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Field experiments with slurry and dicyandiamide: response of potatoes and effects on soil mineral nitrogen

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Abstract

In the period 1983-1985, 18 field experiments with potatoes grown for industrial starch production were set up to investigate the effects of poultry-slurry application on tuber yield and on soil mineral nitrogen. Slurry was applied in autumn with and without the nitrification inhibitor dicyandiamide (DCD) and in spring without DCD. Control treatments without slurry or DCD were included. Various nitrogen fertilizer rates were applied to all slurry treatments. In autumn, following slurry application without DCD, slurry-derived nitrate moved to the 0.3-0.6 and to the 0.6-1 m soil layers. Following DCD-application, most of the slurry-derived nitrate remained in the 0-0.3 m soil layer. Maximum yields as estimated from a nitrogen fertilizer response function were slightly increased by the slurry. Nitrogen supplied from the slurry decreased the amount of fertilizer nitrogen needed for maximum yield. Increasing the amounts of soil mineral nitrogen in June from slurry or applied inorganic nitrogen fertilizer increased residual soil mineral nitrogen at harvest.

Keywords: potatoes, slurry, dicyandiamide, soil mineral nitrogen, nitrate leaching

Introduction

During the past decades the production of animal manures increased dramatically in the Netherlands and other parts of Europe, causing adverse environmental effects (De la Lande Cremer, 1970; Sluijsmans et al., 1978; Wadman et al., 1987; Neeteson & Wadman, 1990). Environmental problems caused by the spreading of animal manures on land depend on the amount of manure applied, the way it is applied and the time of application (e.g. Sluijsmans et al., 1978; Vetter & Steffens, 1981; Prins & Wadman, 1990).

To apply animal manures in spring rather than in autumn reduces the risk of the leaching of nitrate. Another possibility to reduce nitrate leaching following autumn application of animal manures is using the nitrification inhibitor dicyandiamide (DCD) (Amberger, 1986; Amberger et al., 1982; Amberger & Vilsmeier, 1988; Gutser & Amberger, 1984; Pain et al., 1987; Slangen & Kerkhoff, 1984; Vilsmeier & Amberger, 1987).

It has been observed that nitrification of slurry nitrogen may still be important at temperatures as low as about 2-6 °C (Flowers & O'Callaghan, 1983; Vilsmeier & Amberger, 1987; Thompson et al., 1987; Thompson, 1989). It was observed that nitrification in a flinty clay loam treated with farmyard manure for more than a century decreased sharply, when temperature decreased from 5 to 2.5 °C (Addiscott, 1983).

The rate of decomposition of DCD depends on temperature (Amberger & Vilsmeier, 1979; Slangen & Kerkhoff, 1984; McCarthy & Bremner, 1989). The effectiveness of DCD in preventing nitrate formation and hence nitrate leaching further depends on soil type (Slangen & Kerkhoff, 1984; McCarthy & Bremner, 1989). The pH of the soil is another factor which affects the inhibition of nitrification by DCD (Amberger & Vilsmeier, 1988). Furthermore, it has been observed that DCD is susceptible to leaching (Abdel-Sabour et al., 1990; McCarty & Bremner, 1989; Teske & Matzel, 1988). If DCD leaches faster than ammonium, the two may lose contact and the inhibition of nitrification will be less.

The value of organic manures in supplying nutrients and organic matter has long been recognized (Allison, 1973; De Haan, 1980). In arable farming in the Netherlands, animal manures are applied often to potatoes, because of the 'responsiveness' of this crop (Wadman et al., 1987).

However, chloride-containing fertilizers may adversely affect yield and quality of potatoes (Prummel, 1981). Therefore on sandy soils, potato growers prefer autumn application of animal manures rather than spring application, because then manure-derived chloride will largely be leached out.

From model calculations it has been concluded that at economic fertilizer application rates to potatoes, part of the nitrogen given with mineral fertilizers can accumulate as mineral nitrogen in the soil at the time of harvest (Neeteson et al., 1989). This was also concluded from evaluating data from the literature on nitrogen recovery by potatoes (Prins et al., 1988). Recently, it was proposed in the Netherlands to use the mineral nitrogen content in the upper metre of the soil profile in autumn as an indication of the risk of nitrate leaching during the subsequent winter period.

In this paper the results of 18 experiments with starch potatoes are described. The experiments were conducted in the period 1983-1985 in the northeastern part of the Netherlands. Effects on yield of the application of inorganic nitrogen fertilizer and the combination of these fertilizers with poultry slurry were examined. Effects on soil mineral nitrogen were evaluated. Slurry was applied in autumn with or without DCD and in spring without DCD. Part of the results from these experiments has been published earlier (De la Lande Cremer, 1986; Wadman et al., 1989, Wadman & Neeteson, 1992).

Materials and Methods

Description of experiments

In the period 1983-1985, six experiments with potatoes (*Solanum tuberosum*, L.) grown for industrial starch production were conducted annually at various locations

Table 1. Location, description of the soil and dates of planting and harvesting of the potatoes of the 18 field trials.

No	Location	Soil (0-0.3 m)		Year	Date of planting	Date of harvest	Cultivar
		pH	org.mat. (%)				
1	Grolloo	4.4	4.9	1983	Apr. 16	Oct. 12	Prevalent
2	Emmer-Compascuum	4.8	12.5	1983	Apr. 22	Oct. 19	Astarte
3	Borgercompagnie	5.0	22.7	1983	Apr. 15	Sep. 28	Prominent
4	Tweede Exloërmond	5.7	7.4	1983	Apr. 21	Oct. 20	Astarte
5	Veendam	4.7	7.8	1983	Apr. 20	Oct. 31	Prominent
6	Onstwedde	4.5	5.8	1983	Apr. 15	Sep. 20	Mentor + Astarte
7	Emmer-Compascuum	4.8	19.8	1984	Apr. 12	Oct. 26	Prevalent
8	Grolloo	4.6	6.2	1984	Apr. 13	Oct. 17	Astarte
9	Borgercompagnie	5.0	9.7	1984	Mar. 23	Oct. 17	Astarte
10	Tweede Exloërmond	5.2	13.7	1984	Apr. 10	Oct. 25	Prominent
11	Gasselte	5.2	6.3	1984	Apr. 4	Oct. 12	Prominent
12	Onstwedde	4.5	4.2	1984	Apr. 5	Sep. 26	Mentor
13	Borgercompagnie	5.3	13.5	1985	Apr. 19	Nov. 1	Astarte
14	Grolloo	4.0	7.3	1985	Apr. 20	Oct. 1	Prominent
15	Emmer-Compascuum	5.0	13.1	1985	Apr. 25	Sep. 19	Prominent
16	Tweede Exloërmond	5.0	21.7	1985	Apr. 19	Oct. 16	Astarte
17	Stadskanaal	4.6	13.1	1985	Apr. 19	Oct. 4	Prominent
18	Jipsingboertange	4.7	6.3	1985	Apr. 19	Oct. 23	Astarte

in the northeastern part of the Netherlands. The experiments were conducted on sandy soils differing substantially in organic matter content (Table 1). The sandy soils at the locations Emmer-Compascuum, Borgercompagnie, Tweede Exloërmond, Veendam and Stadskanaal were reclaimed from peatland 50-400 years ago: the peaty top layer was put aside and the underlying peat was removed. The top layer was then replaced onto, and mixed with, the subsoil (e.g. De Bakker, 1979).

At each site four treatments with poultry slurry were combined with six inorganic nitrogen fertilizer rates (calcium ammonium nitrate equivalent to 0, 60, 120, 180, 240 and 300 kg nitrogen per ha) according to a split-plot experimental design. The main plots (6 m × 36 m) received one of the slurry treatments: a) no slurry; b) slurry applied in late autumn; c) slurry applied in late autumn with DCD; d) slurry applied in spring (Table 2). The slurry was mixed and applied with a slurry tanker equipped with a computer-controlled application unit especially devised for the application of slurry on experimental fields (Schepers, 1978). On average 264, 263 and 179 kg nitrogen per ha were applied with the slurry in treatments b, c and d, respectively (Table 2). Following application, the slurry was incorporated into the soil as soon as possible to reduce nitrogen losses by ammonia volatilization. Within each main plot, the subplots (6 m × 6 m) received the above inorganic nitrogen fertilizer rates in spring.

The weather conditions during the winter seasons of the experiments are given in Table 3.

Table 2. Amounts and chemical composition of the slurry applied.

Year	Code	DCD	Slurry applied							
			period	amount ($t\ ha^{-1}$)	composition (%)					
					total N	min. N	P_2O_5	K_2O	Cl	org. mat
1982/83	b	–	Nov. 17/ Dec. 8	30.5	0.93	0.38	0.75	0.60	0.14	9.0
	c	+	Nov. 17/ Dec. 8	29.5	0.97	0.38	0.76	0.60	0.14	9.0
	d	–	Mar. 1/ Mar. 2	18.3	1.03	0.58	0.91	0.53	0.14	10.4
1983/84	b	–	Nov. 21/ Nov. 22	29.9	0.98	0.44	0.84	0.61	0.20	8.4
	c	+	Nov. 21/ Nov. 22	29.1	1.02	0.42	0.86	0.61	0.20	8.4
	d	–	Mar. 14/ Apr. 2	20.1	0.71	0.32	0.60	0.39	0.12	7.3
1984/85	b	–	Dec. 4/ Dec. 5	18.9	1.11	0.58	0.84	0.59	0.16	9.3
	c	+	Dec. 4/ Dec. 5	17.4	1.15	0.59	0.87	0.59	0.16	9.7
	d	–	Apr. 18/ Apr. 19	19.3	0.98	0.58	0.78	0.49	0.13	8.8

b: slurry applied in autumn without DCD. c: slurry applied in autumn with DCD. d: slurry applied in spring without DCD.

Table 3. Average temperature and precipitation during the winter seasons of the experimental period (weather station of KNMI at Eelde).

	Temperature (°C)			Precipitation ($mm\ month^{-1}$)		
	1982/83	1983/84	1984/85	1982/83	1983/84	1984/85
Nov.	7.2	5.9	6.7	52	54	68
Dec.	2.8	2.7	3.5	71	53	46
Jan.	5.6	2.7	−3.7	97	146	67
Feb.	0,1	1.0	−1.2	35	47	6
Mar.	5.2	3.0	3.5	91	57	56

Chemical analysis

Soil organic matter was determined following loss on ignition at 550 °C. The pH of the soil was measured potentiometrically in a suspension of 1 volume soil in 5 volumes 1 M KCl. Soil mineral nitrogen (nitrogen in the form of ammonium and nitrate) was determined in all slurry treatments at three nitrogen fertilizer rates, in three layers (0-0.3, 0.3-0.6, 0.6-1 m). It was determined in the autumn and the spring preceding slurry application at the treatments b and c and d, during the growing season of the potatoes and shortly after the harvest of the potatoes. During the first experimental year, at the first three experimental sites in Table 1 only the 0-0.3 and 0.3-0.6 m soil layers were sampled. In the last experimental year soil mineral nitrogen was determined more frequently than in the preceding years. For the determination of soil mineral nitrogen soil samples were first extracted with 1.0 M NaCl. The ammonium and nitrate contents of the extract then were analysed colorimetrically with an AutoAnalyzer (Ris et al., 1981). At each site, the bulk density of the soil was determined for each soil layer and was used to express the ammonium and nitrate contents of the soil in kg nitrogen per ha.

Slurry was analysed after a Kjeldahl destruction, using a mixture of Na_2SO_4 and $CuSO_4$ as a catalyst. In the destruction mixture total nitrogen and phosphorous were measured spectrophotometrically and potassium was determined flamephotometrically.

Slurry was extracted with demineralised water in the proportion 1 to 10, to determine the ammonium content spectrophotometrically and the chloride content potentiometrically. The organic matter content of the slurry was calculated from its dry matter and ash content.

Potato yields

At the end of the growing season subplots (3 m × 4.5 m) were harvested and tuber yield and the 'weight-in-water' of the tubers were determined. Farmers are being paid on the basis of the 'weight-in-water' (w) of the industrial potatoes, because it is a measure of the starch content of the tubers. The 'weight-in-water' is given by:

$$w = w_2 \times (5000 / w_1) \qquad (1a)$$

where w_2 is the weight (g) of w_1 g tubers (approximately 5000 g) immersed in water. The 'weight-for-payment' (Y_P in t ha^{-1}) is given by:

$$Y_P = Y_T \times (w - 100) / 300 \qquad (1b)$$

where Y_T is fresh tuber yield (t ha^{-1}). Equations 1a and 1b were derived empirically by the Dutch starch industry.

Description of crop response to nitrogen and statistical analysis

The yield response to fertilizer nitrogen input was described using a two segment broken stick function (Boyd et al., 1976; Schenk et al., 1989). It was assumed that the slope of the ascending branch of the yield response function was not affected by the slurry treatments within one field trial, leading to the following description of yield response:

$$Y_{p,i,j}(X) = \beta_{1,j} (X - \beta_{2,i,j}) + \beta_{0,i,j} \quad \text{if } 0 \le X \le \beta_{2,i,j} \qquad (2a)$$

and

$$Y_{p,i,j}(X) = \beta_{0,i,j} \qquad \text{if } X > \beta_{2,i,j}, \tag{2b}$$

with: $\beta_{0,i,j}$, $\beta_{1,j}$, $\beta_{2,i,j}$ regression coefficients estimated from non-linear regression analysis; i = index applying to the slurry treatments a, b, c, or d; j = index applying to the trial number 1-18; X = fertilizer nitrogen (kg ha^{-1}).

Residual variance of data on soil mineral nitrogen were tested for skewness and, if necessary, the data were transformed using the logarithmic function:

$$f(x) = \log(x+1) \tag{3}$$

where x denotes the untransformed variable. Then, the analysis of variance (ANOVA) was performed, using a split-plot design.

In the experiments 4-18 (Table 1) soil mineral nitrogen (0-1 m) at harvest ($Nmin_{harv}$) was correlated with soil mineral nitrogen (0-1 m) found previously in June ($Nmin_{June}$) according to the empirical model:

$$\log (Nmin_{harv}) = \alpha_0 + \alpha_1 \, Nmin_{June} \tag{4}$$

It was analysed whether a single regression function could describe this relationship (α_0 and α_1 are the same for each trial) or that differences between trials were significant in this respect.

Results

The course of soil mineral nitrogen during the winter period following slurry application in late autumn with or without DCD

In the autumn, shortly before slurry application, the average amounts of soil mineral nitrogen in the 0-1 m soil layer were 100, 93, 95 and 99 kg per ha (with a standard error of means of 3.5 kg per ha) at the plots receiving treatments a, b, c and d, respectively. In spring the soil was sampled prior to application of fertilizer nitrogen and slurry. For each soil layer the increase in soil ammonium-N from autumn to spring was calculated, averaged over the three years and referred to as the change in soil ammonium-N (Fig. 1A). Because of skewness, tests of significance were used on logarithmic transformed data (Equation 3). It appears that slurry application in late autumn (treatments b and c) increased soil ammonium-N in the upper soil layer in spring (significant at $p < 0.05$). Ammonium-N in the deeper soil layers is only slightly affected by slurry application. It also appears that the use of DCD increased the ammonium-N of the upper soil layer (compare treatments b and c in Fig. 1A; the difference is significant, $p < 0.05$).

The increase in nitrate-N (Fig. 1B) was calculated in the same way as the increase in ammonium-N. Probably mainly because of nitrate leaching, soil nitrate-N on the plots receiving treatments a, c and d decreased during winter (the increase in nitrate-

Apparently, following DCD application, hardly any slurry-derived nitrate-N was leached to the 0.3-0.6 and 0.6-1 m soil layers.

Soil ammonium and nitrate-N during the experimental period of 1984/85 on the plots receiving no fertilizer nitrogen

In the last year of the experiment soil mineral nitrogen was determined more frequently on the plots receiving no fertilizer nitrogen (Fig. 2). Because of skewness, the significance of effects was evaluated following a logarithmic transformation of the data (Equation 3). Shortly before slurry application in autumn (December 1984) small non-significant differences ($p < 0.05$) in soil mineral nitrogen were observed. In the following January and April mineral nitrogen in the upper soil layer of the slurry-treated plots (treatments b and c) was higher than in the untreated plots (treatments a and d). Nitrate-N and ammonium-N in the lower soil layers were the same on all treatments. When comparing the effects of the treatments b and c, it appears that there are no differences in the mineral nitrogen contents of the upper soil layer. For a great part, soil mineral nitrogen of the slurry-treated plots consisted of ammonium-N. The results suggest that in the winter of 1984/85 the application of slurry did not result in a movement of slurry-derived nitrate-N to the deeper soil layers and hence the addition of DCD did not have an effect on nitrate leaching.

The experimental conditions in 1984/85 differed from those of the other two winter seasons, because less slurry was applied and it was applied later in the season (Table 2). Moreover, temperature was lower and there was less precipitation after the slurry application. This may explain the differences between the average movement of nitrate-N after slurry application without DCD during the three winters and the movement during the winter of 1984/85.

Also in May differences in soil mineral nitrogen between the DCD-treated slurry and the autumn-applied slurry without DCD were small and not significant ($p < 0.05$).

In June the ammonium contents of the plots receiving slurry with DCD were higher than the plots treated with slurry without DCD, thus it can be concluded that DCD had until then retarded the nitrification process in the upper soil layer (Fig. 2). In June soil mineral nitrogen is at its maximum, because of nitrogen mineralization and slurry application before that time. From June to July soil mineral nitrogen decreases because of nitrogen uptake by the crop (Fig. 2). In July no differences in soil ammonium-N contents of the various slurry treatments could be observed (Fig. 2).

At harvest, the ammonium contents of the soil are low and no effects of slurry application were present. On average, the three soil layers of the slurry-treated plots had higher mineral nitrogen contents than those of the plots without slurry. Apparently, the potatoes were not able to take up all of the soil mineral nitrogen supplied by the slurry.

Effects of slurry and fertilizer N on tuber yield

The fitted yield responses of trial number 1 are given in Fig. 3. At the other sites si-

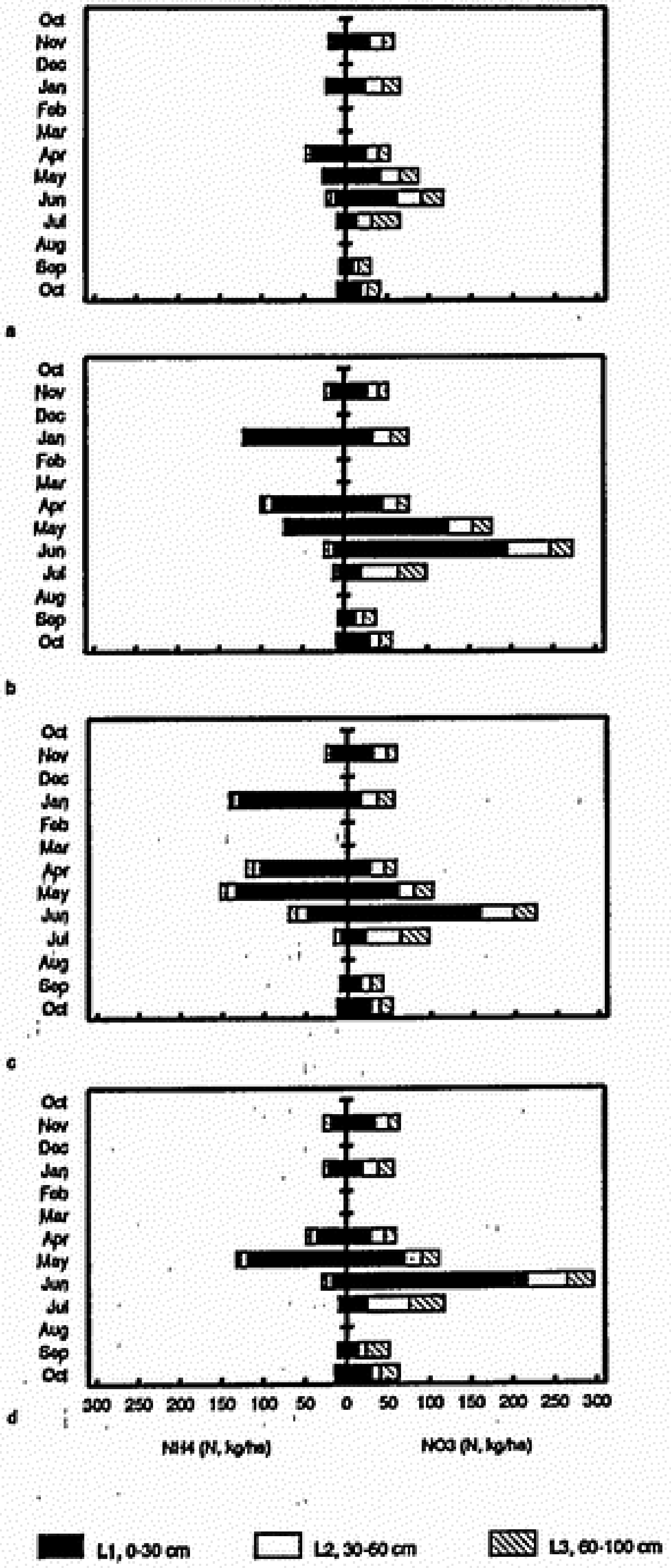

Fig. 2. Mean ammonium and nitrate contents (calculated over six trials) of three soil layers (L1-L3) on plots receiving no fertilizer N in the 1984/85 experimental season following: no slurry application (a); slurry application in autumn without DCD (b); slurry application in autumn with DCD (c); and spring application of slurry without DCD (d).

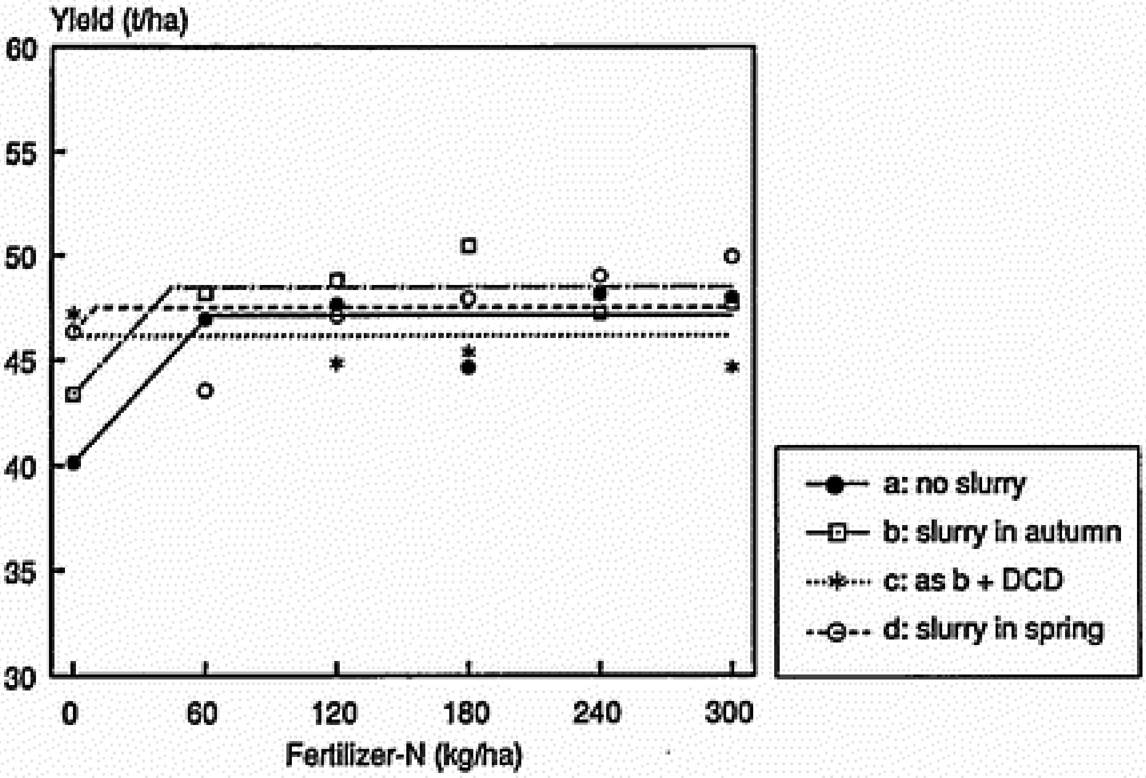

Fig. 3. Yield response of potatoes to fertilizer nitrogen and slurry (Experiment 1 in Table 1).

milar yield response curves were calculated. Maximum crop yield ($Y_{P,i,j}$ Equation 1b) and the optimum fertilizer nitrogen application rate ($\beta_{2,i,j}$ Equation 2b) were determined (Table 4). In Table 4 data on maximum yields as well as on optimum nitrogen fertilization rates are mutually dependent within a single trial. Therefore, significance of treatment effects was not assessed by using ANOVA, but on the appropiate effect per trial a paired t-test was performed (with 17 degrees of freedom). Yields at the optimum level of fertilizer nitrogen application were increased, on average, by about 1 t ha^{-1} following slurry application (Table 4; significant, $p < 0.05$). The optimum application of fertilizer nitrogen was reduced with the application of slurry (Table 4). It can be seen that in 10 of the 18 trials no fertilizer nitrogen was necessary to obtain the maximum yield on the plots receiving the DCD-treated slurry. The effects of DCD on the optimum amount of fertilizer nitrogen were not significant (Table 4; $p > 0.05$). On average, the slurry treatments reduced the optimum amount of nitrogen fertilizer by 72, 87 and 65 kg ha^{-1} for treatments b, c, and d respectively (Table 4). This corresponds to 27 ($= 100 \times 72 / 262$), 33 ($= 100 \times 87 / 263$) and 36% ($= 100 \times 65 / 179$) of the slurry nitrogen, applied in autumn without DCD (b), applied in autumn with DCD (c) and applied in spring without DCD (d), respectively.

Relationship between soil mineral nitrogen in June and soil mineral nitrogen at harvest

The soil mineral nitrogen (0-1 m) contents of 15 trials (numbered 4-18 in Table 1) in June and at harvest time are given in Fig. 4. First soil mineral nitrogen at harvest was related to soil mineral nitrogen in June with identical α_0 and α_1, respectively. By linear regression analysis it was found that the residual variance could be significantly

Table 4. Estimated maximum yield and optimum nitrogen fertilizer rate in 18 trials (Table 1) following non-linear regression analysis using a two segment broken stick yield response function to nitrogen fertilizer input. Yield is expressed as weight-for-payment.

No	Maximum yield (t ha^{-1})				Optimum N-fertilizer rate (kg ha^{-1})			
	a	b	c	d	a	b	c	d
1	47.1	48.5	46.2	47.5	61	44	0	10
2	70.1	68.2	69.6	68.9	187	0	0	0
3	77.7	78.6	81.8	79.9	194	79	11	86
4	44.2	51.7	52.0	49.4	189	173	142	138
5	47.3	47.3	50.7	48.9	171	67	0	0
6	52.1	52.6	50.1	52.8	196	134	64	160
7	66.5	63.8	68.3	66.1	239	18	96	132
8	40.4	40.6	42.5	41.8	0	0	0	0
9	63.1	64.4	64.3	64.1	134	0	0	0
10	54.1	54.0	55.2	55.9	31	0	0	0
11	45.6	46.1	44.7	43.0	194	121	16	134
12	67.6	70.2	71.6	66.7	84	20	0	30
13	62.9	65.2	61.7	65.2	0	0	0	0
14	45.5	47.0	46.1	44.9	0	0	0	0
15	76.2	77.7	79.2	76.7	58	9	52	2
16	69.4	71.9	75.7	67.7	82	27	64	23
17	58.3	58.8	58.3	58.8	130	38	0	72
18	76.0	74.7	76.2	73.7	83	15	24	74
Mean	59.1	60.1	60.8	59.5	113	41	26	48

a: no slurry applied. b, c and d: slurry treatments as in Table 2.

reduced ($p < 0.01$) by using a different α_0 and α_1 for each trial. In such a way 15 curves were calculated each representing the expected relationship between $\text{Nmin}_{\text{June}}$ and $\text{Nmin}_{\text{harv}}$ at a trial. In Fig. 4 the vertical bars represent the range of expected values of $\text{Nmin}_{\text{harv}}$ as found in the 15 trials at given $\text{Nmin}_{\text{June}}$. The processes that cause the wide range found at the level of $\text{Nmin}_{\text{June}}$ of 450 kg ha^{-1} have not been quantitatively determined. From Fig. 4 it is concluded that $\text{Nmin}_{\text{June}}$ is a poor predictor of $\text{Nmin}_{\text{harv}}$ in these trials. It appears, however, that at low $\text{Nmin}_{\text{June}}$ (i.e. at values less than 150 kg ha^{-1}) $\text{Nmin}_{\text{harv}}$ is also relatively low.

Discussion

In the experiments described in this paper it was found that the soil ammonium-N contents during early summer were increased after spring application of slurry and calcium ammonium nitrate. It can thus be concluded that nitrification proceeded rather slow. Probably this was caused by the soil pH, which, compared with other arable soils in the Netherlands, is rather low (Table 1). It has long been recognised that a low pH reduces the rate of nitrification in soil (Alexander, 1965). In more recent literature examples can still be found (Beck, 1979; Bock, 1980; Flowers & O'Callaghan, 1983; Gilmour, 1984; Goodroad & Keeney, 1984; Terry et al., 1981).

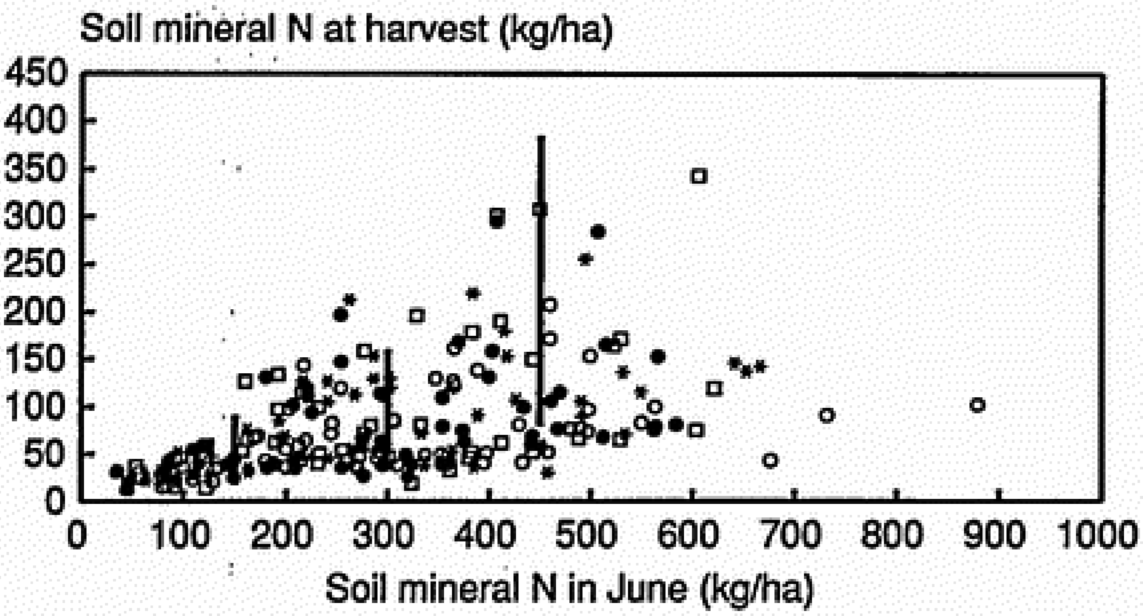

Fig. 4. Relationship between soil mineral nitrogen in June ($\text{Nmin}_{\text{June}}$) and at harvest ($\text{Nmin}_{\text{harv}}$) in 15 experiments (Experiments 4-18 in Table 1). By regression analysis, for each trial a single relationship was estimated between $\text{Nmin}_{\text{June}}$ and $\text{Nmin}_{\text{harv}}$. The vertical bars represent the range of estimates of $\text{Nmin}_{\text{harv}}$ of the 15 experiments at three values of $\text{Nmin}_{\text{June}}$.

However, Cooper (1975) observed that, following the application of pig slurry, a medium loam with pH 5.8 showed a higher nitrification rate than a sandy loam with pH 7.1. He attributed this to the accumulation of nitrite in the soil. Fumigation practiced at some of the fields described in the present paper may further explain the slow process of nitrification observed in our experiments (Lebbink & Kolenbrander, 1974).

As compared with the no-slurry treatment, the application of DCD- treated slurry in late autumn had a similar effect on the decrease of nitrate-N in the 0.3-0.6 and 0.6-1.0 m soil layers (Fig. 1B). Therefore, it is unlikely that nitrate leaching was substantially increased by the application of slurry with DCD in autumn. Apparently, DCD inhibited nitrification sufficiently, although DCD probably leached through the soil profile and, at least partly, lost contact with the ammonium (Abdel-Sabour et al., 1990; McCarty & Bremner, 1989; Teske & Matzel, 1988). It was found that after application of DCD-treated slurry to two soils differing in pH but with comparable texture and organic matter content, nitrification in the soil with pH 5.7 proceeded slower than in the soil with pH 7.2 (Amberger & Vilsmeier, 1988). This may be the reason that in our field experiments DCD behaved rather favourable in preventing nitrate leaching. Therefore, on light textured soils with comparable conditions, but with higher pH values the inhibiting effects of DCD could be less than in our experiments.

In a previous study, based on the same experiments, described in the present paper, DCD did not increase soil mineral nitrogen in spring (Wadman et al., 1989). It seems, therefore, that evaluating the effects of DCD from the total soil mineral nitrogen content in spring, is less suitable than from the distribution of nitrate in the soil profile, because part of the ammonium may be immobilized in the soil biomass, and not detected during analysis for soil mineral nitrogen. Similar results were found elsewhere, as slurry treated with DCD applied to a loess-soil resulted in an increase (as compared with the application of slurry without DCD) of ammonium-derived nitrogen in forms not available for extraction (Amberger, 1986) and, furthermore, additional immobilization of nitrogen in soil was observed using ^{15}N-labelled urea and ammonium sulfate-nitrate following the addition of DCD (Amberger & Vilsmeier, 1982).

Because soil mineral nitrogen was increased later in the growing season and the potatoes responded to the extra nitrogen (Wadman et al., 1989) the conclusion is confirmed that DCD decreased nitrate-N leaching.

The use of potassium sulfate as potassium fertilizer as compared with potassium chloride may increase starch content and tuber yield of industrial potatoes (Prummel, 1981). In the experiments described the slurry applied in spring contained on average 0.13% Cl, and approximately 26 kg chloride per ha was applied. Over a wide range of nitrogen fertilizer levels tested, no yield depressing effects of the spring-applied slurry could be observed. Apparently, the amount of Cl applied was too low to give depressed yields.

Soil mineral nitrogen levels in June correlated well with the amounts of slurry and fertilizer nitrogen applied (Wadman et al., 1989). As soil mineral nitrogen levels at harvest strongly increased with increasing soil mineral nitrogen in June (Fig. 4) and as optimum fertilizer applications were rather low as compared with the nitrogen fertilizer rates applied (Table 4), the levels of nitrogen applied with slurry and fertilizer in these experiments were frequently too high from both an economic and an environmental point of view.

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