Root distribution of cocoa (**Theobroma cacao L.**) as influenced by nitrogen fertilizer*[1/]

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COMPENDIO

Se investigó el efecto de una aplicación continua de fertilizante nitrogenado, en las dosis de 0,0, 45, 90 y 180 kg/ha como urea, sobre la distribución espacial de cacao amazónico. Se tomaron muestras con barreno del suelo a dos distancias del árbol y tres diferentes profundidades. Las raíces fueron separadas del suelo, fraccionadas en pequeñas, medianas y grandes, y secadas en un horno a 70°C por 24 horas.

La distribución vertical de las raíces fue afectada grandemente por los tratamientos de fertilizantes. El tratamiento deprimía, incrementaba o no afectaba la cantidad de raíces, lo que dependía de la fracción radical, profundidad del suelo y dosis de nitrógeno. La cantidad de raíces medianas (1-5mm diam.) se encontró que disminuía al aumentar la dosis de nitrógeno, mientras que la de las grandes aumentaba primero y después caía. El aumento de la dosis de nitrógeno no afectó la cantidad de raíces pequeñas (diámetro menos que 1 mm).

Las dosis bajas a medianas de nitrógeno o aumentaron o disminuyeron la cantidad de raíces, dependiendo de la fracción radical y la profundidad. Cuando hubo una disminución, ella fue más pronunciada que la causada por dosis altas de nitrógeno.

Introduction

EACH part of a plant has a function to perfom and none is more important than the role of the root system which is responsible for the absorption of the much needed water and nutrients from the soil for the healthy and productive development of the plant.

Not much information is available in the literature on the root system of cocoa. Most of the studies carried out are rather descriptive.

The root systems of cocoa growing in different parts of the world have been described by various investigators (3,9,12,18). The descriptions differ only in detail.

Nitrogen application has been found to increase cocoa yield in different parts of the world (5,8,9,10, 13,14,17,18). No information is presented on the effect of such fertilizer on the root system.

Cunningham (4) and Geus (7) have reviewed the results of effects of fertilizers on cocoa.

Among the factors listed by Rogers and Head (16) to affect the growth of the roots of perennial woody species is the soil nutrient status. It has been demonstrated by Bosemark (1) that poor nutrient status alters the character of root growth by increasing the development of the extension roots at the expense of lateral roots whereas high ion concentrations or local fertilizer application stimulated branching.

Cahoon *et al* (2) showed that various nitrogen fertilizer treatments affect the concentration of roots of mature citrus trees in the first 4 feet of soil.

It had earlier been shown that continued application of nitrogen for 6 years dereased root weight of citrus between 13 and 79 cm from the soil surface (6).

This report deals with the effect of continued nitrogen fertilizer application on the distribution of cocoa roots.

Materials and methods

The study was carried out on amazon cocoa in plots W4, W5 and W6 at the Gambari Experimental Station of the Cocoa Research Institute of Nigeria,

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The experimental layout of the plots for a fertilizer trial which started in 1970 has been described by Omotoso and Jacob (15) There were four levels (0 0; 45 0; 90 0 and 180 0 kg/ha) of nitrogen supplied as urea There were two replicates of each treatment with six treated trees in each replicate The trees were at 3 0 m apart,

Three trees from each replicate and another 3 from untreated adjacent plots were sampled Sampling was done at 0 6 and 1 5 m from the trees along the row but across the avenue where the fertilizer was applied

For the sampling, a metal cylinder of internal diameter 10 cm was first driven to a depth of 7.5 cm then 15 cm and finally 30 cm emptying the cylinder at each depth

The soil cores collected were spread out in trays and the cocoa roots were picked and washed clean of soil The roots were then separated to fractions of diameter less than 1 0; diameter 1- 5; and diameter greater than 5 0 mm, dried in an oven at 70°C for 24 hours and weighed

The dry weights of root fractions of the treated trees were expressed as percentages of those of untreated trees

Results

The results are presented in Figures 1 - 5. For easy reference the root fractions will be designated small (diameter < 1mm) medium (diameter 1 - 5 mm) and big (diameter > 5 mm) and the depths of sampling A (0-7 5cm) B (7.5 - 15cm) and C 15-30cm)

Vertical distribution of roots

N_1 effect: At 0 6 m from the tree the quantity of small plus medium roots at depth A was increased (Fig 1) At other depths there was a decrease with an overall slight decrease. The decrease was greater at depth C When all the root fractions were considered together, there was an increase at all depths The increase was about the same at all depths except at depth C where it was smaller

At distance 1 5 m from the tree the quantity of small plus medium roots was affected in the same way as at distance 0 6 m except that the increase at depth A and the decrease at depth B were more pronounced. There was an overall decrease The situation for all root fractions was similar to that for small plus medium roots, except that there was a bigger increase at depth A, no effect at depth B and greater decrease at depth C

N_2 effect: At depth 0 6 m from the tree, the dry weight of small plus medium roots was decreased at all depths (Fig 2). The distribution of these root fractions in the soil profile to the depth sampled was fairly uniform When all root fractions were considered, there was

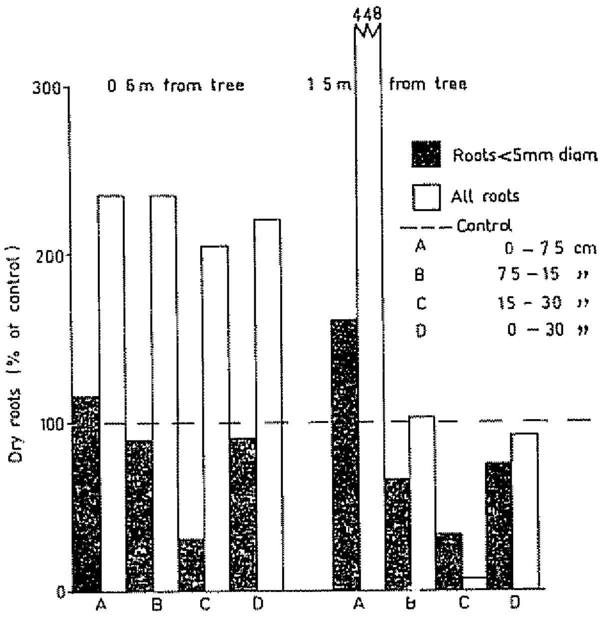

Fig 1—*Vertical distribution of cocoa roots as influenced by 45 0 kg/ha of nitrogen*

When all root fractions were considered, there was an an increase in the amount of roots in depths A and B without any significant change in that at depth C The increase was much greater at depth A The overall effect was a decrease in amount of small plus medium roots with no effect on that of all roots within the depth of sampling

At 1.5 m from the tree, the dry weight of small plus medium roots at depths A and B was not affected

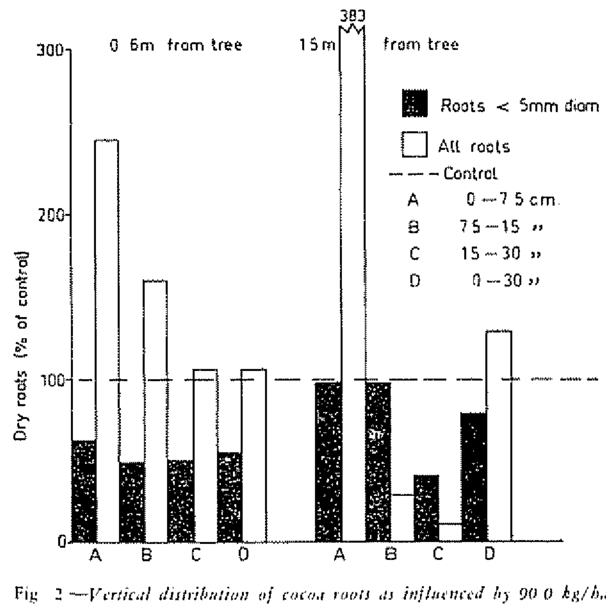

Fig 2 —*Vertical distribution of cocoa roots as influenced by 90 0 kg/ha of nitrogen* while that at depth C was greatly decreased. For all roots, it was a big increase at depth A and decrease at other depths.

The overall effect was a slight decrease in amount of small plus medium and an increase in that of all the roots.

N_3 effect: At 0.6 m from the tree, the quantity of small plus medium roots at depth A was greatly reduced while that at depths B and C was increased. The increase was more at depth C. When all root fractions were considered, the dry weight was decreased at all depths. The decrease was most pronounced at depth C and least at depth A. The overall effect wa· reduced weight of all root fractions. The reduction was less in small plus medium roots.

At 1.5 m from the trees the quantity of all the various root fractions was reduced at all depths except for all roots at depth B where there was an increase.

Comparative effects of nitrogen levels.

Root fractions: It is observed in Fig. 4, that the amount of small roots first falls with increase in nitrogen level before rising and falling again with further increase in N dosage. The amount of medium roots is decreased with increase in N dosage. The quantities of big roots and all the roots initially rose with increase in N dosage to a maximum at N_1 (45 kg/ha) thereafter falling with further increase in N dosage.

Soil depths: At depth A, the amounts of small plus medium and all roots first rose with increase in N dosage to a maximum before falling with further increase in N dosage.

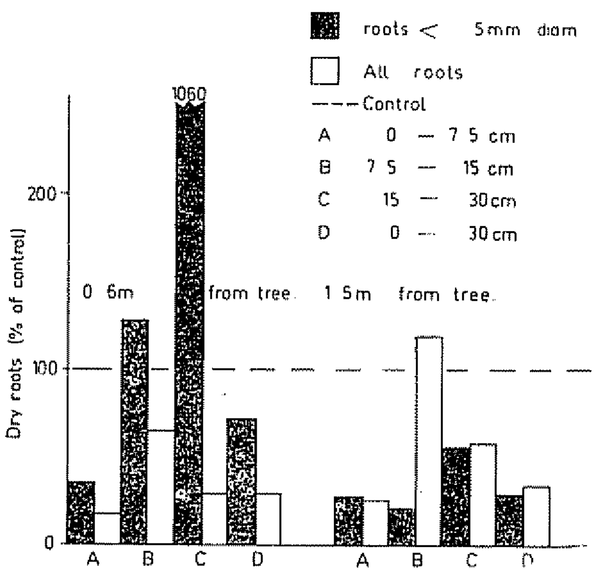

Fig. 3.—*Vertical distribution of cocoa roots as influenced by 180.0 kg/ha of nitrogen*

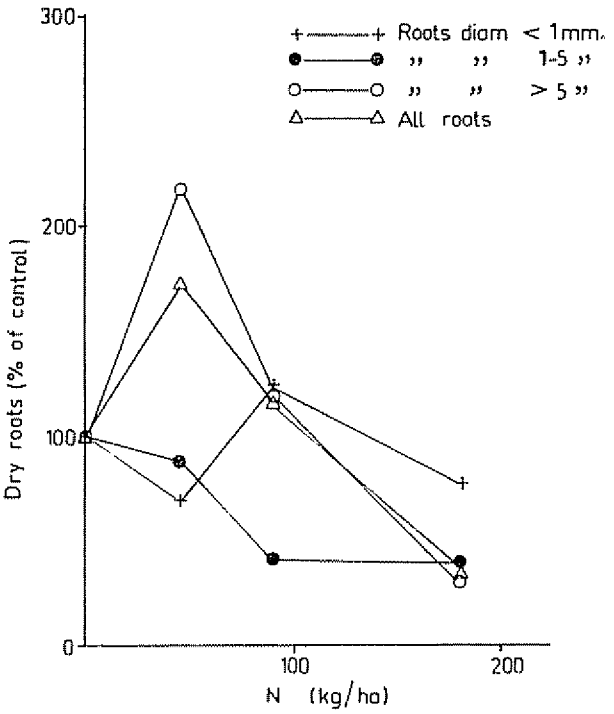

Fig. 4.—*Effect of increasing nitrogen doses on various cocoa root fractions*

At depth B, increase in N dosage decreased quantity of small plus medium roots. For all roots, the quantity first rose, then fell before tending to rise again with increasing N dosage.

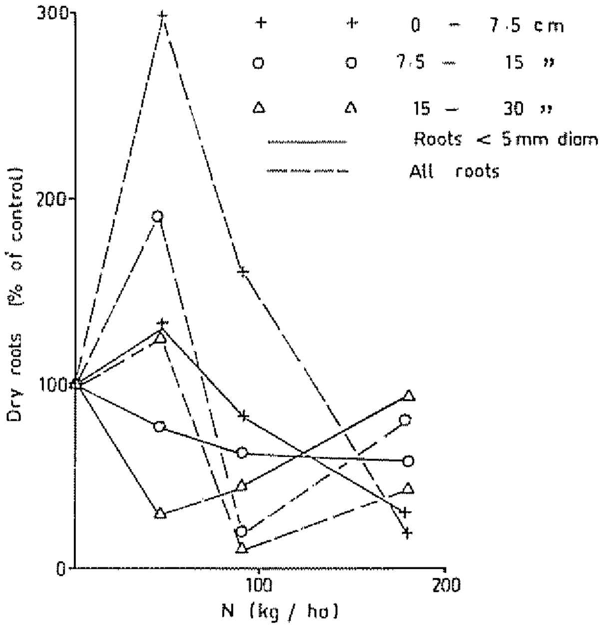

Fig. 5.—*Effect of increasing nitrogen doses on cocoa roots various soil depths.*

The effect of increasing N level on all roots at depth C was similar to its effects on those at depth B. In the case of small plus medium roots there was an initial decrease followed by a rise in their dry weight at depth C.

Discussion

Continued nitrogen fertilizer application has profund effect on the distribution of cocoa roots in the soil. The type and the extent the effect seems to be dependent on the depth of soil and root fraction considered, the level of nitrogen applied and the distance from the base of the tree.

The effect of the fertilizer was more pronounced at 0.6 m than at 1.5 m from the tree. While N_1 increased the amount of small plus medium roots at depth A and decreased it at other depths, N_2 depressed it at all depths and N_3 depressed it at depth A and increased it at other depths. Furthermore, at 1.5 m from the tree N_2 had no effect on this root fraction at depths A and B whereas it was reduced at all depths by N_3. When all the roots were considered, at 0.6 m from the tree N_1 and N_2 were found to increase and N_3 to decrease the amount of roots at all depths. But at 1.5 m from the tree, N_1 and N_2 increased the quantity of roots at depth A and decreased it at other depths whereas N_3 slightly increased it at depth B and decreased it at other depths.

Cahoon *et al* (2) have demonstrated that various nitrogen fertilizer treatments affect the concentration of roots of mature citrus trees.

The variability between the results at the two distances from the tree was likely due to unevenness in the spread of the fertilizer which was hand broadcast.

The observed increase in the quantity of some root fractions by low to medium nitrogen doses seems to confirm the findings of Bosemark (1) while the decrease at high N doses corroborates the results of Ford *et al* (6) on citrus.

The fact that the weight of roots of diameter less than 1 mm was decreased while that of larger ones was increased at low to medium N doses but decreased at high N doses seems to suggest that continued nitrogen fertilizer application is more detrimental to the development of the most absorptive fibrous roots.

Wilkinson and Ohlrogge (19) have shown that the generally recognised increased shoot to root ratios resulting from nitrogen fertilization are caused by nitrogen - increased growth hormone content which in turn inhibits root growth and promotes shoot growth in intact plant.

The tendency for the decrease in root dry weight caused by N_3 at depths greater than 7.5 cm to be less than that caused by N_1 or N_2 can be explained on the basis of preference of roots to ramify in soil zones which contain adequate but not toxic amounts of nutrients. With N_1 or N_2 it may be that the surface of the soil (0-7 cm) had adequate quantity of nitrogen and hence the preference of the roots to ramify more in this zone leading to reduced root growth in deeper zones. With increasce in N, the soil surface may contain toxic amount of nitrogen and as such the roots avoid this zone to ramify in deeper but less toxic zones.

The decrease caused in root, (especially small plus medium roots) growth by high nitrogen doses will be a great disadvantage during the dry season since the volume of the soil occupied by the roots and as such the amount of water available to the plant is reduced. This will cause the effect of moisture stress to be severer on such a plant.

Little or no feeder roots were found beyond a depth of 30 cm from the soil surface. This suggests that cocoa is a superficial feeder. Himme (12) found that only 4 percent of the cocoa principal laterals were more than 30 cm below the collar.

Summary

The effect of continued application of nitrogen fertilizer at 0.0; 45.0, 90.0 and 180.0 kg/ha as urea on the spatial distribution of amazon cocoa roots has been investigated. Soil core samples were taken at two distances from the tree and up to three different depths. The roots were separated from the soil, fractionated to small, medium and large and dried in an oven at 70°C for 24 hours.

The vertical distribution of roots was greatly affected by the fertilizer treatments. The treatment either decreased, increased or did not affect the quantity of roots depending on the fraction, soil depth and dose of nitrogen considered.

The quantity of medium (1-5 mm diam.) roots was found to decrease, and that of bigger ones to first rise before falling with increasing nitrogen dosage. Increasing nitrogen dosage did not affect the quantity of small roots (diameter less than 1 mm).

Low to medium doses of nitrogen either increased or decreased quantity of root depending on the root fraction and depth considered. Where there was a decrease, it was more pronounced than that caused by high nitrogen doses.

Literature cited

1. BOSEMARK, N. O. The influence of nitrogen on root development. Physiologia Plantatarum 7: 497-502. 1954.

2. CAHOON, G. A., MORTON, E. S., JONES, W. W., and GARBER, M. J. Effects of various types of nitrogen fertliizer on root density and distribution as related to water infiltration and fruit yields of Washington Navel oranges in a long-term fertilizer experiment. Proceedings of the American Society for Horticultural Science 74: 289-299. 1959.

3. CHARTER, C. F. Cocoa soils: good and bad. Tafo, Gold Coast, West African Cocoa Research Institute. 1947. 11 p.

4. CUNNINGHAM, R J. A review of the use of shade and fertilizer in the culture of cocoa. West African Cocoa Research Institute Technical Bulletin 6. 1959. 15 p.

5. EVANS, H. and MURRAY, D B. A shade and fertilizer experiment on young cacao. Progress report. *In* Imperial College of Tropical Agriculture. A report on cacao research, 1945-1951. St. Augustine, Trinidad, 1953. pp. 67 - 76

6. FORD, H W, REUTHER, W, and SMITH, P. F. Effect of nitrogen on root development of Valencia Orange trees. Proceedings of the American Society for Horticultural Science 70: 237-244. 1957

7. GEUS, J G de. Fertilizer guide for tropical and subtropical farming. Zurich. 1969

8. HARDY, F. Some soil relations of the root system of cacao; further results of investigations in Trinidad. Tropical Agriculture (Trinidad) 21: 184-195. 1944.

9. ———— Cacao Manual. Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica. 1960. 439 p.

10. HAVORD, G. Manurial and cultural experiments on cacao. *In* Imperial College of Tropical Agriculture. A report on cacao research, 1945-51. St. Augustine, Trinidad, 1953. pp. 104-108.

11. ————, MALIPHANT, G. K, and COPE, F.W. Manurial and cultural experiments on cacao. IV. The effects of fertilizers, shade and spacing on flowering, fruit set and cherelle wilt, River Estate, Trinidad. *In* Imperial College of Tropical Agriculture. A report on cacao research, 1954. St. Augustine, Trinidad, 1955. pp. 80-87.

12. HIMME, M VAN. Etude du systéme radiculaire du cacaoyer. Bulletin Agricole du Congo Belge 50 (6): 1541-1600. 1959.

13. MALIPHANT, G. K. Long-term effects of fertilizers on cacao in relation to shade. *In* Conference Internationale sur les Recherches Agronomiques Cacaoyeres, Abidjan. November 15-20, 1965. pp. 102-108.

14. MURRAY, D. B. A shade and fertilizer experiment with Cacao III. *In* Imperial College of Tropical Agriculture. A report on cacao research, 1953. St. Augustine, Trinidad, 1954. pp. 30-37.

15. OMOTOSO, T. I and JACOB, V J. Fertilizer application on adult amazon cocoa. Cocoa Research Institute of Nigeria. Annual report 1970-71. p. 103, Ibadán, 1972.

16. ROGERS, W S and HEAD, G C. Factors affecting the distribution and growth of roots of perennial woody species. *In* Root growth, ed. W. J. Whittington. Butterworths, London. 1968. pp. 280-295.

17. SMITH, R. W. Amelonado shade and fertilizer experiment. West African Cocoa Research Institute Annual Report 1960-61. 1962. pp. 63-64.

18. WESSEL, M. Fertilizer requeriments of Cacao (*Theobroma cacao* L.) in South Western Nigeria. Koninklijk Instituut voor de Tropen. 1971. pp. 46-56

19. WILKINSON, S R and OHLROGGE, A. J. Mechanism for nitrogen-increased shoot/root ratios. Nature 204: 902-904. 1964.

Reseña de Libros

FREEMAN, CHRISTINA y PYLE, LEO. Methane generation by anaerobic fermentation; an annotaded bibliography. London, Intermediate Technology, 1977. 64p.

Este librito está dirigido a personas involucradas en la construcción, diseño y mejoramiento de los generadores de metano en el Tercer Mundo. Los capítulos en que se ha dividido y las fichas bibliográficas que los componen están comentados críticamente teniendo en cuenta sus aplicaciones al medio rural en pequeña escala.

Cuando los desarrollistas se dieron cuenta de los esfuerzos que se hacían en la India para producir biogas (o "gobar") mediante la digestión anaeróbica de la boñiga de vacunos, se despertó un gran interés en este proceso, que al mismo tiempo que producía un combustible que se podía usar directamente en un quemador elemental, dejaba un residuo que no podía usarse como fuente de humus y nutrimientos para el suelo, Esto era una verdadera tecnología apropiada, no contaminante, y que utilizaba un recurso renovable: los desechos rurales.

El resultado es una profusión de literatura sobre el tema. Los libros técnicos y las patentes industriales tratan de la eliminación de basura municipal y metropolitana, donde en énfasis es en el residuo sólido de poco volumen, y el gas es de menor importancia. El interés de Intermediate Technology se ha manifestado en la compilación de esta bibliografía, que incluye lo que parecen ser los artículos básicos y relevantes más útiles. La introducción es un resumen compacto del estado actual de la cuestión, e incluye diagramas de un sistema de biogas, y de un diseño hindú de un generador de biogas de 4 metros cúbicos. Incluye también un glosario y unos cuadros de rendimientos de varias materias primas que van desde estiércol de varias procedencias, pasto elefante cortado, pulpa de madera, hasta lo que se llama eufemísticamente "suelo nocturno" (alemán: Kot)

Reseña de Libros

ALVA, C.A., ALPHEN, J G van, et al. Problemas de drenaje y salinidad en la costa peruana. — Wageningen, International Institute for Land Reclamation and Improvement (ILRI), Bulletin Nº 16. 1976. 116p.

Este Boletín técnico, presentado en forma de libro, contiene algunas de las conclusiones y resultados del trabajo del CENDRET (Centro de Drenaje y Recuperación de Tierras), que fue un proyecto de cooperación técnica entre el Perú y los Países Bajos, cuya meta principal era la de formar técnicos peruanos especializados en problemas de avenamiento de tierras agrícolas

El trabajo se ha dividido en dos partes totalmente diferenciadas. La primera hace un recuento general de la magnitud del problema del avenamiento (drenaje) y la salinidad de las tierras agrícolas en la costa peruana; la segunda describe algunos de los experimentos realizados para estudiar la recuperación de los suelos salino-sódicos.

La primera parte tiene cinco capítulos y una bibliografía y constituye la tercera parte del boletín. La segunda incluye 10 capítulos, tres anexos y una bibliografía sobre el tema.

Este boletín merece ser analizado desde dos puntos de vista diferentes: el primero es el del contenido técnico y su utilidad para poder comprender los problemas de la recuperación de las tierras agrícolas; el segundo, está relacionado con la presentación del trabajo y su traducción al español.

Desde el primer punto de vista, es necesario aceptar que la primera parte o sección de esta publicación, pretende introducir al lector en el problema del avenamiento de la costa peruana y, para ello, los autores han utilizado el sistema más común, es decir comenzar por hacer un recuento histórico, geográfico y geológico, de la situación existente en los 2.500 kilómetros de la estrecha faja costera que tiene el país andino. A esto, han añadido una descripción sencilla de los orígenes geomorfológicos y geogenéticos de los problemas de avenamiento en la costa peruana, pasando luego a describir, en forma somera, lo que significa un "cono de deyección"; un "valle encajonado" y los problemas de avenamiento y salinidad en estas circunstancias.

Como el proyecto del CENDRET se inició en 1968 y finalizó en 1974, la bibliografía consultada va desde el año de 1956 hasta el de 1974, lo que abona el carácter histórico de la primera parte de esta publicación. Se ha dado énfasis, en el aspecto bibliográfico, a las publicaciones de la Oficina de Estudios de Recursos Naturales (ONERN), que ha trabajado bastante sobre el tema.

En general la primera parte es interesante desde el punto de vista del enfoque sobre los criterios para evaluar los problemas de avenamiento y salinidad que presentan algunos valles de la costa peruana. Tal vez hubiera sido conveniente una discusión mayor sobre la incidencia de factores económicos y sociales en la recuperación de tierras, tema éste que es tratado en forma muy superficial, aun cuando tiene especial gravitación sobre el problema, en su conjunto

Con referencia a la segunda parte o sección de la publicación; aquella que trata de los experimentos de recuperación de los suelos salino-sódicos, se puede decir que aquí reside el principal valor de este trabajo, pues en forma resumida, pero muy completa, se presentan las experiencias realizadas, las que son explicadas con un criterio muy técnico, pero fácilmente entendible, aun para profesionales que no se encuentren interiorizados con la terminología, las técnicas y los métodos descritos.

Unas pocas palabras, ahora, sobre la presentación misma del trabajo. Es evidente que ha sido editado en los Países Bajos, por alguien que si bien conoce bastante el español, no llega a un dominio total del idioma y esto hace que se presenten innumerables errores gramaticales que entorpecen la lectura y demuestran poco respeto, por el idioma y los lectores de habla hispana, a quienes está dirigida la publicación

Hay algunas incongruencias que vale la pena manifestar. Por ejemplo, se utiliza papel "couché" (brillante) de primera calidad en el trabajo. Sin embargo, no se utiliza levantamiento de texto en equipo especial, de modo que se reproduce un trabajo escrito a máquina, sin justificación de márgenes y hasta con distinto tipo de letra. Esto hace pensar en que si bien se pensó en publicar el trabajo a un costo bastante elevado, por la calidad del papel y la impresión, por otra parte no se hizo lo mismo con el proceso previo, desvirtuando así el costo final del trabajo.

Hay, además un trabajo editorial deficiente. Es imposible aceptar que al editor se le haya escapado un error tan garrafal como decir que el Perú tiene una superficie de 1.285.215 *metros* cuadrados, cuando se trata de *kilómetros cuadrados*, o hablar del período *Quaternario*, o decir el *reservoria* de San Lorenzo; o que el exceso de agua tiene su *origin* en ...

Por lo anterior, me da la impresión de que *había* que sacar una publicación sobre los resultados del Proyecto; *había* que hacerlo rápido, pues el proyecto había finalizado hacia más de dos años; y *no había* tiempo de hacerle una buena labor editorial. Resultado: un buen trabajo desde el punto de vista del contenido técnico e histórico; un pésimo trabajo desde el punto de vista editorial. Lástima, pudo haber sido mejor

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