332

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Fate of ammonium-N in pot studies as affected by DCD addition

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Abstract

In pot trials with spring wheat, the effect of the nitrification inhibitor dicyandiamide (DCD) in combination with ^{15}N-ammonium sulfate (AS) on yield, N-uptake and ^{15}N-distribution was investigated. The turnover of DCD was followed as well.

Wheat plants contained 88–90% of the added ^{15}N in grain and straw, 7% in the roots, and 3% remained in the soil.

Yields were reduced by up to 9% in DCD-treated plants, which was likely to be caused by their somewhat lower N-uptake. As the fertilizer application was based on equal N amounts, the balance is due to the uptake of (unlabelled) DCD. High root densities per volume of soil, high temperatures, and the repeated split application of DCD during early growth, favoured the uptake of unaltered (metabolically inactive) DCD which was deposited mainly in leaves or straw. The results are discussed in relation to the applicability of results of pot experiments with DCD to its performance under field conditions.

Introduction

In previous publications the effect of the nitrification inhibitor dicyandiamide (DCD) on the turnover of ^{15}N-ammonium sulfate (AS) in soils under aerobic and anaerobic conditions was investigated [2, 3, 4, 7, 8, 9].

In the following experiment the interactions and N balances of fertilizer nitrogen and the influence of the nitrification inhibitor on plants and soils were investigated by means of ^{15}N-labelled ammonium sulfate. In addition, the availability of nitrogen contained in dicyandiamide (ca. 67%) was studied.

Materials and methods

A mixture of a brown earth derived from loess (Dürnast), pH_{CaCl_2} 6.5, with washed quartz sand (5:2, w/w), was prepared and 7.5 kg filled in pots (diameter 20 cm, 20 cm high).

Spring wheat (*Triticum aestivum*, cv. 'Walter'), were seeded at 25 plants/pot and placed in the greenhouse. The following fertilizer rates were applied:

Basic fertilizer application/pot: 0.3 g N as KNO_3 were added immediately after emergence, 0.45 g P as $CaHPO_4$ was mixed with the soil, and 0.4 g K as K_2SO_4 and 0.2 g Mg as $MgSO_4 \cdot 7 H_2O$ were added as solutions.

^{15}N-fertilizer applications were as follows: 600 mg N were supplied at tillering and 900 mg N at the shooting stage. The control plants received ^{15}N–AS alone, whereas the treatment consisted of 90% ^{15}N–AS + 10% unlabelled DCD. The ^{15}N enrichment was over 90%. Plants were harvested after 17 weeks at full maturity.

Analytical methods (NH_4, NO_3, ^{15}N) were essentially as described earlier [5, 11] and the

total N in plants was determined acc. to Kjeldahl.

DCD content in percolate was measured colorimetrically [10, 11], while DCD in plants was determined as follows: plant material was extracted by homogenization in 80% methanol/water and subsequently purified by partitioning against diethylether (discard ether phase). The conditions for HPLC determination were: Shandon ODS II column, 250 × 4.6 mm, eluted with 2 mM tetrabutylammonium hydrogen sulfate +25 mM NaH_2PO_4 at a flow rate of 0.7 ml · min^{-1} and UV detection at 210 nm.

Results

One week after the final fertilizer application (900 mg N/pot at shooting) pots were percolated with ca. 1 l water/pot and analyzed for various N compounds. Per pot only 0.4 mg NH_4–N and a maximum of 1.7 mg NO_3–N were found in the leachate indicating that most of the supplied N had been taken up by the plants or immobilized.

In contrast, 29% of the supplied DCD were found still unaltered in the percolate. (After analysis, the percolation water was returned to the respective pots).

The yields of grain, chaff and straw were lower by 5 to 9% in the treatments with DCD (Table 1), grain N contents were lower, too. Despite the reduced dry matter yields in the DCD treatment, total N uptake by the vegetative parts was higher by about 60 mg. It has to be pointed out that this is mainly due to an accumulation of DCD. Straw contained 37.4% of the DCD, whereas in the grains 0.3% of the added DCD were recovered.

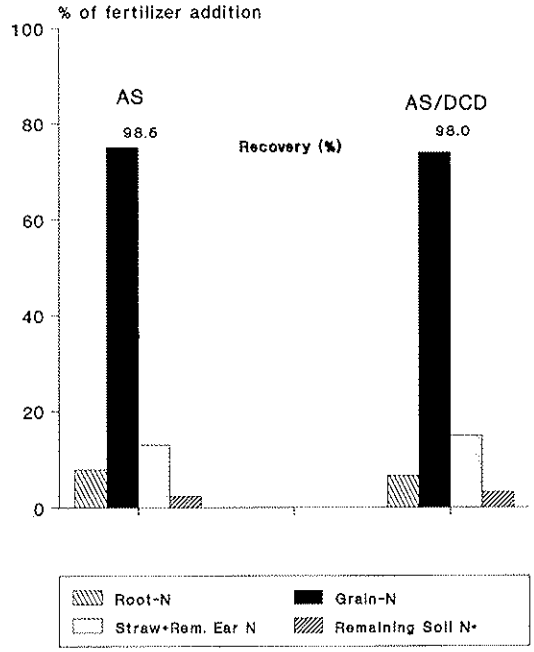

Fig. 1. Fate of ^{15}N labelled ammondium sulfate with dicyandiamide (spring wheat).

In roots, hardly any differences occurred, and no DCD could be detected there. The distribution of the labelled nitrogen in plants and soil was shown in (Fig. 1): Grains accumulated approximately 75% of the supplied AS–N, straw and chaff 13–15%; i.e. the above-ground parts contained as much as 88–90% of the applied ^{15}N fertilizer. The rest of it remained in the soil (3%) and roots (7%). The good utilization of the fertilizer N resulted from a quick uptake of N and low N supply of the soil-sand mixture used in these experiments.

Table 1. Yield and N uptake of spring wheat (cv. Walter), harvested at full maturity, in pot experiments under greenhouse conditions; fertilizer appication: AS = 1500 mg N as $(NH_4)_2SO_4$, AS/DCD = 1350 mg N as $(NH_4)_2SO_4$ + 150 mg DCD–N

Plant part	AS		AS/DCD	
	Yield (g)	N Uptake (mg)	Yield (g)	N Uptake (mg)
Grain	70.5	1358	67.2(2.9)*	1260(69)
Straw	75.6	299	69.7(5.1)*	357(47)*
Roots	32.9	241	30.8(2.8) n.s.	250(20) n.s.
Total	179.0	1898	167.7	1867

* LSD 0.05 in parentheses, n.s. = not significant

Discussion

In the experiments presented here, as in many others, the N contributed by DCD (67% N) is taken into account when calculating the fertilizer dosages. This might be, however, misleading in pot experiments with very high root densities per volume of soil. DCD can be absorbed by the plants via massflow and transported into above-ground parts. There it is deposited and may even be found crystallized esp. at the hydathodes (Wünsch, unpublished). Plant cells are, however, apparently unable to metabolize DCD (Hallinger, personal communication). Thus, even at harvest considerable quantities of unaltered DCD could be detected in the straw. The growing plants therefore had an almost 10% lower supply of 'metabolically active' N, corresponding to the amount of DCD–N in the fertilizer. Total N determinations, however, cover also (non-metabolised) DCD–N taken up by plants. This explains the almost identical N removal in treatments without and with DCD, but lower yields in the latter case.

The relatively high DCD uptake in pot trials (38% of the added amount) had several reasons:

1. High transpiration rates and high root densities in combination with an optimized water supply
2. Higher amounts of DCD (by 60–80%) in pot trials compared to field conditions
3. Relatively slow DCD decomposition in the soil-sand mixture of this experiment.

Thus, much lower DCD concentrations in harvested crops can be expected under field conditions as most of the DCD will be decomposed in the soil. Consequently, field grown cereals contained no DCD in the grain and only a few $\mu g/g$ in the straw (unpublished observations). This shows, that pot experiments may not reflect the behaviour of DCD under field conditions.

In the experiments described above, about 90% of the fertilizer ^{15}N have been incorporated by the plants, which is a very high efficiency. Efficiency rates reported in the literature vary widely [1, 6], which partly can be attributed to immobilization in the soil (fixed in clay minerals and/or incorporated into humic substances), leaching and/or gaseous losses.

Considering the different factors contributing to the N dynamics in soil, it should be stressed that the prediction of the effect of DCD on N-efficiency from pot experiments is only possible to a limited extent.

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