INFLUENCE OF ROOT-KNOT NEMATODES ON THE DECLINE IN VIGOR OF THE RED SPANISH VARIETY OF PINEAPPLE IN PUERTO RICO

L. A. Alvarez-García and Lidy López-Matos[1]

INTRODUCTION

Pineapple growers in Puerto Rico have been quite preoccupied with the loss of vigor and low yields of the Red Spanish variety of pineapples. They have claimed that the loss in vigor indicates a degeneration taking place in this variety when grown for two or more generations in our agricultural environment.

The correctness of this statement perhaps can be accepted in terms of the relation between detrimental biological-parasitic and physicochemical factors responsible in some way for the reduction in yield of pineapples, but probably not in terms of the intrinsic loss of yield potentialities because of modifications of the germ plasm. The second statement seems to have the support of the results of recent investigations carried out at the Agricultural Experiment Station of the University of Puerto Rico, where the loss in vigor of pineapple plants has been associated with unfavorable conditions in the growth medium (1, 2, 3, 4, 5, 6, 7, 8).[2] These investigations have shown that filter-press cake incorporated into the soil and the application of fertilizer containing potassium, phosphorus, and nitrogen (as ammonium sulfate) are beneficial to the development of pineapple plants.

The problem has so far been investigated strictly from a physicochemical standpoint. The relation of biological-parasitic factors has not been considered in previous studies. This circumstance led us to initiate field experiments for the purpose of determining the relation of root nematodes to the decline or loss in vigor of the Red Spanish variety of pineapples in Puerto Rico. The experiments were started during the period 1951–53 in a Bayamón clay loam, a good pineapple soil, at Arecibo.

The first experiment was planted on October 18, 1951.

EXPERIMENTAL METHODS

Field Procedure

Pineapple slips of the Red Spanish variety were selected for uniformity in size and were planted in two rows in the center of beds 4 feet and 6

[1] Plant Pathologist, Head, Plant Pathology Department, and Research Assistant in Plant Pathology, respectively, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P. R.

[2] Numbers in parentheses refer to Literature Cited, p. 72.

inches wide by 15 feet long. The slips were spaced 18 inches between rows and 15 inches between plants. The usual commercial procedure for preparing, planting, and cultivating the land were followed.

The layout of each experiment was that of a randomized split-plot arrangement, consisting of six soil treatments, each treatment replicated six times, and five spray treatments per soil treatment.

Nematocides[3] used for soil treatment were:

1. Dowfume G (methyl bromide, carbon tetrachloride, and ethylene dichloride); methyl bromide, 10 percent by volume, at the rate of 6 cc. per square foot of soil.
2. DD (dichloropropane and dichloropropene) 50 percent per volume, at the rate of 6 cc. per square foot.
3. Dowfume W 85 (ethylene dibromide) 40 percent per volume, at the rate of 6 cc. per square foot.
4. Dowfume N (dichloropropane and dichloropropene) 50 percent per volume, at the rate of 6 cc. per square foot.
5. Dowfume W 40 (ethylene dibromide) 20 percent per volume, at the rate of 9 cc. per square foot.
6. Check, no chemical applied.

The chemicals were injected into the soil at a depth of 6 inches with a Spielden hand injector. All soil treatments were given 15 days before planting.

All plots were sprayed with Aldrex at the rate of 1 gallon per acre of the 25-percent emulsion (2 pounds of Aldrin), diluted in 100 gallons of water, 6 days before planting, to control ants and white grubs.

The planted slips were sprayed with Resitox (2 pounds in 100 gallons of water) containing DDT, and Aldrex to control mealybugs and ants. The Resitox-Aldrex emulsion was sprayed monthly all over the field until July 26, 1952, when Parathion (15 percent) at the rate of 1 pound in 100 gallons of water, was used to control mealybugs. Parathion sprays were discontinued immediately after the pineapple plants began flowering.

The following materials were sprayed on the plants monthly to test their relative effectiveness on the control of *Thielaviopsis* (*Ceratostomella*) *paradoxa* leaf spot, chlorosis, and fruit rot, respectively:

1. Iron sulfate, 25 pounds per acre in 100 gallons of water.
2. Fermate (ferric dimethyl dithiocarbamate), 2 pounds per acre in 100 gallons of water.
3. Dithane Z-78 (zinc ethylene bisdithiocarbamate), 2 pounds per acre in 100 gallons of water.
4. Zerlate (zinc dimethyl dithiocarbamate), 2 pounds per acre in 100 gallons of water.
5. Check (water only).

[3] Chemicals were supplied free by the Dow Chemical Co.

The experiment was conducted in Enrique Landrón's pineapple farm, at Palo Blanco, Arecibo. The soil there is a friable Bayamón silty clay which has been cropped with pineapples for about 20 years. It has a pH of 4.80, and thus is adequate for pineapple-growing, although at the time this work started it was producing very low yields.

Previous examination of the roots from pineapple plants grown in this field showed heavy infestation with nematodes.

Harvesting

The pineapple plants started flowering by January 1953. The fruit was harvested during May and June of the same year. The experimental data recorded were: Number and size of fruits per plot, total weight of the fruit for every soil and spray treatment, and number of slips and suckers produced. As no acetylene treatment was given, only two-thirds of the plants flowered.

EXPERIMENTAL RESULTS AND STATISTICAL INTERPRETATION

Effect of the Soil Treatment on Plant Growth and Fruit Yields

Marked differences in rate of growth were observed among the plants in the plots treated with nematocides and in the plots not fumigated. The plants in the treated plots were greener, stockier, and more vigorous. Those in the check plots were small and to some extent chlorotic.

Plants growing on plots treated with Dowfume W-85 were greener and developed more vigorously.

The effects of the soil treatments on the yield of fruit are shown in table 1. They indicate that, at the 5-percent statistical level, Dowfume W-85 and Dowfume W-40 were superior to Dowfume G and Dowfume N in control-

TABLE 1.—*Effect of different soil treatments on the yield of marketable Red Spanish pineapple fruits grown in Bayamón silty-clay loam at Palo Blanco, Arecibo, P. R.*

Soil treatment	Yield per acre
	Tons
Dowfume G	10.78
DD	13.13
Dowfume W-85	15.92
Dowfume N	12.32
Dowfume W-40	14.87
Check	6.24

L.S.D.: At the 5-percent point = 2.49 tons per acre; at the 1-percent point = 3.39 tons per acre.

TABLE 2.—*Statistical analysis of the effect of different spray treatments on the yield of pineapples*

Spray treatment	Yield per acre
	Tons
Iron sulfate	12.53
Fermate	11.30
Dithane Z-78	11.64
Zerlate	12.34
Check	13.25

L.S.D.: At the 5-percent point = 1.65 tons per acre; at the 1-percent point = 2.26 tons per acre.

ling nematodes. At the 1-percent level, Dowfume W-85 and Dowfume W-40 were superior to Dowfume G.

All soil treatments were significantly superior to the Check, at both the 5-percent and 1-percent levels. In regard to increase in tonnage, the superiority over the Check ranged from 4.54 tons to 9.68 tons per acre, which is equivalent to a production ranging from 70 percent to 200 percent over the Check. This represented a substantial increase in income per acre.

Effect of Spray Treatments on the Yields

The statistical analysis of the yields of plots sprayed with iron sulfate, Fermate, Dithane Z-78, and Zerlate, is presented in table 2. The data show that there were no significant differences at the 1-percent level between the yields of plants sprayed with the different chemicals. At the 5-percent level, the Check was superior to Fermate. Apparently, this chemical had a depressive effect on the yield.

Only a few scattered and insignificant leaf lesions caused by the fungus *Thielaviopsis* (*Ceratostomella*) *paradoxa*, appeared during the growing period.

The fruit in all treatments was free from blemishes and infections. Probably the treatment with DDT and Parathion reduced the fruit injuries from insect attack to a minimum. Fruit injuries are usually associated with secondary infections by saprophytic fungi, which reduce the market quality of the fruits. Insect injuries may also provoke gummosis, but in this experiment the fruit harvested was free of gum.

Table 3 shows that all the spray treatments plus the soil treatments had an effect on the yield superior to the Check, though there were no significant differences between the yields under sprays with the same chemical soil treatment but there were significant differences between soil treatments with the same spray. The rank in descending order was Dowfume W-85,

TABLE 3.—*Effect of different soil and spray treatments combined on the yield of pineapples.*

Spray treatment	Yields per acre for soil treatment indicated—					
	Dowfume G	DD	Dowfume W-85	Dowfume N	Dowfume W-40	Check
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Iron sulfate	10.45	13.77	17.92	12.46	14.60	6.00
Fermate	10.59	12.55	15.44	9.51	12.93	6.77
Dithane Z-78	9.75	13.04	14.77	12.49	14.45	5.36
Zerlate	12.73	11.68	15.90	12.68	15.84	5.19
Check	10.37	14.64	15.58	14.48	16.53	7.88

L.S.D. between the means of spray treatments within each soil treatment: At the 5-percent level = 3.52 tons per acre; at the 1-percent level = 4.67 tons per acre.
L.S.D. between the means of soil treatments with the same spray treatment: At the 5-percent level = 3.83 tons per acre; at the 1-percent level = 5.12 tons per acre.

Dowfume W-40, DD, Dowfume N, Dowfume G, and Check, alone or combined with the spray treatments.

It seems preferable to use the iron sulfate sprays in alkaline soils to prevent chlorosis. The treatments with Dowfume W-85 and iron sulfate produced yields of approximately 18 tons per acre, which is three times that (6 tons per acre) obtained in the check plots.

Effect of Soil Treatments on the Number of Slips Produced per Acre

The data obtained on the mean number of slips produced by Red Spanish pineapple plants grown in plots treated with the various soil fumigants, respectively, are presented in table 4.

According to the above analysis, at the 1-percent level the mean number of slips produced by pineapple plants grown in plots treated with Dowfume

TABLE 4.—*Effect of different soil treatments on slip production by pineapple plants*

Soil treatment	Number of slips per acre
Dowfume G	22,974
DD	36,719
Dowfume W-85	47,432
Dowfume N	32,028
Dowfume W-40	45,386
Check	11,939

L.S.D.: At the 5-percent point = 10,223 slips per acre; at the 1-percent point = 13,943 slips per acre.

TABLE 5.—*Statistical analysis of the effect of different spray treatments on slip production by pineapple plants*

Spray treatment	Number of slips per acre
Iron sulfate	32,215
Fermate	34,577
Dithane Z-78	27,588
Zerlate	33,770
Check	35,584

L.S.D.: At the 5-percent level = 7,657 per acre; at the 1-percent level = 10,444 per acre.

W-85 was significantly greater than the mean number of slips produced by plants in soil treated with Dowfume N, Dowfume G and the Check; Dowfume W-40 was superior to Dowfume G and the Check; and DD was superior to the Check. At the 5-percent level, all the treatments were significantly superior to the Check. A comparison among the chemical treatments showed that Dowfume W-85 was superior to DD, DD to Dowfume G, and Dowfume W-40 to Dowfume N.

Effect of Spray Treatments on the Mean Number of Slips Produced

The statistical analysis of the mean number of slips produced by pineapple plants sprayed with different chemicals is shown in table 5. There was no significant difference between the different sprays at the 1-percent level but at the 5-percent level the Check was superior to all the chemical spray treatments. This indicates that under the experimental conditions,

TABLE 6.—*Effect of different soil and spray treatments combined on the mean number of slips produced by pineapple plants*

Spray treatment	Results of using indicated soil treatment —					Check
	Dowfume G	DD	Dowfume W-85	Dowfume N	Dowfume W-40	
Iron sulfate	19,683	34,682	52,059	29,363	45,819	12,048
Fermate	26,568	41,837	54,853	24,523	45,173	14,520
Dithane Z-78	18,605	31,408	40,546	30,221	36,029	8,712
Zerlate	26,026	34,842	44,960	37,642	49,478	9,680
Check	23,987	41,192	44,741	38,397	50,446	14,733

L.S.D. between two soil-treatment means for the same spray treatment: At the 5-percent level = 14,762 slips per acre; at the 1-percent level = 19,770 slips per acre.
L.S.D. between two spray-treatment means for the soil treatment: At the 5-percent level = 13,998 slips per acre; at the 1-percent level = 18,725 slips per acre.

the chemical sprays were not essential and were even somewhat depressive to the vigor of the pineapple plants.

Effect of Soil and Spray Treatments on Slip Production

Table 6 shows the mean number of slips of pineapple plants under different soil and spray treatments. The data show that there was no significant difference between the spray treatments within each soil treatment or among all soil treatments. Dowfume W-85 and Dowfume W-40 were superior to the others, followed by DD and Dowfume N.

The results on the mean number of suckers produced by pineapple plants undergoing the different soil treatments are presented in table 7. At the 1-percent level, all treatments were superior to the Check, but Dowfume W-85 and Dowfume W-40 were superior to Dowfume G. At the 5-percent level, Dowfume W-85 and Dowfume W-40 were superior to Dowfume N.

In table 8 it can be seen that there were no significant differences between the effects of different spray treatments on sucker production. The number of suckers fluctuated between 9,448 and 10,758.

The combined effect of soil and spray treatments on sucker production

TABLE 7.—*Effect of different soil treatments on sucker production by pineapple plants*

Soil treatment	Number of suckers per acre
Dowfume G	9,357
DD	11,055
Dowfume W-85	13,339
Dowfume N	10,371
Dowfume W-40	12,823
Check	4,517

L.S.D.: At the 5-percent level = 2,316 suckers per acre; at the 1-percent level = 3,159 suckers per acre.

TABLE 8.—*Effect of different spray treatments on sucker production by pineapple plants*

Spray treatment	Number of suckers per acre
Iron sulfate	10,687
Fermate	9,448
Dithane Z-78	9,669
Zerlate	10,629
Check	10,758

L.S.D.: At the 5-percent level = 2,316 suckers per acre; at the 1-percent level = 3,159 suckers per acre.

TABLE 9.—*Effect of different soil and spray treatments combined on sucker production per acre by pineapple plants*

Spray treatment	Results of using indicated soil treatment—					Check
	Dowfume G	DD	Dowfume W-85	Dowfume N	Dowfume W-40	
Iron sulfate	9,680	11,726	15,701	9,790	12,907	4,304
Fermate	9,467	11,184	13,016	7,208	11,080	4,730
Dithane Z-78	7,744	10,971	12,694	10,435	12,048	4,304
Zerlate	10,971	9,467	13,661	11,726	14,197	3,762
Check	8,925	11,939	11,616	12,694	13,875	5,485

L.S.D. between two spray-treatment means for the same soil treatment: At the 5-percent level = 3,704 suckers per acre; at the 1-percent level = 4,953 suckers per acre.

L.S.D. between two soil-treatment means for the same spray treatment: At the 5-percent level = 3,588 suckers per acre; at the 1-percent level = 4,787 suckers per acre.

is shown in table 9. These data indicate that there were no significant differences due to spray treatments when used with the same soil treatment, but that there were significant differences due to soil treatments when used with the same spray treatment.

Effect of Soil Treatments on Size of Fruits

Table 10 shows the effect of the different soil treatments on size of fruit. According to this table the percentages of fruits of the size numbers varied with the different soil treatments, but more larger size fruits were obtained from the plots to which nematocides were applied.

TABLE 10.—*Effect of different soil treatments on size of pineapple fruits produced*

Soil treatment	Percentage of fruits produced of size Nos. indicated														Total	Percent
	16	Percent	18	Percent	24	Percent	30	Percent	36	Percent	42	Percent	48	Percent		
D.[1] G.			22	0.2	968	8.6	2,732	24.3	2,796	24.9	2,732	24.3	2,001	17.7	11,251	100
DD			172	1.4	1,656	13.7	3,657	30.2	2,818	23.3	2,495	20.6	1,312	10.8	12,110	100
D.[1] W-85	22	0.2	301	2.2	2,904	21.6	4,109	30.5	2,947	21.9	2,237	16.6	946	7.0	13,466	100
D.[1] N	22	.2	194	1.7	1,420	12.2	3,248	28.0	2,753	23.7	2,538	21.8	1,441	12.4	11,616	100
D.[1] W-40	43	.3	279	2.1	2,087	15.7	4,109	31.0	3,012	22.7	2,452	18.5	1,291	9.7	13,273	100
Check			22	1.3	387	5.1	1,226	16.2	1,420	18.8	2,065	27.3	2,431	32.3	7,551	100

[1] Dowfume.

DISCUSSION

The results obtained from an experiment with pineapples at Palo Blanco, Arecibo, in Bayamón sandy-loam, demonstrated the beneficial effects of applying fumigants to the soil used for pineapple production.

Pineapple plants grown in plots heavily infested with nematodes produced a mean yield of 6.24 tons of marketable fruits per acre, while those grown in plots treated with fumigants produced higher yields. With the most effective fumigant (Dowfume W-85), a yield of 15.92 tons of pineapples per acre was obtained. The mean increase in yield for all spray treatments was 9.68 tons per acre.

The spray treatments with chemicals containing iron and zinc in organic forms (Fermate, Dithane Z-78, and Zerlate) did not prove superior to iron sulfate sprays. There was no significant difference among the sprays in terms of yield of fruit per acre, at the 1-percent level. However, the Check was superior to Fermate and Dithane Z-78 at the 5-percent level. This seems to indicate a depressive effect of these two chemicals on the plants.

The soil treatments with nematocides increased the production of slips and suckers. According to the data obtained all the pineapple plants in fumigated soil produced significant increases in yield of fruit per acre, in comparison with the Checks. The different soil fumigants also significantly increased the production of slips and suckers.

More larger size fruits were obtained in the plots where nematocides were applied. This is important because larger fruits are sold in the mainland at a higher price.

An Aldrin spray was applied to the soil to control insect pests—especially fire ants (*Solenopsis geminata*) which nurse the mealybugs, and also the white grubs of May bettles (*Phyllophaga spp.*) and the snout beetles (*Diaprepes spp.*) which cause damages to the roots and stems of pineapple plants. Resitox (oil plus DDT) and Parathion efficiently controlled mealybugs, scale insects, aphids, and caterpillars. The importance of controlling these insect pests should not be underestimated. Mealybugs are generally responsible for the mealybug wilt of pineapples, a disease which severely affects the Smooth Cayenne variety. The Red Spanish variety is tolerant, but the mealybugs lower the vitality of the plant and thus the yield per acre is reduced.

This experiment has demonstrated that pineapple cultivation in Puerto Rico can be greatly improved by using soil fumigants.

Yields would probably have been higher if the pineapple plants had been treated with acetylene as is done commercially, but even so the results obtained were practicable. The yield of 18 tons per acre is normal for three-fourths of the crop. It should have been possible to obtain around 24 tons per acre if the plants had been treated with acetylene.

CONCLUSIONS

1. The results of the pineapple experiment conducted at Palo Blanco, Arecibo, during the 1951–53 growing period in a Bayamón sandy-loam soil indicate the importance of controlling root-knot nematodes in pineapple production. The parasites were responsible for the low yields of fruits (6.24 tons per acre), as compared with the fruit produced in the Checks.

2. Fumigation of the soil with Dowfume G, DD, Dowfume W-85, Dowfume N, and Dowfume W-40, was beneficial to the development of the pineapple plants, increasing the yield from 6 to 10 tons per acre, and also producing more fruits of the larger sizes.

3. Dowfume W-85 proved best of all the soil treatments tested. The yield obtained when it was used in combination with the spraying of iron sulfate was up to 18 tons per acre.

4. The so-called degeneration of the Red Spanish variety in Puerto Rico seems to be a loss of vigor due to damage caused by insect and nematode parasites and to improper physicochemical conditions of the soil.

5. The number of suckers and slips produced by soil-treated plants was from two to four times higher, respectively, than the number obtained in the Checks, and the size and vigor of the planting material was far superior to that of the Checks.

6. Pineapple plants grown in soil free from nematodes, white grubs, and mealybugs developed healthy suckers and slips, thus excellent propagating material can be produced in Puerto Rico. It seems, unnecessary, therefore to import Cuban planting material to procure propagating material of high quality.

SUMMARY

1. Pineapple plants planted in nematocide-treated soil, showed greener, stockier, and more vigorous growth than those growing in plots not so treated. The mean yield obtained from pineapple plants cultivated on the nematocide-treated soil was from 10.78 to 15.92 tons of fruit per acre. The Checks produced a mean yield of 6.24 tons per acre.

2. The results of the soil treatments indicated that Dowfume W-85 was superior to all other nematocides, irrespective of spray treatments. The Dowfume W-85 soil treatment combined with iron sulfate sprays produced the heaviest yields, 17.92 tons per acre.

3. The mean number of slips produced per acre obtained with the different soil treatments varied from 22,974 to 47,432, in contrast with 11,939 produced in the Check plots. The highest yield of 47,432 slips per acre corresponds to treatment with Dowfume W-85.

4. The mean number of suckers produced per acre, obtained with the nematocide-treated plots ranged from 9,357 to 13,339, in contrast with a

mean yield of 4,517 produced in the Check plots. Dowfume W-85 was best with a mean yield of 13,337 suckers per acre. This treatment produced 15,701 suckers per acre when combined with iron sulfate sprays, and the percentage of larger fruits (sizes 12 to 36) was 74 (see table 9) as compared with the Check at 40.

5. The percentage of large fruits was higher in all plots treated with nematocides.

RESUMEN

1. Se realizó un ensayo en un terreno del tipo Bayamón lómico-arenoso en la finca del Sr. Enrique Landrón en el barrio Palo Blanco de Arecibo, para probar la eficacia de varios nematocidas.

Se seleccionó un sito infestado con nemátodos (*Meloidogyne*) los cuales causan hernias en las raíces de las piñas. Se probaron los siguientes nematocidas: Dowfume G, DD, Dowfume W-85, Dowfume N y Dowfume W-40.

2. Los aumentos en los rendimientos donde se aplicaron los nematocidas fluctuaron entre 10 y 16 toneladas por acre, en contraste con la producción de los testigos, que solamente produjeron un promedio de 6 toneladas por acre. El mejor fumigante fué el Dowfume W-85, cuya aplicación hizo aumentar el tamaño de las frutas y la producción hasta 18 toneladas por acre, cuando se acompañó el tratamiento con las aspersiones de sulfato de hierro. Esto constituye un aumento de 12 toneladas por acre sobre los testigos.

3. Para eliminar otros factores biológicos adversos se asperjaron las piñas mensualmente con Resitox (emulsión de aceite con DDT) durante los primeros meses de crecimiento y luego se usó el Parathion.

4. Para erradicar las hormigas bravas, que son nodrizas y distribuidoras de las cochinillas en los plantíos, y también eliminar los gusanos blancos de caculos y vaquitas (coleópteros) se incorporó Aldrín al terreno antes de la siembra. El Aldrín también se usó conjuntamente con el Resitox y con el Parathion para asperjar las plantas de piña.

5. En las parcelas fumigadas se aumentó considerablemente la producción de material para la propagación. Se obtuvieron aproximadamente 50,000 "slips" en comparación con sólo 12,000 en los testigos, y 13,000 "suckers" contra 4,000.

6. La "semilla" o material de propagación producida por las plantas sembradas en terreno fumigado y asperjado con Resitox-Algrin y Parathion, no sólo fué mayor, sí que también fué de calidad comparable con la mejor que se importa de Cuba.

Podemos concluir que el uso de fumigantes e insecticidas en el cultivo de la piña hace innecesaria la importancia de semilla de otros países y que la producción de frutas se puede aumentar por lo menos a 18 toneladas

por acre. Este aumento significa el doble de la producción promedio actual en Puerto Rico.

REFERENCES

1. Hernández-Medina, E., Apparent Degeneration of pineapple slips in Puerto Rico, *J. Agr. Univ. P. R.* **36**(3) 302–17, 1952.
2. ——, The beneficial effect of filter press cake on pineapple growth, development, and production, I, Effect on the plant crop, *J. Agr. Univ. P. R.*, **36**(3) 255–80, 1952.
3. ——, The beneficial effect of filter press cake on pineapple growth, development, and production, II, Effect on the ratoon crop, *J. Agr. Univ. P. R.*, **36**(3) 281–301, 1952.
4. Hopkins, E. F., Pagán, V., and Ramírez-Silva, F. J., Iron and manganese in relation to plant growth and its importance in Puerto Rico, *J. Agr. Univ. P. R.*, **28**(2) 43–101, 1944.
5. Pennock, W., Field response of Red-Spanish pineapples to nitrogen, calcium, iron and soil pH, *J. Agr. Univ. P. R.*, **33**(1) 1–26, 1949.
6. Schapelle, N. A., Clorosis de hierro causada por exceso de manganeso; Estación Experimental Agrícola, Río Piedras, Puerto Rico, Informe Bienal 15, 1938–39, 1939–40.
7. ——, Fertilizer studies with pineapples in Puerto Rico, *J. Agr. Univ. P. R.*, **26**(3) 41–60, 1943.
8. ——, Iron chlorosis caused by excessive manganese, Univ. of P. R. Agric. Expt. Sta., Annual Report 1939–40, 57–9, 1941.