INCREASING THE EFFICIENCY OF SOIL APPLIED NITROGEN[1] /

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Resumen

Se investigó el efecto de reducir la nitrificación sobre la absorción de nitrógeno por caña de azúcar y en consecuencia la eficiencia de uso del nitrógeno aplicado al suelo.

*El nitrógeno absorbido correlacionó con el rendimiento de caña de azúcar (r = 0.96**). Por lo tanto, la eficiencia de uso del nitrógeno aplicado al suelo aumentó con la inhibición de la nitrificación y la dentrificación por bacterias (causantes de pérdidas de nitrógeno) cuando se usó inhibidores.*

Introduction

One of the major problems facing the use of mineral fertilizers is the loss through leaching or volatilization.

Nitrogen of all other mineral fertilizers faces the greatest danger of decreased efficiency through its loss in the soil. It has been suggested that nitrogen fertilizers are only to about 30 70% efficiency in the first year of application (1, 3).

The rate of loss of nitrogen through volatilization and leaching was set at about 15 million tons per year world wide, that is about 30% of the total production (7).

The loss of nitrogen by surface water run-off and vertical water movement in the soil is possible when nitrogen is in a mobile state, in the form of nitrate-N in the soil. The ammonium-N in the soil is attached to the soil colloids with a greater force than the more mobile nitrate-N. Because of the rapidity with which the ammonium-N is converted to the nitrate-N form in the soil through the activities of the nitrifying bacteria, the former is subjected to a similar fate in the soil as the nitrate-N.

The rate of loss of nitrogen therefore, depends on the rate and intensity of nitrification in the soil (10). Experiments conducted with marked ^{15}N showed that about 16-31% of applied nitrogen on sandy soils and 11 25% on loamy soil, are lost through denitrification (5). The loss of soil applied nitrogen through leaching and volatilization reduces the efficiency of this fertilizer. It is therefore of economic interest to device a more effective way of using nitrogen fertilizers so as to obtain profitable response.

This study was therefore designed to examine the effect of the suppression of the nitrification process on the effectiveness of the soil applied nitrogen.

Material and methods

Material

Four and a half kilograms of soil (para-brown earth stagnogley) and 1.5 kg of sand were mixed and packed into 10 litre plastic pots. Table 1 shows the important properties of the para-brown earth stagnogley soil, sand and the mixture.

The experiment was conducted in the glasshouse of the Institute for Tropical Agriculture, Liberwolkwitz, Leipzig. It extended over a period of 124 days. Nitrogen was suplied as urea, sodium nitrate, and sulphate of ammonia with and without nitrification inhibitor (Table 2).

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Table 1. Important chemical properties of the para-brown earth stagnogley soil, sand and the soil-sand mixture.

Soil variables	Soil	Sand	Mixture
pH (KCl)	5.100	3.700	5.000
Exchangeable NH_4-N($mgNH_4-N$/ 100 g soil)	0.214	0.000	0.177
Total – N (mgN/100 g soil)	85.633	0.000	66.152
NO_2-N ($mgNO_2-N$/100 g soil)	0.000	0.000	0.000
NO_3-N ($mgNO_3-N$/100 g soil)	0.624	0.000	0.500
Water retention capacity (%)	–	–	25.420

Table 2. The order of Fertilizer/Nitrification-Inhibitor Application to the plants.

Treatment	Nitrogen applied per pot as (g N/pot)	Nitrification inhibitor (ppm)
1	Zero-Nitrogen (Control)	–
2	Urea	–
3	Urea + Inhibitor	8
4	Sodium nitrate	–
5	Sodium nitrate + Inhibitor	8
6	Sulphate of Sulphate of Ammonia	–
7	Sulphate of Ammonia + Inhibitor	8

The sugar cane cuttings were germinated first in pure sand before they were transplanted into the post 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 trated under the name "6194" from the German Democratic Republic.

Method

A basal dose of 0.545 g P as KH_4PO_4, 1.245 g K as K_2SO_4 and 0.150 g Mg as $MgSO_4 \cdot 7H_2O$ was applied to each pot one day before the 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 the absence, 50 ml of the alcohol used to dissolve the inhibitor medium. In an attempt to reduce volatilization, another layer of the soil-sand-mixture was used to cover the top after the application of the basal fertilizer and the inhibitor. Twenty-one days after the sugar cane cuttings were transplanted, the nitrogen fertilizers were applied in solutions injected into the soil.

Water supply was maintained at 80% saturation of the water retention capacity of the soil-sand-mixture.

The nitrogen balance in the soil after the experiment was determined by the difference between the total nitrogen in the soil-sand-mixture before the experiment plus the nitrogen added as fertilizer and the nitrogen left in the soil after harvest plus nitrogen in the plants (stem and leaf)

Soil and plant analysis

Soil samples were taken every seven days to monitor the pH and nitrogen dynamics in the soil. The parameters determined in the soil were:

i) pH – measurment in KCl with pH-meter;

ii) NO_3-N was determined as described by Jackson (2);

iii) NO_2-N by treatment with sulfanil acid and naphthylamine and later measured with the flame photometer;

iv) Total nitrogen by the micro-kjeldahl method as described elsewhere (4);

v) Exchangeable NH_4 N was determined as described by Pertburgski (8)

After harvest, the sugar cane stems and leaves were dried at 55°C and ground for the following analysis:

i) Total – N (without NO_3-N) as described elsewhere (4);

ii) NO_3-N determined by treatment with 1% Cu SO_4 solution, xylenol, 88% H_2SO_4 and 1% NaOH solution

iii) Nitrogen uptake calculated by multiplying the concentration by the leaf and stem yield

Results and discussions

The results of the soil analysis have been discussed by Obatolu (6) The ammonium-nitrogen and the nitrate-nitrogen contents of the soils are presented in Tables 3 and 4.

The nitrification-inhibitor induced an accumulation of ammonium-N in the soil when urea or sulphate of ammonia were used as source of nitrogen (Table 3). The nitrification-inhibitor also suppressed convertion to nitrate-N of urea or sulphate of ammonia as compared to the treatments without inhibitor (Table 4).

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	10.31	11.15	6.80	3.00%	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. NH_3^-–N dynamics in the soil during 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	0.30	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

Figure 1 shows the values of nitrogen uptake by the plants of the different treatments, and it is suggested that the application of nitrogen fertilizer increased the N-uptake by seven to sixteen times the control The N treatments caused differences in N uptake by sugar cane. Plants treated with sulphate of ammonia had the greatest N – uptake and they were followed by plants treated with urea and sodium nitrate, respectively Through the use of the nitrification-inhibitor, N – uptake by sugar cane was increased by 205.05, 24.71 and 16.27 mg N/pot when sulphate of ammonia, urea and sodium nitrate were applied

Figure 2 shows the relationship between the yield (leaf and stem) and the efficiency of the applied nitrogen It is suggested that the yield increases with the efficiency of the N-fertilizer applied, and the correlation coefficient between leaf/stem yield and the fertilizer efficiency is very high ($r = 0.96^{**}$). The ammonium-nitrogen fertilizers (i e urea and sulphate of ammonia) gave higher yield in this experiment than the nitrate fertilizer (sodium nitrate). Increased availability of the ammonium-nitrogen through the application of the nitrification inhibitor appeared to have increased the efficiency of the applied nitrogen and thus agrees with the statement that nitrogen in form of ammonium-N is theoretically more efficiently utilized than nitrate-N, because it is less subject to loss by leaching and volatilization from the soil (9)

The effect of the N-sources and the nitrification inhibitor on the amount of nitrogen lost is shown in the Table 5

Table 5 suggests that the use of the nitrification inhibitor reduced the loss of nitrogen by 24.4, 32.74 and 73.58% respectively when urea, sodium nitrate

Table 5. Nitrogen loss at the end of the experimental period (mgN/pot).

Treatment	Nitrogen loss (mgN/pot)
Control	401.85
Urea	731.06
Urea + Inhibitor	537.85
Sodium nitrate	961.40
Sodium nitrate + Inhibitor	646.60
Sulphate of ammonia	565.15
Sulphate of ammonia + Inhibitor	149.34

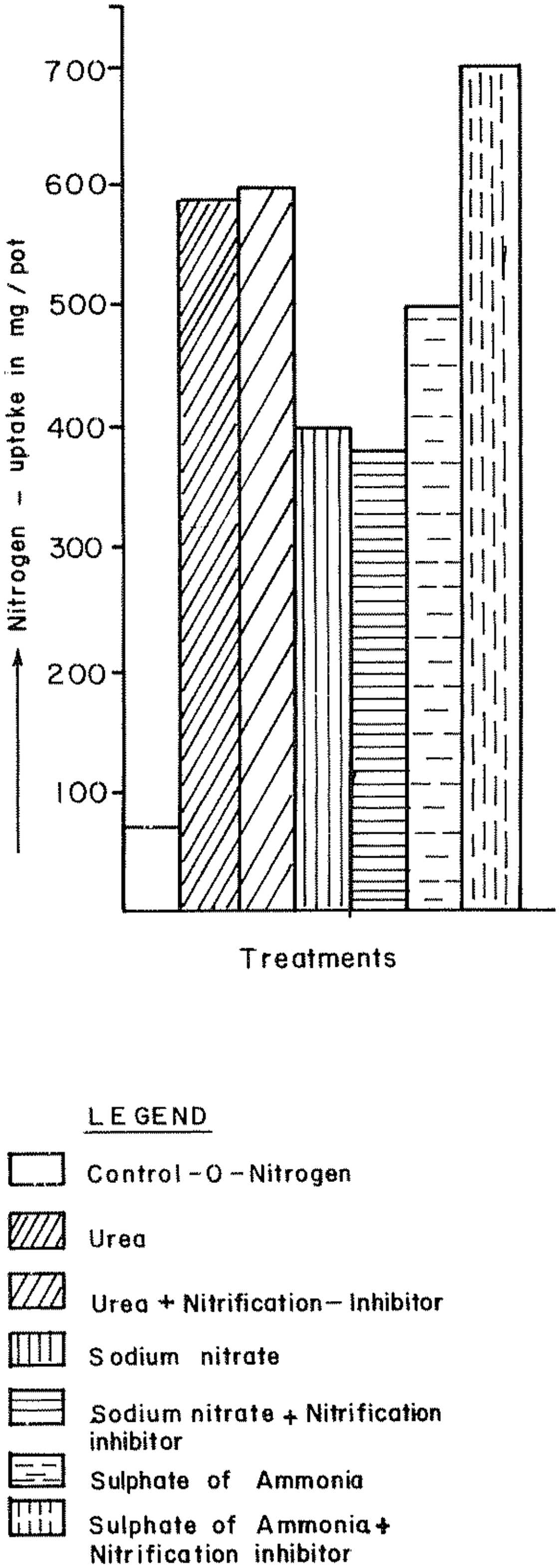

Fig 1 Nitrogen – uptake (mg/pot) of Leaf and stem in relationship to N-source and Nitrification inhibitor

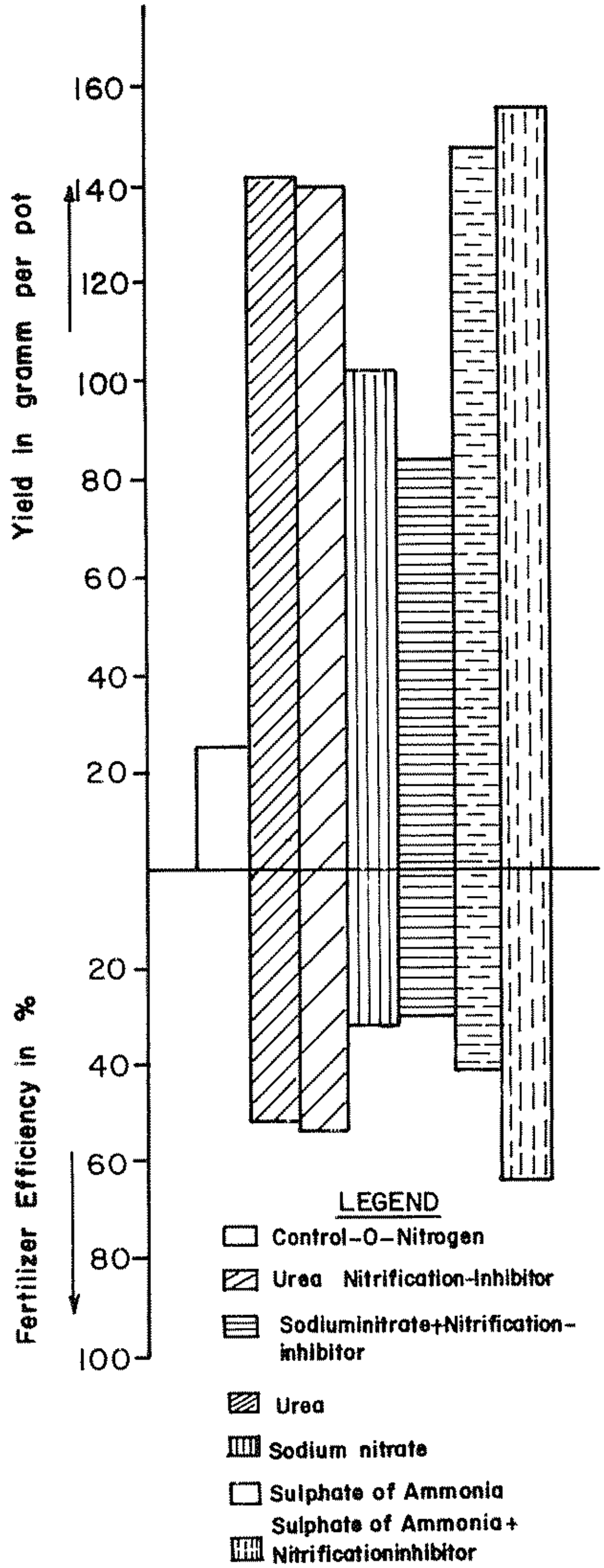

Fig. 2. Leaf and stem yield (gramm/pot) versus Nitrogen fertilizer Efficiency (%).

and sulphate of ammonia were applied, compared to the control.

Therefore it could be suggested that the nitrification inhibitor does not only reduce the nitrification but also the rate of denitrification. This is because there could not have been any nitrogen loss through leaching, since the pots used in this experiment were not perforated at the bottom, thus leaving gaseous escape of nitrogeneous gases as the only source of nitrogen loss. Since the treatments where the nitrification inhibitor was used suffered less loss, it could be inferred, that denitrification which is the process by which the nitrate-N is converted to gaseous forms of nitrogen and lost, is also reduced. The fact that the loss of nitrogen when sodium-N is used is even smaller than when urea is used, seems to buttress this assertion.

The fact that the nitrification inhibitor increased the efficiency of nitrogen fertilizer in sugar cane production may be due to possible reduction of the activity of nitrifying bacteria by the inhibitor. The latter effect is expected to reduce the amount of nitrate-N available for denitrification and increased the availability of ammonium-N. Normally the ammonium-N is not as mobile as the nitrate-N in the soil, consequently the molecules of ammonium-N are held within the reach of the plant roots and the uptake is thus increased, and by the optimization of all other growing conditions, the efficiency is increased.

Summary

The effect of suppression of nitrification on nitrogen uptake by sugar cane and consequently the efficiency of soil-applied nitrogen was investigated.

The uptake of nitrogen highly correlated with the yield of sugar cane plants, the correlation coefficient being 0.96**. Thus, the efficiency of the soil applied nitrogen was increased through the inhibition of nitrification and denitrification by bacteria (consequent sources of nitrogen loss) by use of a nitrification inhibitor.

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Reseña de libros

WHYTE, W. F. y BOYNTON, D. eds. Higher-yielding human systems for agriculture. Cornell University Press. 1983. 342 p.

En esta obra se presenta un resumen de la labor llevada a cabo por un equipo de investigadores patrocinado por "El Comité de Desarrollo Rural del Centro de Estudios Internacionales de la Universidad de Cornell".

El propósito fundamental del libro es exponer una nueva estrategia de desarrollo rural para las regiones tropicales, basada en sistemas de producción para pequeños agricultores. Se considera que esta nueva estrategia debe propender a la realización de investigaciones interdisciplinarias en las mismas fincas y con una participación directa del pequeño agricultor, de tal suerte que tome en cuenta las inquietudes y necesidades de este último. Para ellos el pequeño agricultor es aquel finquero del Tercer Mundo, que a la fecha ha estado al margen de los grandes avances de las ciencias agrícolas y que encara serios problemas debido al tamaño de su finca, al ambiente y a sus escasos recursos. Con base en estas consideraciones sugieren que este agricultor podría mejor denominarse como un "finquero de recursos limitados".

El libro está dividido en las siguientes cinco partes:

I Fundamentos del nuevo enfoque: presenta un análisis de los esfuerzos en investigación y desarrollo rural que se han realizado, y que sirvió de base para reconocer las limitaciones de estos programas y la necesidad de plantear una nueva alternativa.

II Bases biológicas y físicas para el desarrollo de la agricultura de fincas pequeñas: se examina en esta sección el complejo conjunto de factores y elementos del ambiente físico y biótico que influyen sobre los sistemas de producción agrícola.

III Sistemas sociales desde la finca familiar a los programas nacionales: considera la importancia del pequeño agricultor como actor y gestor en esta nueva estrategia de desarrollo agrícola y por lo tanto estudia el papel de los seres humanos en el mejoramiento de aldeas, regiones o aún naciones.

IV Consideraciones organizativas: se discute el papel y la estructura de la organización que debe llevarse a cabo en la finca y en la comunidad para promover con éxito esta nueva estrategia. Así mismo se analizan los problemas de las instituciones gubernamentales responsables de la investigación y del desarrollo agrícola.

V Transcendencia de este nuevo enfoque para la investigación, la educación y las políticas estatales: se hace hincapié en el hecho que este nuevo enfoque de desarrollo rural tendrá una fuerte influencia en la orientación de los programas de investigación agropecuaria, así como en la educación y en las políticas de planificación de los gobiernos.

Los autores de esta obra propician entonces un cambio drástico en buena parte de la investigación agrícola y los programas de desarrollo rural para el pequeño agricultor. Este cambio lleva también implícito una modificación de la actitud tanto del investigador, el extensionista, el agricultor como todas aquellas otras personas que intervienen en el proceso y en la toma final de decisiones. Reconoce el grupo de Cornell, que aunque se favorezca esta nueva opción, no se debe abandonar el enfoque tradicional de la investigación agrícola, sino que ambas tendencias debe coexistir.

Es interesante, que los investigadores agrícolas de las regiones extratropicales se han percatado que la agricultura tropical es mucho más compleja que la de sus regiones y que algunos agricultores en forma práctica han desarrollado en los trópicos sistemas de cultivos múltiples y agrosilvopastoriles, precisamente en respuesta a esta mayor diversidad ambiental del trópico.

Es preciso mencionar que desde 1950, el Programa de Investigación en Café del Gobierno de Costa Rica ha tomado muy en cuenta las necesidades de los pequeños agricultores, así como la diversidad ambiental del área en que se cultiva esta planta, dos aspectos que se enfatizan en esta obra. En igual forma es de justicia recordar, que el Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) en Turrialba, ha desarrollado programas de investigación en cultivos múltiples y sistemas agrosilvopastoriles tendientes a favorecer al pequeño agricultor.

Sin lugar a dudas los estudiosos de la agricultura tropical encontrarán en este libro, material muy valioso para comprender mejor una nueva alternativa de investigación y de desarrollo rural que favorece fundamentalmente al pequeño agricultor, tan necesitado de ayuda y que complementa y enriquece el enfoque tradicional en estos campos.

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