A PARTIALLY ANNOTATED BIBLIOGRAPHY ON ZINC IN THE TROPICS

by

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W. L. Lindsay has written an excellent review of soil-plant zinc relationships ("Zinc in soils and plant nutrition." Advances in Agronomy 24:147-186, 1972) which gives a good picture of our present knowledge about zinc. Rather than summarizing his presentation here I urge the reader to consult this work as a background for the specific articles included in the bibliography.

Abstracting and bibliographic publications were searched for titles indicating articles about zinc in the tropics. The "Bibliography of the literature on the minor elements and their relation to plant and animal nutrition", 4th ed. Volumes I, II and III. Chilean Nitrate Educational Bureau, Inc. 120 Broadway, New York 1948 was searched. The Commonwealth Agricultural Bureaux bibliographies: No. 1077, "Determination of zinc in soil"; No. 1300, "Zinc-phosphorus relationships"; No. 1340, "Determination of zinc and zinc availability"; No. 1532, "Zinc in soil (1971-1969)"; and No. 1533, "Zinc in soil (1969 and before)" were used. The 1965 and 1966 volumes of Tropical Abstracts and the January 1970 through May 1973 volumes of Bibliography of Agriculture were searched. The abstracts from the Commonwealth Agricultural Bureaux publications have been included verbatim. The bibliography prepared by F. R. Cox "Trace Element Deficiencies in Latin America," Chapter 10 in Review of Soils Research in Tropical Latin America, P. A. Sanchez, ed. Soil Science Department, North Carolina State University at Raleigh was used. The 1969, 1970, and 1971 issues of Bibliografia Agricola Latinoamericana were searched for relevant titles.

References were included for countries with more than half their area in the tropics except where the reference indicated that the work was definitely with soils from a part of the country lying entirely outside the tropics.

The bibliography is organized by countries in alphabetical order with a "general" section at the end.

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AUSTRALIA

Burville. 1965. Plant nutrition in Western Australia. J. Agr. W. Australia 6(6):353-371.

Chaudhry, F. M., and Loneragan, J. F. 1970. Effects of nitrogen, copper, and zinc fertilizers on copper and zinc nutrition of wheat plants. Aust. J. Agr. Res. 21(6):865-879.

Dunne, T. C., and Elliott, H. G. 1950. Zinc fertilization for subterranean clover at Kendenup. J. Agr. W. Aust. 27:115-117.

Four pounds of ZnO per acre allowed successful establishment of sub clover on newly cleared sandy timberland.

Hibberd, D. E. 1970. Methods of correcting zinc deficiency in irrigated maize grown on a black earth soil at Darling Downs, Queensland. Queensland J. Agr. An. Sci. 1:89-94.

Kessell, S. L., and Stoate, T. N. 1936. Plant nutrients and pine growth. Aust. Forestry 1:4-13.

In Western Australia, spraying Zn on new pines in the nursery had an immediate and striking effect. Previously only the use of old pine soils or fruiting bodies of Rhizopogon luteolus overcame stunting.

Millikan, C. R., Hanger, B. C., and Bjarnason, E. M. 1969. The mobility of ^{65}Zn in Trifolium subterraneum L. and Antirrhinum majus L. Aust. J. Biol. Sci. 22:311-320.

Morgan, E. T. 1938. Potato fertilizer trials at Burekup, 1937. J. Dept. Agr. W. Aust. 15:93-97.

At Burekup, Western Australia, no Zn response was observed on potatoes.

Smith, W. P. C. 1948. Zinc deficiency of flax. J. Agr. W. Aust. 25:136-142.

Zinc sulfate cured the problem of dieback, which was most severe on gray to gray-brown gritty or gravelly loamy sands to sandy loams with clay at 1 to 2 feet. The symptoms seemed to be in direct proportion to waterlogging. On deeper reddish loams, flax was almost free from dieback. Superphosphate made the problem worse.

Teitzel, J. K. and Bruce, R. C. 1971. Fertility studies of pasture soils in the wet tropical coast of Queensland. 2. Granitic soils. Aust. J. Exp. Agr. Anim. Husb. 11(48):77-84.

ARGENTINA

Mazza, C. A., Grassi, R. L., Santamaria, R. M., et al. 1966. Determinacion de microelementos en suelos del valle inferior del Rio Colorado: Niveles en tomate. Rev. Fac. Agron. Univ. Nac. La Plata 42(2):161-179.

BRAZIL

Arens, K. 1963. The dwarfed plants of the "cerrado" as flora adapted to mineral deficiencies of the soil. In Simposio sobre o Cerado. p. 285-303.

A general article.

Blanco, H. G., Oliverira, D. A., and Haag, H. P. 1972. Absorption of zinc by intact leaves of coffee plants (Coffea arabica L.) II. Effects of different sources of zinc and (pH) solution. Sao Paulo Inst. Biol. Arg. 39(1):13-18.

Catani, R. A., Pellegrino, D., Alcarde, J. C. et al. 1967. Variacao na concentracao e na quantidade de macro e micronutrientes no fruto do cafeeiro, durante o seu desenvolvimento. An. Esc. Sup. Agric. "Luiz de Queiroz" 24:249-263.

Cox, F. R. 1972. Trace element deficiencies. In a Review of Soils Research in Tropical Latin America, pp. 244-263. P. A. Sanchez, Ed. Soil Science Dept. North Carolina State University, Raleigh, North Carolina.

Brazil has a better reporting system than other areas of Latin America and more research effort. Consequently this review draws heavily on work in Brazil. Phosphorus levels and soil texture may be important in the degree of Zn deficiency observed in the field. Severe Zn deficiencies have been noted in corn in the Campo Cerrado of Brazil. This is a good recent review of significant South American trace element research.

Franco, C. M., and Mendes, H. C. Deficiência de microelementos em cafeeiro. (Nota Preliminar) 1953. Bol. Supt. Serv. Cafe S. Paulo. 28:19-22.

Dwarfing and deformity of leaves of coffee were believed caused by Zn deficiency.

Freitas, L.M.M. de, McClung, A. C., and Lott, W. L. 1960. Field studies on fertility problems of 2 Brazilian Campo Cerados, 1958-59. IBEC Res. Inst. Bull. 21.

Corn with Zn content of 16 ppm in the leaf responded to the application of Zn, as did soybeans with 23 ppm. Cotton with 35 ppm Zn in the leaf did not respond to the addition of Zn nor did soybeans with 57 ppm Zn.

Gallo, J. R., Hiroce, R., and Alverez, R. 1968. Levantamento do estado nutricional de canaviais de Sao Paulo pela analise foliar. Bragantia 27(30):365-382.

Sugarcane with 15-18 ppm Zn in the leaf did not respond to Zn.

Gallo, J. R., Hiroce, R., and de Miranda, L. T. 1965. A analise foliar na nutricao do milho. II. Resultados de abubacao com N, P, K, S, and micronutrientes. Bragantia 24, Nota 14:71-77.

BRAZIL (Cont'd)

According to this article about the addition of various fertilizers to corn in relation to foliar analysis, the addition of Zn to corn with 21 ppm Zn in the leaves did not give a response.

Gomide, J. A., Noller, C. H., Mott, G. O., Conrad, J. H., and Hill, D. L. 1969. Mineral composition of six tropical grasses as influenced by plant age and nitrogen fertilization. Agron. J. 61:120-123.

Contents of K, P, Ca, Mg, Cu, Mn, Fe, and Zn are presented for grasses grown in central Brazil in the state of Minas Gerais on sandy loam soil of pH 5.1 with 1% organic matter.

Hardy, F. 1962. Problemas de fertilizacion en el Campo Cerrado de la parte central oriental de Brazil. Turrialba 12(3):128-133.

A general article.

Igue, K., and Bornemisza, E. 1967. El problema del zinc an suelos y plantas de regiones tropicales y de zonal templadas. Fitotecnia Latinoamericna 4(1):29-44.

A recent review.

Igue, K, and Romano Gallo, J. 1960. Zinc deficiency of corn in Sao Paulo. I.B.E.C. Res. Inst. Bull. 20, 18.

Zn-containing sprays of $ZnSO_4$ mixed with other fertilizers and ZnO or "Dithane" applied with the seed partially or completely prevented chlorosis resembling "white-bud" Zn deficiency. 5 kg/ha $ZnSO_4$ banded adjacent to the row with other fertilizers at planting time was cheapest and most effective.

Lott, W. L., McClung, A. C., de Vita, R., et al. 1961. A survey of coffee fields in Sao Paulo and Parana by foliar analysis. IBEC Res. Inst. Bull. 26.

Eight ppm Zn seemed to be critical for coffee.

Malavolta, Euripedes. 1962. On the mineral nutrition of some tropical crops. International Potash Institute, Berne, Switzerland.

Three references are given to work done in Brazil on the study of Zn uptake by coffee leaves. The application of Zn to the leaves resulted in 10 times greater uptake than when Zn was added to nutrient solutions.

Meurer, E. J. 1971. Effect of liming and phosphorus fertilization on production and zinc absorption by corn in four soils of Rio Grande do Sul. Porto Alegre Univ. Rio Grande Sul Fac. Agron. and Vet. Rev. 10:57-58.

McClung, A. C., de Freitas, L.M.M., Mikkelsen, D. S., et al. 1961. Cotton fertilization on Campo Cerrado soils. State of Sao Paulo, Brazil. IBEC Res. Inst. Bull. 27.

Cotton with 26 ppm Zn in the leaves did not respond to additional Zn.

Meuer, E. J., Ludwick, A. E., and Kussow, W. R. 1971. Effect of lime and phosphorus on zinc uptake from four soils of Brazil. Commun. Soil Sci. Plant Anal. 2(5):321-327.

The 0.1 N HCl extractable zinc contents of 4 Brazilian soils were as follows: Aqualf, 1.3 ppm. Haplohumox, 2.2 ppm. Haplorthox, 1.6 ppm. Haplorthox, 1.4 ppm. Liming to pH 5.5 in the greenhouse did not affect Zn uptake, but liming to 6.5 reduced uptake in soils with less than 1.5 ppm Zn and liming to 7.4 affected uptake in all soils. The different rates of P applied had no effect.

Monteiro, M. V., et al. 1968. Aerial spraying with zinc sulfate on coffee trees in the State of Sao Paulo in Brazil. Turrialba 18:189-190.

Nobrega, S. A., and Gargantini, H. 1965. Effect of micronutrients added to mineral fertilizers on potatoes in soils of the Paraiba Valley (Sao Paulo). Bragania 24:33-35.

Supplementing N, P, and K with 20 kg each of manganese sulfate, copper sulfate, iron sulfate, and borax per ha with 10 kg of zinc sulfate, and 0.5 kg ammonium molybdate per ha increased potato yields in mainly organic soils by 64%.

Souza, D. M. de, and Hiroce, R. 1970. Diagnose e tratamento preventivo, no solo, de deficiencia de zinco em cultura de arroz de sequeiro em solos com pH abaixo de 7. Bragantia 29(9):91-103.

Diagnosis and prevention of Zn deficiency in rice on soils with pH less than 7 is discussed.

Souza, D. M. de, and Hiroce, R. 1971. Deficiencia de zinco na cultura de arroz. Lavoura Arrozeiro 24, 261 p. 37-43.

Symptoms deficiency of Zn for rice were brown older leaves (except the edges and main vein) and splitting leaves. The symptoms (on soils with pH less than 7 in Sao Paulo) occurred when there was less than 15 ppm Zn in the leaf. The application of 5 kg of zinc sulfate per ha at planting corrected the problem.

Viegas, G. P., Freire, E. A., and Venturini, W. R. 1961. Adubacao do milho. XXI. Ensaios com diversos fosfatos (7a Serie). Bragantia 20(10): 461-470.

Corn yield response to Zn was observed.

Volkweiss, S. J. 1971. Lime effect on hydrogen ion concentration, aluminum, manganese, and zinc of 10 soils in Rio Grande do Sul and their relationship with yield and absorption of manganese and zinc by corn. Porto Alegre Univ. Rio Grande do Sul, Fac. Agron. Vet. Rev. 10:81-82.

CEYLON

Harler, C. R. 1971. Tea soils. World Crops (5):275.

The common factor of tea soils is their age, which has allowed leaching to produce an acid pH (usually about 5.4). The macro- and micronutrient contents of tea leaves and the S and Cu deficiencies of Malawi and Zn and Mg deficiencies of Ceylon tea soils are mentioned. The problem of loss of micronutrients from tea soils due to the comparatively high rate of leaching and recent increases in tea yield is discussed.

Pavanasasivam, V., and Kalpage, F.S.C.P. 1969. Dithizone extractable Zn in rubber soils of Ceylon. Trop. Agr. (Peradeniya) 125(1/2):15-20.

CHILE

Schalscha, B., Riquelme, G. R., Vergara, H. G.. et al. 1968. Elementos trazas en suelos derivados de cenizas volcanicas. I. "Disponibilidad" de cinc, cobre, hierro y manganeso. Estudio comparativo de diversos metodos de extraccion. Agric. Tec. 28(4):137-143.

COLOMBIA

Cox, F. R. 1972. Trace element deficiencies. In A review of soils research in tropical Latin America, pp. 244-263, P. A. Sanchez, ed. Soil Science Dept. N. C. State Univ., Raleigh, North Carolina.

Several Zn deficiencies have been found in rice grown on high pH soils in the Cauca Valley of Colombia.

Huertas, A. 1963. Response of cotton to foliar sprays of Mg, B, Mn, Zn and Cu. Acta. agron. (Palmira)13:19-35.

Highest yields were given by complete trace-element + NPK treatment. No treatment increased fibre quality.

Vallecilla, C. 1953. La germination del polen de cacao y el creciminto del tubo polinico en relacion con los fertilizantes, sustancias activas, y sustancias menores. Acta. Agron. Colombia 3(3):189-208.

COSTA RICA

Gonzalez, C. A., Perez, J., Eggert, J., and Hopp, H. 1953. Suelo Rico 29:114.

Zn deficiency in coffee is reported.

COSTA RICA (Cont'd)

Marinho, M. L., and Igue, K. 1972. Factors affecting zinc absorption from volcanic ash soils. Agron. J. 64:3-8.

0.01 M sodium EDTA extraction at 1:2 for 30 minutes gave 1.8, 1.3 and 0.7 ppm Zn in 3 volcanic ash soils of Costa Rica. 0.1 N HCl at 1:25 overnight gave 8.1, 4.3, and 2.2. The authors considered the soils deficient yet found little growth response in the greenhouse. With adequate P, the tissue showed 12, 10 and 7 ppm Zn. It is surprising there was no growth response, because other workers using EDTA have found critical Zn levels at 0.8 to 1.4 ppm according to Cox.

Martini, J. A. 1970. Caracterizacion del estado nutricional de los principales andosoles de Costa Rica, mediante la tecnica del elemento faltante en el invernadero. Turrialba 20(1): 72-84.

GALAPAGOS

Laruelle, J., and Stoops, G. 1967. Minor elements in Galapagos soils. Pedologie, Gand 17:232-258.

Content of trace elements in 13 representative profiles agreed with composition of the parent material (mainly basalt, tuffs and pyroclastic materials). The A_1 horizons were generally rich in total Zn, total Ba and extractable Mn, Fe and Cu, and poor in total and extractable Sr. Soils of the humid uplands contained less total Zn, more total Fe, Mn and Ti, and more extractable Fe, Mn, Cu, Zn and Sr than soils of the arid coastal zone. Content and distribution of the trace elements suggest that these soils are of recent origin.

GHANA

Ahenkorah, Y. 1969. A note on zinc deficiency in cacao (Theobroma cacao L.) Ghana J. Agr. Sci. 2(1):3-6.

Ahn, Peter M. 1970. West African Soils. 3rd ed. Vol. I. Oxford Univ. Press, London.

Extensive trials have been carried out in Ghana, but no response of cereals or groundnuts to the addition of Zn was shown. However a zinc deficiency in cocoa was found where heavy additions of rotting cocoa pods upset the nutrient balance of the soil.

GHANA (Cont'd)

Greenwood, M., and Hayfron, R. J. 1951. Iron and zinc deficiencies in cacao in the Gold Coast. Emp. J. Expt. Agr. 19:73-86.

Calcareous soils are rare in cacao-growing areas of the Gold Coast. Zinc deficiency, responsible for mottled sickle-leaf disease, occurs in seedling beds made up with soils from beneath mature cacao trees and was prevalent in trees that received seepage from mounds of rotting pod husks. Soil carrying affected trees have high pH and high content of available P and K. In well-watered plants no case of sickle leaf has been found in soils with pH below 7.5. Zinc uptake is depressed by increase in soil pH, and Zn deficiency can be induced by P fertilizers and intensified by K.

GUINEA

Py, Tisseau M. A., Oury, B., and Ahmada, F. 1957. La culture de l'ananas en Guinee. Published by IFAC. France.

Pineapples in French Guinea often show zinc deficiency.

GUYANA

Evans, H. 1955. Studies in the mineral nutrition of sugar cane in British Guyana. II. The mineral status of sugar cane as revealed by foliar analysis. Trop. Agri. 32:295-322.

Levels of zinc found in sugar cane leaves in British Guyana, St. Kitts, Antigua and Madras are presented.

Legg, S. P., and Sears, L. 1960. Zinc sulfate treatment of paraketosis in cattle. Nature (L.) 181:1061-1062.

Zinc deficiency occurs in cattle receiving feedstuff containing 18-36 mg Zn per kg dry matter in Guyana.

HAWAII

Kanehiro, Y., and Sherman, G. D. 1967. Distribution of total and 0.1 normal hydrochloric acid-extractable zinc in Hawaiian soil profiles. Proc. Soil Sci. Soc. Amer. 31:394-399.

Higher concentrations of 0.1N HCl-extractable zinc were found in surface horizons than in subsoils. Total Zn was less dependent in depth than was acid-extractable Zn. There was a highly significant correlation between total and extractable Zn, but no correlation between soil pH and extractable Zn. The occurrence of Zn deficiency was associated with highly weathered Oxisols or Ultisols, especially where the subsoils had been exposed.

HAWAII (Cont'd)

Lyman, C. and Dean, L. A. 1942. Zinc deficiency of pineapples in relation to soil and plant composition. Soil Sci. 54:315-324.

The critical level of Zn was set at 1 ppm for ammonium acetate and dithizone extraction.

Shoji, K., and Ota, R. M. 1958. Zinc deficiency of coffee. Hawaii Farm Sci. 6(4):3.

Zn-deficient trees receiving foliar sprays containing 2 lb/gal $ZnSO_4$ and 1 lb H_3BO_4 showed marked recovery within 4-8 weeks; B-deficient trees sprayed with H_3BO_3 alone recovered but still showed signs of Zn deficiency. Chlorotic leaves and shoots had much lower than normal dry weights. $ZnSO_4$ should be sprayed every 3-4 months. With fertilizer-grade $ZnSO_4$, 2 lb/100 gal of hydrated lime should be used.

Younge, O. R., and Plucknett, D. L. 1963. Zn deficiency reduces Hawaii crop yields. Hawaiian Farm Sci. 12(1):4-6.

Extreme Zn deficiency in corn and cucumbers, associated with overlimed soil has been seen on the Kauai Branch Experiment Station.

INDIA

Abrol, I. P., Dargan, K. S., and Chand, M. 1972. Add zinc to obtain higher profits from saline alkaline soils. Indian Farming 21(11):15-17, 19.

Ananth, B. R., and Rao, H. H. 1970. Field observations on efficacy of foliar sprays of zinc salts for correcting zinc deficiency in arabica coffee. Indian Coffee 34(1):17.

Apparao, A. 1969. Trace metals in plants diseases. Indian Acad. Sci. Proc., Sect. B 69(3):115-119.

Bandyopadhya, A. K., and Adhikari, M. 1968. Trace element relationships in rice soils: I. Alluvial soils of West Bengal. Soil Sci. 105:244-247.

Contents of total and extractable Zn, Cu and Mn are given in soil samples representing the entire range of alluvial soils in W. Bengal. Amounts were adequate for rice. Correlations are shown between total and extractable Zn, Cu and Mn, and between soil pH and soil organic-matter content and extractable Zn, Cu and Mn.

Bandyopadhya, A. K., and Adhikari, M. 1971. Trace element distribution in profiles of rice soils. Riso 2:151-156.

In alluvial, lateritic and coastal saline soils of W. Bengal, total and available Zn decreased with depth. Similar trends were observed for Cu and available Mn, with total Mn showing irregular variations.

Basu, A. N. 1958. Exchange behavior of Cu, Mn and Zn ions in clays. J. Indian Soc. Soil Sci. 6:71-76.

INDIA (Cont'd)

Basu, A. N., Mukherjee, D. C., and Mukherjee, S. K. 1964. Interaction between humic acid fraction of soil and trace element cations. J. Indian Soc. Soil Sci. 12:311-318.

Crude 'humid acid' was obtained from black cotton soils by extraction with Na_2CO_3, acidification and electrodialysis. Its base exchange capacity was 613 me/100g. Cu-, Mn- and Ni-humates were prepared by leaching with the appropriate salt solutions and the amounts of Cu^{++}, MN^{++} and Ni^{++} and Mn^{++} were generally rather higher than the corresponding release isotherms. Adsorption of the cations in exchange for H^+ increased in the order Zn and Mn<Ni<Cu; order of release to H^+ and Mg^{++} was Mn>Ni>Cu. Release to H^+ was much greater than release to Mg^{++}. Adsorption by humic acid was high but most of the absorbed cation was released in the normal way.

Bhat, K. K. 1945. The die-back disease of citrus trees. Indion Farm. 6:250-253.

The condition is due to malnutrition of an abscure cause. Spraying with Zn and Fe sulphates was beneficial in 3 regions, but improper management was mainly at fault.

Datta, N. P., and Bains, S. S. 1960. Effect of soil application of fertilizer mixture (NPK) alone and in conjunction with soil and/or spray fertilization of micronutrients. Indian J. Agron. 4:258-263.

Application of 40 lb N + 60 lb P_2O_5 + 30 lb K_2O per acre significantly increased yields of sorghum, oats and rape on argillaceious alluvial soil, and paddy on calcareous alluvial soil. The only siginificant yield response to micronutrients was obtained with Mg, Mn and Fe sprays on sorghum.

Dhillon, G. S., Panwar, B. S., Gupta, V. K., and Vig, A. C. 1970. Effect of foliar application of micronutrients on yield of dwarf wheat (pv-18). Indian J. Agron. 15(3):247-250.

Gopala Rao, H. G., and Govindarajan, S. V. 1950. Increased yields of Ragi through zinc salt fertilization. Curr. Sci. 19:242.

Five pounds of zinc sulfate per acre increased the total crop by about 23%.

Govinda Rajan, S. V., and Gopal Rao, H. G. 1951. Influence of minor elements on Mysore Soils and Crops. I. Response of Ragi to zinc salts. Mysore Agric. J. 27:42-44.

Applications of 5 to 10 lb of zinc sulfate per acre to soils in Mysore produced positive response in ragi. The salt was mixed with the oil cake used as a general dressing. Neither Cu nor B influenced yield.

INDIA (Cont'd)

Govinda Rajan, S. V., and Gopala Rao, H. G. 1964. Effect of micronutrients on crop response and quality in Mysore State. J. Indian Soc. Soil Sci. 12:355-361.

Field experiments on red loamy soils showed the beneficial effect of Zn salts on the yield of ragi (Eleusine coracana). Spraying and soaking of seeds with $ZnSO_4$ solution gave results comparable to those of broadcast application. Adding Cu salts to the soil improved paddy yields in some distinct soil zones. N content of sannhemp (Crotalaria juncea) and horsegram (Dolchicos biflorus) was increased by applying salts of B, Mo and V.

Grewal, J. S., Bhumbla, D. R., and Randhawa, N. S. 1969. Available micronutrient status of Punjab, Haryana and Mimachal soils. J. Indian Soc. Soil Sci. 17:27-31.

Exchangeable and active Mn and available Cu were critical in arid brown soils and marginal in serozem and tropical arid brown soils. Both those forms of Mn and available Cu showed significant negative correlations with pH and positive correlations with organic matter. Available Zn was deficient to marginal in most of the soils and was not significantly related to pH, organic matter or $CaCO_3$ content. Available Mo was critical in gray-brown podzolic soils and showed significant positive correlations with pH and $CaCO_3$. Available B was medium to high and was correlated significantly with pH. Exchangeable Mn, available Zn, Cu, Mo and B decreased with depth.

Grewal, J. S., and Randhawa, N. S., and Bhumbla, D. R. 1968. Correlation of soil test with response to the application of zinc to wheat. J. Indian Soc. Soil Sci. 16:97-102.

Wheat yields and uptake of Zn applied to loam, loamy-sand, clay-loam and sandy-loam soils were highly significantly correlated with Zn extracted from soils by dithizone, were significantly correlated with Zn extracted by N NH_4OAc (pH 4.6) 0.2 percent EDTA and 2N $MgCl_2$, but were uncorrelated with Zn extracted by 0.1N HCl. Significant responses to Zn application occurred only on soils containing <0.55 ppm dithizone-extractable Zn.

Gupta, G. P., and Singh, D. 1972. Zinc status of some soils of Indore. J. Indian Soc. Soil Sci. 20(1):49-51.

Surface soil samples from four localities were studied. The total and available Zn varied from 40-131 and from 0.90 to 3.25 ppm respectively. The amount of available Zn decreased with increasing soil pH. The relationship of available Zn to soil $CaCO_3$, organic C, total Zn and clay content were also studied.

Jyotishi, R. P., and Kashyap, R. 1968. Effect of some trace elements as foliar spray under varying levels of nitrogen and phosphorus on protein content of brinjal fruit (eggplant). Indian J. Sci. Indus., Sect. A Agr. and An. Sci. 2(1):27-32.

INDIA (Cont'd)

Kalyanasundaram, N. K., and Mehta, B. V. 1970. Availability of zinc, phosphorus, and calcium in soils treated with varying levels of zinc and phosphorus; a soil incubation study. Plant and Soil 33(3):699-706.

Kanwar, J. S. 1970. Zinc deficiency in Kalyan Sona and IR.8; a case study. Indian Farming 20(3):5-7.

Kanwar, J. S., and Randhawa, N. S. 1967. Micronutrient Research in Soil and Plants in India. A Review. Indian Council of Agricultural Research, New Delhi. 1967, pp. 95.

Katare, D. S., Kashyap, R. P., and Singh, M. P. 1971. Effect of potassium and micronutrient sprays (Zn, Mn and Cu) on onion. Fert. News 16(4):51-52.

Koraddi, V. R., and Seth, J. 1964. Effect of soil and foliar application of micronutrients on yield and quality of wheat. J. Indian Soc. Soil Sci. 12:387-392.

Applying Mn, Zn, B and Cu on a sandy loam soil of medium texture caused a general rise in grain yield. The effect of soil applications of Mn and B was significant. Of foliar treatments, that with Mn gave the greatest grain yield. For the highest straw yields Cu was best applied to the soil and Zn to the leaves. Height and dry matter accumulation were benefited by spraying with B and by applying Zn to the soil; protein content of the grain was increased by spraying B and applying Cu and Mn to the soil. The highest net profit was obtained from applying B to the soil, while applying Zn to the leaves was next most profitable; a combination of micronutrients applied to soil or foliage produced a net loss of money.

Krishnamoorthy, C. 1959. Improving soil fertility conditions with special reference to minor elements. Proc. Indian Acad. Sci. 49B:338-348.

The demand of rice for trace elements, except Fe and Mn, could be met by the amounts in rain and irrigation water; the black cotton soils of the Tungabhadra Project are poor in N and P and have $CaCO_3$ nodules containing 0.7 percent Mn; in anaerobic conditions, under swamp rice, reduction of Mn increases the exchangeable supply, rice shows toxicity symptoms and the Fe: Mn ratio in the leaves falls below the usual 0.8-1.2. Green manuring to render Fe available, using shallow drains to carry away Mn from the root zone and applying super (50 lb/acre P_2O_5) and $(NH_4)_2SO_4$ (half at planting and half two months later) improve the condition. B content of the soil is high but not toxic. Cu deficiency symptoms are rare. Zn is probably adequate.

Krishnamoorthy, C, Venkateswarlu, J., Reddy, M. G. R., and Rao, G. V. M. M. 1971. Zinc deficiency in rice in Andhra Pradesh In Int. Symp. Soil Fert. Eval. New Delhi, Proc. 1:955-967, 149-155.

A considerable amount of data including leaf analyses for Zn, Mn, Fe, etc. is presented.

INDIA (Cont'd)

Meelu, O. P., and Randhawa, N. S. 1970. Comparative efficiency of zinc from various sources for maize. Indian J. Agr. Sci. 40(7):637-644.

Meelu, O. P., and Randhawa, N. S. 1971. Stability constants of zinc-humic acid complexes. Indian J. Agr. Sci. 4(9):730-736.

Meishri, M. B., and Mehta, B. V. 1971. Effect of different forms of zinc on the yield and chemical composition of wheat (S-227) grown in soil having marginal value of available zinc. Bansilal Amritlal College of Agriculture Magazine 23:85-100.

In field experiments on loamy coarse sand low in CEC, N and organic matter and at threshold levels of available P and Zn (0.52 ppm), Zn application had an overall beneficial effect and increased the total dry matter significantly. In yield response, a decreasing order of effectiveness of $ZnSO_4$, zincated superphosphate, zinc dust, foliar spray of $ZnSO_4$ solutions was observed. The total uptake of Zn, N, P, K, and Mg was increased by Zn application but the total uptake of Fe, Mn, Cu and Ca remained unaffected.

Misra, S. G., and Tiwari, R. C. 1966. Retention and release of copper and zinc by some Indian soils. Soil Sci. 101:465-471.

Varying symmetries of Cu and Zn (amounts equivalents to the NH_4 exchange capacity of the soil expressed in meq) were added to a black soil, a red soil and an alkali soil and amounts of Cu and Zn retained were determined. As increased symmetries of Cu and Zn were added, NH_4 exchange capacity of the soil tended to increase. Other factors like $CaCO_3$, soluble carbonates, and pH of the soils also affected Cu and Zn retention. The amount of Cu and Zn extracted by neutral normal NH_4 acetate was always less than the NH_4-exchange capacities of the soils. Even at the 4 symmetry level of addition, Cu and Zn did not occupy all the exchangeable positions in the respective soils.

Misra, S. G., and Tiwari, R. C. 1966. Studies on the chemistry of copper and zinc applied to three different soils - a comparative study. Soil Sci. Pl. Nutr. 12(3):6-10.

Black soil retained more Cu and Zn than rod and alkali soils did. Presence of soluble carbonates in alkali soil resulted in precipitation of the soluble Cu^{++} or Zn^{++} added. At 1-symmetry level (amount of Cu or Zn applied equivalent to the cation-exchange capacity of the soil) Cu retention by the soils was always greater than Zn retention. Removal of organic matter from red and black soils decreased Zn retention to a greater extent than Cu retention. Removal of carbonates from red and black soils decreased Cu retention more than Zn retention; removal of carbonates from alkali soil had the reverse effect. Amounts of the 0.1n HCl-soluble-and neutral n-NH_4-acetate-soluble fractions were greater for Cu than for Zn, hence the "fixed" form of Zn was always greater than that of Cu. When increased symmetries of Cu and Zn were applied, cation-exchange capacities of the soils were only slightly affected and the contribution of the exchange process to Cu and Zn retention by the soils was only partial.

INDIA (Cont'd)

Mithyantha, M. S., Perur, N. G., and Hadimani, A. S. 1971. Evaluation of different extractants for the determination of available zinc in some soils of Mysore State. Intern. Symp. on Soil Fert. Evaln. New Delhi. pp. 969-974.

Dithizone was the best extractant, followed by sodium phosphate, EDTA, HCl and ammonium acetate.

Mohapatra, A. R., and Kibe, M. M. 1971. Response of tomato to zinc fertilization in a zinc-deficient soil of Maharashtra. Indian J. Agr. Sci. 41(8):650-654.

Nene, Y. L. 1972. Khaira disease of rice (Oryza sativa L.) Indian J. Agr. Sci. 42(2):87-95.

Zinc deficiency is the cause.

Padhiyar, B. P., Mehta, B. V., and Trivedi, B. S. 1971-1972. Effect of zinc, copper and molybdenum on yield and composition of wheat grown on coarse loamy sand of Torna. Bansilal Amritlal Coll. Agr. (Anand India) Mag. 24:32-45.

Rahaja, P. C., Yawalkar, K. S., and Singh, R. 1959. Crop response to micronutrients under Indian conditions. Indian J. Agron. 3:254-263.

Paddy responded to soil application of Cu in various states and to Mn and Zn sprays at Coimbatore; wheat responses to Cu, Mn and Zn soil treatments and sprays are reported from New Delhi but on desert soils of Rajasthan no such responses occurred; jowar responded to Cu in Khandesh and Bangalore; the micronutrient needs of bajri appeared to be low; in Mysore State B and Zn improved ragi; cotton responded to Mn, Zn and B in Madhya Pradesh, Indore and Gujrat; quality but not quantity of cane sugar in Andhra Pradesh and Bihar was improved with Cu, Mn and Zn; gram on sandy soils of Sabour and Islampur (Bihar State) responded to Mn, but on desert soils in Rajasthan it showed no response to B, Mn or Cu.

Rai, K. D. 1959. Zinc sulphate as a corrective of chlorosis in maize on the heavy alkaline soils of the central rainlands, Tozi, Sudan. Indian J. Agron. 4:82-91.

Zn spraying two weeks after emergence at concentrations up to 0.4 percent had no effect on yields on well-drained heavy clay (pH 8.5-9.5), but increased grain yields, mainly due to increase in the number of grains per cob, on badly drained clay. One hundred and two hundred grams Zn per feddan were equally effective. High Zn concentrations were better than 0.1 percent. Chlorosis was associated with poor root development. When maize was sown early and after dwarf sorghum (which removed much soil moisture) no chlorosis appeared.

INDIA (Cont'd)

Rai, M. M., and Chimania, B. P. 1971. Evaluation of extractants for determining zinc and response of applied zinc in shallow black soils of Madhya Pradesh. (wheat and maize). J. Indian Soc. Soil Sci. 19(4):395-402.

Rai, M. M., Gupta, S. K., and Shitoley, D. B. 1971. Evaluation of extractants for determining zinc in soil and response of applied zinc by plants. Intern. Symp. Soil Fert. Evaln., New Delhi, pp. 975-983.

On deep black soils, N ammonium acetate extracts of Zn correlated best with maize response. The next best was dithizone-ammonium acetate.

Rai, M. M., Shitoley, D. B., Pal, A. R., et al. 1970. Available micronutrient status of deep black soils of Madhya Pradesh. Indian Soc. Soil Sci. 18(4):383-389.

Mn and Mo were found to be sufficient, B and Cu slightly deficient and Fe and Zn moderately deficient in these soils. Fe was correlated with organic C (r = 0.156), exchangeable Mn with pH and organic C (r = -0.420 and 0.260 respectively) active Mn with organic C (r = 0-0.165) Mo with pH and $CaCO_3$ (r = 0.465 and 0.435 respectively) and B with pH and organic C (r = 0.310 and 0.284 respectively). Cu and Zn were not correlated with organic-C, pH, or $CaCO_3$.

Rajagopal, V., and Mehta, B. V. 1971. Effect of zinc and phosphorus application on response and chemical composition of hybrid maize grown on Torana soil. Indian J. Agr. Sci. 41(2):156-166.

Sadaphal, M. N., and Das, N. B. 1961. Effect of micronutrient elements on wheat. II. Effect on yield and chemical constituents. J. Indian Soc. Soil Sci. 9:257-267.

Soil and foliar applications of Cu, Mn, Zn and Mg increased grain yield; Mn was the most effective of the soil applications and Mg of the foliar treatments. Mg and Cu were equally effective as soil or foliar treatments; Mn was better applied to leaves and Zn to soil. The protein content of grain increased when Mn or Zn was applied to the soil or when any of the elements was applied on the foliage. Ash and Ca contents were not affected but P contents were increased by all treatments.

Sharma, R. B., and Motiramani, D. P. 1969. Zinc status of the soil of Madhya Pradesh. J. Indian Soc. Soil Sci. 17:19-26.

In investigations of soils from 38 districts, covering six soil groups, total- and available-Zn contents were highest in black soils and lowest in alluvial soils. Available Zn was closely correlated with total Zn and comprised 8.4 percent of the total. Generally a negative correlation occurred between pH and available Zn. No consistent relationship between available Zn and $CaCO_3$, nor any positive correlation with organic C was found. Available Zn was more abundant in the 0-50 cm layer. Only 2.82 percent of samples analyzed had <1 ppm available Zn (1 ppm is considered the critical limit for a possible deficiency).

INDIA (Cont'd)

Shrivastava, S. S. 1969. Effect of foliar application of zinc on growth, fruiting behaviour, and quality of pineapple. Indian J. Hort. 26(3/4):146-150.

Shukla, U. C. 1971. Organic matter and zinc availability in soils. Geoderma 6(4):309-314.

Singh, D., Gupta, G. P., Deo, P. G., et al. 1968. Correlation of zinc with pH and calcium carbonate in soil. JNKVV Res. J. 2:118-124.

The available- and total-Zn contents in the top nine inches of 124 samples from four different regions of the Indore district were 0.9-3.25 ppm and 40-131 ppm respectively. Available Zn was negatively correlated with soil pH. In some regions, available Zn was negatively correlated with the $CaCO_3$ content whereas total Zn and $CaCO_3$ were positively correlated.

Singh, M. P. 1970. Control khaira disease of paddy through curative treatment early. Indian Farming 19(10):19, 48.

Zinc deficiency is the cause.

Singh, R. M., and Jain, G. L. 1964. Response of paddy to iron and zinc. Indian J. Agron. 9:273-276.

Soil application at 2.53 kg/ha zinc increased dry weight and tillering, and foliar application also increased grain yield. At lower levels foliar spray was superior to soil application. Zn increased crude protein and P and Ca content of grain, but response to Fe was poor.

Singh, S. P. 1963. Effect of foliar spray of micronutrients on growth and yield of Brassica compestris var. sarson. Indian J. Agric. Sci. 33:232-239.

In field trials B, Mn, Zn, were applied at 250, 500 or 750 ppm, Cu at 25, 50 or 75 ppm and Mo at 20, 40 or 60 ppm in the first season. Only B and Zn were applied in the second season. Yields were increased significantly by spraying with B and Zn at 500 ppm.

Takkar, P. N., Mann, M. S., and Randhawa, N. S. 1971. How zinc deficiency affects wheat yields. Indian Farming 21(9):31-32.

Tomar, N. K., Dev., G., and Randhawa, N. S. Zinc deficiency: A major problem for apples in Kulu Valley. Indian Hort. 15(1):5.

Tripathi, R. S., and Pande, H. K. 1971. Studies on toxicity factors and nutritional imbalance in soil for wheat culture in acid lateritic soil. Intern. Symp. on Soil Fert. Eval., New Delhi, Vol. 1, pp. 821-830.

Al is thought toxic. Yield improved as pH was increased from 5.3 to 6.2 and to 7.2. Mo, Zn and Cu at 15 kg/ca also helped. There was not an outstanding response, however.

INDIA (Cont'd)

Subba Rao, I. V., and Datta Biswis, N. R. 1971. Effect of micronutrients on a high-yielding variety of wheat. Intern. Symp. on Soil Fert. Eval. 1971. New Delhi, pp. 1027-1038.

Cu and Mn helped yields on alluvial soil from Delhi. Zn, Fe and Mo helped yields on black soil from Mandasaur in Madhya Pradesh.

Venkateswarly, J. 1971. Phosphorus and zinc deficiency in Andhra Pradesh. Indian Farming 21(2):35-37.

Venkateswarlu, J., Roufunnisa, K. V., Rao, K. V. S., et al. 1971. Crop response to available zinc in the soils of the Nagarjunasagar project (Andhra Pradesh). Proc. Intern. Soil Fert. Eval. 1:993-998.

A method for Zn-fixation studies based on the P-fixation studies developed by the International Soil Testing Programme is presented. The available Zn in 17 soils varied from 0.4 to 2.04 ppm. The recovery of added Zn was nearly linear and roughly 25 percent of it was extractable. The critical soil Zn value was about 0.6 ppm, below which economic responses were obtained to added Zn.

JAPAN

Ishizuka, Y., and Tanaka, A. 1962. Inorganic nutrition of rice plant. VII. Effect of boron, zinc and molybdenum level in culture solution on yields and chemical composition of the plant. J. Sci. Soil Manure, Japan 33:93-96.

Yoshida, S., and Tanaka, A. 1969. Zinc deficiency of the rice plant in calcareous soils. Soil Sci. Plant Nutr. 15:75-80.

KENYA

Bock, K. R. Robinson, J. B. D., and Chamberlain, G. T. 1958. Zinc deficiency induced by mercury in coffea arabica. Nature (London) 182:1607-1608.

Chamberlain, G. T. 1959. Trace elements in some East African soils and plants I. Cobalt, beryllium, lead, nickel, and zinc. E. Afr. Agr. J. 25:121-125.

The acetic acid extractable Zn level in Kenya is generally high, about 20 to 45 ppm, in the surface horizon.

French, M. H. 1955. Earth-eating and the mineral needs of livestock. E. Afr. Agr. J. 20:168-175.

Co is associated with "Nakuruitis" in Kenya.

MALAWI

Bray, G. T. 1951. The cultivation and production of tung oil, Part 2. World Crops 3:299-302.

In Malawi, the cause of bronzing of Tung trees on deep red lateritic loams is excess $Ca_3(PO_4)_2$ in the soil coupled with zinc deficiency. The application of zinc sulfate in spring and autumn is an effective remedy.

MEXICO

Laird, R. J., and Rodriguez, G. H. 1965. Fertilacion de maiz de temporal en regiones de Guanajuato, Michoacan y Jalisco. INIA Mexico-Folleto Tecnico 50.

Zinc responses were noted in two areas out of twenty-two tested.

PANAMA

Blue, W. G., Ammerman, C. B., Loaiza, J. M., et al. 1969. Compositional analyses of soils, forages, and cattle tissues from beef-producing areas of Eastern Panama. Bioscience 19(7):616-618.

Silvey, M. W. 1971. Zinc uptake by Hyparrhenia rufa (Nees) Stapf and Indigofera hirsuta L. in selected Eastern Panamanian soils. Ph.D. Thesis, Univ. of Florida.

PAPUA (NEW GUINEA)

Bleeker, P., and Austin, M. P. 1970. Relationships between trace element content and other soil variables in some Papua-New Guinea soils as shown by regression analyses. Aust. J. Soil Res. 8:133-143.

The trace elements in six soils could be divided into three groups on the basis of regression analyses and profile distribution: Cu, Zn, Ni; Co, Mn; Cr, Cu concentration in soil was related to Cu concentration in the parent material and percentage clay in the soil horizon ($R^2 = 0.89$). Zn and Ni were similarly related to percentage clay. Mn and Co were mainly related to a fluctuating water table ($R^2 = 0.59$). Chromium was related to the percentages of the 50-75, 150-210, and 420-1200 μ sand fractions ($R^2 = 0.84$).

PERU

Puiggros, J., Franciosi, R., and Morin, C. 1969. Nutritional study of Washington Navel oranges in the central coast of Peru. Proc. Int. Citrus Symp. 1st 1968. 3:1613-1617.

PHILIPPINES

Lockhard, R. C., Ballaux, J. C., and Liongson, E. A. 1972. Response of rice plants grown in three potted Luzon soils to additions of B, S, and Zn. Agron. J. 64(4):444-447.

PUERTO RICO

Abruna, F., Vicente-Chandler, J., Becerra, L. A., and Lugo, R. B. 1965. Effect of liming and fertilization on yields and foliar composition of high-yielding sun-grown coffee in Puerto Rico. J. Agr. Univ. P. R. 49:413-428.

Symptoms of Zn deficiency were cleared when high-yielding sun-grown coffee on Los Guineos clay (limed to pH 6.2) was sprayed with zinc sulfate.

Bonnet, J. A. 1969. Influence of varieties and seasons upon the mineral nutrient levels of coffee leaves from Puerto Rico. J. Agr. Univ. 53(3):177-186.

Hernandez Medina, E. 1964. Magnesium, an important nutrient in pineapple production in a Bayamon sandy clay. J. Agr. Univ. P. R. 48:17-24.

The addition of Zn to pineapple on Bayamon sandy clay (pH 5.0, lateritic) had no effect on yield.

Hernandez, Medina, E., and Lugo Lopez, M. A. 1969. Effect of minor nutrient elements and magnesium upon the growth development and yields of plantains. J. AGr. Univ. P. R. 53:33-40.

The inclusion of Zn in an otherwise complete micronutrient spray for plantains on Lares clay fertilized and limed to pH 6.0 caused a significant increase in yield.

Jensen, J. H. 1937. Chlorosis of Citrus in Puerto Rico. Phytopathology. 27(6):731.

Beneficial effects of zinc sulfate sprays in the control of leaf chlorosis on grapefruit were noted. Diseased trees were found only on alkaline soils.

Landrau, Jr., P., and Samuels, G. 1956. Results of lime and minor-element fertilizer research in Puerto Rico. 1945-1950. J. Agric. Univ. P. R. 40:224-234.

The addition of fritted trace elements (including zinc) to pineapples increase yields, presumably because the supply was protected against immediate leaching However, there was no response to the trace element addition in sugarcane on Santa Isabel silty clay or Tiburones muck. The addition reduced yields of acerola on Sabana Seca sandy clay. Zinc sulfate increased 12-month sugarcane yields on Coto clay, but not the yield of the ratoon crop. Zinc sulfate at 25 to 100 pounds per acre was applied to cane on Lares clay and Toa silty clay loam with no apparent clear-cut response. On San Anton, Santa Isabel silty clay loam, Tiburones muck and Via silty clay, some response to Zn was noted. Zinc and magnesium sulfate sprayed or applied to the soil at an old grapefruit orchard in Arecibo on Sabana Seca sandy clay cured symptoms of Zn and Mg deficiency, and the spray corrected heavy leaf shedding.

Landrau, Jr., Samuels, P. G., Alers-Alers, S., and Gonzalez-Molina, C. 1959. The influence of fertilizers on tobacco yields. J. Agric. Univ. P. R. 43:56-69.

There was no response of tobacco to fritted trace elements (containing Zn and other micronutrients) on Mabi clay or Caguas clay.

Pennock, W. 1940. Mottled-leaf disease in grapefruit. P. R. Agr. Expt. Sta., Ann. Report 1939, pp. 68-69.

Three spray applications of zinc sulfate minimized mottled leaf in Citrus grandis L. The "frenching" of the leaves reduced yield of fruit.

TOBAGO

Lucie-Smith, M. N. 1951. The cultivation of West Indian limes. J. Agric. Soc. Trin. Tob. 51:354-366.

Zinc applications may be necessary for limes. They grow best on deep acid sandy loam and on most Tobago soils except those derived from coral.

TRINIDAD

Weir, C. C. 1965. A survey of the mineral nutrition of Valencia orange in Trinidad. Exp. Agr. 1(3):179-184.

UGANDA

Bredon, R. M. 1964. Mineral requirements of cattle in East Africa with special reference to Uganda. Agric. Vetr. Chem. and Agric. Eng. 4:6-10.

Long, M. I. E., Ndyanabo, W. K., Marshall, B., and Thornton, D. D. 1969. Nutritive value of grasses in Ankole and the Queen Elizabeth National Park, Uganda. IV. Mineral content. Trop. Agr. (Trin.) 46:201-209.

Stephens, D. 1969 Fertilizer manure and trace elements in continuous cropping rotations in South and West Uganda. E. Afr. Agr. For. J. 34:401-407.

Thornton, D. D., Long, M. I. E., and Marshall, B. 1969. Mineral status of dairy farms in the parts of Buganda and Busoga bordering Lake Victoria, Uganda. I. General ecology and soils. Trop. Agr. (Trin.) 46:269-278.

ZAIRE

Ferrand, M., Bachy, A., and Ollagnier, M. 1951. Minor element deficiencies in soils of the Middle Congo. Compt. rend. 233:1218-1220.

Yields of palm oil were increased an average of 60 percent in three years by the annual application of fertilizer containing Zn, Cu or Mn (250 g/tree) and 40 percent by B or Mg. Without any of these elements there was no response to N, P, or K. The minor elements, especially Mg and Mn also increased tree vigor.

GENERAL

_____. 1966. Symposium on trace elements in soils and plants (1964). J. Indian Soc. Soil Sci. 12(4):1-466.

Borchardt, G. A., and Harward, M. E. 1971. Trace element correlation of volcanic ash soils. Soil Sci. Soc. Amer. Proc. 626-631.

Cox, F. R. 1972. Micronutrients In A review of soil research in tropical Latin America, pp. 244-254, P. A. Sanchez, ed. Soil Science Dept., North Carolina State University, Raleigh, N.C. (Processed).

Evans, H. 1959. Proceedings of the 10th Congress of the International Society of Sugarcane Technologists. 10:473.

Discusses symptoms and levels of Zn found in sugarcane leaves under field conditions.

Fernando, M. 1936. Mottle-leaf of citrus: Its incidence and control. Trop. Agr. 86:332-334.

Zinc-controllable mottle leaf of citrus is not closely related to soil type.

Igue, K., and Bornemisza, E. 1967. The problem of zinc in soils and plants in tropical and temperate regions. Fitotec. Latineam 4(1):29-44.

A review with 74 references.

Lindsay, W. L. 1972. Zinc in soils and plant nutrition. Adv. in Agron. 24:147-186.

An excellent review.

Malavolta, E. 1962. On the mineral nutrition of some tropical crops. Intern. Potash Inst. Berne, Switzerland.

Photographic color plates of zinc-deficiency symptoms in orange, coffee, and eucalyptus are given. Zn and Cu deficiencies occurring in Queensland, Australia and causing "crook-neck" of pineapples are discussed.

Marchal, J. 1971. Oligo-elements in pineapples. Fruits 26(4):263-277.

Mogilner, I., Orioli, G. A., Henain, A., et al. 1963. Effect of some major elements (P, K, N) and minor elements, applied in irrigation and by spraying, on the yield of, and content of saccharose in, sugarcane. (Preliminary experiment). Bonplandia 1:245-257.

Prasad, R. N., and Pagel, H. 1970. Available zinc in important soils of the arid and humid tropics. Beitr. Trop. Landw. VetiMed. 8, 145-156.

Available Zn (CH_3COONH_4-soluble, at pH 4) in soils was higher in humid regions (1.666 ppm) than in arid regions (0.364 ppm), and tended to decrease in the order: Fersiallitic soils, ferrallitic soils, Vertisols, Rendzinas and arid soils. Available Zn showed significant positive correlations with clay (and silt) and humus levels, and negative correlations with pH, exchangeable Ca, degree of saturation (S and T values), K supply as well as available P (Truog); its level decreased with depth in the profile. Values

of available Zn in relation to soil properties are given in tables. 45 references.

Quintela, R. 1964. Fertilizing citrus and spraying with nutrient solutions. Univ. Montevideo Fac. Agron. Bol. 73, p. 26.

Applying a 3-6-4-2 (N-P-K-Mg) fertilizer in September, January and April, and spraying in winter at six-weekly intervals with solutions of Cu, Mn, S and Zn increased yields of Citrus reticulata by 30 percent to 68 percent, the highest increase being from younger trees. Increase in yield was due to number and not size of fruits. Treated trees showed no signs of chlorosis, frequent in spring on untreated trees.

Rodriguez, S. J. 1962. The chemical composition of green coffee beans and coffee leaves as related to soil and foliar applications of secondary and minor elements. Diss. Abstr. 23:784-785.

Fe, Mn, Zn, B, Mo and Mg were applied to a lateritic soil. Percentages of total and non-reducing sugars in coffee-beans were depressed by omission of Mo from the foliar application.

Singh, Y., and Pandy, C. H. 1972. Studies on effects of rates and methods of zinc application in rice. Riso 21(3):201-207.

Stone, E. L. 1968. Microelement nutrition of forest trees: A review. In "Forest Fertilization: Theory and Practice". Symp. For. Fertil. 1967. (Tennessee Valley Authority, Knoxville, U.S.A.), pp. 132-175.

185 references: B, Zn, Cu, Fe, Mn, Mo. Deficiency and its control; excess. Contents in soil and in many tree species. Zn-accumulator species.

Srivastava, R. P. 1964. Effect of trace elements on the growth characteristics of bananas. Sci. & Cult. 30:352-355.

Trace elements were applied as foliar sprays at 4 ppm, 30, 90 and 150 days after planting. Zn was most beneficial, followed by Cu, B and Mo. Mn was only slightly useful.

Takazawa, F., and Sherman, G. D. 1947. The polargraphic determination of zinc in soils. J. Ass. Off. Agric. Chem. Wash. 30:182-186.

Tolhurst, J. A. H., Fernando, L. H., and Tillekeratne, L. M. de W. 1966. Zinc foliar sprays: Recommendations 1966. Tea Q. 37, Part 2: 73-74.

$ZnSO_4$ solutions were used successfully with no wetting agent or other additive. For separate application, four sprayings annually are suggested. A safe concentration is 1 lb $ZnSO_4$ per 2 gall water. At equivalent Zn rates, ZnO is as effective as $ZnSO_4$. Mixing either compound with Cu_2O fungicidal formulations had no effect on their efficiency.

GENERAL (Cont'd)

Watson, J. P. 1970. Contributions of termites to development of zinc anomaly in Kalahari sand. Trans. Instn. Min. Metall., Sect. B, 79:53-59.

Analyses of termite mounds on the sand indicated anomalous concentrations of Ag, Au, Mo, Pb and Zn. The Kalahari sand at the Zn anomaly was 8 m deep and rested on mica schist; the termite mounds contained more Zn than topsoils (0-60 cm) but significantly less than subsoils (60-274 cm) did. The source of the Zn was weathered mica schist at 10 m. Zn was distributed by upward movement of Zn in soil water and possibly in groundwater. The subsoil contained 30-119 ppm of Zn.

Wells, N. 1960. Total elements in topsoils from igneous rocks: An extension of geochemistry. J. Soil Sci. 11:409-424.

A discussion of S. W. Pacific trace element contents in soils as a function of the original parent material and the organic matter content of the soil.

Westfall, D. G., Anderson, W. B., and Hodges, R. J. 1971. Iron and zinc response of chlorotic rice grown on calcareous soils. Agron. J. 63:702-705.