Role of phosphorus and copper on growth and nutrient composition of Arabica coffee grown in sand culture*1/

E. A. ADUAYI**

COMPENDIO

Se cultivaron plantas de Coffea arabica *L. (cv 'S.L. 34'), de dos años y que no estaban en floración, en arena, con varias combinaciones de cobre y fósforo. Se observaron aumentos en el número de hojas y yemas florales en los niveles de P de 90 a 140 ppm en presencia de niveles de Cu de 1064 y 5064 ppm, los que produjeron también el mejor crecimiento de la planta. Sin embargo, con tratamientos más altos de Cu, se observaron síntomas severos de toxicidad de Cu, que consistían en reducción del número de hojas. Al aumentar la concentración de los tratamientos de P aumentó el contenido total de clorofila. El N foliar disminuyó en las concentraciones altas de Cu en presencia de P. Se observaron aumentos en el P y K foliares, y disminuyeron en el Ca y Mg foliares, representados por síntomas de deficiencia severa, cuando se aumentaron las concentraciones de los tratamientos de P. Se observaron aumentos en P y Cu foliares y radicales en todas las combinaciones de tratamiento, obteniéndose la concentración más grande de estos elementos en las raíces. La tendencia hacia acumulación aumentada en N, P y Cu en las raíces resultará probablemente en un aumento de síntesis de proteína y en un incremento subsecuente de complejos de proteína Cu dentro de las raíces.*

Introduction

THE EXCESSIVE use of copper in coffee plantations to control fungal infections has raised a series of questions. In spite of its effectiveness in disease control, Cu has been found to induce deleterious effects on plant growth and nutrition (3, 9, 13, 14) in several crops, particularly at high concentrations.

Work on *Coffea arabica* L. in Kenya (1) showed that the application of copper fungicides to coffee plantations at the recommended rate (8) increased soil available-Cu and also leaf-Cu concentration. High accumulation of Cu in the growth media, did not only show severe symptoms of toxicity in the leaves and roots but also affected the uptake of some mineral nutrient elements and caused severe derangement of the internal structures of the cells. In an attempt to control fungal infections in coffee, it is likely that some adverse effects of high Cu on coffee nutrition will occur. As long as the use of copper fungicides in Kenya is inevitable as at the present, it is desirable, therefore, to suppress the level of available Cu in the growth media and thus reduce its toxicity effects on the plant. This may be achieved by the use of nutrient elements that could increase plant growth and at the same time depress the excessive uptake of Cu by the plant.

In coffee management, phosphatic fertilizers are liberally applied. Such an agronomic practice could affect the Cu nutrition of the plant. It is the purpose of this study to observe the influence of applying varying levels of Cu and P on plant growth and the uptake of mineral elements in coffee leaves and roots.

Materials and Methods

Non-flowering two-year old *Coffea arabica* L. (cv. 'S.L. 34') plants were selected for uniformity from the nursery and transferred to the greenhouse. Their roots and leaves were washed free of soil and other deposits,

* Received for publication June 30th, 1977

1/ I am grateful to Dr. C. Bould and Professor R. B. Contant for their encouragement during the course of this study.

** Soil Science Department, University of Ife, Ile- Ife, Nigeria

first with tap water and finally with deionized rain water. The seedlings were then potted in a 1:2 ratio of sterile purified riversand (particle size, 0.5 to 1.5 mm) and polyethylene granules. They were then allowed to grow in the media supplied with deionized rain water for two weeks and then in complete nutrient solution formulated according to Hewitt (5) for four weeks before the commencement of the P, Cu and the complete nutrient solution treatments. The nutrient solution contained an initial P concentration of 40 ppm and 0.064 ppm of Cu.

The treatments consisted of six concentrations of Cu (as Cu_2O), designated Cu_0, Cu_1, Cu_2, Cu_3, Cu_4 Cu_5, corresponding to 0.064, 1.064, 5.064, 10.064, 50.064, 100.064 ppm Cu respectively and six concentrations of P (as KH_2PO_4) designated P_0, P_1, P_2, P_3, P_4, P_5, corresponding to 40, 90, 140, 240, 440, 840 ppm P, respectively. There were three replications.

Pot contents were flushed twice weekly with deionized rain water, to prevent accumulation of precipitated salts in the bottom of the pots. The nutrient solution plus the P and Cu treatments were fed-back to each pot six times daily after they had drained into reservoirs and were prepared afresh twice weekly to ensure reasonable constancy of the nutrient composition.

Records were made of the number of leaves, branches and flower buds, and per cent leaf-fall

Chemical Analysis

Samples of plant tissue were collected at the end of the experiment (12 months) rinsed in deionized water, washed in 0.1 N HCl and rinsed again in deionized water. The washed samples were dried in an oven at 65-70°C. The dried samples were ground in a Wiley micro-hammer stainless steel mill using a 1 mm sieve and stored in sealed plastic containers.

Bofere chemical analysis, an appropriate amount of each ground sample was re-dried overnight at 105°C and then placed in a dessicator. This was done to eliminate the need for converting calculations to an oven-dry basis. Colorimetric determinations of total N, and P were carried out on a Technicon auto-analyser; N being determined by the alkaline sodium phenate-sodium hypochlorite method and phosphorus by the molybdo-vanadate method for the simultaneous Kjeldahl N-Free H_2SO_4/ selenium digest solution. Concentrations of K, Ca and Mg were determined by dissolving the washed samples in 0.5N HCl, and Cu was determined in nitric-perchloric acid digest solution and read on an atomic absorption spectrophotometer. Total chlorophyll content in fresh leaves was determined by grinding 1g of the fresh-leaf sample in a mortar with 4 ml of pure acetone. The ground sample was extracted into 80 ml of alkaline acetone (containing 9 volumes of 80% acetone to 1 volume of 0.1M K_2CO_3), mixed thoroughly in a Waring blender run at high speed for 1 minute. Another 20 ml of the extractant was used for rinsing. The extract was then filtered twice and the absorbance measured in a spectrophotometer at 660 mμ and compared with known total chlorophyll standards.

Results

At the end of the experiment (12 months), visible effects of treatments on the growth of the coffee plants were observed.

As shown in Table 1, increase in P application increased leaf number significantly when compared with the control; the highest number being obtained at 140 ppm P treatment. The same trend occurred at Cu_1P_0.

Table 1.—Total leaf number per plant as influenced by Cu and P treatments

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
Cu_0	102	116	252	146	190	168	162
Cu_1	128	140	134	172	208	156	156
Cu_2	152	127	142	142	150	139	142
Cu_3	92	124	107	83	88	71	94
Cu_4	78	97	101	86	81	80	87
Cu_5	87	83	79	98	84	72	84
Mean	107	115	136	121	134	114	

LSD* at 5% = 31

In this and the following Tables, Cu_0, Cu_1, Cu_2, Cu_3, Cu_4 Cu_5 represent 0.064, 1.064, 5.064, 10.064, 50.064, 100.064 ppm Cu respectively; P_0, P_1, P_2, P_3, P_4, P_5 represent 40, 90, 140, 240, 440, 840 ppm P, respectively.

* LSD refers in all Tables to significant differences between any two means

Table 2.—Branch number per plant as affected by Cu and P treatments

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
Cu_0	13	14	20	20	23	24	19
Cu_1	18	21	18	20	24	21	20
Cu_2	15	17	18	18	18	10	16
Cu_3	9	11	9	6	9	5	8
Cu_4	8	8	8	6	6	6	7
Cu_5	6	9	6	7	7	6	7
Mean	11	13	13	13	15	12	

LSD at 5% = 5

except that the highest leaf number was obtained at treatment Cu_1 P_4. The pattern for Cu treatment at 5.064 ppm and increasing P applications was irregular.

At Cu_3P_0, the general trend was an increase in leaf number as the P concentrations increased from Cu_3P_1 to Cu_3P_2, followed by a decrease at P levels higher than P_2. There were no significant increases at the highest Cu concentrations (Cu_4, Cu_5) when P application was increased.

Table 2 indicates an increase in the number of branches per plant when increasing levels of P were added to Cu_0 and Cu_1. The same trend was observed for treatment Cu_2P_0 and increasing P levels, except for a decrease in branch number at the Cu_2P_5 treatments.

At Cu levels of 50.064 and 100.064 (Cu_4, Cu_5) the addition of P from P_0 to P_2 did not show any significant difference in the number of branches.

At Cu_0, flower bud number increased slightly with increasing P levels, as shown in Table 3.

At Cu_1 (1.064 ppm Cu) increasing P levels decreased flower number and at higher Cu concentrations additional P first increased flower bud number, but with increasing concentration it either reduced flower buds number or had no significant effect.

It was observed that the flower buds produced on the coffee plants, at low Cu levels (from Cu_0 to Cu_2) in combination with increasing levels of P developed normally and blossomed, while those produced in trees treated with higher Cu levels remained dormant and in some cases abscissed at the end of the experiment.

Table 3.—Flower bud number per plant as affected by Cu and P treatments.

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
Cu_0	57	70	82	83	61	67	70
Cu_1	127	119	82	92	92	67	97
Cu_2	178	188	135	162	146	131	157
Cu_3	135	223	141	168	118	79	144
Cu_4	45	90	121	42	52	60	62
Cu_5	22	27	29	20	25	26	24
Mean	94	119	98	95	76	72	

LSD at 5% = 36

Table 4.—Total chlorophyll content of the leaves as affected by varying concentrations of Cu and P in sand culture.

(mg/100 g fresh weight)

Treatments (ppm Cu)	Total Chlorophyll	Treatments (ppm P)	Total Chlorophyll
Cu_0 (0.064)	337.3	P_0 (40)	410.0
Cu_1 (1.064)	236.3	P_1 (90)	498.3
Cu_2 (5.064)	223.3	P_2 (140)	498.0
Cu_3 (10.064)	180.0	P_3 (240)	536.7
Cu_4 (50.064)	162.0	P_4 (440)	538.7
Cu_5 (100.064)	150.7	P_5 (840)	483.3
LSD at 5%	22.69		21.95

Chlorophyll

Copper concentrations from 1.064 ppm to 100.064 ppm resulted in decreased total leaf-chlorophyll content.

Table 5.—Nitrogen concentration in the leaves and roots of coffee plants as affected by Cu and P treatments.

(% in dry matter)

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
				Leaves			
Cu_0	3.25	2.86	3.13	3.24	3.11	3.12	3.11
Cu_1	3.10	3.10	3.13	3.18	3.18	3.12	3.13
Cu_2	3.04	2.92	2.90	2.78	2.78	2.58	2.83
Cu_3	2.78	2.67	2.52	4.48	2.50	4.42	2.56
Cu_4	2.42	2.61	2.56	2.44	2.50	2.39	2.48
Cu_5	2.55	2.58	2.52	2.50	2.30	2.34	2.46
Mean	2.85	2.79	2.79	2.77	2.72	2.66	
LSD at 5% = 0.25							
				Roots			
Cu_0	2.57	2.48	2.23	3.03	2.92	3.21	2.74
Cu_1	2.27	2.58	2.51	2.54	2.60	3.06	2.59
Cu_2	2.15	2.47	2.66	2.91	2.76	3.45	2.73
Cu_3	2.20	2.34	2.85	3.05	3.40	2.82	2.77
Cu_4	2.31	2.36	2.45	2.75	2.76	2.79	2.57
Cu_5	2.39	2.23	2.02	2.03	2.09	2.60	2.22
Mean	2.31	2.41	2.45	2.71	2.75	2.98	

LSD at 5% = 0.53

compared to the control; being markedly reduced at Cu concentrations greater than 10.064 ppm (Table 4). The effect of P on the chlorophyll content contrasted with the Cu effect. Whereas Cu levels decreased chlorophyll in the leaves, all P levels increased it. Thus, at P concentration greater than P_0, a consistently marked increase was observed in total chlorophyll.

Nitrogen

As indicated in Table 5, a slight but consistent decrease occured in leafN at Cu levels of Cu_2, Cu_3 and Cu_5 at increasing application of P, except for a marked increase in leaf-N observed at Cu_3P_3 and Cu_3P_5. Leaf-N increased slightly at Cu_4 with increasing P concentration. At Cu_5, a significant decrease was observed only with P_4. With the exception of a decrease at Cu_0P_1 and Cu_0P_2 and the highest Cu level (Cu_5), root-N was generally increased over the control at Cu treatments from Cu_1 to Cu_4 in combination with P levels from P_1 to P_5.

Table 6.—Phosphorus concentration in coffee leaves and roots as affected by Cu and P treatments

(% in dry matter)

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
			Leaves				
Cu_0	0.26	0.28	0.37	0.41	0.76	1.16	0.54
Cu_1	0.25	0.27	0.33	0.38	0.58	0.77	0.43
Cu_2	0.28	0.34	0.37	0.41	0.75	0.80	0.49
Cu_3	0.21	0.21	0.27	0.29	0.50	0.65	0.35
Cu_4	0.16	0.21	0.21	0.26	0.36	0.53	0.28
Cu_5	0.17	0.16	0.20	0.21	0.37	0.42	0.25
Mean	0.22	0.24	0.29	0.32	0.55	0.72	

LSD at 5% = 0.19

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
			Roots				
Cu_0	1.22	1.15	0.77	1.33	1.55	1.34	1.22
Cu_1	0.91	1.39	0.95	0.96	1.45	1.29	1.15
Cu_2	0.85	1.28	1.35	1.39	1.66	1.19	1.28
Cu_3	0.78	1.20	1.22	1.30	1.53	1.60	1.27
Cu_4	0.57	0.94	1.06	1.14	1.49	1.60	1.13
Cu_5	0.83	0.66	0.80	1.20	1.26	1.34	1.01
Mean	0.86	1.10	1.02	1.22	1.49	1.39	

LSD at 5% = 0.66

Table 7.—Potassium concentration in coffee leaves and roots as affected by Cu and P treatments

(% in dry matter)

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
			Leaves				
Cu_0	2.27	2.81	2.83	3.58	4.45	5.15	3.60
Cu_1	2.67	2.86	3.17	3.66	3.62	4.14	3.35
Cu_2	3.00	3.32	3.57	3.63	4.39	5.40	3.88
Cu_3	2.95	3.13	3.08	3.46	3.91	3.89	3.40
Cu_4	3.14	3.49	3.44	3.55	4.06	4.34	3.67
Cu_5	3.01	3.03	3.48	3.76	3.75	4.43	3.58

LSD at 5% = 0.06

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
			Roots				
Cu_0	2.26	1.91	2.14	1.87	1.09	1.39	1.78
Cu_1	2.10	2.37	2.10	1.42	1.58	1.28	1.81
Cu_2	1.83	1.82	1.58	1.34	1.33	0.75	1.44
Cu_3	1.50	1.57	1.30	0.96	0.93	0.65	1.15
Cu_4	1.43	1.50	1.59	1.37	0.91	0.64	1.24
Cu_5	0.94	1.29	1.49	1.43	1.38	1.00	1.25
Mean	1.68	1.75	1.69	1.40	1.20	0.95	

LSD at 5% = 0.75

Phosphorus

The concentration of P in parts of the coffee plant as affected by Cu and P treatments is shown in Table 6.

At all Cu levels, increasing P treatments consistently increased the concentrations of P in the leaves. These increases were significant at Cu levels from Cu_1 to Cu_5 in the presence of P treatments at P_4 and P_5 with the exception of a non-significant effect at Cu_3P_1 and Cu_5P_1. Root-P increased with increasing P treatments at all Cu levels. A greater proportion of plant-P accumulated in the roots than in the leaves.

Potassium

Table 7 shows the distribution of K in parts of the plant. At all levels of Cu, increasing levels of P increased leaf-K, the increase being greatest at the lower Cu levels. At the highest levels of P, increasing levels of Cu decreased leaf-K. The contrary trend was observed in root-K. Increasing levels of P at all levels of Cu generally decreased root-K; similarly, increasing levels of Cu at all levels of P decreased root-K. Potassium accumulated more in the leaves than in the roots.

Calcium

A significant decrease in leaf-Ca was observed (Table 8) at treatment combinations of increasing Cu and P_3, P_4 and P_5.

At low levels of Cu increasing P levels depressed root-Ca; at intermediate levels it increased root-Ca and at the highest level the effects were variable. Generally, Ca was higher in the roots than in the leaves.

Magnesium

With a few exceptions, all Cu levels in the presence of increasing levels of P resulted in a marked decrease in leaf-Mg as indicated in Table 9.

Table 8.—Calcium concentration in the leaves and roots of coffee plants as affected by Cu and P treatments.

(% in dry matter)

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
			Leaves				
Cu_0	1.24	1.18	0.83	0.69	0.44	0.61	0.83
Cu_1	1.21	0.96	0.95	0.67	0.52	0.32	0.77
Cu_2	1.50	1.04	0.78	0.51	0.60	0.37	0.80
Cu_3	1.27	1.04	0.85	0.85	0.82	0.70	0.92
Cu_4	1.08	0.88	0.92	0.87	0.78	0.89	0.90
Cu_5	1.17	0.97	0.93	0.73	0.92	0.91	0.94
Mean	1.25	1.01	0.88	0.72	0.68	0.64	
LSD at 5% = 0.26							
			Roots				
Cu_0	1.70	1.00	0.90	1.04	0.86	0.92	1.07
Cu_1	1.59	1.79	1.12	0.83	0.98	0.74	1.18
Cu_2	1.34	1.07	1.18	1.03	1.02	1.32	1.16
Cu_3	1.17	1.32	1.44	1.48	1.52	1.52	1.41
Cu_4	0.93	0.94	1.08	0.87	1.31	1.36	1.08
Cu_5	1.20	0.86	0.93	0.97	0.81	1.21	1.00
Mean	1.32	1.16	1.11	1.04	1.08	1.18	

LSD at 5% = 0.50

Table 9.—Magnesium concentration in the leaves and roots of coffee plants as affected by Cu and P treatments.

(% in dry matter)

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
			Leaves				
Cu_0	0.38	0.34	0.33	0.27	0.20	0.19	0.28
Cu_1	0.38	0.40	0.33	0.30	0.23	0.17	0.30
Cu_2	0.36	0.30	0.27	0.26	0.22	0.13	0.26
Cu_3	0.28	0.29	0.25	0.25	0.25	0.25	0.26
Cu_4	0.27	0.23	0.28	0.30	0.23	0.24	0.26
Cu_5	0.31	0.29	0.26	0.23	0.21	0.21	0.25
Mean	0.33	0.31	0.29	0.27	0.22	0.20	
LSD at 5% = 0.04							
			Roots				
Cu_0	0.34	0.35	0.34	0.35	0.32	0.25	0.32
Cu_1	0.41	0.45	0.40	0.28	0.31	0.23	0.34
Cu_2	0.34	0.41	0.31	0.27	0.32	0.15	0.30
Cu_3	0.32	0.38	0.27	0.27	0.18	0.14	0.26
Cu_4	0.31	0.28	0.29	0.28	0.21	0.17	0.26
Cu_5	0.26	0.28	0.31	0.30	0.22	0.20	0.26
Mean	0.33	0.35	0.32	0.29	0.26	0.19	

LSD at 5% = 0.13

Increasing Cu treatments in the presence of P at 40, 90 and 140 ppm first increased and finally decreased root-Mg. But at P above 140 ppm, there was a general decrease in root-Mg.

It is worth noting that, for the major nutrients, significant Cu and P interactions occurred in the leaves only.

Copper

The concentration of Cu in the leaves and roots of the coffee plant is shown in Table 10. When compared with the control, increasing Cu treatments increased leaf-Cu at all levels of P except for a decrease at Cu_4P_1, Cu_4P_2, and Cu_5 at all levels of P. Increasing P had little effect on root-Cu at low levels of Cu; however, it increased root-Cu at intermediate levels of Cu and reduced root-Cu at the highest level of Cu. Increasing levels of Cu increased root-Cu at all levels of P the increase being greatest at low P and least at high P, relative to the control treatment.

Table 10.—Copper concentration in the leaves and roots of coffee plants as influenced by Cu and P treatments.

(ppm in dry matter)

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
			Leaves				
Cu_0	63	64	48	61	41	36	52
Cu_1	69	99	74	38	28	34	57
Cu_2	47	77	52	113	154	140	97
Cu_3	120	153	136	132	168	286	166
Cu_4	173	146	137	191	224	285	193
Cu_5	245	164	179	162	160	226	189
Mean	120	117	104	116	129	168	

LSD at 5% = 53

Treatments	P_0	P_1	P_2	P_3	P_4	P_5	Mean
			Roots				
Cu_0	197	199	179	296	247	303	237
Cu_1	692	758	627	554	556	679	661
Cu_2	1393	2330	2979	3648	3401	3970	2954
Cu_3	3309	2824	4244	5890	7625	6813	5117
Cu_4	7753	6733	6559	6856	7066	7783	7125
Cu_5	6729	5192	6234	6175	5112	4909	5725
Mean	3346	3006	3470	3903	4018	4076	

LSD at 5% = 1354

Discussion

An increase in Cu treatment from Cu_0 to Cu_1, and P from P_0 to P_3 produced a marked increase in growth. In general, P at all levels was instrumental in promoting the vigorous growth of leaves and branches. At the intermediate level, in combination with P, Cu produced more flower buds. Montoya *et al.* (7) observed that increases in leaf and branch nodes were positively correlated with the fruiting capacity of the coffee plant. This may be reflected in the increase in flower bud number.

Increasing Cu concentrations induced severe defoliation and produced progressively deleterious effects on nutrient uptake. However, in the case of Ca and Mg distribution in the plants, increasing P concentrations had the opposite effect. The effect of adequate Cu (0.064 - 1.064 ppm Cu) on the total chlorophyll content is due possibly to increased oxidase activity subsequently improving the metabolic activities in the plant (2). This is possible in view of the fact that Cu is an integral constituent of several widely spread enzymes in the plant. Nason and McElroy (10) showed that the function of Cu was an indirect one, and that an adequate amount of it had a protective effect against chlorophyll degradation, increases photosynthetic activity and retards physiological ageing of the plant. The effect of increasing levels of P on plant growth and chlorophyll accumulation in the leaves would probably increase the photosynthates —the energy source for active nutrient uptake— and thus, result in increased dry matter production.

The rather high plant-K, (particularly leaf-K) was induced by the KH_2PO_4 carrier for P (see Materials and Methods) and this, in combination with the varying levels of P was associated with the decline in the concentration of Ca and Mg in parts of the plant. It is also probable that formation of insoluble precipitates of Ca and Mg with phosphates in the nutrient solution could be partly responsible for the reduced uptake of Ca and Mg by the plant. Working with Arabica coffee, Robinson and Chenery (12) observed an antagonistic effects of high plant-K on the uptake and distribution of Mg, resulting in Mg deficiency. Hipp and Gerard (6) found that high P depressed Ca and Mg in tomato; and Rhoads (11) found the same for tobacco.

The combination of various levels of Cu and P shows a significant increase in N and P content of the plant. As has been shown by Dekock *et al.* (4) the increase in N content would result in increased protein synthesis. Additional P in the presence of increasing Cu treatments increased P content of the plant. The roots of young non-fruiting coffee plants may, from these data, be regarded as highly effective organs for N, P and Cu accumulation as was indicated in the concentration of these elements in the roots. This situation is likely to lead to an increase in root-protein concentrations, and, to increased formation of Cu-protein complexes within the root.

In the presence of intermediate Cu concentration (1.064-5.064 ppm Cu), the addition of P from 90 to 140 ppm, could improve coffee plant growth.

Summary

Non-flowering two-year old *Coffea arabica* L. (cv. 'S.L. 34') plants were grown in sand culture and treated with varying combinations of copper and phosphorus. Increases in the number of leaves and flower buds were observed at P levels of 90 to 140 ppm in the presence of Cu levels of 1.064 and 5.064 ppm which also produced the best plant growth. However, at higher Cu treatments, severe Cu toxicity symptoms were observed as indicated in reduced leaf number. Increasing the concentration of P treatments increased the total chlorophyll content. Leaf-N was decreased at high Cu concentrations in the presence of P. Increases in leaf-P, -K and decreases in leaf-Ca and -Mg resulting in severe deficiency symptoms, were observed at increasing P treatment concentrations. Leaf- and root-P and -Cu

were increased at all treatment combinations with the greatest accumulation of these elements appearing in the roots. The tendency towards increased N, P and Cu accumulations in the roots would probably result in an increase in protein synthesis and a subsequent increase in Cu-protein complexes within the roots.

Literature cited

1. ADUAYI, E A. - Composition of soil and coffee leaves on plantations under varying copper fungicide spraying regimes. Tropical Agriculture (Trinidad) 53: 63-68. 1976.

2. BAILEY, L F. and McHARQUE, J S. Effects of boron, copper, manganese and zinc on the enzyme activity of tomato and alfalfa plants in the greenhouse. Plant Physiology 19: 105-116. 1943.

3. CASTILLO, L. J. and PARRA, J. Efecto tóxico del cobre en semilleros de café. Cenicafé 10: 109-117. 1959.

4. DEKOCK, P C., CHESHIRE, M.V. and HALL, A - Comparison of the effect of phosphorus and nitrogen on copper-deficient and sufficient oats. Journal of the Science of Food and Agriculture 22: 437-440. 1971.

5. HEWITT, E J. Sand and water culture methods used in the study of plant nutrition. 2nd ed. Farnham Royal, C.A.B. 1966. 238p.

6. HIPP, B.W. and GERARD, C J. Magnesium-phosphorus interrelationships in tomatoes. Agronomy Journal 61: 403-405. 1969.

7. MONTOYA, L A., SYLVAIN, P G., and UMAÑA, R. Effect of light intensity and nitrogen fertilization upon growth differentiation balance in *Coffea arabica* L. Coffee 3: 97-104. 1961.

8. MULINGE, S.K. Control of coffee berry disease and leaf rust in 1971. Kenya Coffee 36:9-12. 1971.

9. NAG RAJ, T R. and GEORGE, K V. A note on Bordeaux toxicity in coffee seedlings. Indian Coffee 24: 452. 1960.

10. NASON, A. and McELROY, W D. Modes of action of the essential mineral elements. *In* Steward, F C., ed. Plant Physiology, New York, Academic Press. 1963. pp. 451-536.

11. RHOADS, F.M. Effect of phosphorus fertilization by cigar wrapper tobacco. Communications in Soil Science and Plant Analysis 3: 87-95. 1972.

12. ROBINSON, J B.C. and CHENERY, E M. Magnesium deficiency in coffee with special reference to mulching. Empire Journal of Experimental Agriculture 26: 259-273. 1958.

13. SMITH, P F. and SPECHT, A W. Heavy-metal nutrition in relation to iron chlorosis of citrus seedlings. Proceedings of the Florida State Horticultural Society 65: 101-108. 1953.

14. STRUCKMEYER, B E., PETERSON, L A., and HSI - MEI TAI, F. Effects of copper on the composition and anatomy of tobacco. Agronomy Journal 61: 932-936. 1969.

Notas y Comentarios

Carrizo contaminante de mercurio

Un estudio publicado en *Nature* (4 de agosto de 1978) muestra que el carrizo que crece en suelos contaminados con mercurio puede ser parcialmente responsable de una contaminación atmosférica de mercurio, al absorber activamente y emitir el polulante al aire. Jack Kozuchowski y David Johnson, del Colegio de Ciencia Ambiental y Forestal, de la Universidad del Estado de Nueva York, midieron el mercurio emitido en dos lugares del lago Onondaga por *Phragmites communis*, que se encuentra en las orillas del lago, contaminadas fuertemente con mercurio de una fábrica local. Los resultados fueron comparados con una estación de control sobre un arroyo cerca de White Lake, una zona natural no contaminada al sur de Syracuse, también en el Estado de New York. Sus mediciones muestran claramente que en el primer lugar se emitió cuatro veces más mercurio que el lugar testigo, y que en el segundo, los resultados fueron aún más dramáticos: más de 19 veces más mercurio fue emitido a la atmósfera. Los autores señalan que el mercurio no era emitido de noche cuando los estomas de las hojas estaban cerrados, lo que sugiere un nexo de la emisión de mercurio con la transpiración y la fotosíntesis. Encontraron también que la cantidad emitida dependía del nivel de contaminación en los sedimentos que rodeaban a las cenizas. Los autores también creen que *Phragmites* no es la única planta vascular capaz de hacer esta absorción y emisión de mercurio.

Nueva técnica de control de la polilla de las almendras

La liberación de machos estériles por irradiación no es el único método de control que utiliza el instinto sexual de los insectos para destruir sus poblaciones. Las trampas con feromonas pueden considerarse como otro método. Y ahora, la incapacidad de diferentes razas de la polilla de la almendra *(Caudra cautella)* de reproducirse después de aparearse se está explorando como un medio posible para controlar la población especialmente los insectos de productos almacenados *(Agricultural Research* vol 26, Nº 1, p. 15)

El entomólogo John H Brower, del laboratorio de Insectos de Productos Almacenados, en Savannah, Georgia, descubrió que las polillas iraníes hembras eran incompatibles con los machos de razas de los Estados Unidos. En cruces de hembras iraníes con machos norteamericanos, el apareamiento y la oviposición eran normales pero los huevos eran casi todos infértiles. En contraste, los cruces recíprocos fueron normales en fertilidad de los huevos. Así, la incompatibilidad fue de una sola vía.

Este tipo de incompatibilidad reproductiva es susceptible de ser usada para suprimir poblaciones naturales mediante la liberación de grandes números de machos incompatibles, sanos y agresivos para conseguir pareja, pero estériles.

El Dr. Brower se apresura a señalar que la idea no se ha lanzado para el control de poblaciones de insectos en zonas geográficas grandes, sino más bien en áreas cerradas pequeñas o aisladas, como por ejemplo bodegas. Piensa que sería difícil para operaciones de campo porque sólo se podrían liberar los machos. El liberar hembras a la par de machos resultaría en que la raza extranjera reemplace a la raza nacional.

Notas y Comentarios

La peste porcina en Brasil

Hay alarma y cierta confusión sobre los porcinos de Brasil. A comienzos de mayo, en el Estado de Río de Janeiro, se anunció un brote de la letal peste porcina africana, que a comienzos de la década de los novecientos sesenta exterminó casi todos los 400 mil cerdos de Cuba. La peste no puede ser controlada por ninguna vacuna conocida, y podría matar casi todos los 40 millones de cerdos del Brasil, el cuarto lugar en la población porcina mundial. El virus puede ser acarreado por el agua, ropa, zapatos, animales y por camiones. También se ha presentado la peste porcina en la República Dominicana.

Una vez confirmada la presencia de la enfermedad, se intentó una medida radical al anunciar funcionarios del gobierno una propuesta de sacrificar los 250 mil cerdos de Río de Janeiro. Ante los gruñidos de los productores, se anunció que serían eliminados sólo los cerdos en piaras infectadas; en total, dos meses después del brote, de unos 14 mil. Una suerte de cordón sanitario se ha tendido alrededor de Río, pero se han registrado (fines de julio) brotes en 49 lugares, desde Piaui en el noreste hasta Santa Catarina, 3000 kilómetros al sur. Los agricultores han protestado por diagnósticos mal hechos, que atribuían a la peste porcina africana la muerte de cerdos sin vacunar por enfermedades porcinas corrientes.

Los veterinarios temen ahora que la peste africana ha estado presente por algún tiempo en el país, sin ser detectada. Una posible fuente de transmisión fue la entrada ilegal hace dos años de barcos angoleños que llevaban refugiados y sus pertenencias, incluso cerdos.

Se está pagando compensación a los agricultores por matar animales sanos, pero el precio no es lo suficientemente alto para prevenir que algunos productores traten de ocultar brotes de la enfermedad. Las amas de casa se han mostrado escépticas de la seguridad del gobierno de que la carne de cerdo infectada es inofensiva para el consumo humano. A pesar de escenas televisadas de ministros comiendo *feijoada*, un plato popular tradicional de frijoles y puerco, el consumo doméstico de cerdo ha bajado súbitamente en dos tercios.

Una consecuencia es que las importaciones de maíz se espera que se eleven a un nivel sin precedentes de 2 millones de toneladas, para poder alimentar el exceso de pollos que se consumirán en lugar de los cerdos. El temor de que los productos brasileños puedan transmitir la peste porcina ha causado que Alemania Oriental cancele órdenes de harina de soya brasileña.

Con mayor justificación, el gobiero peruano ha adoptado medidas drásticas para impedir la entrada de la peste al país. Se considera que son escasas las probabilidades de que Brasil erradique con éxito esta muerte negra de los cerdos.

El cemento como mejora del suelo

Un poco de cemento Portland aplicado al suelo antes de pasar el arado, un mes antes del sembrío, ha aumentado los rendimientos de caña de azúcar en las grandes plantaciones de Queensland, Australia, en casi un 50 por ciento (*New Scientist* vol. 79, p. 188). Este sorprendente resultado ha emergido de los ensayos de campo de Australian Bureau of Sugar, en que se investigaban asertos de que el silicato de calcio aplicado a los suelos ácidos aumentaba significativamente los rendimientos del cultivo.

Michael Haysom, el supervisor de los ensayos, encontró que mientras el silicato puro mejoraba por cierto las cosechas, era demasiado caro para aplicarlo comercialmente. Así, se recurrió al cemento Portland como una alternativa relativamente barata. En una prueba, cuatro toneladas de cemento aplicadas por hectárea aumentaron los rendimientos en un 44 por ciento, mientras que se tuvo un aumento de 33 por ciento con la aplicación de 2,5 toneladas.

Los agrónomos de Bureau creen que los mejores rendimientos son debidos al magnesio y al hierro, y esperan conseguir mejoras similares en la producción de yute, arroz y sorgo. El método es claramente de muy amplia aplicación a cultivos en los suelos ácidos de textura gruesa de Queensland.

Curso sobre producción moderna de café

Un curso intensivo sobre producción moderna de café se realizará en el Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), en Turrialba, Costa Rica, del 10 de setiembre al 8 de octubre de 1978. Tiene por objetivo proporcionar a los participantes información técnica y práctica sobre el cultivo moderno del café. Se dará más énfasis a aquellos que más inciden en la alta productividad del cultivo. Se hará uso de conferencias, seminarios, discusiones de grupo, giras educativas, y prácticas de campo.

El curso está organizado por promecafé (Programa Cooperativo para la Protección y Modernización de la Caficultura en México, Centroamérica y Panamá), un organismo del IICA, con la colaboración del CATIE. Está dirigido a los ingenieros agrónomos que trabajan en café con los organismos cafetaleros o ministerios de los países que componen Promocafé, esto es, México, América Central y Panamá.

Los conferenciantes serán técnicos de reconocida competencia, especializados en las distintas partes del cultivo tecnificado del café. Los coordinadores serán Carlos Enrique Fernández, de parte del IICA, y Gilberto Gutiérrez, de parte del Ministerio de Agricultura y Ganadería de Costa Rica.