The tests for significance (table 3) of data taken 6 months after final soil treatments based on the biological assay of nematode populations shows that for all fumigants the higher dosage levels used were superior to the lower levels. The effects of 4 applications of all fumigants was superior to 2 applications. Nemagon drenched or injected gave significantly greater reductions in nematodes than did the granular nemagon. VC 13 was superior to all nemagon treatments. All fumigants gave highly significant reductions in root-knot nematodes when compared to no treatment.

The test for significance of plants weights (table 4) showed 2 applications of the fumigants gave higher total plant weights at harvest, six months after final treatment, than 4 applications. There were no significant differences between dosage levels or fumigants, however the untreated plots gave higher plants weights than the fumigated.

The data on plant weights show some inconsistencies with the nematode data. Reductions in nematodes would be expected to result in increased plant growth. Previous work has shown definite plant response to soil fumigation. Some explanation may be given for the results obtained in these tests. Two applications of VC 13 at 27 gallons per acre were phytotoxic to ligustrum resulting in definite stunting and leaf curling. This effect lasted for several months. No observable phytotoxicity to gardenia or boxwood from VC 13 was noted. This phytotoxicity offset to some extent the beneficial effects of nematode control.

It is believed however that the failure to show plant response consistent with nematode control lies in faults of sampling. Plant weights were obtained by pulling the plants, shaking the soil from the roots and weighing the entire plant. Heavily galled and knotted roots were harder to free of soil and apparently weighed more than fibrous root systems. It is believed that if top weights only had been taken results would have been more consistent.

Because of the nature and extent of the root systems of the plants at harvest and the original galled roots that still remained on the plants, a satisfactory gall rating of individual plant roots was not possible.

Summary

Nemagon at 2 and 4 gallons technical per acre used as a drench, injected and applied broadcast in granular form and VC 13 at 13 and 27 gallons per acre drenched gave significant reductions in root-knot nematodes when used around plants in place. For all plots and combinations of numbers of applications and dosage levels VC 13 was superior to nemagon. Nemagon drenched and injected was superior to nemagon granular. The higher dosage levels used were significantly better than the lower. Four applications of nemagon at monthly intervals was superior to two but was not better than two applications of VC 13.

CHEMICAL STUDIES ON THE ROOTS AND LEAVES OF COCONUT PALMS AFFECTED BY LETHAL YELLOWING[1]

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The coconut palm in Florida is used primarily as an ornamental on boulevards and on some large lawns. In some areas a disease of these palms termed "lethal yellowing" is causing much concern since control or prevention treatments are not known. Symptoms of this disease have been described by van Weerdt and coworkers (6). The purpose of the work reported in this paper was to determine whether or not the composition of roots and leaves would indicate nutrient differences between the healthy and the diseased palms. All of the samples are from Key West.

Analytical Methods and Results

The root samples from the coconut palm, *Cocos nucifera*, were washed to remove soil debris, dried and weighed. The ash content was obtained after 4 hours at 500°C. After homogenizing the ash in a mortar, a 10 milli-

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TABLE 1

Spectographic data on dry roots of Cocos nucifera relative to symptoms of lethal yellowing infection

Sample	Copper ppm	Iron ppm	Tin ppm	Manganese ppm	Aluminum ppm	Molybdenum ppm	Silicon %	Fe/Mn ratio
Healthy palms not in diseased area								
H324	36	700	0	110	150	4.0	1.5	6.3
325	4	60	4	11	40	2.0	2.0	5.4
326	52	800	1	7	150	0.7	2.0	114.0
327	26	1100	2	60	250	2.5	2.0	18.3
328	25	1000	8	85	150	8.0	1.5	11.9
329	5	80	10	14	90	2.0	1.6	5.7
330	20	360	26	15	250	1.5	2.0	24.0
333	8	70	12	15	100	2.0	2.0	4.7
336	110	50	0	18	110	10.0	3.5	2.8
337	90	1000	1	20	150	1.0	1.0	50.0
338	24	720	3	60	60	2.0	3.0	12.0
Palms apparently healthy but near a palm showing symptoms								
331	5	10	-	1	80	0.5	1.0	10.0
332	9	80	9	6	9	1.0	.2	13.3
334	63	900	1	30	160	0.5	1.9	30.0
335	3	45	4	3	250	0.5	1.0	15.0
339	28	90	8	9	45	90.0	1.5	10.0
340	34	610	1	34	250	2.0	2.0	18.0
341	26	650	100	19	330	3.3	2.2	34.2
342	63	1200	40	4	200	1.5	2.2	300.0
343	1.6	15	2	6	50	.3	.5	2.5
344	1.5	25	3	3	90	.5	1.5	8.3
Palms with first symptoms								
345	28	1500	3	20	300	1.0	1.5	75.0
346	38	68	38	8	14	1.5	1.8	8.5
347	58	870	46	15	12	.6	1.6	58.0
348	50	550	2	8	200	1.0	1.5	68.8
349	29	480	2	60	250	1.0	2.0	8.0
Palms well advanced in decline								
350	1	20	20	1	200	.2	1.0	20.0
351	5	270	5	27	5	.3	2.2	10.0
352	1	380	5	24	150	1.0	.7	15.8
354	44	800	37	7	100	.7	.5	114.0
355	2	30	5	0.5	50	.5	1.5	60.0
Palms already dead								
356	3	40	3	8	75	—	.8	5.0
357	22	75	2	22	200	1.3	1.1	3.4

TABLE 2

Composition of Roots of Cocos Nucifera Relative to Symptoms of Lethal Yellowing Infection (oven-dry basis)

Sample	Ash %	Ca %	K %	Mg %	Na %	B ppm	Mn ppm	Root Type	Location
Healthy palms not in diseased area									
H324	9.0	1.48	1.63	1.63	2.24	6.5	41.7	fine	Boulevard
H325	9.0	.71	2.38	1.34	1.97	5.1	5.0	mixed	Boulevard
H326	7.4	1.32	1.62	1.11	2.04	5.1	7.0	course	Boulevard
H327	8.6	1.77	.65	1.16	1.72	-	15.3	mixed	Lawn
H328	8.5	1.24	2.21	1.59	3.00	5.3	-	mixed	Boulevard
H329	9.8	2.62	2.55	2.76	1.47	3.1	13.8	fine	Boulevard
H330	5.1	.49	1.45	1.55	1.37	1.2	6.3	course	Lawn
H333	10.1	3.10	1.84	2.44	.85	10.8	12.0	fine	Street
H336	11.2	2.45	.52	.61	.29	8.3	10.3	fine	Street
H337	10.1	1.98	2.01	1.57	1.54	9.3	8.9	mixed	Deep roots
H338	6.1	.62	.57	1.56	-	7.4	-	course	Deep roots
Palms apparently healthy but near a palm showing symptoms									
H331	5.1	1.38	2.16	0.66	0.43	.7	.9	course	Street
H332	9.3	2.83	1.22	.76	.40	3.1	3.6	mixed	Street*
H334	6.3	1.56	1.70	1.33	1.33	27.1	-	fine	Lawn*
H335	5.7	-	2.76	1.90	.41	1.6	6.6	mixed	Lawn
H339	11.2	3.04	1.31	1.22	.85	-	10.0	fine	Street
H340	6.8	1.06	1.44	1.32	3.51	2.4	2.8	mixed	Street
H341	6.5	1.42	1.80	1.43	.69	1.9	4.9	course	Street*
H342	7.9	2.18	2.07	.73	1.36	2.8	5.2	mixed	Street
H343	3.2	.59	1.95	.71	.33	1.6	4.8	course	Street
H344	4.9	.50	.55	.68	2.29	4.0	2.0	mixed	Street*
Palms with first symptoms									
H345	5.7	0.55	1.41	1.23	1.21	.4	8.3	course	Street
H346	7.6	.66	1.17	.69	1.20	23.9	29.6	course	Lawn
H347	5.8	1.42	1.63	1.32	1.08	17.8	18.5	course	Street
H348	5.7	1.25	1.61	.78	.68	1.9	4.3	course	Street
H349	4.8	.61	2.00	1.46	.99	5.0	3.0	course	Street
Palms well advanced in decline									
H350	2.2	0.28	.58	.53	.63	15.5	.8	course	Street
H351	5.4	1.16	.86	.85	.81	2.1	6.0	course	Street
H352	4.8	1.25	.99	1.45	.73	5.7	13.3	course	Street
H354	7.4	2.97	2.18	1.19	1.64	13.3	5.9	mixed	Lawn
H355	5.0	.93	.83	.80	.69	.8	2.4	course	Street
Palms already dead									
H356	4.9	.31	.69	2.64	1.22	16.6	12.0	course	Lawn
H357	4.4	.75	1.74	1.36	1.28	1.5	1.5	mixed	Street

* Tree sample was near or adjacent to palms exhibiting well advanced symptoms of decline.

gram sample was taken for spectographic analysis and the remainder dissolved in 0.36 N sulfuric acid for subsequent analysis of Ca, Mg, K, Na, Mn, and B. Spectographic data were obtained semi-quantitatively by comparison with standards of known concentration. Calcium was determined by the flame photometer using standards in the same acid concentration and by oxalate titration. Possible contamination from the calcium carbonates in the soil was reduced by careful washing and screening of the roots. Potassium and sodium were determined by the flame photometer using appropriate dilution and standards. Manganese and boron methods were those described by Jackson (2) and other methods used were those described by Fiskell et al. (1).

All types of leaf samples were dried, ground finely and 5 grams ashed and dissolved in acid for analysis as described for the root samples. Using neutral ammonium acetate as the extracting solution, the soil which is composed of finely divided coral and oolite was found to contain 1200 pounds of calcium, 800 pounds of magnesium, 90 pounds of sodium, 20 pounds of potassium, and from 1 to 17 pounds of phosphorus, each on the basis of a million pounds of the soil.

In table 1 the data obtained from the spectographic analysis are reported. The samples are grouped according to the diagnosis of symptoms of lethal yellowing. The only samples known to be fertilized were H327, H330, H334, H335, H346, and H354. From examination of the data in this table, these roots were not different in composition from roots taken from trees growing on Roosevelt boulevard or streets which were not likely to have been fertilized. There is not a consistent trend for these elements to change relative to the disease symptoms. The wide variability in all the elements among samples is indicative of the heterogeneity of the soil matrix and the fill materials used. The tin content presumably arose from fill materials. Since roots accumulate heavy metals on their surfaces and perhaps within certain cell structures in the roots, these analysis show that even with advanced decline there is not likely to be a great change in the content of most of these elements over those from healthy trees. This is somewhat surprising since the diseased trees have very few fibrous roots but instead the roots are rather coarse and woody; this deterioration of the roots is a diagnostic feature of the disease. There does seem to be less copper and possibly less manganese present in the advanced stage of the lethal yellowing, but this may be the result of less surface of root per unit weight as would be expected from the characteristic decline in root development with the progress of the disease. The iron-manganese ratios above 10 are indicative of the low manganese availability in the soil, usually associated with the marl soils of south Florida.

In Table 2 chemical data on the root composition are shown. The significant decrease in the ash content from 8.5 percent to about 5 percent in roots from the diseased trees is important in the interpretation of the effect of the disease on the tree. It is dealt with in the discussion of the results. Otherwise, the variation in values for calcium, potassium, magnesium, and sodium is larger within the designated groups. In the case of sample H346 the boron and manganese may reflect the fertilization, and in sample H354 the higher potassium content than others in the group may be from the fertilization used. The boron level is very low in most of the roots. Manganese in all cases is very low for roots.

In the leaf composition given in Table 3 there is good evidence of potassium withdrawal from the leaf tips, and to a lesser extent sodium also decreases, as the stage of the lethal yellowing becomes more advanced. This is shown in samples 2, 3, 4, compared to samples number 1 or 9 and those from the healthy trees numbered 5,6,7,10, and 12. Calcium and magnesium values do not show this trend. From the data for Tree A, B, and C, sampled alike, the potassium is lower in the tip of the yellowing frond than at the base of the frond and much lower than in the upper green fronds. The potassium content is much higher in the inflorescence than in the fronds, as is to be expected, and sodium is lower than in the leaves. Manganese found in the leaves is at a very low level. Boron values are highest for the older trees and apparently are not associated with the stage of the lethal yellowing disease.

Discussion and Conclusions

The chemical composition of the roots and leaves of coconut palms in samples from Key West showed a very wide range for most elements. This in itself indicated soil conditions were also variable and in many locations may

TABLE 3

Leaf composition of coconut at several stages of lethal yellowing

	Sample source of leaflets	Disease stage	Mineral Composition of Dry Matter					
			K %	Ca %	Mg %	Na %	Mn ppm.	B ppm.
1.	Older tree	Medium	0.67	0.27	0.61	0.18	7	49
2.	Older tree	Advanced	.10	.38	.60	.20	5	60
3.	Older tree	Advanced	.09	.30	.61	.25	10	86
4.	Young tree	Advanced	.35	.29	.74	.29	9	50
5.	Healthy tree	Healthy	1.04	.17	.47	.51	22	80
6.	Tree from Boulevard #1	Healthy	1.33	.35	.69	.67	8	33
7.	Tree from Boulevard #2	Healthy	.62	.35	1.15	.39	13	37
8.	Healthy tree	Healthy	1.34	.34	.80	.40	—	40
9.	Tree near house	Diseased	.79	.29	.74	.52	15	33
10.	Tree 2	Healthy	1.05	.37	1.05	.30	—	30
11.	Tree 3	Medium	1.38	.12	.74	.94	16	53
12.	Tree 4	Healthy	.93	.17	.59	.49	19	18
13.	Tree A, young, leaflets from tip of yellow lower frond.	Early	.70	.28	.97	.24	6	6
14.	As above, but from base of same frond.	"	.81	.44	1.11	.71	8	10
15.	As above, leaflets from base of medium lower frond.	"	1.52	.15	.80	.41	19	29
16.	Tree B, young, leaflets from tip of yellow lower frond.	Medium	.55	.13	.88	.23	10	27
17.	As above, but from base of the same frond.	"	.73	.28	.88	.47	8	20
18.	As above, but from base leaflets of medium still green frond.	"	1.09	.55	1.05	.35	14	13
19.	Tree C, young, tip leaflets of yellow lower frond.	Diseased	.67	.13	.84	.61	7	27
20.	As above, but base leaflets of same frond.	"	.98	.41	.88	.93	8	37
21.	As above, but base leaflets of youngest frond.	"	2.35	.17	.36	.29	12	27
22.	As above, but base leaflets of lower frond still green.	"	1.63	.23	.80	.78	10	9
	Inflorescence, spadix	Diseased	4.48	.49	.93	.14	14	20

not have favored good plant growth since one or more nutrients may be in short supply. Ability of the palms to obtain potassium from this very poor soil was surprising. Likely the brackish water provided a type of nutrient medium along with the marl that can be used tolerantly by these palms. However, the vigor of those trees was much less than in coconut plantations in the Caribbean or other areas. Fruiting either does not occur on many trees or is of low quality. Fertilization of these palms with a complete fertilizer containing a minor element mixture of low solubility to prevent both fixation and leaching might increase general vigor by providing a better balanced and available source of these elements. However, unless the roots can be kept healthy, then fertilizer might be of little value to a tree infected with the lethal yellowing disease. Susceptibility to the disease has not been correlated with the lack of vigor of the root system, although root deterioration was found useful in predicating the direction of spread the disease was likely to take (6).

From the works of Reyne (4) there were no clearly defined disease symptoms of potassium, magnesium, sulfur, calcium, or iron deficiencies in coconut palm. He pointed out that since the coconut palm is a monocotyledon it is incapable of healing a wound; that is secondary growth does not occur at the site of the injury. However, sclerenchyma tissue which formed an outer layer in the roots was quite impervious to water and protected the vital part of the root within which the living processes occurred. In the root samples studied here, the roots must hold even mobile nutrients such as potassium or sodium rather tenaciously since large amounts of the elements were present in the woody roots even of trees dead or well advanced in decline. The disease might injure the young roots or the development of young feeder roots. In this connection injury by the kidney-shaped nematode, *Rotylenculus*, and other species (6) may take on a nutritional aspect. One possibility is that nutrients of feeder roots might be consumed by the nematodes. Oteifa (3) concluded from his studies with a root-knot nematode that the nematode had a high potassium requirement and appeared to interfere with the potassium nutrition of its host, causing nutritional injury unless excess potash was supplied. The data in tables 2 and 3 indicated that some roots were very much lower in potash than others and the same was true for the leaves, but stage of the disease was not evidently the principal factor involved.

As has been pointed out by Sampson (5), the root system of palms was developed greatly in fertilized zones. In his work, potash demand by the coconut palm started early in the development of the fruit. He found a rather elastic transfer of potash from one part of the tree to another. He also reported that the coconut palm had a large capacity to form branch rootlets from old ones or from a site of injury. This capacity apparently has ceased when the lethal yellowing disease has occurred in palms at Key West. A comparison of the data obtained by Sampson from coconut palms grown on a deep red sandy loam very low in calcium and data in the present study from the marl soil of Key West showed roots and leaves were slightly higher in calcium, magnesium, and potash in the Florida samples. These coconut trees, as other workers have found, must possess a great ability to obtain nutrients, or in other words the root system must be a highly efficient one. Any destruction of the root system must therefore impose a critical strain on the coconut palm in obtaining nutrients.

Since manganese is at a very low level in the soil, some manganese deficiency would seem likely in the roots and leaves. This would result in loss of plant vigor and chlorosis of the leaves but with the yellowing most likely in the younger leaves. As described (6), lethal yellowing disease first showed in the yellowing on the tops of the lower fronds and chlorosis progressed toward the crown as the older fronds died. If the tree failed to respond within a few weeks to manganese fertilization or manganese sprays, along with complete fertilizer, then the lethal yellowing factor or nematode damage might be the factor involved. In an area where healthy palms make a well developed root system, those trees with very few small roots and with coarse, woody roots might be at an early stage of lethal yellowing. If the lethal yellowing effect is brought under control, then fertilization to stimulate new root growth might benefit the tree.

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PRODUCTION OF TREE ROSES ON ROSA FORTUNEANA STOCK

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In Florida, producing roses by grafting container-grown stock and marketing the young bushes in bloom four to five months later has proved a satisfactory way of supplying local markets with good quality plants on rootstocks preferred in this region. Producing roses under field conditions and marketing dormant plants has proved less successful in Florida than in regions where winters are more severe and the period of winter dormancy is prolonged.

This discussion is presented to point out the possibility of local production of "tree roses," rose plants with the scion variety grafted on standards or trunks, one foot to five feet above ground level. Including tree-forms of suitable varieties among the container-grown rose plants already offered for sale can attract interest to utilization of locally produced roses and widen the selection available for use in decorative plantings.