THE EFFECT OF THREE SOURCES OF NITROGEN FERTILIZER ON THE YIELD AND QUALITY PARAMETER OF SUGAR-CANE (*Saccharum officinarum* L.)[1] /

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Resumen

El rendimiento de plantas de caña de azúcar fue estudiado bajo el efecto de tres fuentes de nitrógeno (nitrato de sodio, urea y sulfato de amonio) con o sin inhibidores de la nitrificación.

Mediante el empleo de inhibidores de la nitrificación se logró mayor rendimiento –aunque no significativo estadísticamente– cuando se utilizó sulfato de amonio como fuente de nitrógeno, comparativamente con urea y nitrato de sodio

El contenido de sustancias minerales de las plantas de caña de azúcar, el cual incide en su calidad, no se vio afectado como resultado del uso de las diferentes fuentes de nitrógeno o de inhibidores de la nitrificación

Otros indicadores de calidad, como el contenido de NO_3–N de la planta, no fueron adversamente afectados por el uso de alguno de los fertilizantes nitrogenados

Introduction

The issue of the nitrogen-nutrition of sugar plants has been controversial, because views vary as regards the form of nitrogen that is utilised best by the plants. Sugar-beet, for example, is believed to thrive better in a predominantely nitrate-nitrogen environment. Various views have been expressed as regards whether sugar-cane thrives better in a predominantly nitrate –or ammonium– nitrogen medium (5).

It has, however, not been easy to establish a predominantly ammonium-nitrogen medium, because of the activities of nitrifying bacteria and other micro-organisms which convert such ammonium-nitrogen into oxidized forms such as the nitrite– and nitrate– nitrogen. Thus a close to pure ammonium-nitrogen nutrition of plants can only be induced through the paralysis of the activities of the micro-organisms

Various chemical and physical means are now being employed to inhibit the activities of the micro-organisms. These include substitutes of piridine and pirimidene traded under the name "N-serve" and "Toyo-Koatsu Am" and partial sterilization of the soil through use of water vapour (8, 14).

The different sources of nitrogen, with or without the nitrification inhibitor, are expected to have consequences on the yield and quality parameters that could affect sugar processing

This study was therefore designed to examine the effects of the three sources of nitrogen on the yield and the quality parameters of sugar-cane

Materials and methods

Six kilogram soil (para-brown earth stagnogley)-sand mixture was packed into each pot used for the experiment, and there was 4 5 kg soil to 1 5 kg sand.

Plastic pots of 10 litre capacity were used. Table 1 reflects the important properties of the para-brown earth stagnogley soil, sand and the mixture.

The sugar-cane plants used were from Cuba of the variety B4362 treated prior to planting against rot-

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ting. They were germinated first in pure sand before they were transplanted into the pots.

The water supply corresponded with 80% saturation of the water retention capacity of the soil-sand mixture. There was one plant per pot and each treatment was replicated 5 times in a complete randomised design. The nitrification inhibitor used is a new development currently traded under the name "6194" from the German Democratic Republic.

A basal dose of 0.545 g of P given as KH_4PO_4, 1.245 g of K given as K_2SO_4 and 0.150 g of Mg given as $MgSO_4 \cdot 7H_2O$ was applied to each pot one day before the sugar-cane plants were transplanted. The nitrification inhibitor was applied at the rate of 8 ppm per pot (i.e. 50 ml of the solution) or, in its absence, 50 ml of the alcohol used to dissolve the inhibitor. Twenty-one days after the sugar-cane cuttings were transplanted, the nitrogen fertilizers were applied in a solution injected into the soil.

The treatment combinations are in Table 2.

Soil and plant sampling and analysis method

The soil samples were taken with the help of a boring auger specially constructed to suit the pot-experiment, and sampling started a week after the nitrogen fertilizer was applied. About 180 g of soil was taken every week, and the following parameter determined:

- pH-measurement in KCl (1:2.5 soil/solution ratio) with the pH-meter
- NO_3-N content by the method described by Jackson (10);
- NH_4–N determined as described by Peterburgski (14)
- NO_2–N by treatment with sulfanil-acid and χ-Naphthylamine and later measured with the photometer
- Total nitrogen by the half-microkjeldahl method described by Kunze *et al* (11).

Table 1. Important chemical properties of the soil, sand and their mixture, utilized for sugar-cane planting.

Chemical property	Soil	Sand	Mixture
pH (kcl)	5.100	3.700	5.000
Exchangeable NH_4–N ($mg\ NH_4$–N/100 g soil)	0.214	0.000	0.177
Total–N(mg N/100 g soil)	85.633	0.000	66.152
NO_2–N(mg NO_2–N/100 g soil)	0.000	0.000	0.000
NO_3–N(mg NO_3–N/100 g soil)	0.624	0.000	0.507
Water retention capacity (%)	–	–	25.420

Table 2. Fertilizer treatment combination to sugar-cane plants.

Water Supply	Series	1 g N/pot given as	ppm inhibitor	Number of pots for	
				Analysis	Harvest
80% saturation of the water retention capacity	1	–	–	1	4
	2	Urea	–	1	4
	3	Urea	8	1	4
	4	Sodium nitrate	–	1	4
	5	Sodium nitrate	8	1	4
	6	Ammonium sulphate	–	1	4
	7	Ammonium sulphate	8	1	4

After the transplantation of the sugar-cane plants, weekly observations were made as to whether there would be any colourations, diseases or damage.

Growth in height was also recorded and the number of leaves taken note of.

Yield was determined by harvesting the sugar-cane plants at the 19th week of growth. The sugar-cane stems and leaves were harvested separately. The plant materials were first oven dried at 55°C and later to determine the dry matter yield at 105°C in an oven for 3 hours.

The sugar content determination was done by pressing the saft out of the fresh stem and measuring with a refractometer.

The following mineral content analyses were carried out on the 55°C dried plant materials after grinding them to powder:

- Total nitrogen (without NO_3–N) determined by the method described in Kunze *et al.* (11).
- NO_3–N determined by treatment with 1% $CuSO_4$ solution, xylenol, 88% H_2SO_4 and 1% NaOH.
- P-content determined as described by Arhenius (2).
- K– and Na– determination as described by Baron and Riehm (3),
- B-determination as described by Mac Dougal and Biggs (12).

Results and discussion

The results of the soil analysis are presented in Tables 3 and 4. These results have been fully discussed elsewhere (13), but suggest that the use of the nitrification inhibitor caused an accumulation of NH_4–N in the soil when urea or sulphate of ammonia was used as a source of nitrogen (Table 3), resulting in the slow conversion of NH_4–N of urea or sulphate of ammonia to NO_3–N as reflected in Table 4. This ensured a predominantly NH_4–N nutrition.

The representation in Figure 1 shows the yield (stem and leaves) as harvested after the sugar-cane plants had achieved physiological ripness at about the 19th week of growth.

Table 3. NH_4–N dynamics in the soil during experimental period.

Treatment	Weeks of the experiment								
	1	2	3	4	5	6	7	8	19
Control	0.40	1.32	1.32	0.53	0.53	1.59	1.81	1.24	1.12
Urea	14.30	17.07	13.49	12.26	10.32	11.15	6.80		3.99
Urea + inhibitor	18.07	21.09	19.75	13.94	11.80	11.77	5.17	2.29	2.13
Sodium nitrate	1.32	1.06	0.88	0.00	0.00	2.39	3.16	1.76	2.26
Sodium nitrate + inhibitor	2.03	2.65	1.50	1.94	0.00	2.66	1.81	1.42	6.41
Sulphate of ammonia	21.17	22.95	14.10	12.00	13.08	8.94	5.26	2.11	1.55
Sulphate of ammonia + inhibitor	20.53	24.89	21.60	14.29	9.59	13.98	9.26	6.90	1.28

Table 4. NO_3–N dynamics in the soil during the experimental period.

Treatment	Weeks of the experiment								
	1	2	3	4	5	6	7	8	19
Control	0.04	0.09	0.08	0.08	0.08	0.00	0.29	0.0	0.00
Urea	0.00	2.64	0.00	0.08	0.17	0.00	0.24	0.24	0.00
Urea + inhibitor	0.06	0.04	0.08	0.08	0.17	0.00	0.36	0.00	0.00
Sodium nitrate	18.70	7.43	14.52	9.82	8.94	3.14	1.42	0.12	0.00
Sodium nitrate + inhibitor	12.56	9.69	9.72	2.04	0.33	0.08	0.24	0.08	0.00
Sulphate of ammonia	0.20	0.88	1.35	0.34	0.08	0.00	0.45	0.17	0.00
Sulphate of ammonia + inhibitor	0.32	0.69	0.41	0.08	0.17	0.00	0.25	0.00	0.00

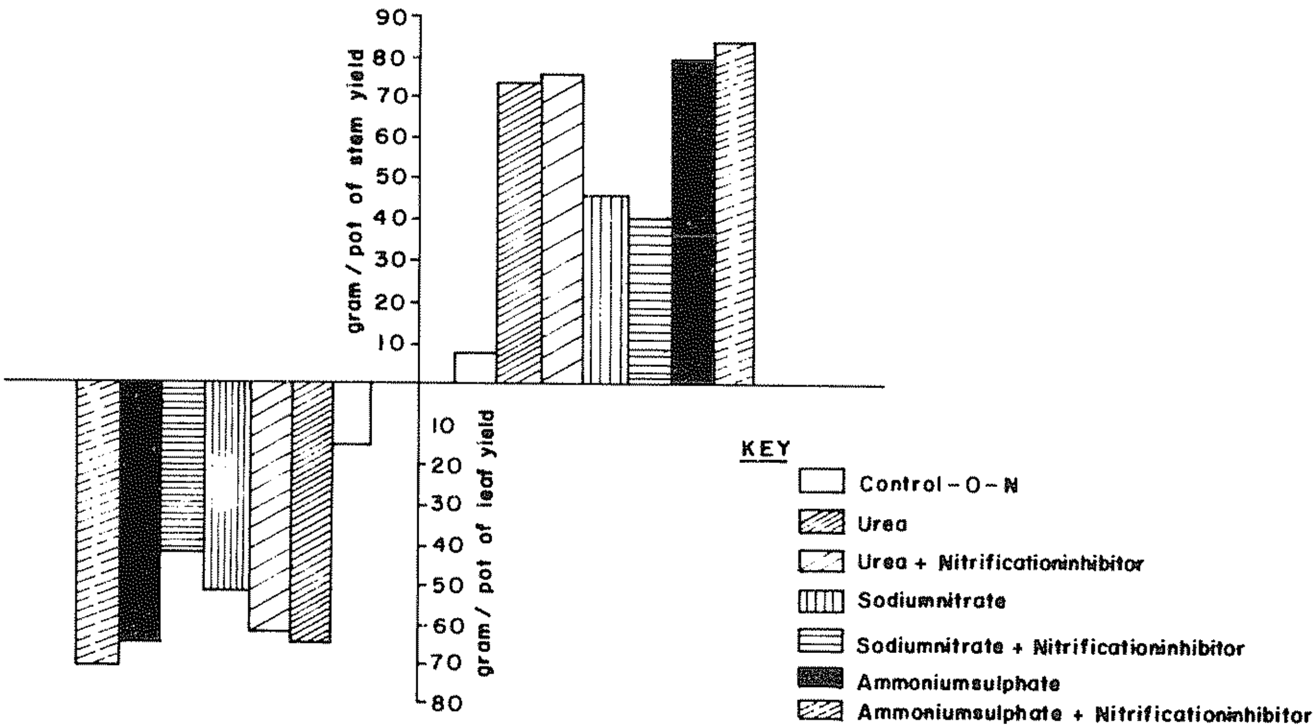

Fig. 1 Stem and leaf yields in gram per pot (Dry substance)

From the results, it is suggested that the treatments with urea or sulphate of ammonia fertilizers had higher yields than the sodium nitrate fertilizer treatment. It has, however, not been well established which form of nitrogen fertilizer is better suited for sugar-cane production of urea or sulphate of ammonia (5). The results of this experiment showed that sulphate of ammonia, with a stem yield range of 70.94 g/pot to 89.13 g/pot (average at 82.86 g/pot) therefore 5.56 g/pot to 8.81 g/pot higher stem yield than the urea treatment which had a range of 64.96 g/pot to 95.55 g/pot (average at 75.67 g/pot), is better utilized by sugar-cane than the latter. Although these results are not statically significant, they however show the general tendency. The leaf yield of the sodium nitrate treatment of 15.94 g/pot – 65.95 g/pot (average at 47.73 g/pot) was lower than that of urea with 56.79 g/pot – 73.66 g/pot (average at 65.13 g/pot) and sulphate of ammonia with 61.68 g/pot – 72.64 g/pot (average at 69.59 g/pot). The results enumerated above, and reflected in Figure 1, also indicate a better performance of sulphate of ammonia than urea.

The results of this experiment agree with the conclusions reached in a review work (1), that of all N-fertilizers used for sugar-cane production, urea and sulphate of ammonia are the most acceptable. It has been established that the performance of N-fertilizers depends more or less on the soil pH. On soils with low pH-values, urea does better than sulphate of ammonia, while on well buffered soils with pH close to 7.0 the performances are almost equal (5). Since the experimental conditions for all the treatments were the same in this trial, with a pH of the nutrient medium at 5.0 (acidic) and sulphate of ammonia still emerged slightly superior to urea, it could be inferred that the SO_4-ion in it is responsible for the better effects on the yield (1). Sulphur is a necessary component of adenosintriphosphate (ATP) used in the process of energy transmission by plants.

The sugar yield as shown in Table 5 was higher by the application of urea or sulphate of ammonia than by sodium-nitrate. The treatments with sulphate of ammonia fertilizer with an average yield of 73.19-75.19 g/pot as compared to urea with 68.05-63.87 g/pot recorded higher yield than the latter. The results thus agree with those published by Gordon (9) where a higher yield was recorded by the use of sulphate of ammonia as compared to urea.

The sugar content of the stems as recorded at harvest is presented also in Table 5. From these results it would appear that the N-source has very little effect on the sugar content. However, the use

Table 5. Sugar yield and sugar content in relation to type of N-fertilizer (g/pot).

Series	Sugar yield	Sugar content
Control – 0 – N	7 83	15 50
Urea	68 05	16 30
Urea + nitrification inhibitor	63 87	14 10
Sodium nitrate	39 73	14 40
Sodium nitrate + nitrification-inhibitor	33 60	15 20
Ammonium sulphate	73 50	14 40
Ammonium sulphate + nitrification-inhibitor	75 19	14 00

of the nitrification inhibitor caused in most cases a slightly lower content of sugar than when it was not used It was also noticed that the urea treatments recorded generally higher sugar content than those of sulphate of ammonia.

In Figure 2, the NO_3–N content of the plant materials at the time of harvest are reflected

This shows that the greater part of the absorbed NO_3–N by the plants was concentrated in the leaves The values of less than 1.51-1 99% NO_3–N of the dry matter considered toxic to cattle (4) is thus still within the safe limit when it is considered as feed to animals Through the use of the nitrification inhibitor, however, the NO_3–N content of the plant materials could further be decreased This is because the treatments where the nitrification inhibitor were used recorded lower levels of NO_3–N than the treatments where the nitrification inhibitor was not employed This was more so when either urea or sulphate of ammonia was used

Tables 6 and 7 show the values obtained for the mineral contents of the plant materials These results indicate a reduction in the K-content of the leaves

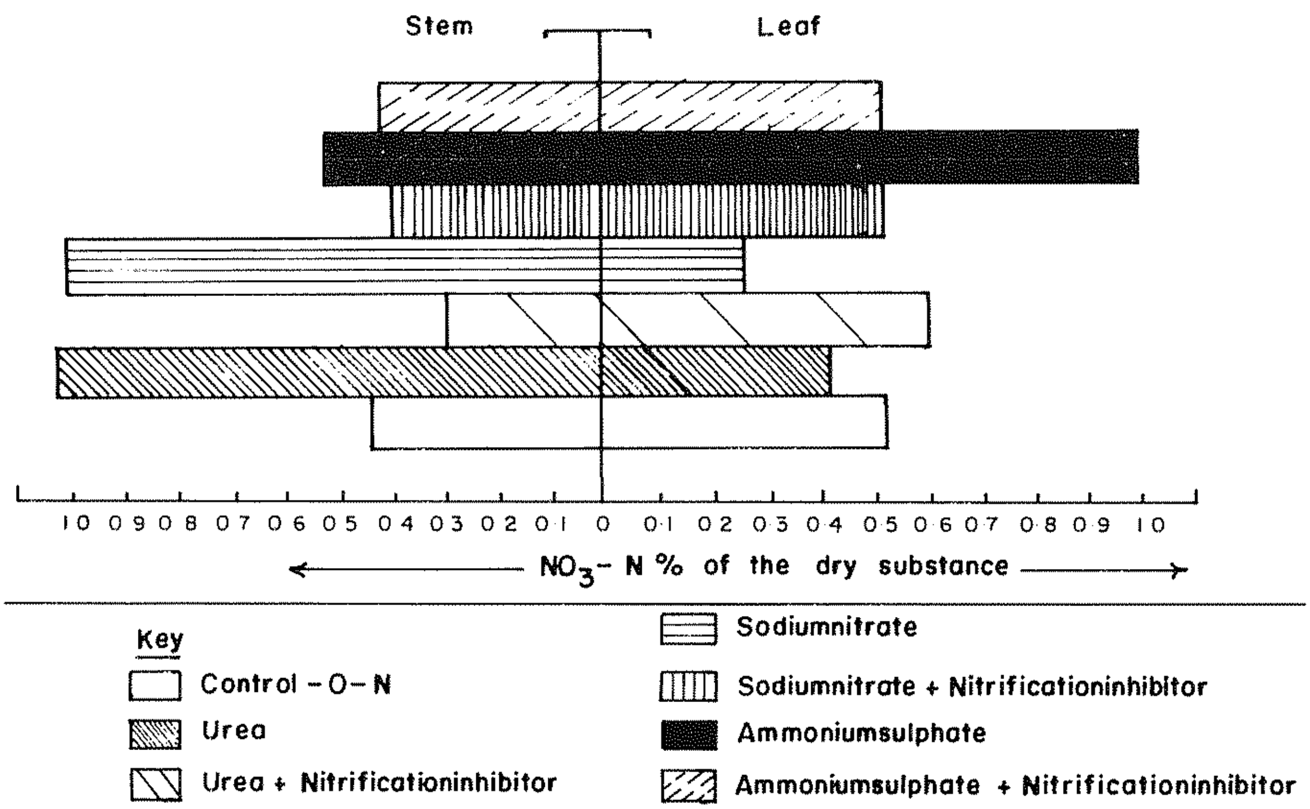

Fig. 2 Effect of the N-type on NO_3 – N content of the plant materials.

Table 6. **Mineral contents of the plant leaf.**

Series	K	Na	P	Ca	Mg	B	Mn	Cu
	in percentage of dry substance					in ppm		
Control 0–N	2.28	0.025	0.32	0.47	0.33	11.82	456.50	3.49
Urea	1.24	0.025	0.22	0.56	0.62	15.13	470.17	2.57
Urea + nitrification inhibitor	1.34	0.021	0.27	0.58	0.67	20.38	412.91	3.75
Sodium nitrate	1.22	0.042	0.16	0.52	0.63	16.05	187.29	2.14
Sodium nitrate + nitrification-inhibitor	1.37	0.047	0.19	0.54	0.57	14.51	213.96	2.56
Ammonium sulphate	1.12	0.015	0.29	0.57	0.72	17.25	585.44	5.12
Ammonium sulphate + nitrification-inhibitor	1.21	0.018	0.38	0.52	0.27	19.34	606.94	4.30

Table 7. **Mineral content of the plant stem.**

Series	K	Na	P	Ca	Mg	B	Mn	Cu
	in percentage of dry substance					in ppm		
Control 0–N	0.85	0.031	0.21	0.30	1.27	5.35	294.36	3.48
Urea	0.86	0.023	0.16	0.23	0.38	6.97	117.90	3.62
Urea + nitrification-inhibitor	0.81	0.023	0.11	0.29	0.28	7.00	104.53	4.58
Sodium nitrate	1.14	0.052	0.16	0.22	0.26	4.31	66.82	2.16
Sodium nitrate + nitrification-inhibitor	1.16	0.052	0.17	0.31	0.23	6.99	64.54	3.50
Ammonium sulphate	0.85	0.017	0.16	0.39	0.86	3.76	263.24	3.76
Ammonium sulphate + nitrification-inhibitor	0.76	0.019	0.16	0.26	0.48	9.13	188.05	5.10

through N-fertilizer application, but increase in the Ca, Mg and B-contents. This could be due to the multiple interaction of elements, whereby through the introduction of one element, the concentrations in the plant of the other elements could result (6).

With the application of sodium nitrate as a source of nitrogen, a decrease in the P, Ca and Mn contents of the plant materials was noted when compared with the other sources of nitrogen (urea or sulphate of ammonia). However, the treatments with urea had higher levels of K, Na, Ca and Mg contents in the leaves and stems but lower levels of P, B, Mn and Cu contents than the sulphate of ammonia treatments.

While boron and manganese were basically concentrated in the leaves, copper (another micronutrient) appears to be evenly distributed in all parts of the plant.

In general, the plants were adequately supplied with all nutrient elements according to the levels of requirements quoted from De Geus in Franke (7).

The stem content of Na, Ca, Mg and K become important, when one considers that these elements influence the crystallisation of sugar when the concentration is too high (15). The results as presented in Table 7 suggest an increase in P and Mg contents of the stem through N-fertilizer application except by the application of sodium-nitrate fertilizer. Urea and sulphate of ammonia as source of nitrogen also seem to decrease the stem content of K and Na while sodium-nitrate fertilization had the reverse effect.

Summary

Three sources of nitrogen viz: sodium nitrate, urea and sulphate of ammonia, were used with or without a nitrification inhibitor, and their effects compared on the yield of sugar-cane plants.

Through the use of the nitrification inhibitor, a higher but non-significant yield was recorded from the treatment with ammonium sulphate as the source of nitrogen, over those of urea or sodium nitrate.

The mineral contents of the sugar-cane plants, that affect the quality, were not adversely affected as a result of the use of any of the N-sources and the nitrification inhibitor.

Other quality parameters, e.g. NO_3–N content of the plant, were not adversely affected by the use of any of the N-fertilizers

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Reseña de libros

RICALDI, V. y ESCALERA, S., eds. La roca fosfórica, fertilizante de bajo costo. Primera Conferencia Latinoamericana de Roca Fosfórica, octubre 1983. Tomos 1 y 2. Editorial Arol S.R.L. Cochabamba, Bolivia, 1984. 530 p.

En dos tomos que agrupan los aspectos de proyección y exploración geológica con minería y metalurgia (Tomo 1) y aplicación agrícola (Tomo 2), se incluyen los trabajos presentados en la primera conferencia latinoamericana de Roca Fosfórica, realizada en Cochabamba, Bolivia, en octubre de 1983. En total se incluyen 35 trabajos, relacionados con rocas fosfóricas de Colombia, Brasil, Bolivia, Ecuador, Argentina y México y su empleo como fertilizante en los mismos países más Perú y Costa Rica.

En el Tomo I se presentan descripciones y estimados de los principales yacimientos de roca fosfórica en América Latina; se ahonda en las génesis y composición de las rocas, con una sección dedicada a trabajos relacionados con el tratamiento del material para sus diferentes usos. En términos generales podría concluirse que el conocimiento geológico, minero y metalúrgico de la región recién inicia su etapa de desarrollo, excepción hecha de Colombia y Brasil donde pareciera haber más conocimiento y aplicación de tecnología.

En el Tomo II se agrupan las experiencias obtenidas con la aplicación de roca fosfórica con fines agrícolas, ganaderos y forestales. Se incluyen trabajos teóricos y prácticos que cubren todos los aspectos relacionados con las reacciones y respuestas de la roca fosfórica en varios ambientes de América Latina. Como corolario vale la pena mencionar la alta respuesta a la roca en suelos de tipo oxídico con pH menor a 5.5, así como la poca respuesta en suelos derivados de cenizas volcánicas o en suelos con pH mayor a 5.5. Se podría pensar en un efecto de enmienda y de fertilizante fosfatado simultáneo en Oxisoles y Ultisoles, así como en Inceptisoles del trópico húmedo.

Algunos trabajos sobre mezclas de roca fosfórica con microorganismos o a través de reacciones de tipo acídico (como compost de tipo aeróbico) proporcionan otra opción para mejorar la solubilidad de la roca fosfórica, aunque en este caso en pequeña escala debido al volumen de material a manejar.

En términos generales, son pocos los trabajos que estiman al efecto residual de la roca fosfórica, aunque se menciona este aspecto principalmente para cultivos perennes y forrajes. Habría que poner atención, principalmente en el futuro, no sólo a la reactividad del producto, sino también al suelo y al clima en que crece el cultivo al que se apliquen, para así obtener una figura más clara con relación a la respuesta a este fertilizante en la América Latina.

Es de elogiar la pronta edición de los tomos que aquí se comentan, puesto que este es un trabajo normalmente lento. Ambos tomos pueden adquirirse escribiendo a: Grupo Latinoamericano de Investigación de Roca Fosfórica, Casilla 183, Cochabamba, Bolivia.

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