J. Agr. Sci. Tech. (2013) Vol. 15: 409-419

Agronomic Evaluation of a Fertilizer with D-CODER Technology: A New Mechanism for the Slow Release of Nutrients

M. Arrobas[1*], and M. Ângelo Rodrigues[1]

ABSTRACT

D-CODER is a fertilizer with a new slow-release mechanism consisting of an organo-mineral matrix that releases the nutrients only in the presence of growing plants. Pot and field experiments were carried out to study the release pattern of N from D-CODER. The experiments included grown and bare soil plots. The fertilizer treatments were D-CODER, ammonium nitrate (ANpreplant), and the control. A fourth treatment was added to the cultivated plots, consisting of splitting the ammonium nitrate application of 25% at preplant and 75% as top-dressing (ANsplit). In the bare soil pots, 35 days after the fertilizer application (DAFA), NO_3-N concentrations in the extracts of anion exchange membranes incubated in the soil for ANpreplant, D-CODER, and the control treatments were 118.5, 82.5 and 34.5 mg L^{-1}, respectively, suggesting that part of N from D-CODER had not yet been released. In the pots cultivated with ryegrass, 209 DAFA, N recoveries for D-CODER, ANpreplant, and control treatments were 0.94, 0.86 and 0.20 g pot^{-1}, respectively, suggesting that in the presence of the growing plants the release of N from D-CODER had not been restricted. Furthermore, soil NO_3-N levels in the bare soil plots of the field experiment were significantly higher in D-CODER (38.1 and 6.8 mg kg^{-1} on November and March) in comparison to ANpreplant (26.3 and 5.1 mg kg^{-1} on Nov. and March) treatments, suggesting that N from D-CODER was better protected from leaching. In the absence of growing plants, D-CODER provided some protection of N at least until 65 DAFA. In cultivated soils, it seemed less effective, particularly if the risk of nitrate leaching persisted for a long period of time. In these situations, a split application of N was a better strategy.

Keywords: Anion exchange membranes, Nutrient bioavailability, Rhizosphere-controlled fertilizers, Slow-release fertilizers.

INTRODUCTION

Losses of nitrates from agriculture to groundwater and release of several hazardous N gases into the atmosphere, particularly nitrous oxide (N_2O), are major environmental concerns associated with agricultural activities (Smil, 2001). One approach receiving attention to mitigate the problem has been the use of slow- and controlled-release fertilizers (Guertal, 2000; Carreres *et al*., 2003) and nitrification and urea hydrolysis inhibitors (Macadam *et al*., 2003; Di and Cameron, 2005) as a means of increasing N use efficiency.

The slow- and controlled-release fertilizers reduce the initial bioavailability of nutrients or increase the time period when they are available for a number of different mechanisms. The slow-release fertilizers are derived from the condensation of urea with different aldehydes. The controlled-release fertilizers include sulphur-coated urea and other conventional fertilizers encapsulated with a wide range of synthetic or natural

[1] Mountain Research Centre (CIMO), Polytechnic Institute of Bragança, Ap 1172, 5301-855 Bragança, Portugal.
*Corresponding author; e-mail: marrobas@ipb.pt

[DOR: 20.1001.1.16807073.2013.15.2.3.2]

polymers, which gradually release the nutrients into the soil solution (Trenkel, 2010). The nitrification inhibitors act on *Nitrosomonas,* which slows the oxidation of NH_4^+ to NO_2^- during nitrification, and extends the presence of the ammoniacal form in soil. Urease inhibitors, in turn, retard the hydrolysis of urea (Trenkel, 2010). Slow- and controlled-release fertilizers may have advantages over conventional fertilizers in environments of difficult N management, such as in flooded rice fields (Carreres *et al*., 2003), sandy soils (Guertal, 2000), nurseries, pots and containers (Walker and Huntt, 1999; Fernández-Escobar *et al*., 2004; Oliet *et al*., 2004) and vegetated roofs (Emilsson *et al*., 2007), or when a part of N fertilizer is applied at preplant (Malakouti *et al*., 2008). Nitrification inhibitors may improve crop productivity (Pasda *et al*., 2001), but they have usually been proposed as a means of reducing N_2O emissions to the atmosphere during nitrification and subsequent denitrification (Linzmeier *et al*., 2001; Macadam *et al*., 2003; Hatch *et al*., 2005) and nitrate leaching (Williamson *et al*., 1998; Di and Cameron, 2005). Urease inhibitors, in turn, can be effective in reducing N losses by ammonia volatilization (Zaman *et al*., 2009).

A new range of fertilizers which control the bioavailability of nutrients in the soil have been developed by Timac AGRO-INABONOS (Erro *et al*., 2007b). The nutrients are present in a water-soluble fraction and also in a fraction not soluble in water but soluble in organic acids. The fertilizer retains the insoluble fraction of the nutrients in a molecular matrix where the nutrients are inserted. The matrix consists of metallic phosphates prepared in the presence of a humic acid: metal-humic phosphates (Erro *et al*., 2007b). The nutrients are made available as the matrix disintegrates by the action of rhizospheric organic acids released by plants and microorganisms. The fertilizers with such a mechanism were classified as rhizosphere-controlled fertilizers (Erro *et al*., 2007a). From a theoretical point of view, it seems to be a very significant forward step within the group fertilisers that restrict nutrient availability, since the nutrients will be available only in the presence of growing plants. The rhizosphere-controlled fertilizers are sold as compound fertilizers under the commercial trade D-CODER (Erro *et al*., 2007b).

Taking into account that D-CODER fertilizers are currently on the market, it is of interest to test their agronomic performances under field conditions. Thus, the objective of this work was to examine the release pattern of nitrogen from a D-CODER fertilizer in field and pot experiments and also in bare soil and in the presence of growing plants. The performance of D-CODER will be compared with a conventional fertilizer, whose nutrients are fully available after soil application, and a non-fertilized control. Measurements included soil inorganic-N, plant N nutritional status indices, dry matter yield and plant N recovery.

MATERIALS AND METHODS

Pot Experiments

The soil used for pot experiments was collected near the location the field experiments were carried out. The soil was sieved (6 mm mesh) and dried at 40ºC. Selected soil physical and chemical properties are presented in Table 1.

Pots filled with 15 kg of dry soil were subjected to three fertilizer treatments, and organized as three independent experiments with reference to how the soil N availability was monitored. Each treatment included six replications (6 pots). The fertilizer treatments consisted of: (1) D-CODER (Timac AGRO-INABONOS, European Patent EP 1612200), a NPK compound fertilizer with 20% N (2.5% NH_4-N and 17.5% urea-N), 7% P_2O_5 and 10% K_2O; (2) ammonium nitrate (20.5% N), applied at preplant (ANpreplant); and 3) control, no N added. The N rate of the fertilized treatments

[DOR: 20.1001.1.16807073.2013.15.2.3.2]

Table 1. Selected physical and chemical soil properties.

Parameter		Parameter		Parameter	
Clay (%)	24.5	Organic-C (g kg^{-1})[a]	9.9	Exch. Ca^{++}($cmol_c$ kg^{-1})	9.7
Silt (%)	19.8	pH (soil/water $_{1:2.5}$)	5.6	Exch. Mg^{++}($cmol_c$ kg^{-1})	4.6
Sand (%)	55.7	P_2O_5 (mg kg^{-1})[b]	20	Exch. K^+($cmol_c$ kg^{-1})	0.1
Texture	Loam	K_2O(mg kg^{-1})[c]	100	Exch. Na^+($cmol_c$ kg^{-1})	0.3
				CEC ($cmol_c$ kg^{-1})	14.8

[a] Walkley-Black, [b, c] Egner-Rhiem.

was equivalent to 75 mg kg^{-1} dry soil. The pots of ANpreplant and control treatments were supplemented with superphosphate 18% and potassium chloride to balance phosphorus (P) and potassium (K) levels with D-CODER treatment. The three experiments subjected to the above-mentioned treatments were: (1) bare soil, where the soil nitrate levels were monitored by anion exchange membranes (AEM) inserted directly into the soil; (2) ryegrass (*Lolium multiflorum* Lam.), where soil N availability was determined by plant N recovery through sequential cuts during the growing season; and (3) ryegrass, grown for 62 days until the first cut, followed by the application of a non-selective glyphosate-based herbicide (*N*-(phosphonomethyl) glycine; 360 g L^{-1} of active ingredient, applied at the rate of 1 L ha^{-1}), and soil nitrate levels monitored by AEM. In experiments 1 and 3, after a long period of monitoring soil nitrate levels, ryegrass was sown (reseed in experiment 3) at 170 days after the fertiliser application (DAFA), which was followed by two cuts of biomass.

The pot experiments started on March 31, 2009, with the mixture of soil and fertilizer. On April 1, ryegrass was sown in the experiments 2 and 3. Thereafter, several cuts of ryegrass and incubation periods of AEM were carried out. The sequence for those steps is presented in Table 2.

The pots were kept under a sheet of corrugated asbestos cement to avoid the direct incidence of precipitation that could have reduced soil aeration and also an excessive exposure to sunlight that could have overheated the soil. The pots were regularly watered with distilled water to allow plant growth and soil microbial activity.

The AEM methodology consisted of the burial of 1 by 2 cm AEM strips directly into the soil at a depth of 10 cm and kept under incubation for a period of five days. After being removed from the soil, the AEM were washed thoroughly with distilled water and subsequently eluted in 20 ml 0.5M HCl (Rodrigues *et al*., 2006; Arrobas *et al*., 2011). The AEM were regenerated in 0.5M $NaHCO_3$ for reuse. Nitrate concentrations in the AEM extracts were determined by UV-visible spectrophotometry (Clesceri *et al*., 1998). The biomass of the ryegrass cuts was dried in a forced air oven at 70ºC. The dry samples were ground, and total N concentration determined in a Kjeltec Auto 1030 Analyser.

Table 2. Sequential steps and activities carried out on pot experiments from March 31st 2009 to August 19th 2010.

	Mar	Apr	May		Jun			Jul	Aug		Sep		Oct	Dec	Mar	Jul	Aug
	31	1	4	1	4	6	26	2	5	17	16	17	16	3	3	19	19
Pot experiment 1	a		c		c			c	c		c	b	d	d	d	d	d
Pot experiment 2	a	b		d			d			d			d				
Pot experiment 3	a	b		d		f		c	c		c	b	d	d	d	d	d

(a) Mixture of soil and fertilisers; (b) Ryegrass sowing; (c) AEM removed; (d) Ryegrass cut, (f) Glyphosate application.

[DOR: 20.1001.1.16807073.2013.15.2.3.2]

Field Experiments

The experiments were conducted in the Sta Apolónia farm in Bragança (41º49'N, 6º46'W), NE Portugal, in a Eutric Cambisol, whose main properties are presented in Table1. The cumulative monthly precipitation and average air temperature during the experimental period as well as the daily precipitation in the period between October 16 and November 18, 2009 are presented in Figure 1.

Two independent experiments were carried out. In one of the experiments, the fertilizer treatments were applied to a winter forage crop and in the other the soil was kept uncultivated for the autumn/winter growing season. The experiments started on October 16, 2009. The winter forage received four fertilizer treatments: D-CODER, applied at preplant (100 kg N ha^{-1}); ammonium nitrate applied at preplant (100 kg N ha^{-1}) (ANpreplant); ammonium nitrate split into two applications (25 kg N ha^{-1} at preplant and 75 kg N ha^{-1} as topdress in March 31, 2010) (ANsplit); and the control, with no N added. The experiment on the bare soil did not receive the ANsplit treatment. Both experiments were arranged as completely randomized designs with three replications. As D-CODER is a compound NPK fertilizer, the P and K rates of the other treatments were balanced with superphosphate 18% and potassium chloride. In the uncultivated plots, weeds were controlled with two applications of glyphosate on November 12, 2009, and March 31, 2010. Soil nitrate levels were monitored in both experiments on November 19, 2009, and March 26, 2010. Soil samples were taken from the 0-20 cm layer and frozen until analysis. Inorganic-N was extracted using 20 g soil and 40 ml 2 *M* KCl, shaking for an hour and filtering through a Whatman 42 filter paper. The extracts were analyzed for NH_4^+ and NO_3^- by UV-Vis. spectrophotometry. Plant N recovery was determined for the winter forage from samples taken (from 0.25 m^2) on March 30 and May 26, 2010, after drying at 70ºC, ground and analyzed for total N.

On June 7, 2010, maize (*Zea mays* L.) was sown both in the experiment previously cropped with the winter forage and in the experiment where the soil was kept uncultivated during the winter. Maize was sown with a precision vacuum seeder after seed-bed preparation by chisel plough and roller. A solid set sprinkler system irrigated the crop during the growing season. Nitrogen nutritional status of maize was monitored with the portable SPAD-502

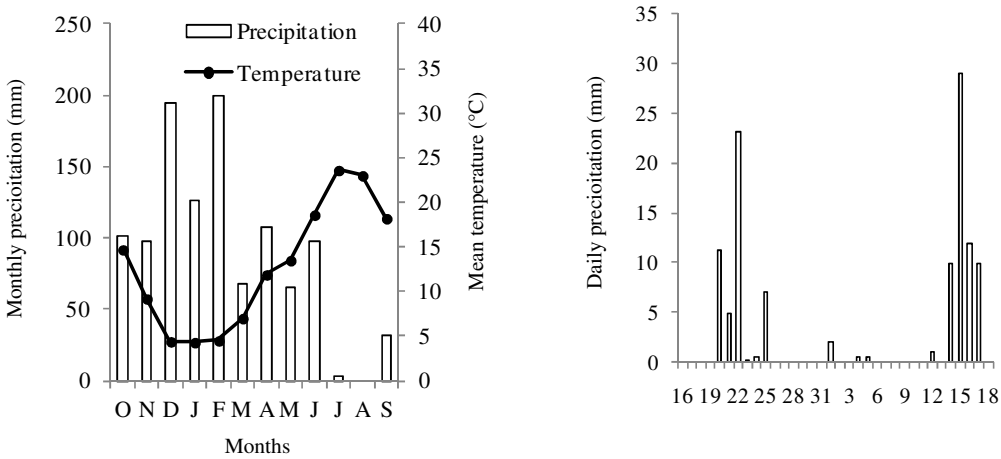

Figure 1. Cumulative monthly precipitation and average air temperature between October 2009 and September 2010 (Left) and daily rainfall from October 16 to November 18, 2009 (Right).

[DOR: 20.1001.1.16807073.2013.15.2.3.2]

chlorophyll meter (Minolta, Japan) on July 24 and Aug. 26, 2010. Soil inorganic-N levels were determined on July 7, 2010. At harvest, the stalk nitrate test was also performed as proposed by Binford *et al.* (1990). Dry matter yield and N recovery were determined from field samples of 1 m^2.

Data analysis was carried out using JMP statistical software. After ANOVA examination, the means with significant differences ($\alpha < 0.05$) were separated by the Tuker–Kramer HSD test.

RESULTS

Pot Experiments

In the bare soil pots, soil nitrate levels were significantly higher ($\alpha < 0.05$) in ANpreplant in comparison with D-CODER for the first two sampling dates (Figure 2a). Following 93 DAFA, soil nitrate levels remained the highest in ANpreplant pots, but they were not significantly different than that of D-CODER. Soil nitrate levels in control pots were always significantly lower than those in the fertilized treatments. Nitrogen recovery in the sequential cuts of ryegrass at 209 to 476 DAFA was consistently higher in D-CODER in comparison with the other treatments (Figure 2b). In control pots, significantly less N was recovered than in fertilized treatments from the second cut at 247 DAFA.

In the pots sown with ryegrass, N recovery in the D-CODER treatment was significantly higher than that of ANpreplant from the sampling date of 87 DAFA (Figure 3). In the last sampling date (209 DAFA), N recovery in the D-CODER treatment was 0.94 to 0.86 g pot^{-1} higher than ANpreplant. In the control pots, N recovery was lower than that of the fertilized treatments from the first cut in 62 DAFA.

In the pots where the ryegrass was controlled with glyphosate after the first cut, nitrate concentrations in AEM extracts were not significantly different in the fertilized treatments (Figure 4-a). In the control pots, soil nitrate levels and N recovery were always very low in comparison with fertilized treatments. Nitrogen recovery in the above-ground biomass was higher in D-CODER than in ANpreplant, but the means were only statistically significant at 247 and 317 sampling dates (Figure 4-b).

Field Experiments

On November 19, soil NO_3-N levels in the cultivated plots were significantly higher

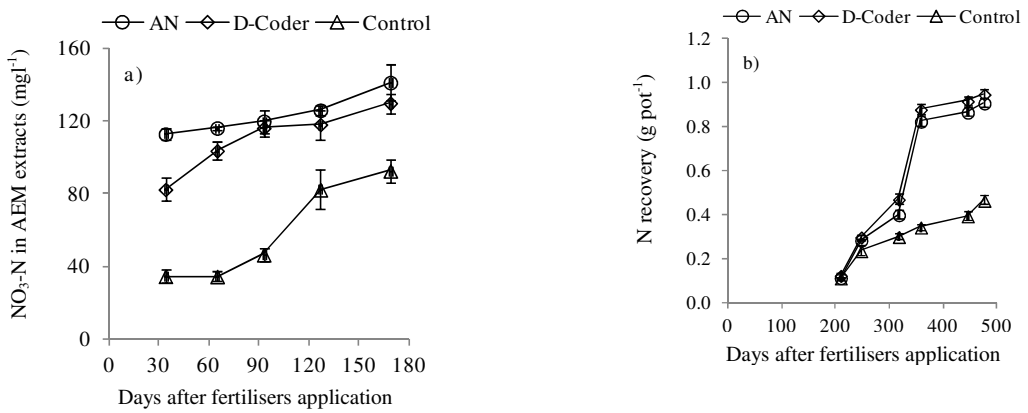

Figure 2. (a) Nitrate concentrations in anion exchange membranes (AEM) extracts during the initial period where the pots were kept uncultivated, and **(b)** Nitrogen recovered by ryegrass in the cuts performed from 209 to 476 DAFA in the second part of experiment 1. Error bars indicate confidence limits for the mean ($\alpha < 0.05$).

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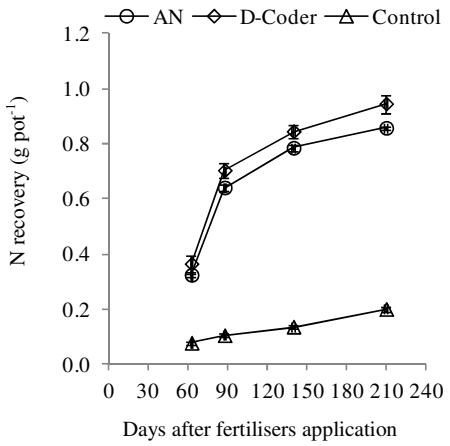

Figure 3. Nitrogen recovered by ryegrass in five cuts performed between sowing and 209 days after fertilizer application. Error bars indicate confidence limits for the mean (α< 0.05).

(α< 0.05) in ANpreplant and D-CODER treatments in comparison with ANsplit and the control (Table 3). From November to March, soil NO_3-N levels decreased and no significant differences were found among treatments on the last date. November and March soil NO_3-N levels in the bare soil plots were significantly higher in D-CODER than in ANpreplant (Table 3). In the control plots, soil NO_3-N levels were lower compared to the fertilized treatments. No significant differences were found in soil NH_4-N levels among treatments in any sampling date.

Mean dry matter yields and N recoveries by winter forage from March sampling were slightly higher in ANpreplant in comparison to D-CODER (Table 4. The mean values of ANsplit were significantly lower than that of ANpreplant. On the contrary, mean dry matter yields and N recoveries from May sampling were significantly higher in ANsplit than in any of the other fertilized treatments. The mean dry matter yield and N recovery values of the control treatments were significantly lower than that of the fertilized treatments.

No significant treatment differences were noted in maize analyses (soil inorganic-N, stalk nitrate test, SPAD readings, dry matter yield and N recovery) (Table 5). During the maize growing season, soil nitrate levels, dry matter yields, and N recoveries in the plots previously kept as bare soil were higher than the cultivated ones.

DISCUSSION

The pot experiments demonstrated that D-CODER was able to restrict N release in the absence of growing plants, since soil nitrate levels in D-CODER pots were significantly lower than that recorded in ANpreplant until 65 DAFA. Even in the further analyses performed at 93, 127 and 169 DAFA, soil nitrate levels in D-CODER never reached the values recorded in ANpreplant, suggesting that a little fraction of N persisted and was not

Table 3. Soil inorganic-N in November and March in the winter-cultivated plots and in those kept as bare soil through the application of a glyphosate-based herbicide.

Soil occupation	Fertilizer treatment	November 19 NO_3-N (mg kg^{-1})	November 19 NH_4-N (mg kg^{-1})	March 26 NO_3-N (mg kg^{-1})	March 26 NH_4-N (mg kg^{-1})
Winter crop	ANsplit	17.3 b	3.1 a	1.9 a	3.1 a
	D-CODER	22.4 a	3.8 a	1.9 a	4.7 a
	ANpreplant	22.6 a	4.3 a	1.9 a	4.9 a
	Control	17.7 b	3.3 a	2.2 a	2.6 a
Bare soil	D-CODER	38.1 a	3.0 a	6.8 a	3.5 a
	ANpreplant	26.3 b	2.0 a	5.1 b	2.7 a
	Control	18.0 c	2.9 a	4.7 c	2.7 a

Mean values followed by the same letter in columns, within each soil occupation, are not significantly different by Tukey-Kramer HSD test (α<0.05).

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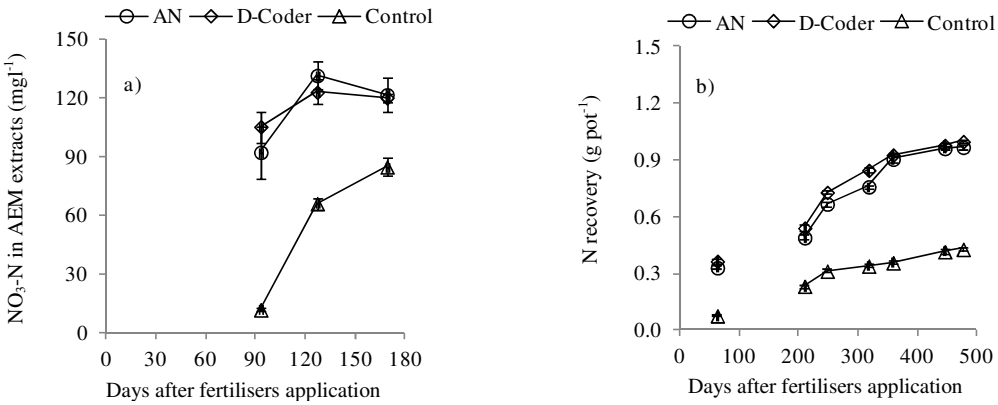

Figure 4. (a) Nitrate concentrations in anion exchange membranes (AEM) extracts in experiment 3, that started with the sown ryegrass which was controlled with glyphosate after the first cut, and **(b)** nitrogen recovered in the above-ground biomass in the first cut and in several other cuts performed after the reseeding of the ryegrass. Error bars indicate confidence limits for the mean (α< 0.05).

released in bare soils. The results of the field experiments showed that November soil nitrate levels were higher in D-CODER than in ANpreplant plots. However, the results of pot and field experiments are not necessarily contradictory, they may be explained by heavy precipitation (60 mm) occurring in the week preceding soil sampling (Figure 1). Thus, it seems that N from D-CODER was better protected from leaching in comparison to that of ammonium nitrate, which in that period would have been entirely in the nitrate form. Nitrogen protection from leaching by D-CODER technology was demonstrated from the early work of Erro *et al.* (2007a). March soil nitrate levels were much lower than November levels, likely due to the heavy rains that fell in December, January, and February, which created favourable conditions for N losses from leaching (Mulla and Strock, 2008) and/or biological denitrification (Coyne, 2008). Soil NH_4-N levels were always low and no significant differences were found among treatments. Nitrification may occur very quickly, limiting NH_4^+ accumulation in soil, as recorded by Rodrigues (2004) from an incubation experiment conducted in similar agro-ecological conditions.

In the cultivated pots, N recovered by ryegrass was significantly higher in D-CODER than ANpreplant treatments. In the presence of growing plants, D-CODER did not restrict N release, which is in accordance with product advertising (Erro *et al.*, 2007b). In addition, the higher values of N recovery in D-CODER pots may mean that soil N losses

Table 4. Dry matter yield, tissue N concentration and N recovery by the winter crop on March and May as a function of fertilizer treatment.

Fertiliser treatment	March 30			May 26		
	DM yield (g m^{-2})	N conc. (g kg^{-1})	N recovery (g m^{-2})	DM yield (g m^{-2})	N conc. (g kg^{-1})	N recovery (g m^{-2})
ANsplit	162.1 b	14.9 a	2.42 b	958.2 a	6.3 a	6.25 a
D-CODER	183.7 ab	15.5 a	2.85 ab	691.6 b	4.6 b	3.18 b
ANpreplant	207.5 a	15.6 a	3.25 a	783.9 b	4.3 b	3.22 b
Control	118.4 c	15.2 a	1.82 c	545.3 c	4.3 b	2.34 c

Mean values followed by the same letter are not significantly different by Tukey-Kramer HSD test (α< 0.05).

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Table 5. Soil inorganic-N, dry matter yield, tissue N concentration, and N recovery by maize as a function of fertilizer treatments and previous soil use.

Previous soil use	Fertiliser treatment	NO_3-N (mg kg^{-1})	NH_4-N (mg kg^{-1})	DM yield (g m^{-2})	N conc. (g kg^{-1})	N recovery (g m^{-2})
Winter crop	ANsplit	2.5 a [a]	1.2 a	988 a	21.9 a	21.6 a
	D-CODER	2.7 a	1.2 a	810 a	21.4 a	17.3 a
	ANpreplant	3.4 a	2.9 a	858 a	21.5 a	18.4 a
	Control	3.3 a	0.9 a	790 a	21.6 a	17.0 a
	Average	3.0	1.6	862	21.6	18.6
Bare soil	D-CODER	4.7 a	2.2 a	1393 a	22.4 a	31.2 a
	ANpreplant	5.7 a	2.5 a	1184 a	22.0 a	26.0 a
	Control	5.2 a	1.6 a	1034 a	21.8 a	22.5 a
	Average	5.2	2.1	1204	22.1	26.6

[a] Mean values followed by the same letter in columns, within each previous soil use (winter crop or bare soil), are not significantly different by Tukey-Kramer HSD test ($\alpha < 0.05$).

were reduced. The slow release of N from D-CODER may have lowered the nitrification rate and consequently the accumulation of NO_3^- in soil, which are conditions that can reduce N losses during nitrification (Norton, 2008) and biological denitrification (Coyne, 2008). In the field, differences in soil nitrate levels between D-CODER and ANpreplant were not significant, likely due to the heavy rainfall that occurred in the week before sampling. Dry matter yields and N recoveries in winter forage were also similar in D-CODER and ANpreplant treatments. Dry matter yields and N recoveries in the final harvest in May were significantly higher in ANsplit than in any of the other treatments. It is well-known that splitting the N rate is one of the best ways to increase N use efficiency (Havlin *et al*., 2005; Raun and Schepers, 2008). The field results may also suggest that plant root activity solubilized N from D-CODER that was not readily absorbed by plants and, subsequently, leached out or denitrified.

In the pots where ryegrass was sown (or reseeded) after a long period of bare soil, N recovery was slightly higher in D-CODER than in ANpreplant pots, but the mean values were not statistically different. The results are attributed to greater N losses during nitrification and denitrification in ANpreplant pots, as discussed above. The results from the pots kept uncultivated suggest the presence of a persistent N fraction in D-CODER fertilizer that was not available in the absence of plants. It was probably the solubilization of this persistent fraction that explains the slight increase of N recovery observed in D-CODER pots in the experiment consisting of the late sown (or reseeded) ryegrass. Trends observed in the pots of late sowing were not confirmed in maize, probably due to the largest experimental variability and N losses during winter from all plots. Maize dry matter yields and N recoveries were higher in the plots kept uncultivated during winter in comparison with those previously cultivated with winter forage. In spite of the effect of winter rains on N losses, the residual fertility was slightly higher in the uncultivated plots.

The D-CODER fertilizer lowered N availability in the absence of plants until 65 DAFA. Seemingly, in the presence of plants, N was completely solubilized. Thus, fertilizers with the D-CODER technology seem to be best suited to situations where protection against leaching is needed only for the early phases of the growing season. These results suggest D-CODER technology is not effective after crop establishment and no gains occur over conventional fertilizers if the risks of N leaching and denitrification persist throughout the growing season. Splitting a conventional N fertilizer is a better strategy in those situations.

[DOR: 20.1001.1.16807073.2013.15.2.3.2]

ACKNOWLEDGMENTS

The authors thank Rita Diz and Ana Pinto for laboratory assistance and José Rocha for fieldwork. Financial support was provided by the Mountain Research Centre–Polytechnic Institute of Bragança.

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[DOR: 20.1001.1.16807073.2013.15.2.3.2]

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ارزیابی زراعی یک کود شیمیایی با فناوری D-CODER: سازو کاری نو برای کند رهایی عناصر غذایی

م. آروباس و م. آنجلیو رودریگز

چکیده

ماده D-CODER کودی شیمیایی است با سازو کاری نو برای کند رهایی عناصر غذایی که شامل ماتریکسی معدنی-آلی است و عناصر غذایی را فقط در حضور گیاه درحال رشد در محیط رها میسازد. مطالعه حاضر به منظور بررسی شیوه رها سازی نیتروژن از ماده مزبور در مزرعه و گلدان انجام شد. این آزمون در زمین کشت شده و زمین نکاشت پیاده شد. تیمار های کودی شامل کود D-CODER، نیترات آمونیوم (ANpreplant) و شاهد بود. تیمار چهارمی به آزمون در زمین کشت شده افزوده شد که شامل تقسیط نیتروژن به صورت ۲۵٪ در مرحله قبل از کاشت و ۷۵٪ به صورت سرک (ANsplit)

[DOR: 20.1001.1.16807073.2013.15.2.3.2]

بود. در گلدانهای بدون کاشت، ۳۵ روز بعد از افزودن کود، غلظت نیتروژن نیتراتی (NO_3-N) در عصاره غشاهای (ممبران) تبادل آنیونی که در خاک نگهداری و خوابانده شده بودند در تیمارهای نیترات آمونیوم (ANpreplant)، D-CODERو شاهد به ترتیب 82.5،118.5 و ۳۴.۵میلی گرم در لیتر بود و چنین نشان میداد که بخشی از نیتروژن D-CODER هنوز آزاد نشده بود. در گلدانهایی که در آنها رایگراس کشت شده بود، ۲۰۹ روز بعد از افزودن کود، باز یابی نیتروژن از D-CODER ، نیترات آمونیوم قبل از کاشت، و شاهد به ترتیب ۰.۹۴۰، ۰.۸۶ و ۰.۲ گرم در گلدان بود این نتایج اشاره میکرد که در حضور گیاه در حال رشد، آزاد سازی نیتروژن ازD-CODER محدود نشده بود. همچنین، در زمین نکاشت در آزمون مزرعه ای، مقدار نیتروژن نیتراتی خاک در تیمار-D CODER(برابر ۳۸.۱ و۶.۸ میلی گرم در کیلو گرم در نمونه برداری ماه نوامبر و مارچ) به طور معنی داری بیشتر از تیمار نیترات آمونیوم قبل از کاشت (برابر ۲۶.۳ و۵.۱ میلی گرم در کیلو گرم در نمونه برداری ماه نوامبر و مارچ) بود.بر این اساس، نیتروژن در کودD-CODER به صورت بهتری در برابر شستشو و تلفات عمقی محافظت شده بود. در غیاب گیاه در حال رشد، این کود تا حدودی از تلفات نیتروژن تا ۶۵ روزبعداز کوددهی محافظت کرده بود. در زمین کشت شده، به نظر میرسد که این کود تاثیر کمتری دارد به ویژه در شرایطی که خطرات شستشو ونفوذ عمقی برای دوره ای طولانی وجود داشته باشد. در چنین شرایطی مصرف تقسیطی نیتروژن راه کار بهتری است.

[DOR: 20.1001.1.16807073.2013.15.2.3.2]