# MAGNESIUM UPTAKE AND ITS INTERACTION WITH OTHER ELEMENTS IN THE BANANA LEAF

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# SOME STUDIES ON Mg IN BANANA

CHAUDHRY

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AN ABSTRACT OF THE THESIS OF

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Title: Magnesium uptake and its interaction with other elements in the banana leaf.

A study was conducted to evaluate $MgCl_2$, $MgSO_4$, $Mg(NO_3)_2$, chelated Mg, and $SM_3$ in different forms and rates as sources of Mg for the banana plant. The relation of Mg to other elements in the banana leaf was also studied. Banana plants, Musa nana variety Cavendish, were planted on the campus of the American University of Beirut, Lebanon, during the fall of 1966. The differential treatments were applied to the plants on July 6, 1967. Leaf samples were collected twice, i.e., on July 16 and August 5, 1967. Samples from both dates were analysed for their inorganic composition separately for lamina and petiole with midrib tissues (hereafter referred to as petioles). No phytotoxic effects resulting from any of the treatments were observed on leaves. Foliar sprays of $MgSO_4$ at the rates of 14 and 21 g Mg per plant and of $MgCl_2$ and $Mg(NO_3)_2$ at the rate of 5 g Mg per plant induced increases in Mg of both petioles and laminae collected on July 16, 1967. These increases were found to persist in the leaf samples collected one month after the aplication of treatments. The remaining treatments consisting of a soil application of $MgCl_2$ at 28 g Mg per plant, chelated Mg used at 5, 10 and 15 g Mg per plant, and $SM_3$ used separately as foliar, soil, and soil cum foliar sprays each at 4 g $SM_3$ per plant did not increase Mg contents in the leaves collected during the first sampling. However, in the samples collected later, increases in Mg were observed in petioles and laminae of plants receiving $MgCl_2$ soil applications, and both foliar and soil sprays of $SM_3$. Chelated Mg used at the rate of 15 g Mg per plant was also found to increase Mg in the laminae.

All the treatments applied in this experiment induced variations in the inorganic composition of leaf tissues. The level of Mg in the tissues seemed to have no direct effect on the elements that showed variation. However, increase in the level of tissues was found, in many instances, to be accompanied by a lower level of K.

Magnesium sulphate at 14 g Mg per plant, besides increasing Mg in tissues, produced no undesirable effects on tissue inorganic composition, and in particular it neither decreased K nor increased Ca. Among the materials tested, $MgSO_4$ at 14 g Mg per plant appears to be an efficient, inexpensive source of Mg when used as foliar spray for bananas.

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# I. INTRODUCTION

The banana is one of the major fruit crops of the world and occupies an important place in international trade. The fruit contains about 20% carbohydrates and is rich in vitamins and minerals. With respect to the amount of food material produced per unit area, the banana exceeds all other crops. It is one of the most profitable agricultural enterprises (36).

In Lebanon and Pakistan 3000 and 38000 hectares respectively were devoted to banana in 1965 (2, 16).

An important factor in banana cultivation is magnesium nutrition. This nutrient contributes to better growth and higher yields, and its deficiency has been reported in many areas (4, 8, 22). This study was conducted to evaluate $MgCl_2$, $MgSO_4$, $Mg(NO_3)_2$, chelated Mg, and $SM_3$ in different forms and rates as sources of Mg for the banana plant.

## II. REVIEW OF LITERATURE

Magnesium is a part of the chlorophyll molecule and thus has a direct effect on photosynthesis. Its ions have been found to activate numerous enzymes responsible for regularizing various physiological processes of the plants (27, 32, 35, 38, 39). It also facilitates the movement of carbohydrates from leaves to stems (27). The deficiency of this element usually results in interveinal chlorosis and poor, stunted growth of the plants and consequently reduces their yield (8, 9, 14, 31).

The addition of Mg to fertilizers did not, in most instances, affect the uptake of other elements (28, 33). However, there were some cases where the addition of Mg resulted in an increase of P in peas, potatoes, and apples without any addition of P to the fertilizers (5, 30, 41). Yoshida (43) reported that Seo and Ichikawa obtained a positive correlation between Mg and the P content of their tomato plants. They observed that with a medium supply of P, an increase in the Mg content of nutrient solutions led to a higher content of P in plants. A similar effect was found on the absorption of Ca by Spinach plants (18).

Fudge (15) studied the effect of Ca and Mg on K absorption in citrus. He observed that the amount of K absorbed from three units of $K_2O$ applied to a soil low in Ca and Mg was almost the same as the amount absorbed from ten units of $K_2O$ on soil to which Ca and Mg were

added. Johnson et al. (20) reported that, in many cases, a higher Mg content in celery tissues was associated with low levels of Ca and K. However, the authors found that these effects were not universally true. It was reported that the depressive effect of Mg on the Mn uptake by the different crops varies substantially. Magnesium was found, in some cases, to exert great depressing effects while in others, no apparent influence was recorded. This effect of Mg was associated with the amount of Mn in the growth media (24). Chandler (6) reported that a deficiency of Zn in bananas may have been the result of excess Mg. Johnson et al. (20) also reported that the absorption of Na was independent of the influence of Mg.

Different sources of Mg have been tried to correct the Mg deficiency of crops ; of these, $MgSO_4$ has been used most widely.

Hohlt and Maynard (18) observed that the Mg concentration in spinach tissue increased in proportion to the levels of Mg applied to the nutrient solution. They further found that lamina tissue contained more Mg than either the petiole or the lamina + petiole. The difference tended to become greater as the Mg level was increased; this suggests that Mg is deposited in Lamina tissue when there is a sufficient supply. It has been reported by Elsie (11) that foliar spray with 2% epsom salt ($MgSO_4.7H_2O$) applied nine times annually raised the Mg level in apple leaves. Soil application of epsom salt was also found to increase the available Mg in the soil; however, there was very little uptake of Mg by the plants. Southwick and Smith (37) found that foliar spray of $MgSO_4$ was useful for correcting the Mg deficiency in apples. Soil application of the salt was also

beneficial but was very slow in its action. Johnson et al. (20) reported that spraying the crop with $MgSO_4$ corrected the Mg deficiency in celery by increasing the level of Mg in the plants. A similar effect of $MgSO_4$ spray has been observed in bunch grapes by Scot and Scot (34). Lot (25) found that $MgSO_4$, both as a foliar spray and a soil application was ineffective in correcting the Mg deficiency chlorosis of Muscadine grapes. Mirza (29) sprayed pot grown banana plants at the rate of 33.50 grams $MgSO_4$ per plant. The chemical analysis of the leaf revealed that there was no significant increase in the Mg content of treated plants over control.

The magnesium deficiency in Valencia oranges was corrected to a great extent with a spray of $Mg(NO_3)_2$ at 0.1% Mg concentration. Magnesium sulphate in this case proved ineffective even at 0.25% Mg concentration (3). Fisher and Walker (13) found that nitrate and chloride salts of Mg were more rapidly absorbed by the apple leaves than the commonly used $MgSO_4$. A similar advantage of the chloride over the sulphate salt of Mg has been reported by Hagler for grapes (17). Embleton and Jones (12) reported that $Mg(NO_3)_2$, when applied as a foliar spray, corrected the Mg deficiency of oranges.

Walker and Fisher (42) reported that the chelated Mg was less effective than the $MgSO_4$ foliar spray in correcting the Mg deficiency of apple orchards. Soil application of chelate was still less effective.

All forms of seaweed have for centuries been applied to the land as fertilizers, where proximity to the sea coast has made this material available. Seaweed has been reported to be a good substitute

for farm yard manure to supply minor elements. The recent trend is to use liquid extracts of the weed; such preparations show their effect on crops more quickly than the "weathered" material used in the past (10, p. 428). The $SM_3$ (Sea Magic) is one such preparation produced by Chase Organics (Great Britain) Ltd, Shepperton, Middlesex, England. The manufacturer claims that it releases from the soil major plant nutrients and trace elements present only in unavailable form and also enables the plant to make better use of nutrients in fertilizers. It brings the soil into biological equilibrium and thus insures that plant foods are taken up in "balanced" proportions. The manufacturer also claims that its application provides considerable protection against diseases and pests. However there is no published data that might support these claims.

According to information supplied by Chase Organics Ltd,[1] the Jamaica Banana Board conducted an experiment in 1963 to study the effect of $SM_3$ on the growth and yield of bananas. Four levels of $SM_3$, i.e., four pints, six pints, eight pints and ten pints per acre, were used. The extract was mixed with water and sprayed on the foliage of the plants. The initial application was made in mid-March, when the plants were about six months old. The second application was six months later in mid-September. The results showed a favourable response in terms of yield and the length of shooting periods. The bunches emerged on an average of eight and a half weeks earlier where $SM_3$ was applied. The Mn content increased

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1. Chase Organics (Great Britain) Ltd. Gibraltar House, Shepperton, Middlesex, England.

in the leaves of plants treated with $SM_3$ at the rate of four pints per acre. Higher rates of $SM_3$ showed inconsistent decreases of Mn in the leaves. There was no difference in the levels of major elements in the leaves as a result of these treatments.

## III. MATERIALS AND METHODS

Preliminary trial. Preliminary trials were undertaken in the summer of 1966 to determine the rates and methods of application for some of the materials to be employed in the major study. The treatments were applied to six-month-old banana plants of the Cavendish variety (Musa nana) growing in 100 L asbestos cement barrels. Visual observations were made of these plants to detect any damage to the plants that may have resulted from the treatments. The Mg content of the leaf samples was determined by using the method described by Toth et al. (40). The treatments applied and results obtained are summarized in Table 1.

Major study. The major study was conducted on the campus of the American University of Beirut, Beirut, Lebanon. The dwarf banana Musa nana variety Cavendish was used. Suckers were collected in the fall of 1966. The unfolded leaves of each sucker were removed, leaving the pseudostems intact. The suckers were then planted two meters apart in rows two and a half meters wide. This fall planting allowed only for a short period of growth. However, the growth resumed with the beginning of spring and by mid-May, 1967, there was enough leaf area for the application of foliar spray treatments. By then each plant had at least five open leaves.

Superphosphate, potassium sulphate and ammonium sulfo-nitrate were applied to the plants on March 15, 1967 at the rates of one, one

Table 1. Results from preliminary treatments applied to supply Mg to six-month-old banana plants of the Cavendish variety during the summer 1966.

| Treatments | Total material used in g/plant | Mg in g/plant | Results |
|---|---|---|---|
| Control | - | - | - |
| $MgSO_4.7H_2O$; foliar spray | 71.5 | 7.0 | No increase in Mg of leaves of treated plants over control. |
| $MgSO_4.7H_2O$; foliar spray | 143.5 | 14.0 | Magnesium in leaves of treated plant increased over control. |
| $MgSO_4.7H_2O$; foliar spray | 215.25 | 21.0 | |
| $MgCl_2.6H_2O$; foliar spray | 58.0 | 7.0 | Magnesium in leaves of treated plants increased over control, but was accompanied by a severe burning of the foliage. |
| $Mg(NO_3)_2.6H_2O$; foliar spray | 74.7 | 7.0 | |
| $MgSO_4.7H_2O$; soil application | 287.0 | 28.0 | |
| $MgSO_4.7H_2O$; soil application | 574.0 | 56.0 | No increase in leaf Mg content of treated plants over control. |
| $MgSO_4.7H_2O$; soil application | 861.0 | 84.0 | |
| $Mg(NO_3)_2.6H_2O$; soil application | 298.7 | 28.0 | |
| $MgCl_2.6H_2O$; soil application | 235.7 | 28.0 | Leaf Mg content of treated plants increased over control. |

half, and one kilogram respectively per plant. The plants were again fertilized on June 20, 1967, with ammonium nitrate at the rate of one-fourth kilogram per plant.

The area between the plants was sprayed three times with weedicides to control weeds. The first two sprays consisted of Dowpon[1] at a dilution rate of 100 g per 10 liters of water while the third spray was made of Gramoxone[2] at a dilution rate of 100 ml per 18 liters of water. These sprays were applied on April 31, May 15, and June 6, 1967. Nemagon[3], at a rate of 20 ml per plant, was diluted in water, and added to the soil on June 16, 1967, to control the nematode population of the soil.

The plants were watered regularly. The followers that appeared were removed. This was carried out to cut down competition with the mother plants for the uptake of nutrients.

The randomized complete block design with five replications was used for the application of the treatments. The treatments were alloted to the plants at random and were applied on July 6, 1967. These are shown in Table 2.

The rates and methods used for the application of $MgSO_4$, $MgCl_2$ and $Mg(NO_3)_2$ were made in the light of the results obtained from the preliminary trial, which are given in Table 1. Since $MgSO_4$ foliar spray at the rate of seven grams of Mg per plant and soil applications of $MgSO_4$ and $Mg(NO_3)_2$ were found not to increase Mg in

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1. A trademark of 2, 2-dichloropropionic acid.
2. A trademark of 1, 1-dimethyl-4, 4'-dipyridilium dichloride.
3. A trademark of 1, 2-dibromo-3-chloropane.

Table 2. Treatments applied to supply Mg to field grown banana plants of the Cavendish variety on July 6, 1967.

| Material used | Quantity of material used in g/plant | Mg in g /plant | Methods of application |
|---|---|---|---|
| None (control) | - | - | - |
| Magnesium sulphate ($MgSO_4.7H_2O$) | 143.5 | 14.0 | Foliar spray |
| Magnesium sulphate ($MgSO_4.7H_2O$) | 215.25 | 21.0 | Foliar spray |
| Magnesium nitrate ($Mg(NO_3)_2.6H_2O$) | 53.30 | 5.0 | Foliar spray |
| Magnesium chloride ($MgCl_2.6H_2O$) | 41.60 | 5.0 | Foliar spray |
| Magnesium chloride ($MgCl_2.6H_2O$) | 235.70 | 28.0 | Soil application |
| Chelated Mg[1] | 111.10 | 5.0 | Soil application |
| Chelated Mg | 222.20 | 10.0 | Soil application |
| Chelated Mg | 333.30 | 15.0 | Soil application |
| $SM_3$ (seaweed extract) | 4.0 | -2 | Foliar spray |
| $SM_3$ (seaweed extract) | 4.0 | - | Soil spray |
| $SM_3$ (seaweed extract) | 4.0 | - | Soil cum Foliar spray |

1 Magnesium polyflavonoid (4.5% Mg), purchased from Esso Research and Engineering Company, U.S.A.
2 According to the manufacturer $SM_3$ contains a trace of Mg.

the plants, these treatments were not used in the final study. Similarly, foliar sprays of $MgCl_2$ and $Mg(NO_3)_2$ were used at reduced rates with a hope that such reduction would save the foliage from burning as had been observed in the preliminary trial. The rate of $SM_3$ employed was that recommended by the manufacturer.

To prepare the foliar sprays, the quantity of the material to be used per plant was dissolved in one and a half liters of distilled water. The solution, so prepared, was sprayed thoroughly on both surfaces of the leaves of each plant, using a fine atomizer hand-sprayer. In cases where the leaf surface became wet before the solution had been completely applied, the spraying was temporarily stopped. The leaves were allowed to dry for a while and then were again sprayed with the remainder of the solution. In this manner, the spray material was not allowed to drip.

For soil treatments other than $SM_3$, the quantity of material used per plant was thoroughly mixed with soil. Then the mixture was applied uniformly around the plant and was worked into the soil by hand to prevent contamination of adjacent plants.

Soil application of $SM_3$ was executed by mixing the material with water and then spraying the mixture on the soil surface around the plant. When applied as a soil cum foliar spray, the solution was sprayed both on the soil surface around the plant as well as on the leaves of the plant. This latter method was recommended by the manufacturer. The plants were watered immediately after the application of the treatments; the water was put into a basin around each plant.

Leaf samples were collected 10 days and 30 days after the application of the treatments. The third and fifth leaves from each plant were cut and brought to the laboratory. They were washed immediately with detergent by rubbing both surfaces with a sponge, rinsed in tap water, immersed in 0.1% hydrochloric acid for about 30 seconds, and then washed twice with distilled water. The lamina and the petiole with mid-rib (hereafter referred as petiole) of each leaf were separated soon after the washing. The identical tissues of the two leaves of the same plant were put together in a paper bag and dried in an oven at 70 ± 1°C for four days. The dried leaf tissues were ground through a Wiley mill using a 40 mesh sieve. Each ground sample was collected in a clean dry bottle. Before weighing, the ground samples were dried by placing the bottles with their caps off in the oven at 70 ± 1°C for about 12 hours. The sample bottles were then recapped and cooled in a desiccator. The lamina and petiole tissues of each plant, collected on both sampling dates, were analysed separately.

Magnesium, P and Fe were determined chlorimetrically with a Beckman Model B Spectrophotometer. Potassium and Na were determined spectrophotometrically with a Beckman Flame Attachment to the Beckman Model B Spectrophotometer. The methods followed in analysis are those described by Toth et al. (40). Nitrogen content was determined by the Kjeldahl method (19). Water soluble nitrate - N was determined by the phenyl disulphonic acid method as described by Johnson and Ulrich (21). Zinc, Mn, Cu and Ca were determined with Perklin-Elmer Atomic Absorption Spectrophotometer Model 303, following

the appropriate procedure for each element as described by the manufacturer (1).

The results presented in the chapter, headed "Results and Discussion" are the means of five samples of five replications. The Least Significant Test of significance described by LeClerg et al. (23) was employed to compare effects of treatments with the control.

# IV. RESULTS AND DISCUSSION

The visual observations and chemical analysis of the elements Mg, N, P, K, Ca, Na, Fe, Cu, Mn, Zn and the compound nitrate -N showed the following results.

There was no apparent injury to the banana plant as a result of the application of all the materials used to increase Mg. All plants were found to be normal in appearance and growth.

From each plant two samples were taken on two separate dates. The laminae and the petioles of the two leaves taken on each date were analyzed separately for their inorganic components. The data are calculated on the basis of dry weight and are reported as the averages of five replications. For each element analyzed, a separate table has been prepared showing the effect of the different treatments. Each table contains the values secured separately for the laminae and petioles. The table also includes the value for each sampling date, i.e., July 16 and August 5, 1967. All the comparisons were made with control except where it has been otherwise noted.

## Uptake of Mg from Different Sources and Treatments

The uptake of Mg from different treatments, determined as the percentage of Mg in dry weight of lamina and petiole tissues is given in Table 3.

Table 3. Magnesium content in the leaf tissues of bananas under different treatments expressed as percent dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + Midrib | Lamina | Petiole + Midrib |
| None (control) | .62 | .53 | .38 | .36 |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray. | .73** | .66** | .47** | .47** |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray. | .96** | .68** | .53** | .44** |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray. | 1.11** | .64** | .57** | .47** |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application. | .62 | .62 | .49** | .47** |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar spray. | 1.02** | .63* | .60** | .46** |
| Chelated Mg (5 g Mg/plant); soil application. | .53 | .50 | .43 | .33 |
| Chelated Mg (10 g Mg/plant); soil application. | .53 | .46 | .43 | .33 |
| Chelated Mg (15 g Mg/plant); soil application. | .67 | .55 | .50** | .35 |
| $SM_3$ (4 g of $SM_3$/plant); foliar spray | .70 | .45 | .45* | .43* |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | .65 | .53 | .49** | .42* |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | .54 | .42 | .41 | .36 |
| L.S.D. at 5% level | .10 | .09 | .05 | .05 |
| L.S.D. at 1% level | .13 | .12 | .07 | .07 |

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

Foliar sprays of $MgSO_4$ at the rate of 14 g and 21 g Mg per plant and foliar sprays of $MgCl_2$ and $Mg(NO_3)_2$, each at the rate of 5 g Mg per plant, significantly increased the Mg content of both the laminae and petioles of the treated plants over that of the control. This increase was first observed in samples collected on July 16, 1967, 10 days after the application of the treatments, and was maintained in the samples collected on August 5, 1967, 30 days after application of the treatments. The leaf tissues of the plants receiving $MgCl_2$ soil application and applications of chelated Mg and $SM_3$ showed no increase of Mg in the samples collected on July 16, 1967. However, in the samples collected on August 5, 1967, $MgCl_2$ soil application and $SM_3$ soil spray and foliar spray increased the Mg concentration both in the lamina and the petiole tissues of the treated plants over control. Similarly, chelated Mg used at the rate of 15 g Mg per plant was also found to increase Mg in the lamina tissues of the treated plants over control from the second sampling.

Comparison of the treatments shows that foliar sprays of $MgCl_2$ and $Mg(NO_3)_2$ were more efficient than $MgSO_4$ foliar spray in increasing the Mg concentration in the lamina tissues from the first sampling. The difference was significant at the 5% level. The results from the lamina tissues of the second sampling show that there was no difference in the amount of Mg in the tissue from $MgCl_2$ foliar spray when compared with the other treatments which were found to increase Mg over the control. The $Mg(NO_3)_2$ foliar spray added more Mg than chelated Mg, the $MgCl_2$ soil application, and $SM_3$ and $MgSO_4$ foliar sprays. The concentration of Mg in the laminae of

plants receiving the former treatment was 1.02% in the samples collected on July 16, 1967 and 0.60% in the samples collected on August 5, 1967. Such an effect of $Mg(NO_3)_2$ over $MgSO_4$ has been reported by Bar-Akiva (3), who found spraying of 0.1% $Mg(NO_3)_2$ effective in controlling the Mg deficiency of Valencia oranges where $MgSO_4$, at the rate of 0.25% Mg, did not induce any increase. According to Walker and Fisher (42), chelated Mg proved even less effective than $MgSO_4$. Thus it can be concluded safely that the greater effectiveness of $Mg(NO_3)_2$ agrees with the findings of Bar-Akiva and Walker and Fisher. The increase in the Mg content of the tissues of plants treated with $SM_3$ is in disagreement with the results reported by the Jamaica Banana Board. They found no effect of $SM_3$ on the Mg content of banana leaves.

The data presented in Table 3 further show that the treatments applied during this study resulted in an almost similar increase of Mg in both the lamina and petiole. Comparative values for Mg were higher for laminae than those for petiole tissues. The data given in Table 3 also show that foliar sprays of $MgSO_4$, $MgCl_2$, and $Mg(NO_3)_2$ were rapid in increasing the Mg content of the leaf tissues while soil application of $MgCl_2$, chelated Mg at 15 g Mg per plant, and $SM_3$ used both as a soil spray and a foliar spray were slow to show their effect. That Mg foliar sprays act more quickly than soil applications of materials containing Mg has been reported by Johnson et al. (20) and Walker and Fisher (42).

The samples collected on August 5, 1967, from the control as well as the treated plants were lower in their Mg concentration than

those of July 16, 1967. The Mg in the samples from the control plants collected on July 16, 1967 was 0.62% in the laminae and 0.53% in the petioles while, in samples from second leaf harvest, it was 0.38% in laminae and 0.36% in the petioles. This latter finding suggests that Mg is used up to a greater extent during the summer months when growth is very rapid.

## Effect of Treatments on the N Content of the Leaf Tissues

The data on the N content of the leaf tissues of the plants under different treatments are given in Table 4. The statistical analysis of the results shows that these treatments did not affect the N content of the lamina tissues collected on both dates. However, most of the treatments applied resulted in a significant decrease of the N content in leaf petioles. The maximum decrease in N was found in the plants from the last sampling receiving $SM_3$ soil cum foliar spray. The concentration of N in this treatment was 1.23% against 1.72% found in the petioles of the control plants. The concentration of N in the lamina tissues of all plants receiving treatments to increase Mg ranged from 3.51 to 3.86%.

The decrease was independent of the Mg concentrations in the tissues. Therefore it can be concluded that the concentration of Mg in tissues had no relative effect on the decrease of N in the banana plants. This decrease could be due to the fact that the addition of Mg improved growth and resulted in greater consumption of N in the petioles from where N is distributed to the leaf laminae.

Table 4. Nitrogen content in the leaf tissues of bananas under different treatments expressed as percent dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + midrib | Lamina | Petiole + midrib |
| None (control) | 3.77 | 1.94 | 3.54 | 1.72 |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | 3.70 | 1.83 | 3.55 | 1.41* |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | 3.58 | 1.84 | 3.63 | 1.48* |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | 3.51 | 1.65* | 3.62 | 1.39* |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | 3.75 | 1.68* | 3.69 | 1.50 |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar spray | 3.78 | 1.97 | 3.57 | 1.52 |
| Chelated Mg (5 g Mg/plant); soil application | 3.78 | 1.58** | 3.60 | 1.44* |
| Chelated Mg (10 g Mg/plant); soil application | 3.86 | 1.66* | 3.81 | 1.49* |
| Chelated Mg (15 g Mg/plant); soil application | 3.84 | 1.53** | 3.63 | 1.41* |
| $SM_3$ (4 g of $SM_3$/plant); foliar spray | 3.78 | 1.54** | 3.67 | 1.50 |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | 3.80 | 1.70* | 3.66 | 1.61 |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | 3.75 | 1.51** | 3.61 | 1.23* |
| L.S.D. at 5% level | n.s | .234 | n.s | .238 |
| L.S.D. at 1% level | n.s | .312 | - | - |

n.s Non-significant
* Significant at 5% level
** Significant at 1% level

## Effect of Treatments on the Nitrate-N Content of the Leaf Tissues

The treatments applied during this experiment had no effect on the nitrate-N content of the laminae except in one case where an increase over the control was observed in the plants treated with $Mg(NO_3)_2$. This increase was found in the tissue of the first sampling. The concentration of nitrate-N obtained in the laminae of plants receiving this treatment was 0.14%, which was about two and one-half times higher than other treatments. This increase seems to be due to the absorption of nitrate from $Mg(NO_3)_2$. All the treatments applied to the plants resulted temporarily in a decrease in the nitrate-N content of the petiole tissues. No such decrease was found in the tissues collected in the second sampling. On the contrary, an increase in the nitrate-N of the petioles was observed in the second sampling in plants receiving a foliar spray of $Mg(NO_3)_2$ and a soil spray of $SM_3$.

## Effect of Treatments on the P Content of the Leaf Tissues

The data on P concentration in the oven-dried leaf tissues of the banana plants under different treatments are given in Table 6. Statistical analysis of the data shows that there was no significant difference in the P content of the leaf tissues as a result of the treatments applied to the plants. The concentration of P in the petioles was low compared to that found in the laminae. The P content in the tissues of plants receiving different treatments ranged from .17% to .24% in laminae and .11% to .17% in petioles.

Table 5. Nitrate-N content in the leaf tissues of bananas under different treatments expressed as percent dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + midrib | Lamina | Petiole + midrib |
| None (control) | .05 | .61 | .07 | .58 |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | .05 | .51* | .05 | .54 |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | .06 | 0.43** | .06 | .52 |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | .06 | .42** | .07 | .54 |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | .04 | .50** | .06 | .49 |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar spray | .14** | .49** | .06 | .62* |
| Chelated Mg (5 g Mg/plant); soil application | .06 | .47** | .06 | .50 |
| Chelated Mg (10 g Mg/plant); soil application | .05 | .51* | .06 | .58 |
| Chelated Mg (15 g Mg/plant); soil application | .05 | .47** | .06 | .51 |
| $SM_3$ (4 g of $SM_3$/plant); foliar spray | .06 | .48** | .07 | .53 |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | .06 | .51* | .07 | .67* |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | .05 | .40** | .06 | .57 |
| L.S.D. at 5% level | .016 | .08 | n.s | .010 |
| L.S.D. at 1% level | .021 | .11 | - | - |

n.s Non-significant
* Significant at 5% level
** Significant at 1% level

Table 6. Phosphorus content in the leaf tissues of bananas under different treatments expressed as percent dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + midrib | Lamina | Petiole + midrib |
| None (control) | .19 | .14 | .20 | .14 |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | .19 | .14 | .20 | .13 |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | .20 | .17 | .19 | .14 |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | .22 | .16 | .19 | .14 |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | .24 | .15 | .17 | .12 |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar application | .21 | .17 | .18 | .13 |
| Chelated Mg (5 g Mg/plant); soil application | .20 | .13 | .19 | .12 |
| Chelated Mg (10 g Mg/plant); soil application | .21 | .13 | .20 | .14 |
| Chelated Mg (15 g Mg/plant); soil application | .20 | .13 | .20 | .13 |
| $SM_3$ (4 g of $SM_3$/plant); foliar spray | .24 | .14 | .18 | .11 |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | .21 | .17 | .20 | .12 |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | .24 | .17 | .19 | .13 |
| L.S.D. at 5% level | n.s | n.s | n.s | n.s |

n.s Non-significant

## Effect of Treatments on the K Content of the Leaf Tissues

The data for the K content of leaf tissues of the plants treated in this experiment with compounds aimed at increasing Mg are presented in Table 7. These results show that $MgCl_2$ foliar spray induced a significant decrease in the K content of the lamina tissues. The percentage of K in the laminae of plants treated with $MgCl_2$ was 3.32 as against 3.85 for control in the first sampling, and 3.07 as against 3.53 for the second sampling. The level of Mg attained in the laminae with this treatment was the highest in the first sampling and the next highest in the second sampling, i.e., 1.11% and .56% respectively. Magnesium sulphate foliar spray at the rate of 21 g Mg per plant, $MgCl_2$ soil application, foliar sprays of $Mg(NO_3)_2$ and $SM_3$ also induced a decrease in the K content of the lamina tissues from samples collected 30 days after application of the treatments. The decrease of K, in this case, was also associated with an increased Mg level in the tissues. Similarly, $MgSO_4$ foliar spray at the rate of 21 g Mg per plant, $MgCl_2$ soil application, chelated Mg at the rate of 5 g Mg per plant, soil spray of $SM_3$ and soil cum foliar spray of $SM_3$ decreased the K content of petioles significantly in samples collected 30 days after the application of the treatments. The only three treatments which increased the K content in the tissues were soil cum foliar spray of $SM_3$, soil spray of $SM_3$ and chelated Mg at the rate of 15 g Mg per plant. The $SM_3$ soil cum foliar spray increased K in the laminae from the first sampling while $SM_3$ soil spray and chelated Mg increased it in the laminae from the second sampling.

Table 7. Potassium content in the leaf tissues of bananas under different treatments expressed as percent dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + midrib | Lamina | Petiole + midrib |
| None (control) | 3.85 | 7.65 | 3.53 | 7.05 |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | 3.79 | 7.22 | 3.54 | 6.79 |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | 3.64 | 8.13 | 3.07** | 5.34** |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | 3.32** | 7.30 | 3.07** | 6.89 |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | 3.90 | 6.82 | 3.08* | 6.25* |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar application | 3.55 | 7.38 | 2.99** | 6.57 |
| Chelated Mg (5 g Mg/plant); soil application | 3.77 | 7.56 | 3.31 | 6.11* |
| Chelated Mg (10 g Mg/plant); soil application | 4.15 | 7.89 | 3.78 | 7.43 |
| Chelated Mg (15 g Mg/plant); soil application | 3.98 | 7.40 | 3.93* | 6.97 |
| $SM_3$ (4 g of $SM_3$/plant); foliar spray | 3.99 | 7.01 | 2.91** | 6.68 |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | 4.11 | 7.61 | 3.91* | 5.03** |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | 4.47** | 7.65 | 3.42 | 6.05** |
| L.S.D. at 5% level | .372 | n.s | .34 | .74 |
| L.S.D. at 1% level | .495 | - | .45 | .99 |

n.s Non-significant
* Significant at 5% level
** Significant at 1% level

By studying the data presented in Table 7, it is evident that, in most cases, an increase in the Mg content of the leaf tissues was associated with a decrease in K. The effect was more obvious in the leaf tissues of the samples collected 30 days after the application of the treatments. Similar depressive effects of Mg on K have been reported in celery (20).

The concentration of K was found to be higher in the laminae than in the petioles of the plants. Potassium ranged from 2.99% to 4.47% in the laminae of plants receiving the different treatments while in petioles, its range was from 5.03% to 8.13%. Such extreme differences in the K content of these banana tissues has been reported by Martin-Prevel (26). The range of K found by this worker in the laminae was from 3.03% to 3.84% while in petioles, it was from 6.70% to 9.30%.

Effect of Treatments on the Ca Content of the Leaf Tissues

The data presented in Table 8 show that the treatments applied to increase Mg in banana tissues had no effect on the Ca content of the petioles collected 10 days after the application of the treatments. Chelated Mg at the rate of 15 g Mg per plant and $SM_3$ used as a foliar spray induced an increase in the Ca content of the lamina tissues collected on the first sampling date. The percentage of Ca in the lamina tissues of the plants receiving chelated Mg at the rate of 15 g Mg per plant and $SM_3$ foliar spray was 1.80 and 1.85 respectively. However, chelated Mg did not similarly affect the Ca content of the lamina tissues from the second sampling. In this

Table 8. Calcium content in the leaf tissues of bananas under different treatments expressed as percent dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + midrib | Lamina | Petiole + midrib |
| None (control) | 1.39 | 2.06 | .98 | 1.70 |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | 1.36 | 2.01 | .91 | 1.67 |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | 1.67 | 2.13 | 1.08 | 1.91 |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | 1.43 | 2.03 | .95 | 1.79 |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | 1.63 | 2.18 | 1.09 | 1.89 |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar spray | 1.35 | 2.08 | .96 | 1.62 |
| Chelated Mg (5 g Mg/plant); soil application | 1.57 | 2.02 | .98 | 1.95 |
| Chelated Mg (10 g Mg/plant); soil application | 1.44 | 1.99 | .88 | 1.61 |
| Chelated Mg (15 g Mg/plant); soil application | 1.80** | 2.12 | 1.07 | 1.93 |
| $SM_3$ (4 g of $SM_3$/plant); foliar spray | 1.85** | 2.31 | 1.26** | 2.12** |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | .42 | 2.12 | 1.23** | 1.76 |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | 1.32 | 1.74 | 1.08 | 1.64 |
| L.S.D. at 5% level | .303 | n.s | .133 | .234 |
| L.S.D. at 1% level | .404 | - | .178 | .312 |

n.s Non-significant
** Significant at 1% level.

later sampling, plants treated with $SM_3$ foliar spray were significantly higher in their Ca content for all the tissues analyzed. A similar increase was found in plants treated with $SM_3$ soil spray, but the increase in this case was confined to the lamina tissues. In the samples collected 30 days after application of treatments, the concentrations of Ca in the laminae of the plants treated with $SM_3$ foliar spray and $SM_3$ soil spray were 1.26% and 1.23% respectively. The concentration of Ca in the laminae of the control plants for this sampling date was 0.98%.

The data given in Table 8 show that, in general, variation in the Mg content of leaf tissues had no effect on Ca. The increase of Ca in the plants under $SM_3$ treatments cannot be due to the increased level of Mg in the tissues because the levels of Mg attained in other treatments had no effect on the Ca content of the tissues. $SM_3$ seems to have an inherent potential to increase Ca in banana plants. This effect of $SM_3$, however, is in disagreement with the findings of the Jamaica Banana Board, where $SM_3$ was found to have no effect on Ca content of the leaf tissues. If it is established that $SM_3$ produces such an effect, then $SM_3$ should not be used on calcareous soils where excess Ca is already a problem.

### Effect of Treatments on the Na Content of the Leaf Tissues

Chemical analysis of the samples collected 10 days after application of treatments shows that $MgCl_2$ foliar spray and chelated Mg at the rate of 10 and 15 g Mg per plant resulted in a decrease of Na in the laminae of the treated plants over control. The difference was

Table 9. Sodium content in the leaf tissues of bananas under different treatments expressed as ppm dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + midrib | Lamina | Petiole + midrib |
| None (control) | 581 | 1149 | 858 | 1585 |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | 534 | 1375 | 955 | 1639 |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | 586 | 1320 | 807 | 1440 |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | 445** | 1728** | 968 | 1740 |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | 552 | 1596** | 756 | 1614 |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar spray | 717** | 1638** | 828 | 1462 |
| Chelated Mg (5 g Mg/plant); soil application | 549 | 1555** | 795 | 1689 |
| Chelated Mg (10 g Mg/plant); soil application | 407** | 1467** | 675 | 1633 |
| Chelated Mg (15 g Mg/plant); soil application | 409** | 1156 | 663 | 1320** |
| $SM_3$ (4 g of $SM_3$/plant); foliar spray | 504 | 1765** | 839 | 1919 |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | 489 | 1627** | 770 | 1472 |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | 509 | 1761** | 811 | 1750* |
| L.S.D. at 5% level | 99 | 267 | n.s | 164 |
| L.S.D. at 1% level | 131 | 356 | - | 218 |

n.s Non-significant
* Significant at 5% level
** Significant at 1% level.

significant at 1% level. The $Mg(NO_3)_2$ application, however, resulted in an increase of Na in the laminae from the first sampling. The concentration of Na in the laminae from this treatment was 717 ppm, which is quite high when compared with other treatments. The level of Na obtained, however, is not considered toxic. According to Chapman (7 p 590), Bidner-Barhava and Ravikovitch reported 0.07% Na (700 ppm) in the lamina of the third leaf as an intermediate range for bananas. The results from these samples further show that $MgCl_2$ foliar spray, $MgCl_2$ soil application, chelated Mg used at the rates of 5 g and 10 g Mg per plant and all applications of $SM_3$ increased the content of Na in the petioles of the treated plants over control in the tissues samples collected on July 16, 1967. The $SM_3$ soil cum foliar spray also resulted in an increase of Na in the petiole tissues collected on August 5, 1967. Chelated Mg used at 15 g Mg per plant caused a significant decrease in the Na content of the petioles collected on this second sampling date.

The treatments did not affect the Na content of the laminae from the second sampling.

Effect of Treatments on the Fe Content of the Leaf Tissues

The statistical analysis of the data reported in Table 10 shows that there was no significant difference between the Fe content of the lamina tissues of the treated and the untreated plants from the first sampling date. However, in leaves from the second sampling date, foliar spray of $MgSO_4$ at the rate of 14 g Mg per plant resulted in a highly significant increase of Fe in the lamina tissues of the

Table 10. Iron content in the leaf tissues of bananas under different treatments expressed as ppm dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + midrib | Lamina | Petiole + midrib |
| None (control) | 110 | 51 | 104 | 49 |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | 118 | 57 | 140** | 58 |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | 114 | 57 | 104 | 39 |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | 114 | 48 | 118 | 40 |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | 109 | 50 | 101 | 45 |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar spray | 114 | 44 | 115 | 41 |
| Chelated Mg (5 g Mg/plant); soil application | 109 | 64 | 113 | 40 |
| Chelated Mg (10 g Mg/plant); soil application | 999 | 67* | 115 | 71** |
| Chelated Mg (15 g Mg/plant); soil application | 100 | 64 | 117 | 50 |
| $SM_3$ (4 g of $SM_3$/plant); foilar spray | 106 | 54 | 101 | 45 |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | 118 | 60 | 107 | 44 |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | 103 | 70** | 116 | 55 |
| L.S.D. at 5% level | n.s | 13.8 | 14.6 | 10.8 |
| L.S.D. at 1% level | - | 18.4 | 19.5 | 14.4 |

n.s Non-significant
* Significant at 5% level
** Significant at 1% level

treated plants over control. The plants receiving chelated Mg at the rate of 10 g Mg per plant were higher in the Fe content of their petioles than the control. This increase was present in the samples from both dates. A similar increase in Fe was also observed in the petioles of the plants treated with $SM_3$ soil cum foliar spray, but this was only apparent in the leaves sampled on July 16, 1967.

From studying both Tables 3 and 8, it appears that variation in the Mg concentration of the leaf tissue has no effect on the Fe content. An increase in Fe obtained in plants treated with $MgSO_4$, chelated Mg or $SM_3$ seems due to the direct effect of these materials and not to the lower or higher concentration of Mg.

Effect of Treatments on the Mn Content of the Leaf Tissues

The data for the Mn content of the leaf tissues of plants under different treatments are reported in Table 11. The statistical analysis shows that there was no significant difference between the Mn content of the lamina tissues of the treated and untreated plants during the first sampling date. During the second sampling, however, a significant decrease of Mn was observed between the laminae of the plants receiving $MgCl_2$ foliar spray, $MgCl_2$ soil application and applications of chelated Mg and $SM_3$ foliar spray and the laminae of control plants. The Mn content in the laminae of plants receiving these treatments varied from 152 to 261 ppm while in similar tissue of the control for the same sampling date, the concentration was found to be 334 ppm.

Comparison of the data acquired from treated plants with the

Table 11. Manganese content in the leaf tissues of bananas under different treatments expressed as ppm dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + midrib | Lamina | Petiole + midrib |
| None (control) | 267 | 58 | 334 | 86 |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | 279 | 33** | 316 | 116** |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | 293 | 48 | 300 | 83 |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | 285 | 98** | 187** | 104* |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | 264 | 48 | 171** | 88 |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar spray | 289 | 35** | 314 | 79 |
| Chelated Mg (5 g Mg/plant); soil application | 297 | 48 | 199** | 67* |
| Chelated Mg (10 g Mg/plant); soil application | 315 | 26** | 152** | 111** |
| Chelated Mg (15 g Mg/plant); soil application | 303 | 34** | 261** | 72 |
| $SM_3$ (4 g of $SM_3$/plant); foliar spray | 256 | 42* | 249** | 82 |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | 238 | 57 | 294 | 65* |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | 244 | 58 | 312 | 76 |
| L.S.D. at 5% level | n.s | 13.6 | 45.7 | 16.2 |
| L.S.D. at 1% level | - | 18.1 | 60.9 | 21.5 |

n.s Non-significant
* Significant at 5% level
** Significant at 1% level

control shows that $MgSO_4$ (14 g Mg/plant) and chelated Mg (10 g Mg/plant) first resulted in a decrease but were later found to cause an increase in the Mn content of the petioles. The plants receiving $MgSO_4$ (14 g Mg/plant) and chelated Mg (10 g Mg/plant) had 33 and 26 ppm of Mn respectively in the petioles from the first sampling as against 58 ppm found in control. In the second sampling, the concentrations of Mn obtained in the petioles of plants treated as above were 116 and 111 ppm respectively. The petioles secured from control plants during this later sampling had a concentration of 86 ppm Mn. The decrease and increase observed were significant at the 1% level. Magnesium chloride foliar spray also induced a significant increase in the Mn content of the petioles of the treated plants over control. The increase was present in both samplings.

Effect of Treatments on the Cu Content of the Leaf Tissues

The Cu concentration in the leaf tissues of the plants under different treatments is given in Table 12. Foliar spray of $MgSO_4$ at 21 g Mg per plant, soil application of $MgCl_2$, chelated Mg used at the rate of 5 g and 10 g Mg per plant and applications of $SM_3$ were found to increase significantly the Cu content of the laminae of the treated plants over control in the samples collected on July 16, 1967. Leaf samples collected 30 days after application of treatments showed no such increase induced by these treatments. During this latter sampling, it was found that $Mg(NO_3)_2$ at 5 g Mg per plant and chelated Mg at 15 g Mg per plant increased the Cu in the laminae of the treated plants over control. The increase in the Cu content of

Table 12. Copper content in the leaf tissues of bananas under different treatments expressed as ppm dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + midrib | Lamina | Petiole + midrib |
| None (control) | 21 | - | 28 | - |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | 23 | - | 29 | - |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | 27* | - | 24 | - |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | 23 | - | 32 | - |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | 26* | - | 27 | - |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar spray | 23 | - | 35** | - |
| Chelated Mg (5 g Mg/plant); soil application | 26* | - | 29 | - |
| Chelated Mg (10 g Mg/plant); soil application | 26* | - | 28 | - |
| Chelated Mg (15 g Mg/plant); soil application | 25 | - | 33* | - |
| $SM_3$ (4 g of $SM_3$/plant); foliar spray | 28* | - | 30 | - |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | 29* | - | 24 | - |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | 29* | - | 29 | - |
| L.S.D. at 5% level | 4.8 | - | 4.4 | - |
| L.S.D. at 1% level | - | - | 5.9 | - |

* Significant at 5% level
** Significant at 1% level

the plants under $Mg(NO_3)_2$ treatment was significant at 1% level.

The concentration of Cu in the petiole tissues of the plants was very low and could not be detected by the instrument employed.

Effect of Treatments on the Zn Content of the Leaf Tissues

Foliar and soil cum foliar spray of $SM_3$, each at 4 g $SM_3$ per plant, foliar sprays of $MgSO_4$ at the rate of 14 g and 21 g Mg per plant, soil application of $MgCl_2$ at 28 g Mg per plant, and chelated Mg used at the rate of 10 g Mg per plant significantly increased the Zn content of the laminae of treated plants over control in samples collected on July 16, 1967. In leaves sampled later such increases were observed in plants receiving $MgSO_4$ foliar spray at 14 g Mg per plant and foliar sprays of $MgCl_2$ and $Mg(NO_3)_2$ each at 5 g Mg per plant, and soil application of chelated Mg at the rate of 5 g Mg per plant. An increase was also observed in petiole tissues from the second sampling in plants receiving foliar sprays of $MgSO_4$ at 21 g Mg per plant, of $MgCl_2$, and $Mg(NO_3)_2$ each at 5 g Mg per plant. Soil application of $MgCl_2$ at 28 g Mg per plant and chelated Mg at 5 g Mg per plant also increased Zn in the petioles from the second sample. Magnesium chloride and $SM_3$ soil cum foliar spray were found to decrease Zn in the petioles from the first leaf collection.

Table 13. Zinc content in the leaf tissues of banana under different treatments expressed as ppm dry weight.

| Treatments applied on July 6, 1967 | July 16, 1967 | | August 5, 1967 | |
|---|---|---|---|---|
| | Lamina | Petiole + midrib | Lamina | Petiole + midrib |
| None (control) | 38 | 76 | 35 | 37 |
| $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | 51* | 60 | 49** | 46 |
| $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | 55* | 76 | 37 | 66** |
| $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | 44 | 54** | 44* | 48* |
| $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | 54* | 90 | 42 | 68** |
| $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar spray | 40 | 71 | 43* | 51* |
| Chelated Mg (5 g Mg/plant); soil application | 43 | 70 | 49** | 50* |
| Chelated Mg (10 g Mg/plant); soil application | 50* | 84 | 38 | 39 |
| Chelated Mg (15 g Mg/plant); soil application | 45 | 70 | 35 | 36 |
| $SM_3$ (4 g of $SM_3$/plant); foliar spray | 48* | 65 | 39 | 42 |
| $SM_3$ (4 g of $SM_3$/plant); soil spray | 46 | 60 | 36 | 46 |
| $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | 48* | 53** | 36 | 34 |
| L.S.D. at 5% level | 9 | 16 | 7 | 9 |
| L.S.D. at 1% level | - | 21 | 9 | 12 |

* Significant at 5% level
** Significant at 1% level

# V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The present study was undertaken to evaluate the uptake of Mg and traces the interaction of Mg with other elements in the banana leaf.

The experiment was laid out using a randomized complete block design with five replications. Dwarf bananas of the Cavendish variety, Musa nana were used as the test plants. They were planted in the fall of 1966 on the campus of the American University of Beirut, Lebanon. The following materials, in different forms and rates were applied on July 6, 1967.

Foliar spray. $MgSO_4$, at the rate of 14 and 21 g Mg per plant.

$MgCl_2$ at the rate of 5 g Mg per plant.

$Mg(NO_3)_2$ at the rate of 5 g Mg per plant.

$SM_3$ at the rate of 4 g $SM_3$ per plant.

Soil application. $MgCl_2$ at the rate of 28 g Mg per plant.

Chelated Mg at three different rates of 5, 10 and 15 g Mg per plant.

$SM_3$ at the rate of 4 g $SM_3$ per plant.

Soil cum foliar spray. $SM_3$ at the rate of 4 g $SM_3$ per plant.

Leaf samples consisting of the 3rd and 5th leaf counting from the most recently unfolded leaf were collected twice, July 16 and August 5, 1967.

The laminae and petioles were oven-dried and analyzed for the following:

Mg, N, P, K, Ca, Na, Fe, Cu, Zn, Mn, and Nitrate-N.

No phytotoxic effects were observed on leaves in any treatment. The following results were obtained.

Regardless of treatment and time of sampling the Mg content was observed to be less in the petioles than the laminae. Foliar sprays of $MgCl_2$, $Mg(NO_3)_2$ and $MgSO_4$ caused an increase in the Mg content of the laminae and petioles in both leaf samplings. The highest increase in the Mg content in the two samplings of laminae was obtained with foliar sprays of $Mg(NO_3)_2$ and $MgCl_2$. Chelated Mg at the rate of 15 g Mg per plant, $MgCl_2$ soil application and both soil and foliar spray of $SM_3$ increased the Mg content only in the leaves sampled 30 days after the application of the treatments. An increase in the Mg content of the plants under the chelated Mg treatment resulted only in the laminae while the latter three treatments increased the Mg concentration both in the laminae and petioles of the treated plants over control.

The phosphorus content of both the laminae and petioles from the two samples was not affected by the treatments.

Magnesium chloride decreased the K content in the lamina tissues over control. The decrease was observed in both leaf samples. Foliar sprays of $MgSO_4$ at 21 g Mg per plant, and those of $MgCl_2$, $Mg(NO_3)_2$ and $SM_3$, and soil application of $MgCl_2$ also induced a significant decrease in the K content of laminae from the second sampling. A decrease in K was also observed during this second sampling from the petioles of plants receiving $MgSO_4$ foliar spray at 21 g Mg per plant, $MgCl_2$ soil application, chelated Mg at 5 g Mg per plant and both soil,

and soil cum foliar sprays of $SM_3$. Magnesium sulphate foliar spray at the rate of 14 g Mg per plant did not affect the K content of either the lamina or petiole tissues collected on both dates. Chelated Mg at 15 g Mg per plant and $SM_3$ soil spray induced an increase in the K content of petioles from the second sampling. Such an increase in the K content of laminae was also observed in the first sampling of plants receiving $SM_3$ soil cum foliar spray.

Chelated Mg at the rate of 15 g Mg per plant increased the Ca content of the laminae from the leaves sampled first. $SM_3$ foliar spray caused an increase in Ca content of laminae of the first and second samples and the petiole of the latter.

All the treatments with the exception of $MgSO_4$ and chelated Mg at 15 g Mg per plant increased the Na content in the petioles from the first sampling. In the second sampling, chelated Mg treatment at the rate of 15 g Mg per plant caused a decrease in the petiole content of Na with no apparent effect on the Na in the laminae. In contrast to Mg chelate, $SM_3$ soil cum foliar spray treatment increased the Na content of the petioles from the second sampling.

The elements N, Mn, Fe and the Nitrate-N in lamina tissues collected on July 16, 1967 were not affected by the treatments. In only one case did $Mg(NO_3)_2$ increase the Nitrate-N. Similarly, in laminae from the second sampling, no significant variation from control was observed in the concentrations of N and Nitrate-N. However, there was a significant increase in the Fe content of the plants treated with $MgSO_4$ foliar spray at 14 g Mg per plant. Magnesium chloride both as foliar spray and soil treatment, chelated Mg at 5, 10 and 15 g Mg

per plant and $SM_3$ foliar spray at 4 g $SM_3$ per plant resulted in decreasing Mn in the laminae of treated plants over control. The decrease was observed in samples collected on August 5, 1967. Foliar spray and soil application of $MgCl_2$, chelated Mg at 5, 10 and 15 g Mg per plant and all forms of $SM_3$ applications were found to decrease the N content of the petioles collected on July 16, 1967. However, no such decrease in samples collected later on August 5, 1967 was observed for plants receiving $MgCl_2$ soil application, and $SM_3$ foliar and soil spray. Magnesium sulphate at both 14 and 21 g Mg per plant did not show any effect on the N content of petioles from the first sampling but was found to decrease it in petiole samples collected on August 5, 1967. There was no effect of $Mg(NO_3)_2$ on the N content of petioles for both dates. In petioles from the first sampling, a significant decrease was found in Nitrate-N in plants receiving treatments aimed to increase Mg. During the second sampling no such depressive effect on Nitrate-N of petioles was observed. On the contrary, $Mg(NO_3)_2$ and $SM_3$ soil spray resulted in increasing the Nitrate-N content in the petioles. The treatments did not affect the Fe content of the petioles collected on July 16, 1967, except where chelated Mg used at 10 g Mg per plant and $SM_3$ soil spray increased the Fe concentration over the control. The petioles of plants from the later sampling receiving chelated Mg at 10 g Mg per plant were also higher than control in their Fe content. The rest of the treatments showed no variation in the Fe content in the petioles of treated plants over control. $MgSO_4$ (14 g Mg per plant) and chelated Mg (10 g Mg/plant) first induced a decrease in the Mn content of the petioles but later

an increase was observed. Magnesium chloride caused an increase in the Mn content of the petioles collected on both dates. The $SM_3$ foliar spray, chelated Mg at 15 g Mg per plant and $Mg(NO_3)_2$ foliar spray induced a decrease in the Mn content of the petioles of treated plants over control in the first sampling. Similarly $SM_3$ soil spray and chelated Mg at 5 g Mg per plant showed a decrease of Mn in the petioles of leaves collected later on August 5, 1967.

The $MgSO_4$ foliar spray at 21 g Mg per plant, $MgCl_2$ soil application, chelated Mg at 5 and 10 g Mg per plant, and $SM_3$ applied in all forms increased the Cu in laminae collected on July 16, 1967. However, the only increase observed in the second sampling was in plants receiving $Mg(NO_3)_2$ foliar spray and chelated Mg at 15 g Mg per plant. The concentration of copper in petioles was too low to be determined.

Magnesium sulphate foliar spray at both 14 and 21 g Mg per plant, $MgCl_2$ soil application, chelated Mg at 10 g Mg per plant, and foliar and soil cum foliar spray of $SM_3$ increased Zn in laminae collected on July 16, 1967. These treatments did not affect the Zn content of petioles from this sampling except where $SM_3$ soil cum foliar spray was found to decrease it. A decrease in the Zn content of petioles from the first sampling was also observed in plants receiving $MgCl_2$ foliar spray. Foliar sprays of $MgCl_2$ and $Mg(NO_3)_2$ and chelated Mg at 5 g Mg per plant resulted in an increase of Zn in both petiole and lamina tissues which were collected on August 5, 1967. Magnesium sulphate foliar spray at 14 g Mg per plant also caused an increase of Zn in the lamina samples for this date. A similar increase was found in the petioles of plants receiving $MgSO_4$ foliar spray at 21 g Mg per

plant and $MgCl_2$ soil application at 28 g Mg per plant.

The experimental results indicate that foliar sprays of $MgCl_2$ and $Mg(NO_3)_2$ were efficient and rapid sources for supplying Mg to the banana plant. These treatments, however, caused a decrease in the K content of the laminae. If this reduction is taken into consideration, the use of these sprays to add Mg to the banana plant is not advisable unless K can be maintained at an effective level. Similarly, the increase in the level of Mg in plants receiving $MgCl_2$ soil application was associated with a decrease of K in the tissues collected 30 days after the application of the treatments. Hence, the application of this material to supply Mg to the banana plant seems undesirable unless K can be maintained at a sufficient level. Foliar spray of $MgSO_4$ at the rate of 14 g Mg per plant might be a good remedy to the Mg deficiency in the banana plant because its use significantly increased the Mg content and did not affect most of the inorganic contents of the tissues studied. Magnesium sulfate was found to increase Mg 10 days after its application, and this increase was maintained a month later. $SM_3$ was found to increase the Mg uptake, yet its use cannot be recommended without further investigations because it increased simultaneously the Ca content of the leaf. In the calcareous soils of Lebanon, where Ca is abundantly available and a problem, any increase of Ca through the use of $SM_3$ may cause a nutritional imbalance. The same is true for chelated Mg used at 15 g Mg per plant. This treatment was found to increase the Mg level after having increased Ca in the laminae.

It can be concluded that Mg can be applied to the banana through

foliar sprays. Magnesium sulphate at 14 g Mg per plant was found to be the most effective and the safest to use under the experimental conditions. However, further studies that examine the growth and yield of the crop are necessary. Throughout the tissue analysis conducted in this experiment, the petioles and laminae of the 3rd and 5th leaves were separately combined and analyzed because the amounts of material obtained from one leaf were insufficient for running analysis. A comparison with standard published data has not been possible because a combined analysis of the third and fifth banana leaves has not been done elsewhere.

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# APPENDIX

## Calculation of Means and Statistical Analysis

Table 14 is a sample table. It shows calculation of means and statistical analysis for the Mg concentration in the petioles of plants, receiving different treatments, collected on July 16, 1967. The data presented in column three of Table 3 have been taken from the last column of this table. All the other data reported in Chapter IV have been calculated accordingly.

Table 14. Mg in the petioles with midrib tissues of bananas under different treatments, collected on July 16, 1967, expressed as percent dry weight.

| Material used (July 6, 1967) | %Mg in dry matter from each replication | | | | | |
|---|---|---|---|---|---|---|
| | R-I | R-II | R-III | R-IV | R-V | Mean |
| 1. None (control) | .53 | .54 | .56 | .45 | .58 | .53 |
| 2. $MgSO_4.7H_2O$ (14 g Mg/plant); foliar spray | .75 | .61 | .65 | .58 | .71 | .66 |
| 3. $MgSO_4.7H_2O$ (21 g Mg/plant); foliar spray | .63 | .73 | .58 | .66 | .81 | .68 |
| 4. $MgCl_2.6H_2O$ (5 g Mg/plant); foliar spray | .59 | .60 | .64 | .65 | .71 | .64 |
| 5. $MgCl_2.6H_2O$ (28 g Mg/plant); soil application | .64 | .60 | .62 | .65 | .59 | .62 |
| 6. $Mg(NO_3)_2.6H_2O$ (5 g Mg/plant); foliar spray | .53 | .66 | .58 | .58 | .78 | .63 |
| 7. Chelated Mg (5 g Mg/plant); soil application | .58 | .45 | .51 | .41 | .56 | .50 |
| 8. Chelated Mg (10 g Mg/plant); soil application | .40 | .42 | .41 | .49 | .57 | .46 |
| 9. Chelated Mg (15 g Mg/plant); soil application | .57 | .59 | .46 | .45 | .67 | .55 |
| 10. $SM_3$ (4 g of $SM_3$/plant); foliar spray | .41 | .39 | .40 | .53 | .53 | .45 |
| 11. $SM_3$ (4 g of $SM_3$/plant); soil spray | .49 | .59 | .45 | .49 | .65 | .53 |
| 12. $SM_3$ (4 g of $SM_3$/plant); soil cum foliar spray | .44 | .41 | .40 | .36 | .48 | .42 |

Analysis of Variance

| Due to | d.f. | M.S. | F. ratio |
|---|---|---|---|
| Replications | 4 | .025 | 5.00** |
| Treatments | 11 | .037 | 7.40** |
| Error | 44 | .005 | - |