EFFECT OF SOIL APPLICATION OF NEMATICIDES ON INORGANIC LEAF COMPOSITION OF POT-GROWN BANANA PLANTS

by

Nematollah Ahmadi

A Thesis Submitted to the Faculty
of Agricultural Sciences in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE IN AGRICULTURE

Major: Horticulture

Minor: Agricultural Economics

Approved:

In Charge of Major Work

Chairman, Graduate Committee

American University of Beirut

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ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. Ramzi M. Khalidy for his invaluable advice and guidance in directing this investigation, and for his excellent comments on the preparation of the manuscript.

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ABSTRACT

A one-year study was conducted during the years 1962-63 on the campus of the American University of Beirut, to determine the effect of the nematicide, Nemagon, on the control of nematodes and its influence on the inorganic leaf composition of pot-grown banana plants of the dwarf cavendish variety. The nematicidal treatments consisted of three ml. and six ml. of 75% E.C. formulation, and twenty grams and forty grams of 20% by weight of granulated Nemagon per plant. The treatments were repeated after six months from the date of the first application. Individual plants also received 60 grams of N and 23 grams and 40 grams of each of P and K fertilizers, respectively. Two sets of leaf samples were collected on two different dates. The first sample was collected seven months after the first treatment, while the second sample was collected ten months after the first treatment. The first leaf sampling was delayed two months due to a hail storm that stripped the leaves. Soil samples were also taken for nematode count and identification.

Presence of a high population of the root-knot nematodes and the true spiral nematodes in the soil of the control plants were established. The liquid Nemagon at either of the two rates of application gave a complete control of nematodes in the soil. However, neither of the two rates of the granulated Nemagon gave as good a control of the root-knot nematodes as that of the liquid Nemagon.

Statistical analysis of the data from leaf chemical analysis revealed that nematicides could be used as a mean of improving the

nutritional status of the nematode-infested banana plants. The elements N, P, and to a lesser extent K and Mg were found to increase in the leaves of the plants treated with the nematicide. The results for other elements, namely petiole nitrate-N and lamina nitrate-N, Ca, Na, Fe, Mn and (Ca + Mg)/K ratio, were either inconsistent for the two sampling dates, or small variations were observed between the treated plants and the control.

Studying the influence of age on the mineral composition of the leaves, it was found that leaf N, P, and K were significantly decreased, while leaf Ca, Mg, (Ca + Mg)/K, Mn, and petiole nitrate-N were significantly increased, as the leaves advanced in age. The results obtained for the leaf Na, Fe, and lamina nitrate-N content as affected by the leaf age were inconsistent for the two sampling dates.

The control of nematodes in banana soil was found to improve the uptake and utilization of some plant nutrients. This indicates better plant performance, and it is expected to increase yield and cut down on cost of fertilizer. The increase in yield and saving on fertilizer could cover the cost of the nematicidal treatment and provide a slight increase in profit to the grower.

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INTRODUCTION

Plant parasitic nematodes have been established as a serious problem in agriculture and are causes of great economic losses. Although infested plants may not be killed, a general decline in root and shoot growth of the plants and the consequent reduction in yield is attributed to the damage caused by nematodes. It has been estimated that nematodes cause an annual loss of 250 million dollars in cultivated crops in the U.S.A. (15). The loss for the State of California alone was estimated to be between 90 to 140 million dollars annually (1).

Banana is one of the numerous plant species attacked by nematodes (8, 17, 28, 37, 42). The symptom of the attack on banana trees in manifested by root and rhizome necrosis resulting in varying degrees of retarded growth, yellowing of the leaves, and falling of mature plants in cases of severe infestation (45). This makes the rapidly expanding world banana industry, with am annual production of about 20 million tons of fruit and a trade volume of 4 million tons per year, confronted with the problem of controlling this pest (3, 40).

In Lebanon, a survey conducted by Khalidy (17) revealed that more than 94 percent of the uprooted banana suckers inspected in different parts of the country were infested with root-knot nematodes at the time of planting. This finding constitutes a major problem for the agriculture of Lebanon, where the banana crop covers a surface area of 2,800 hectares, with an estimated annual production of 28,500 tons of banana fruit (18). Although the nematode problem is severe, no work has been conducted in relation to nematode control in this country. Consequently, this study was undertaken to investigate the effect of a nematicide, namely 1,2-dibromo-3-chloropropane hereafter referred to as Nemagon+, on the leaf mineral composition of banana plants grown in pots.

+ Nemagon, trademark for the Shell Chemical Incorporation, is 1,2-dibromo-3-chloropropane.

REVIEW OF LITERATURE

Nematode-Host Relationship

Considerable attention has been given to study the effect of nematodes on the nutrition of host plants. This parasite has caused a marked drop in leaf K concentration of nematode infested citrus (9), sour cherries (19), and walnuts (25). Maung and Jenkins (26) found a lower total accumulation as well as percent concentration of N, K, P, Na, Mg and Ca in tops of tomato plants severely infested with Meloidogyne incognita. The same authors reported on the work of Wilforth and Wimmer who observed a lower Ca, P, Mg, N and K content in sugar beet plants infested with Heterodera schachtii. Under greenhouse conditions, Lownsberg (25) observed that walnut trees infested with Pratylenchus vulnus were deficient in K. Similarly, Feldman and co-workers (9) in Florida found that leaves of oranges and grapefruits on rough lemon rootstock infested with Radopholus similis had a lower concentration of K and N than healthy trees. The leaf content of P in healthy and infected trees was found to be the same. It was, therefore, concluded that citrus trees infested with R. similis are able to take up N, P and K from the soil, but not with the same degree of efficiency as that of healthy trees.

The nutrient status of host plants further influences reproduction, growth and activity of nematodes. Potassium fertilizer was found to increase the rate of development of the females of Meloidogyne incognita to maturity, and the nematode damage to the host plant could be reduced by decreasing the level of K supplied to the host (32). Penetration of nematode larvae in a nematode-resistant variety of soybean was increased as the level of N and K were increased (39). Kirkpatrick et al. (20) working on sour cherries found an increase in the population of Xiphenima americanum and Pratylenchus spp. as the leaf N increased and the leaf K decreased. In another experiment the same workers reported a significant increase in the population of X. americanum and P. penetrans on Montmorency sour cherries worked on Mazzard rootstock, when the rate of applied K fertilizer was high (19). It was further found that neither N, nor P fertilization, significantly affected the number of the kind of nematodes.

Nematode Control by Nemagon

Control of nematodes by soil fumigation has gained in popularity during the last few years. Fumigants, particularly when used as post-planting treatments, should not show phytotoxicity at the specified nematicidal dose. Nemagon, when applied at the recommended rates has been established to show no phytotoxicity as a post-planting nematicide on tomatoes, bananas, grapes, strawberries, citrus, figs and many ornamental plants (4, 11, 21, 27, 33, 46).

Soil fumigation with Nemagon gave a satisfactory control of nematodes in established banana plantations in the Jordan Valley, where a sharp decline in yield of the second ratoon had been associated with the presence of Rotylenchus spp. and Helicotylenchulus spp. (46). Price (34) conducted an experiment in the Cameron on the control of parasitic nematodes in bananas. He found that the application of Nemagon at the rate of 3 gallons per acre would be economically justified, if an increase of 10 percent in crop yield were obtained due to nematode control. A relatively high yield was obtained from nematode-free banana plants compared with plants started from nematode-infested seeds (24).

In established vineyards, a marked reduction in population of nematodes was obtained when Nemagon was applied at the rate of 1.25 - 10 gallons per acre of active ingredients, and the yield of grape vine was significantly increased due to the control of nematodes (35). Likewise, Nemagon when used at the rate of 140-280 pounds per acre of five percent granulated form or 0.4-0.8 gallons of the liquid form per acre gave a satisfactory control of root-knot nematodes in strawberry plantings (33).

In California, control of nematodes by Nemagon has been reported to improve yield of lemons and Dancy tangerines by 21 percent (4). Suit and co-workers (43) reported a consistent erradication of R. similis from infested citrus seedlings when Nemagon was used at the rate of 4 gallons per acre. They also reported that application of the liquid Nemagon in sprinkler irrigation gave a better control of nematodes than the granulated form. Similarly, in Arizona, Nemagon applied with flood irrigation produced satisfactory control of citrus nematodes (36). Morton (29) and Gilpatrick, et al., (10) also reported that the liquid form of Nemagon gave a better control of nematodes than the granulated form.

Association of Nematodes with Fusarium Wilt of Banana

Fusarium wilt of banana, better known as Panama Disease, caused by Fusarium oxysporum f. cubense has been known for some time as the most destructive disease of banana plants in Central America. Newhall (31) reported that the incidence of Panama Disease did not increase when banana plants were infested with Meloidogyne spp. of nematodes in the presence of Fusarium oxysporum, while R. similis and Fusarium oxysporum caused twice as many plants to develop the disease as compared with plants that were infested with Fusarium alone. Loos (22) observed that infestation of banana roots with either R. similis or M. incognita was not a pre-requisite for the wilt disease infection. However, he reported that the presence of R. similis shortened the period between the time of inoculation of plants with Fusarium oxysporum and the appearance of the disease. Association of R. similis with Panama Disease of banana has been reported by Sasser, et al., (37). R. similis was also found to be the cause of black head disease of banana (23). The incidence of Fusarium wilt disease of cowpeas (44) and carnations (38) have been also reported to increase in the presence of nematodes.

Leaf Sampling of Banana

Investigators have conducted experiments to determine the age at which the banana leaves when used for chemical analysis would best indicate the general nutritional status of the plant. Attempts have also been made to find a definite part or section of a leaf which upon analysis will furnish an index for the nutrition of the plant. The first seven youngest leaves of banana plants have been so far used for the purpose of chemical analysis by most of the investigators (2). Hewitt (12), in his investigation in Jamaica found that the section from the central lamina of the third leaf is the best representative sample to indicate the plant nutritional conditions. This finding has been confirmed by Murray (30) who also found that the third leaf was the best leaf for the purpose of chemical analysis. The latter, however, suggested that older leaves will provide a better indication for the macro elements that tend to accumulate with the age of the leaf.

Effect of Age on the Inorganic Composition of Banana Leaves

Battikhah (6) and Mirza (28) have presented an extensive review of the available literature on the effect of age on the leaf inorganic composition of banana plants. These workers have reported that leaf N, P and K decreased, while Ca, Mn, and Mg increased as the leaves advanced in age. In case of Fe, Battikhah (6) reported an accumulation of this element in the older leaves of banana plants, while Mirza (28) found no difference in the Fe content among leaves of various age groups.

MATERIALS AND METHODS

This study was conducted on the campus of the American University of Beirut using banana plants of the dwarf cavendish variety, *Musa nana*, which is the only commercial variety of banana grown in Lebanon (17).

Banana suckers were secured from the Damour area on September 6, 1962. The roots upon inspection were almost invariably showing slight attack of the root-knot nematodes. This has been also reported by Mirza (28) who obtained his experimental banana plants from the same area. Twenty five suckers of more or less uniform size and age (about six months) were planted in 100 liter asbestoscement barrels filled with a sandy-clay soil. About a month later, on November 12, 1962, the soil in each barrel was mixed with about 2,000 c.c. of soil previously secured from a banana plantation known to be severely infested with nematodes.

Chemical fertilizers applied per plant were 60 grams of pure N as ammonium-sulfa-nitrate; 23 grams of P as ordinary superphosphate and 40 grams of K as potassium sulfate. Nitrogen was applied in four equal doses of 15 grams each, while K and P were applied in a single dose.

The experimental banana plants were randomly treated with two applications of the nematicides at six months interval. The first application was administered on November 26, 1962. There were four treatments and a control. Each treatment was replicated five times. The treatments consisted of:

A. Control, without any nematicide application.

B. Three ml. of 75% E.C. (Emulsifiable Concentrate) formulation of

Nemagon per plant diluted in six liters of water and applied to the soil around the plant.

C. Six ml. of 75% E.C. Nemagon per plant diluted in six liters of water and applied to the soil around the plant.

D. Twenty grams of 20% by weight of granulated Nemagon per plant incorporated into the top 10 to 15 cms. of soil.

E. Forty grams of 20% by weight of granulated Nemagon per plant incorporated into the top 10 to 15 cms. of soil.

The same nematicidal treatments were repeated on May 15, 1963.

On June 20, 1963, the first leaf sample was collected. Due to a previous hailstorm on May 1, 1963 which destroyed all the unrolled leaves, leaf development was delayed and it was only possible to collect leaves number one and three, starting from the youngest or the last completely unrolled leaf as leaf number one. The second leaf sample was collected on September 3, 1963 and included leaves one, three and five.

The collected leaves were brought to the laboratory, where leaf petiole and lamina were seperately washed as described by Brown (7). The samples were oven-dried at 70°C for a period of 48 hours and then ground, using a Wiley mill with a 40-mesh sieve.

The method of chemical analysis employed varied for each of the elements. Water-soluble nitrate-N was determined in the leaf lamina and petiole by the phenol-disulfonic acid method (48). The excess chloride was precipitated by the addition of silver sulfate. For further analysis only leaf lamina was used. Total N was determined by the Kjeldahl method (14). Iron, P, Mn and Mg were analyzed for colorimetrically, using a Beckman Model B spectrophotometer, while Ca, K and Na were determined spectrographically on a Beckman Model DU spectrophotometer with a flame attachment (16, 47).

At the end of the experiment, a soil sample representing each treatment was taken by obtaining approximately 1,000 c.c. of soil from the top 15-20 cms. of each of the five barfels under the same treatment. Then the collected soil samples from each of the replicates were thoroughly mixed and about 2,000 c.c. of the mixed soil was sent to the laboratory for the nematode count and identification. The extraction of nematodes from the soil was done by the sieving and Baermann method.[+]

Statistical analysis of the data was based on the split-plot design as described by Snedecor and Cochran (41). The individual plant was considered as the main-plot and the leaf number as the sub-plot.

The data for the chemical analysis presented hereafter in the text are calculated on the oven-dry weight basis and reported as percentages.

[+] The counting and identification of the nematodes was done through the courtesy of the Shell Co. Laboratory of the Woodstock Agricultural Research Center, England.

RESULTS AND DISCUSSION

I. Identification and Counting of Nematodes

The results obtained from the soil analysis for the identification and counting of the plant parasitic nematodes are reported in Table I. The data acquired show that every 200 c.c. of soil from the barrels that received no nematicide treatment contained 7,170 and 3,660 of the root-knot nematodes, Meloidogyne larvae, and the true spiral nematodes, Helicotylenchus spp., respectively. Such a high population of nematodes is considered to be a case of severe infestation. It was observed that the roots of the plants under the control treatment were highly galled and some rotting of the roots had occured. On the other hand, a complete erradication of the nematodes present in the soil was achieved in the barrels treated with either of the two rates of three ml. and six ml. of 75% E.C. formulation of Nemagon. Although the granulated Nemagon at the two rates employed, namely twenty and forty grams of 20% by weight, gave a complete control of the spiral nematodes, it was not as effective in the control of the root-knot nematodes. The nematicidal treatments are, hereafter, referred to as lower and higher rates of either the liquid or the granulated Nemagon. The soil from the barrels under the lower rate of the granulated Nemagon contained a population of 1,540 Meloidogyne larvae per 200 c.c. of soil, and that of the higher rate of the granulated Nemagon contained 83 of the same nematode.

It was found that the use of Nemagon in the liquid form was more effective in the control of all the nematodes present in the soil, as compared with the granulated form. This could be attributed to the rather shallow application of the granulated Nemagon. The liquid Nemagon apparently penetrated effectively with the irrigation water in which it was diluted, and produced a good control of all the nematodes in the soil. The findings of other workers have also indicated that liquid Nemagon gave a better control of nematodes than the granulated form of this material (10, 29, 43). It was further revealed that the application of the lower rate of the liquid Nemagon gave as good a control of nematodes as that of the higher rate.

TABLE I

POPULATION COUNT AND IDENTIFICATION OF THE PLANT PARASITIC NEMATODES IN A SAMPLE OF 200 C.C. OF SOIL AS AFFECTED BY THE NEMATICIDE TREATMENTS.

Nemagon treatment per barrel	No. of plant parasitic nematodes per 200 c.c. of soil	
	Meloidogyne larvae	*Helicotylenchus* spp.
Control	7,170	3,660
3 ml. 75% E.C.	0	0
6 ml. 75% E.C.	0	0
20 gms. 20% by weight granule	1,540	0
40 gms. 20% by weight granule	83	0

II. Results of Leaf Inorganic Chemical Analysis

Two sets of leaf samples were collected on two dates and analyzed for their inorganic chemical composition. The results acquired for every individual element from each of the two harvesting dates are summarized and presented in one table.

A. Water Soluble Nitrate-N of the Leaf Petiole. The results for the chemical analysis of the water soluble nitrate-N content of the leaf petiole for the June harvested samples, reported in Table II, show that there was a slight non-significant decrease in the petiole nitrate-N concentration of the plants treated with the liquid form of Nemagon, as compared with the control. The control plants had a mean petiole nitrate-N content of 1.164%, while those under the lower and the higher rates of the liquid Nemagon had a mean of 0.947 and 1.062%, respectively. Percent nitrate-N content of the petiole of the plants that received the granulated Nemagon treatments were not different from that of the control. The variation among the treatments was more pronounced in the younger leaf namely leaf number one. It was further observed that there was a significant increase in the nitrate-N content of the leaf petiole as the leaves advanced in maturity. Petiole number one had a mean nitrate-N content of 0.963%, while petiole number three had a mean of 1.255%.

The data for the September harvested samples follow almost the same trend as that of the June harvested samples. Although a decrease in the petiole nitrate-N content of the plants under liquid Nemagon treatments was observed, the decrease was only statistically significant in the plants that received lower rate of the liquid Nemagon. The mean nitrate-N content of these plants was 0.757%, as compared with 1.108% for the control.

TABLE II

VARIATION IN THE AVERAGE WATER SOLUBLE NITRATE-N CONTENT OF BANANA LEAF PETIOLES AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHT.

Nemagon treatment per plant	June samples			September samples			
	Petiole number		Mean of treatments	Petiole number			Mean of treatments
	1	3		1	3	5	
Control	1.068	1.260	1.164	0.739	1.280	1.306	1.108
3 ml. 75% E.C.	0.830	1.064	0.947	0.784	1.051	1.051	0.985
6 ml. 75% E.C.	0.794	1.330	1.062	0.384	0.951	0.934	0.757
20 gms. 20% by weight granule	1.134	1.348	1.241	0.733	1.245	1.361	1.113
40 gms. 20% by weight granule	0.990	1.272	1.131	0.847	1.290	1.438	1.192
Mean of petioles	0.963	1.255	-	0.698	1.163	1.232	-

L.S.D. between means	Level of significance	June samples	September samples
Petiole number	1%	0.082	0.159
	5%	-	0.118
Treatment	1%	N.S.	N.S.
	5%	"	0.255

Studying the effect of leaf age on the nitrate-N content of the petiole, it was found that petiole number one had a significantly lower nitrate-N content than either petiole number three or five. The difference between the mean nitrate-N concentration of petiole numbers three and five was not significant. When comparing the results of the two sampling dates, it was observed that nitrate-N concentration was lower in petiole number one of the September harvested samples, as compared with the same leaf number of the June harvested samples. Petiole number one of the June harvested samples had a mean nitrate-N content of 0.963%, and that of the September harvested samples had a mean of 0.698%.

The decrease in the amount of petiole nitrate-N content of the plants treated with the liquid Nemagon might be explained on the basis of the accomplishment of better growth due to a complete erradication of nematodes found in the soil. Consequently, a faster rate of conversion of inorganic nitrate-N into other forms of N toward the biosynthesis of protein in the plants must have occured. Furthermore, the lower nitrate-N content of petiole number one and the larger reduction in the nitrate-N content of the plants under the liquid Nemagon treatment of the September harvested samples, as compared with the samples harvested in June, could have been brought about by a faster rate of leaf development. The leaves of the September harvested samples had developed in a shorter period of time than those of the June harvested samples, due to better growing conditions for bananas during the months of June through September.

TABLE III

VARIATION IN THE AVERAGE WATER SOLUBLE NITRATE-N CONTENT OF BANANA LEAF LAMINAE AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHT.

Nemagon treatment per plant	June samples			September samples			
	Leaf number		Mean of treatments	Leaf number			Mean of treatments
	1	3		1	3	5	
Control	0.2122	0.1827	0.1975	0.1570	0.1179	0.1945	0.1565
3 ml. 75% E.C.	0.1953	0.2200	0.2077	0.1950	0.1214	0.1443	0.1536
6 ml. 75% E.C.	0.2079	0.2238	0.2158	0.1397	0.1103	0.1563	0.1355
20 gms. 20% by weight granule	0.2241	0.2324	0.2283	0.1673	0.1538	0.1776	0.1662
40 gms. 20% by weight granule	0.2757	0.2497	0.2607	0.1584	0.1676	0.2102	0.1787
Mean of leaves	0.2222	0.2217	-	0.1635	0.1342	0.1766	-

L.S.D. between means	Level of significance	June samples	September samples
Leaf number	1%	N.S.	0.0357
	5%	N.S.	0.0267
Treatment	1%	N.S.	N.S.
	5%	N.S.	N.S.

B. Water Soluble Nitrate-N of the Leaf Lamina. Percent nitrate-N concentration of the leaf lamina, as shown in Table III, did not follow the same trend as that of the petiole. There was an indication of a higher nitrate-N content in the leaves of the plants that received the granulated form of Nemagon as compared with the control, but the differences were not statistically significant. On the other hand, there was a slight decrease in the lamina nitrate-N content of the plants that received the lower rate of the liquid Nemagon for the samples harvested in September. These samples had a mean nitrate-N content of 0.1355%, as compared with the control that had a mean of 0.1565%.

When studying the effect of the leaf age on the nitrate-N content of the leaf lamina, it was found that there was no difference between leaf numbers one and three of the June harvested samples. For the September harvested samples, however, it was found that leaf number three had a significantly lower nitrate-N content than either leaf number one or five. Leaf number three had a mean nitrate-N content of 0.1342%, followed by leaf number one having a mean of 0.1635%, and leaf number five having a mean of 0,1766%. It was also observed that the nitrate-N content of the leaf lamina was lower in all the samples harvested in September; as compared with those harvested in June. The slow rate of leaf development for the June harvested samples could have allowed for the increased accumulation of nitrate-N in the leaf lamina.

C. Total Nitrogen. The results of the chemical analysis for the leaf N content are reported in Table IV. Leaf N content was lower in the plants grown in the barrels with a higher population of nematodes in the soil. Percent leaf N concentration of the June harvested samples was significantly increased in all the plants under the nematicide treatment, except those that received the higher rate of the liquid Nemagon. Immediately following the second application of the nematicide, it was observed that the plants under the higher rate of the liquid Nemagon treatment showed symptoms of weak growth, but recovered in about two weeks time. The weak growth was probably due to a slight toxicity caused by the nematicide at this rate of application per barrel. This might have been the reason for the lower leaf N concentration in the June harvested samples of those plants.

The September harvested samples showed a highly significant increase in the leaf N content of all the plants under the nematicide treatment, except the plants that received the lower rate of the granulated Nemagon, where the leaf N content remained almost the same as that of the control. Soil from the barrels that received the lower rate of the granulated Nemagon had 1,540 Meloidogyne larvae per 200 c.c. of soil sample. This relatively high count of nematodes could have caused a depressing effect on the leaf N content. The difference observed between the leaf N content of the two sampling dates in case of the plants treated with the lower rate of the granulated Nemagon could also be attributed to the nematode population in the soil. It seems that after the application of this treatment a good number of the nematodes were killed. However, due to the rapid loss of the nematicidal activity, a nematode build up occured. This build up must have caused the reduction in total N in the leaves of the September harvested samples. Reports from work done elsewhere have shown that there was a regular increase in leaf N content of plants growing in nematode-free soil (9, 26).

TABLE IV

VARIATION IN THE AVERAGE TOTAL NITROGEN CONTENT OF BANANA LEAVES AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHT.

Nemagon treatment per plant	June samples			September samples			
	Leaf number		Mean of treatments	Leaf number			Mean of treatments
	1	3		1	3	5	
Control	3.80	3.70	3.75	3.46	3.47	3.12	3.35
3 ml. 75% E.C.	4.20	4.01	4.10	4.10	3.92	3.55	3.86
6 ml. 75% E.C.	4.01	3.85	3.93	4.02	4.11	3.57	3.90
20 gms. 20% by weight granule	4.18	3.88	4.03	3.86	3.60	3.36	3.61
40 gms. 20% by weight granule	4.29	3.95	4.12	4.07	3.85	3.39	3.77
Mean of leaves	4.10	3.88	-	3.90	3.79	3.40	-

L.S.D. between means	Level of significance	June samples	September samples
Leaf number	1%	0.09	0.11
	5%	-	0.08
Treatment	1%	N.S.	0.29
	5%	0.21	0.21

Present leaf N concentration significantly decreased as the leaves advanced in age. This is in agreement with the finding of Mirza (28) who reported a similar trend. The third leaf from the control plants, growing under a high nematode population in the soil, had a mean N content of 3.70% and 3.47% for the June and September harvested samples, respectively. According to Hewitt (12), who reported a concentration of 2.60% N in the third leaf of banana plants as the level of adequacy, such concentrations of 3.70 and 3.47% N in the third leaf are considered adequate for optimum growth. This definitely indicates that excess N fertilizer was applied. However, it has to be kept in mind that the experimental plants were grown in pots and were of a different variety than those employed by Hewitt (12).

D. Phosphorous. The results of the chemical analysis for the leaf P content are presented in Table V. Upon studying the June harvested samples, it was found that there was a significant increase in the percent leaf P concentration of the plants that received both rates of the liquid Nemagon and the higher rate of the granulated Nemagon. The plants that received the lower rate of the granulated Nemagon had almost the same leaf P content as those of the control.

In the September harvested samples the leaf P content was only significantly increased in the plants that received the higher rate of liquid Nemagon. There was also a slight increase in the leaf P concentration of the plants treated with the higher rate of the granulated Nemagon. Leaves from the plants that received the lower rates of both the liquid and the granulated Nemagon, contained nearly the same amount of P and were not statistically different from that of the control.

TABLE V

VARIATION IN THE AVERAGE PHOSPHOROUS CONTENT OF BANANA LEAVES AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHT.

Nemagon treatment per plant	June samples			September samples			
	Leaf number		Mean of treatments	Leaf number			Mean of treatments
	1	3		1	3	5	
Control	0.2160	0.1801	0.1981	0.2298	0.1642	0.1381	0.1774
3 ml. 75% E.C.	0.2535	0.1985	0.2260	0.2370	0.1805	0.1440	0.1871
6 ml. 75% E.C.	0.2690	0.2032	0.2361	0.2742	0.2071	0.1710	0.2175
20 gms. 20% by weight granule	0.2179	0.1793	0.1986	0.2428	0.1649	0.1380	0.1819
40 gms. 20% by weight granule	0.2426	0.1995	0.2210	0.2545	0.1759	0.1444	0.1916
Mean of leaves	0.2398	0.1921	-	0.2477	0.1785	0.1471	-

L.S.D. between means	Level of significance	June samples	September samples
Leaf number	1%	0.0132	0.0129
	5%	-	-
Treatment	1%	0.0213	N.S.
	5%	0.0154	0.0227

Maung and Jenkins (26) have reported a decrease in the percent P concentration in tops of tomato plants infested with root-knot nematodes, M. incognita, while Feldman and co-workers (9) reported that leaf P content of citrus trees was not affected by the presence of burrowing nematodes, R. similis.

There was a highly significant decrease in the leaf P content as leaves advanced in age. This is in agreement with the findings of Mirza (28), Battikhah (6), Murray (30) and Hewitt (13), who have reported similar decrease of P in the older leaves.

E. Potassium. Table VI shows that there was an increase in the percent leaf K concentration in all the plants under the nematicide treatment for both sampling dates. However, the increase was not statistically significant from the control for both sampling dates. Furthermore, there was an indication that the leaves of the plants treated with the liquid Nemagon, where a complete erradication of the nematodes in soil was achieved, contained slightly higher K than the plants treated with granulated Nemagon. Increase in leaf K content of plants growing in nematode-free soil has been reported by many investigators (9, 18, 25, 26).

Percent leaf K content was significantly decreased in leaves number three and five, as compared with leaf number one. Battikhah (6) and Mirza (28), also found a decrease in the banana leaf K concentration as the leaves advanced in maturity.

F. Calcium. The results obtained for the analysis of leaf Ca concentration, presented in Table VII, show somewhat different trends

TABLE VI

VARIATION IN THE AVERAGE POTASSIUM CONTENT OF BANANA LEAVES AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHT.

Nemagon treatment per plant	June samples			September samples			
	Leaf number		Mean of treatments	Leaf number			Mean of treatments
	1	3		1	3	5	
Control	4.84	4.00	4.47	4.72	3.86	3.81	4.13
3 ml. 75% E.C.	5.05	4.38	4.71	4.83	4.02	4.18	4.34
6 ml. 75% E.C.	5.24	4.56	4.90	5.08	4.11	4.47	4.55
20 gms. 20% by weight granule	5.01	4.15	4.58	4.87	3.83	4.11	4.27
40 gms. 20% by weight granule	5.18	4.25	4.72	4.85	4.00	3.80	4.22
Mean of leaves	5.08	4.26	-	4.87	3.97	4.07	-

L.S.D. between means	Level of significance	June samples	September samples
Leaf number	1%	0.24	0.30
	5%	-	0.23
Treatment	1%	N.S.	N.S.
	5%	N.S.	N.S.

between the two sampling dates. In the samples harvested in June, there was a slight reduction of leaf Ca concentration of the plants that received either rates of liquid Nemagon, as compared with the control. On the other hand, leaf Ca content of the plants under the liquid Nemagon was slightly increased for the September harvested samples. It was further observed that the June harvested samples contained a higher leaf Ca content than the samples harvested in September, which could be attributed to the slow rate of leaf development prior to the month of June.

There was a significantly higher accumulation of Ca in older leaves. Leaf number one had the lowest mean Ca concentration, followed by leaf numbers three and five, respectively. Leaf number one from the September harvested samples had a mean Ca content of 0.56% followed by 1.30% and 1.96% for leaves number three and five, respectively. This is in accordance with the findings of Mirza (28), Battikhah (6), and Murray (30).

G. Sodium. No differences in leaf Na content was observed among the experimental plants, as seen in Table VIII, for both sampling dates. This indicates that Na uptake neither was influenced by the nematodes in the soil nor by the nematicide.

Upon studying the effect of the leaf age on the percent Na concentration, it was found that there existed a different trend between leaves harvested in June as compared with those harvested in September. In the samples harvested in June, leaf number one had a significantly higher Na content than leaf number three. The former leaf had a mean of 0.0611%, while the latter had a mean of 0.0498%. When comparing the between the two sampling dates. In the samples harvested in June, there was a slight reduction of leaf Ca concentration of the plants that received either rates of the liquid Nemagon, as compared with the control. On the other hand, leaf Ca content of the plants under the liquid Nemagon was slightly increased for the September harvested samples. It was further observed that the June harvested samples contained a higher leaf Ca content than the samples harvested in September, which could be attributed to the slow rate of leaf development prior to the month of June.

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Upon studying the effect of the leaf age on the percent Na concentration, it was found that there existed a different trend between leaves harvested in June as compared with those harvested in September. In the samples harvested in June, leaf number one had a significantly higher Na content than leaf number three. The former leaf had a mean of 0.0611%, while the latter had a mean of 0.0498%. When comparing the

TABLE VII

VARIATION IN THE AVERAGE CALCIUM CONTENT OF BANANA LEAVES AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHTS.

Nemagon treatments per plant	June samples			September samples			
	Leaf number		Mean of treatments	Leaf number			Mean of treatments
	1	3		1	3	5	
Control	1.13	2.22	1.67	0.69	1.29	1.71	1.23
3 ml. 75% E.C.	0.76	1.66	1.21	0.58	1.33	2.20	1.37
6 ml. 75% E.C.	0.80	1.86	1.33	0.42	1.05	1.74	1.07
20 gms. 20% by weight granule	1.05	2.11	1.58	0.53	1.40	1.98	1.30
40 gms. 20% by weight granule	0.95	2.05	1.50	0.60	1.45	2.15	1.40
Mean of leaves	0.93	1.98	-	0.56	1.30	1.96	-

L.S.D. between means	Level of significance	June samples	September samples
Leaf number	1%	0.18	0.33
	5%	-	-
Treatment	1%	N.S.	N.S.
	5%	N.S.	N.S.

TABLE VIII

VARIATION IN THE AVERAGE SODIUM CONTENT OF BANANA LEAVES AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHT.

Nemagon treatment per plant	June samples			September samples			
	Leaf number		Mean of treatments	Leaf number			Mean of treatments
	1	3		1	3	5	
Control	0.0558	0.0557	0.0558	0.0743	0.0870	0.1017	0.0876
3 ml. 75% E.C.	0.0646	0.0529	0.0587	0.0689	0.0844	0.1080	0.0871
6 ml. 75% E.C.	0.0573	0.0499	0.0536	0.0776	0.0834	0.1052	0.0887
20 gms. 20% by weight granules	0.0737	0.0458	0.0598	0.0733	0.0998	0.1004	0.0912
40 gms. 20% by weight granule	0.0542	0.0449	0.0496	0.0796	0.0792	0.1140	0.0968
Means of leaves	0.0611	0.0498	-	0.0746	0.0903	0.1058	-

L.S.D. between means	Level of significance	June samples	September samples
Leaf number	1%	0.0084	0.0025
	5%	-	-
Treatment	1%	N.S.	N.S.
	5%	N.S.	N.S.

above two results obtained from the September harvested leaves, a reversed trend was observed for the September harvested leaves, where a highly significant increase in leaf Na content was observed as the leaves advanced in age. Mirza (28), reported that leaf number five had the highest amount of Na, followed by leaf numbers one and three, respectively.

H. Magnesium. Table IX shows that the percent leaf Mg concentration was increased in all the plants that received the nematicide treatment, as compared with the control. The increase was highly significant in the June harvested samples for all the plants that were treated with either rates or forms of Nemagon. The mean leaf Mg content of the control plants from the June harvested samples was 0.5488%. Although a similar trend was observed for the September harvested samples, the differences were not statistically significant. The increase in the leaf Mg content of the treated plants was similar to the finding of Maung and Jenkins (26), who also found an increase in Mg concentration of tomato plants grown in nematode-free soil. It was also revealed that there was a significant increase of Mg content in the older leaves. Leaf number one from the June harvested samples had a mean Mg content of 0.6428% and leaf number three had a mean of 0.7678%. Similar build up of this element in the older leaves of banana plants has been reported by other investigators (6, 28).

I. Iron. It was observed that leaf Fe content was significantly increased only for the plants that received the lower rate of the granulated Nemagon, as compared with the control for the June harvested samples. Control plants had a mean leaf Fe content of 0.0090% while the

TABLE IX

VARIATION IN THE AVERAGE MAGNESIUM CONTENT OF BANANA LEAVES AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHT.

Nemagon treatment per plant	June samples			September samples			
	Leaf number		Mean of treatments	Leaf number			Mean of treatments
	1	3		1	3	5	
Control	0.4529	0.6448	0.5488	0.5777	0.6075	0.6731	0.6195
3 ml. 75% E.C.	0.7131	0.8230	0.7681	0.6305	0.6530	0.7943	0.6926
6 ml. 75% E.C.	0.7726	0.8256	0.7991	0.6180	0.6377	0.7800	0.6786
20 gms. 20% by weight granule	0.6196	0.7599	0.6898	0.6041	0.6509	0.7379	0.6643
40 gms. 20% by weight granule	0.6559	0.7856	0.7207	0.6049	0.6127	0.7592	0.6589
Mean of leaves	0.6428	0.7678	-	0.6071	0.6324	0.7489	-

L.S.D. between means	Level of significance	June samples	September samples
Leaf number	1%	0.0341	0.0371
	5%	-	0.0277
Treatment	1%	0.1142	N.S.
	5%	0.0828	N.S.

plants treated with the lower rate of the granulated Nemagon had a mean of 0.0110%. Otherwise, there was no significant difference in leaf Fe content of plants that received the nematicide treatment as compared with the control. There was no difference of Fe content between leaf number one and three from the June harvested samples. However, a significant build up of Fe was observed in the older leaves from the leaves harvested in September. Leaf number one from the September harvested samples had a mean of 0.0078%, while the means for leaves number three and five were 0.0099 and 0.0120%, respectively. These findings are reported in Table X. Battikhah (6) reported a higher Fe content in the older leaves of banana plants, while Mirza (28) found no difference in the Fe content among leaves of various age groups.

J. Manganese. The data for the leaf Mn content are reported in Table XI. There was a significant increase in the leaf Mn content of the plants from both sampling dates, having received either rates of the granulated Nemagon as compared with the control. Control plants had a leaf Mn content of 0.0100%, and plants under the lower and the higher rates of the granulated Nemagon had means of 0.0120 and 0.0140%, respectively. The results from the two sampling dates for the plants treated with the liquid Nemagon showed different patterns. A highly significant increase in the leaf Mn content from the September harvested samples of the plants under the liquid Nemagon was observed. While the said element was decreased in plants under liquid Nemagon treatment for the samples harvested in June. No information was found in the literature on the effect of nematodes and nematicides on leaf Mn content.

It was further found that the Mn concentration was significantly

TABLE X

VARIATION IN THE AVERAGE IRON CONTENT OF BANANA LEAVES AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHT.

Nemagon treatment per plant	June samples: Leaf number 1	June samples: Leaf number 3	June samples: Mean of treatments	September samples: Leaf number 1	September samples: Leaf number 3	September samples: Leaf number 5	September samples: Mean of treatments
Control	0.0079	0.0100	0.0090	0.0080	0.0099	0.0109	0.0096
3 ml. 75% E.C.	0.0099	0.0100	0.0100	0.0080	0.0104	0.0114	0.0099
6 ml. 75% E.C.	0.0096	0.0083	0.0090	0.0080	0.0099	0.0146	0.0108
20 gms. 20% by weight granule	0.0109	0.0111	0.0110	0.0074	0.0099	0.0118	0.0097
40 gms. 20% by weight granule	0.0102	0.0093	0.0097	0.0077	0.0096	0.0112	0.0095
Mean of leaves	0.0097	0.0097	-	0.0078	0.0099	0.0120	-

L.S.D. between means	Level of significance	June samples	September samples
Leaf number	1%	N.S.	0.0009
	5%	N.S.	-
Treatment	1%	0.0016	N.S.
	5%	0.0011	N.S.

TABLE XI

VARIATION IN THE AVERAGE MANGANESE CONTENT OF BANANA LEAVES AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHT.

Nemagon treatment per plant	June samples			September samples			
	Leaf number		Mean of treatments	Leaf number			Mean of treatments
	1	3		1	3	5	
Control	0.0046	0.0154	0.0100	0.0035	0.0093	0.0108	0.0078
3 ml. 75% E.C.	0.0054	0.0120	0.0087	0.0042	0.0138	0.0225	0.0135
6 ml. 75% E.C.	0.0025	0.0148	0.0086	0.0042	0.0120	0.0269	0.0144
20 gms. 20% by weight granule	0.0091	0.0150	0.0120	0.0030	0.0099	0.0175	0.0101
40 gms. 20% by weight granule	0.0113	0.0167	0.0140	0.0037	0.0137	0.0190	0.0121
Mean of leaves	0.0066	0.0148	-	0.0037	0.0118	0.0193	-

L.S.D. between means	Level of significance	June samples	September samples
Leaf number	1%	0.0023	0.0022
	5%	-	-
Treatment	1%	N.S.	0.0034
	5%	0.0033	0.0025

increased in older leaves. Similar results have been reported in the literature (6, 28). Also, when comparing Mn content of similar leaf numbers for the two sampling dates, it was observed that the September harvested samples had a lower concentration than the samples harvested in June. It was, therefore, concluded that the leaf Mn concentration was greatly affected by the rate of the leaf development. The accumulation of this element was less when the rate of leaf development was slow, and more when the rate of growth was fast.

K. <u>(Ca + Mg)/K ratio</u>. The ratio of (Ca + Mg)/K, presented in Table XII, was calculated by adding the percent concentration of Ca and Mg in each individual leaf and dividing it by the percent K concentration of the same leaf. The ratio was slightly lower in the leaves of the plants under the nematicide treatment for the June harvested samples, but the differences were not statistically significant. The results from the samples harvested in September did not show the same pattern as those of the June harvested samples. The above ratio was slightly lower in the plants that received the higher rate of liquid Nemagon. On the other hand, the plants under both rates of granulated Nemagon as well as the lower rate of liquid Nemagon showed a slightly higher ratio, as compared with the control. The differences observed between the two sampling dates were affected mainly by the pattern of variation in leaf Ca content. It has been reported that a low figure for the said ratio is desirable in banana plants growing on calcarious soils (5). The chemical analysis of banana leaves growing on such soils show a high Ca and Mg and a low K concentration, thereby resulting in a disturbance of the normal nutritional balance of the plants (5). This ratio was further found to be significantly higher in the older leaves, as compared with the younger leaves.

TABLE XII

VARIATION IN THE AVERAGE RATION OF (Ca + Mg):K CONTENT OF BANANA LEAVES AS INFLUENCED BY AGE OF THE LEAF AND THE NEMATICIDE TREATMENT. VALUES ARE EXPRESSED AS A MEAN OF FIVE REPLICATES AND AS PERCENT OF OVEN-DRIED WEIGHT.

Nemagon treatment per plant	June samples			September samples			
	Leaf number		Mean of treatments	Leaf number			Mean of treatments
	1	3		1	3	5	
Control	0.380	0.727	0.553	0.272	0.494	0.624	0.463
3 ml. 75% E.C.	0.290	0.574	0.432	0.253	0.489	0.719	0.487
6 ml. 75% E.C.	0.298	0.587	0.442	0.204	0.411	0.562	0.392
20 gms. 20% by weight granule	0.333	0.692	0.513	0.239	0.551	0.665	0.478
40 gms. 20% by weight granule	0.313	0.682	0.498	0.253	0.530	0.768	0.517
Mean of leaves	0.323	0.652	-	0.244	0.495	0.668	-

L.S.D. between means	Level of significance	June samples	September samples
Leaf number	1%	0.060	0.078
	5%	-	-
Treatment	1%	N.S.	N.S.
	5%	N.S.	N.S.

SUMMARY AND CONCLUSION

A study was conducted to investigate the effect of the nematicide, Nemagon, on the control of nematodes and its influence on inorganic leaf composition of pot-grown banana plants of the dwarf cavendish variety, Musa nana. Two forms of Nemagon, each at two rates, namely twenty and forty grams of 20% by weight granulated and three and six ml. of 75% E.C. formulation, were used.

From the results obtained in this study, it was established that erradication of nematodes in banana soil was possible by use of soil fumigation with nematicides. The most economical and effective treatment, under the conditions of this experiment was found to be three ml. of 75% E.C. formulation of Nemagon per plant applied with irrigation water twice a year at six months interval. Neither of the two rates of the granulated Nemagon were as effective in the control of root-knot nematodes as that of the liquid Nemagon.

Two sets of leaf samples were harvested, one in June and the second in September, and analyzed for their inorganic composition. Percent concentration of lamina nitrate-N was slightly increased in the plants that received the nematicide treatments. Petiole nitrate-N content was slightly decreased in plants receiving either rates of the liquid Nemagon. The decrease in the petiole nitrate-N of the plants under the said treatments might be explained on the basis of better growth paralleled by a faster rate of conversion of nitrate-N into other forms of N in the plant. This accomplishment could be due to a complete erradication of the nematodes in the soil.

Nitrogen and P were significantly increased in all the treated plants as compared with the control. It was also observed that there was a slight increase in the leaf K and Mg concentration of the treated plants specially those plants that received either of the two rates of the liquid Nemagon. Leaf Mn concentration was significantly increased in the plants under the granulated Nemagon treatments for both sampling dates. While plants under the liquid Nemagon treatments did not follow the same trend for the two dates of sampling. Little variations were observed in the percent leaf concentration of Fe, Na, and Ca as well as the (Ca + Mg)/K ratio of plants treated with nematicide as compared with the control.

Studying the effect of leaf age on the mineral composition of the leaves, it was found that leaf N, P, and K were significantly decreased in the older leaves as compared with the younger ones. On the other hand, there was a significant increase in the concentration of Ca, Mg, (Ca + Mg)/K, Mn, and petiole nitrate-N as the leaves advanced in age. It was also observed that the results obtained for leaf Na, Fe, and lamina nitrate-N were not consistent for the two sampling dates in showing the effect of age on the concentration of these elements.

It is concluded that the control of nematodes by soil application of post-planting nematicides is possible. The said control was found to improve the uptake and utilization of some plant nutrients. Nitrogen, P and to a certain extent K and Mg were found to increase in the leaves of the plants growing in nematode-free soil. The increase in these elements indicates better performance of the plant, which should lead to higher yield of banana fruit. At the same time, lesser amount of fertilizer may be required per plant in banana plantations where nematodes are under control. The saving on the cost of fertilizers and the return from higher yields could pay for the extra expenses involved in controlling nematodes.

It is recommended that in case of repeating the above experiment, lower amounts of fertilizers be used to be able to detect the extent of the effect of the nematicidal treatments on tissue composition.

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