grams caused a significant decrease in stem weight as shown in Table 9. The reason for the lack of substantial increase in stem weight as a result of increased rates of nitrogen fertilization is not known. A similar response has been reported on apple trees (5).

3. Effect on stem length:- The results obtained from this study showed a significant increase in the stem length of nitrogen fertilizer. However with the increase in the rate of nitrogen fertilizer application there was no corresponding significant increase in stem length. Plants receiving 100 grams nitrogen fertilizer increased on the average by 14 cms, while those receiving 200 and 400 grams nitrogen fertilizer increased by 17 cms. A careful examination of Table 10 shown that plants not treated with nitrogen fertilizer decreased 5 cms. under their original stem length. Butler (4) found out that increase in stem length is parallel to the increase in nitrogen fertilization. It seems that Butler in his field experiment did not add high rates of nitrogen fertilizer to see the ineffect of nitrogen on stem length. The rate applied by said worker was four ounces of sodium nitrate per tree per month.

4. Effect on rate of leaf production:- It was observed from Table 11 that an apparent increase in rate of leaf production of plants treated with nitrogen fertilizer occurred over plants not treated with nitrogen fertilizer. The 200 grams nitrogen fertilized plant had the maximum rate of leaf production namely seven leaves in 91 days, while

it took the non fertilized plants 137 days to produce the same number of leaves. There was no significant difference in rate of leaf production among plants that received different rates of nitrogen fertilizer. All fertilized plants produced leaves at about the same rate.

Table 9: Effect of nitrogen fertilizer on stem weight.

	Increase in stem weight (kgs)			
	Nitrogen fertilizer (grams)			
Replication	0	100	200	400
I	2.28	2.95	1.42	0.91
II	1.14	1.82	0.91	0.45
III	1.59	2.27	0.45	0.68
IV	2.50	1.82	1.14	0.88
Mean of treatments	1.88	2.22	0.98	0.73

L.S.D. between means at the 1% level.

Treatment = 0.99

Observed F:

Treatment = 12.56 **

Replication = N.S.

** Statistically significant at the 1% level.

Table 10: Effect of nitrogen fertilizer on stem length.

	Increase in stem length (cms)			
	Nitrogen fertilizer (grams)			
Replication	0	100	200	400
I	-7	20	18	17
II	-5	11	18	18
III	-5	17	14	17
IV	-3	7	18	16
Mean of treatments	-5	14	17	17

L.S.D. between means at the 1% level.

Treatment = 11

Observed F:

Treatment = 23.0 **

Replication = N.S.

** Statistically significant at the 1% level.

Table 11: Effect of nitrogen fertilizer on rate of leaf production.

	Rate of leaf growth (days)			
	Nitrogen fertilizer (grams)			
Leaf	0	100	200	400
1	30	24	18	23
3	68	48	40	45
5	103	71	66	69
7	137	98	91	107

SUMMARY AND CONCLUSION

The study reported in this thesis was undertaken to evaluate known methods of banana leaf sampling under local conditions, and to determine the content of the different inorganic elements in leaves on the axis of a banana plant. The study was also undertaken to better understand the effect of nitrogen fertilizer on leaf inorganic composition, and growth.

The conclusions drawn from this study are as follows:

1. Inorganic leaf analysis as influenced by the age of the leaf and the nitrogen fertilizer treatments produced the following results:

   a. Nitrogen: Nitrogen start accumulating in the younger leaves and reaches a maximum in the third leaf. This is followed by a decrease in nitrogen with the increase in the leaf age. Leaf nitrogen was found to increase with the application of nitrogen fertilizer. However the increase was not apparent when higher rates of nitrogen fertilizer were applied.

   b. Phosphorous: The older the banana leaves the less phosphorous content in them. Medium nitrogen fertilizer application tended to depress phosphorous in the leaves of bananas, while either the absence of nitrogen fertilizer or its presence in very high amounts caused an increase in phosphorous content in banana leaves.

c. Potassium: Potassium leaf content was found to decrease from leaf one to five. There was no difference between leaf five and seven. The low nitrogen fertilizer treatments did not have any effect on leaf potassium content. However the highest rate of nitrogen fertilizer induced a significant increase in potassium content of the leaves.

d. Calcium: An increase in calcium content in the leaves was found as they become older in age. The different rates of nitrogen fertilizer showed no effect on calcium content of banana leaves.

e. Magnesium: Rapid increase in magnesium was found with increase in leaf age. However the nitrogen fertilizer treatments did not influence the magnesium leaf content.

f. Manganese: The increase in manganese leaf content was found to be directly proportional to leaf age. There was no effect on manganese leaf content from nitrogen fertilization.

g. Iron: Iron content of banana leaves increased with leaf age. However in older leaves the increase was insignificant. The nitrogen fertilizer treatments did not affect iron content in the leaves.

2. Leaf area, stem weight, stem length and rate of leaf production as affected by different rates of nitrogen fertilizer application.

a. Leaf area: Banana leaf area was found to be constant although the rate of nitrogen fertilizer were varied.

b. Stem weight: Banana plants treated with 100 grams nitrogen fertilizer had the maximum increase in stem weight, while the non treated plants showed a greater stem weight than the 200 and 400 grams nitrogen fertilized plants.

c. Stem length: The nitrogen fertilized banana plants on the whole had about three times as much increase in stem length over the non-nitrogen fertilized plants. No significant difference was observed among plants receiving the fertilizer.

d. Rate of leaf growth: There was a definite influence of nitrogen on rate of leaf growth. Nitrogen fertilized plants produced more leaves in less time. The amount of nitrogen fertilizer applied did not alter the rate of leaf production.

From the results obtained in this study it was observed that the 100 gram nitrogen fertilizer produced sufficient growth and good performance during the first eight months of growth. This finding indicates that excess amounts of nitrogen fertilizer are being employed in banana plantation before the onset of flowering. It is worthwhile to continue this study through harvest to establish a more valid picture of the need of nitrogen in bananas. Further it was found that under the conditions of this experiment phosphorous and magnesium were deficient and their effect should be further studied. The other elements analysed for seemed to be sufficient except for calcium in non-fertilized plants that was deficient according to standards set by Murray (11).

BIBLIOGRAPHY

1. Boland, D.E. Annual Reports, Banana Board Res. Dept. Jamaica pp. 11-12 (1957-58).

2. ________________. Annual Reports, Banana Board Res. Dept. Jamaica, pp. 12-14 (1959).

3. Brown, J.C. Iron chlorosis, Ann. Rev. Plant Phys. 7:171-190 (1956).

4. Butler, A.F. Fertilizer experiments with Gros Michel banana. Trop. Agr. 37:31-50 (1960).

5. Gardner, V.R., F.C. Bradford and H.D. Hooker. The Fundamentals of Fruit Production, 3rd ed. McGraw-Hill Company, New York, pp. 267-270 (1952).

6. Hasselo, H.N. Premature yellowing of lacaton bananas. Trop. Agr. 38:29-34 (1961).

7. Hewitt, C.W. Leaf analysis as a guide to the nutrition of banana. Emp. J. Exp. Agr. 23:11-16 (1955).

8. Horwitz, W. (chairman). Official Methods of Analysis. Assoc. Agr. Chem. Inc. Washington, 9th ed. (1960).

9. Khalidy, R., and G.J. Piquer. Banana growing in Lebanon. Rep. No. 24 Inter. Meeting Banana Prod. Abidjan, Ivory Coast (1960).

10. Von Loesecke, H.W. Banana, Vol. (1) 2nd ed. Interscience Pub. L.T.D. New York (1950).

11. Murray, D.B. The effect of deficiencies of the major nutrients on growth and leaf analysis of the banana, Trop. Agr. 37:97-106 (1960).

12. Panse, V.G. and P.V. Sukhatme. Statistical Methods for Agricultural Workers. Indian Council of Agr. Res. New Delhi (1954).

13. Reynold, K.P. The Banana, Honghton Muffling Pub. Comp. New York (1927).

14. Simmonds, N.W. Bananas, Longman Green Comp. L.T.D. London (1959).

15. Steward, F.C. and S.R. Freiberg. Physiological investigations on the banana plant, Ann. Bot. 24: 147-157 (1960).

BIBLIOGRAPHY

1. Boland, D.E. Annual Reports, Banana Board Res. Dept. Jamaica pp. 11-12 (1957-58).

2. ________________. Annual Reports, Banana Board Res. Dept. Jamaica, pp. 12-14 (1959).

3. Brown, J.C. Iron chlorosis, Ann. Rev. Plant Phys. 7:171-190 (1956).

4. Butler, A.F. Fertilizer experiments with Gros Michel banana. Trop. Agr. 37:31-50 (1960).

5. Gardner, V.R., F.C. Bradford and H.D. Hooker. The Fundamentals of Fruit Production, 3rd ed. McGraw-Hill Company, New York, pp. 267-270 (1952).

6. Hasselo, H.N. Premature yellowing of lacaton bananas. Trop. Agr. 38:29-34 (1961).

7. Hewitt, C.W. Leaf analysis as a guide to the nutrition of banana. Emp. J. Exp. Agr. 23:11-16 (1955).

8. Horwitz, W. (chairman). Official Methods of Analysis. Assoc. Agr. Chem. Inc. Washington, 9th ed. (1960).

9. Khalidy, R., and G.J. Piquer. Banana growing in Lebanon. Rep. No. 24 Inter. Meeting Banana Prod. Abidjan, Ivory Coast (1960).

10. Von Loesecke, H.W. Banana, Vol. (1) 2nd ed. Interscience Pub. L.T.D. New York (1950).

11. Murray, D.B. The effect of deficiencies of the major nutrients on growth and leaf analysis of the banana, Trop. Agr. 37:97-106 (1960).

12. Panse, V.G. and P.V. Sukhatme. Statistical Methods for Agricultural Workers. Indian Council of Agr. Res. New Delhi (1954).

13. Reynold, K.P. The Banana, Honghton Muffling Pub. Comp. New York (1927).

14. Simmonds, N.W. Bananas, Longman Green Comp. L.T.D. London (1959).

15. Steward, F.C. and S.R. Freiberg. Physiological investigations on the banana plant, Ann. Bot. 24: 147-157 (1960).

16. Toth, S.J., A.L. Prince, A. Wallace, and D.S. Mikelsen. Rapid quantitative determination of eight mineral elements in plant tissue by a systematic procedure involving use of a flame photometer. Soil Sc. 66:459-466 (1948).

17. Wallihan, E.F. Iron chlorosis, What is it? Calif. Citr. 38:414 (1953).