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Urea, ammonium sulfate and dicyandiamide transformations in Costa Rican soils

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Abstract. The transformations of urea, ammonium sulfate and dicyandiamide (DCD) were studied in an Inceptisol and three Andisols from Costa Rica, considering the influence of temperature and DCD as a nitrification inhibitor.

Nitrification was very slow with or without DCD in the strongly acid Inceptisol. A higher urea dose resulting in higher pH was well nitrified without DCD and appreciably retarded by DCD.

In Andisols nitrification was retarded as long as a higher DCD level existed. Higher temperatures accelerated the DCD-breakdown and were followed by a quicker nitrification. The decomposition of DCD was slower compared with the Inceptisol. According to these experiments DCD is suitable as a nitrification inhibitor in tropical soils.

Introduction

As many other areas of the wet tropics, Costa Rican agriculture depends heavily on nitrogen fertilization. Little is known of the fate of fertilizer nitrogen in soils of the region, except that under many conditions nitrification is quite rapid [1, 7] and that leaching is intensive, which results in considerable N losses.

Under temperate conditions, the nitrification retarder dicyandiamide (DCD) has given satisfactory results for reducing leaching losses of nitrogen [1–5]. In preliminary field experiments it contributed to a more efficient nitrogen use, particularly if used with rather low nitrogen levels [6] in Costa Rica.

This substance was tested on four soils from Costa Rica, an Inceptisol and three Andisols in incubation experiments, with regard to its effect and its rate of degradation at different temperatures. These aspects have not been investigated yet under tropical conditions, in accordance with a rather complete literature review [8] while they are rather well understood in soils of temperate regions [9, 10].

Materials and methods

Some properties of the soils are given in Table 1. The Andisols had pastures as their native vegetation and the Inceptisol represents the zero nitrogen plot in a banana fertilization experiment.

Table 1. Properties of the studied soils from Costa Rica.

Vegetation	Banana		Pasture	
Soil type	Inceptisol	Andisol I	Andisol II	Andisol III
$pH_{(H_2O)}$	5.3	6.2	5.5	5.8
$pH_{(KCl)}$	4.8	5.6	5.0	4.9
Total N %	0.84	n.d.	n.d.	n.d.*
Total C %	5.96	2.11	2.76	5.79
Sand %	54	68**	49**	43**
Silt %	24			
Clay %	22	32	51	57

* = not determined.
** = Sand and silt together.

For the Inceptisol experiment 50 g air-dry soil received 10 mg N as urea or as ammonium sulfate with or without 1 mg N as dicyandiamide or 30 mg N as urea with or without 3 mg N as DCD (soil depth 2–3 cm ≅ 130–200 kg N/ha). For the Andisol experiment 30 g of air-dry soil was mixed with 6 mg N as ammonium sulfate and 0.6 mg N as DCD. The samples were adjusted to about three fourths of field capacity and incubated at 20 °C or 30 °C for periods of up to 8 weeks. The flasks allowed a gas exchange and the water losses during the experiments were replaced with distilled water. The extraction of nitrate and dicyandiamide was carried out shaking the soil (30 g or 50 g) with 200 ml distilled water for one hour, centrifuging (20 min at 16000 rpm) and filtering.

Ammonium was determined in the soil-water solution with an ammonium specific electrode (Orion 95–10), DCD and NO_3 with HPLC as recommended by Vilsmeier [12].

Results and discussion

Inceptisol experiments

As shown in Fig. 1 urea (200 mg N/kg soil) was hydrolyzed completely in two weeks, with no detectable effects of temperature (20 ° or 30 °C) or the presence of DCD. This quick decomposition of urea in soils of Costa Rica confirms work by Acevedo and Pereira [1] who obtained similar results. The ammonium formed under these conditions remained largely as a cation in spite of rather adequate conditions for nitrification, except a low pH (pH_{KCl} 4.8). The slight nitrification observed was enhanced by temperature and markedly reduced by DCD (Fig. 1).

The NO_3^- formed in spite of lacking reduction of the ammonium values, is probably a result of the mineralization of part of the high organic matter level, shown in Table 1 for the Inceptisol.

When ammonium sulfate was used as N source the findings were similar. The

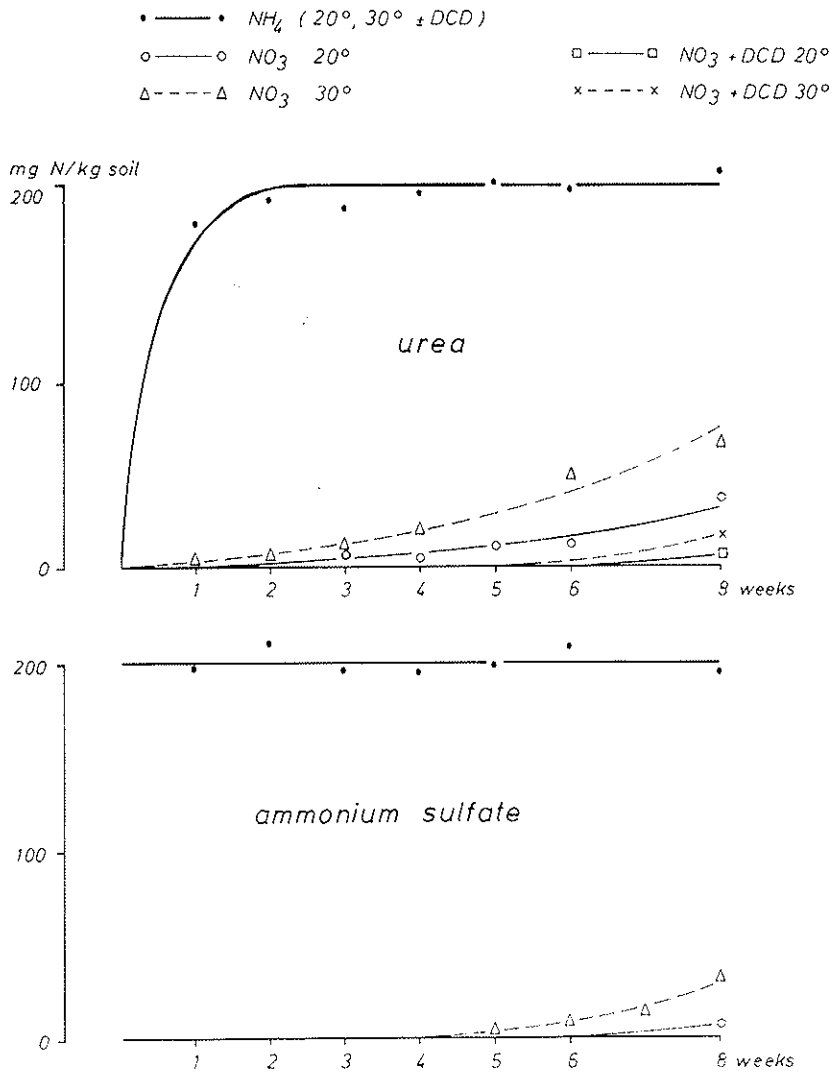

Fig. 1. Decomposition of urea and ammonium sulfate with and without dicyandiamide depending on temperature on Inceptisol.

concentration of ammonium was quite constant during the experiment, independent of temperature and the presence of DCD.

In the second part of the experiment, the urea nitrogen level was raised to 30 mg per 50 g soil which is in line with the cultivation practice of banana production (about 130–200 kg N/ha as surface application). This resulted in an appreciable increase of the soil pH (Table 2) and in a rapid nitrification under these conditions (Fig. 2).

The higher temperature increased the speed of nitrification which was com-

Table 2. $pH_{(H_2O)}$ values for the Inceptisol experiment.

Incubation time (weeks)	Urea (50 g soil)		Ammonium sulfate (10 mg N, 50 g soil)
	(10 mg N)	(30 mg N)	
1	5.7	6.6	5.3
3	5.6	5.8	5.3
5	5.4	5.5	5.3

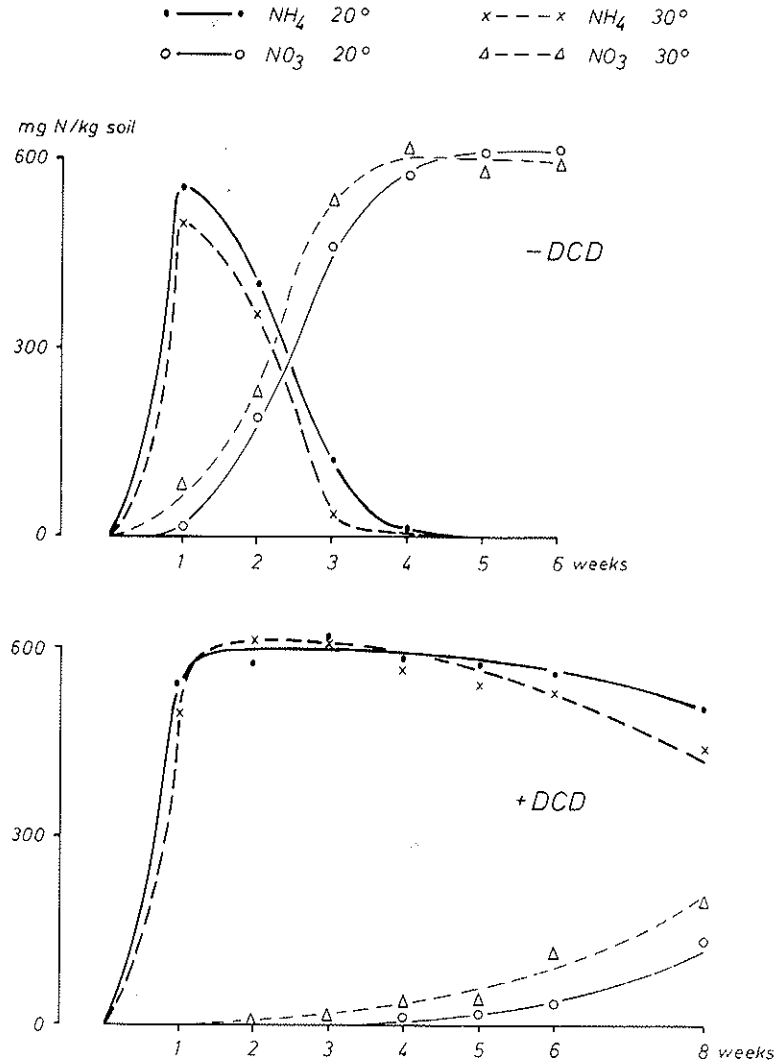

Fig. 2. Decomposition of urea with and without dicyandiamide depending on temperature on Inceptisol.

Table 3. Dicyandiamide decomposition in an Inceptisol at 2 different temperatures and concentrations (mg N of undecomposed DCD/kg soil).

mg DCD-N/kg soil	Temperature (°C)	Incubation time in weeks			
		2	4	6	8
20	20	16	11	4	0
	30	14	8	1	0
60	20	52	36	24	10
	30	46	34	11	0

plete in about four weeks confirming the results reported for soils from the same area by Gomez and Blue [5].

The effect of DCD under these conditions was notable (Fig. 2). After 8 weeks at 20 °C not less than 83 percent of the nitrogen applied as urea could be recovered as ammonium. For 30 °C the percentage was somewhat lower (73%) but still indicating a strong retardant action. The addition of DCD retarded the process somewhat better at a lower than at a higher temperature. The more rapid DCD decomposition at higher temperature (Table 3) is well known for temperate conditions [10].

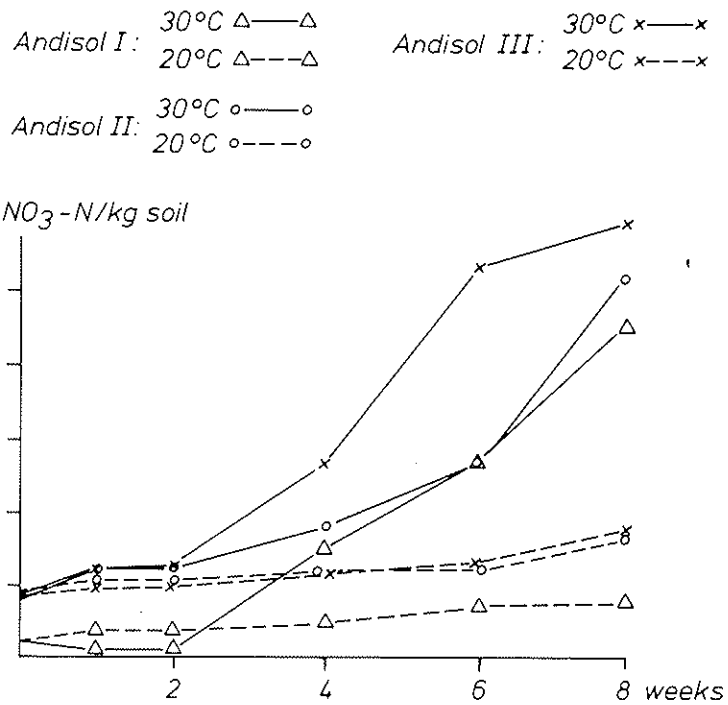

Fig. 3. Nitrification of ammonium sulfate with dicyandiamide depending on temperature on Andisols.

Table 4. Dicyandiamide decomposition in Andisols at 2 different temperatures (mg N of undecomposed DCD/kg soil).

Andisols	Temperature (°C)	Incubation time in weeks			
		2	4	6	8
I	20	17	10	7	5
	30	15	7	4	2
II	20	16	9	7	5
	30	14	4	5	1
III	20	18	13	11	10
	30	15	8	2	3

Andisol experiments

In these experiments, only the nitrification of ammonium sulfate in presence of DCD was investigated.

Figure 3 shows a much quicker nitrate formation at the higher temperature. As long as an appreciable DCD level exists nitrification is retarded (Table 4). DCD was decomposed more or less completely after 8 weeks. At a higher temperature, this process increases.

The decomposition of DCD in Andisols was markedly slower than it would be expected from data in comparable experiments of Sinz [9] with soils from Bavaria (Fed. Rep. Germany). It is believed that the strongly adsorbing properties and the large surface of the Andisols is the explanation for this observation.

According to our experience so far, an addition of dicyandiamide to mineral fertilizers (10% of total N) is suitable to reduce losses of N by leaching and denitrification and thus to increase yields. Sufficient precipitation and soil temperatures below 10 to 15 °C are the main prerequisits. Due to partly very high precipitation, N losses in the humid tropics are remarkable. Since the degradation of DCD was sufficiently slow in the selected soils at 20 °C and 30 °C (i.e. a pronounced inhibition of nitrification was observed lasting 4 to 6 weeks) an economic use of DCD seems to be practicable. To enable final conclusions, further experiments are necessary.

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