Ammonia Band Spacing Effects on Ammonium Persistence in the Band

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Abstract

Results from four field experiments (1991 and 1992) showed that anhydrous ammonia (AA) concentration in the band increased NH_4-N persistence in the Hord and Sharpsburg soils in 1992, but not in the Cass and Zook soils in 1991. In 1992, average half-life across both soils was increased from 14 days when applied in a 38 cm spacing to 66 days when applied in a 152 cm spacing (every other row) at the high application rate (224 kg N ha^{-1}). A half-life of 66 days indicates 25% of the applied AA would be present in the ammonium form 132 days after application. Thus, "every other row AA" spacing could provide a low cost management practice that could potentially compare to or be superior to presently used nitrification inhibitors.

Introduction

Injection of anhydrous ammonia (AA) into the soil results in NH_4-N distribution in a localized circular shaped band along the line of injection. The size and NH_4-N concentration on the AA band varies with application rate, soil physical conditions, organic matter content and band application spacing. High AA concentrations, which cause very high pH in the band area are often considered to be inhibitory to nitrification, keeping the fertilizer N in the NH_4-N form for a longer period of time compared to lower concentrations. Keeping N in the NH_4-N form is generally believed to increase fertilizer N efficiency by reducing movement of NO_3-N to deeper soil depths and/or denitrification losses. Since increasing AA application band width (at the same application rate) results in increased AA concentration in the band, knife spacing is a management tool that could have potential for increasing fertilizer N efficiency. This assumes increased knife spacing does not negatively affect crop yield. Increased knife spacing for applying AA could be a low cost management tool similar to nitrification inhibitors.

This report discusses only the effects of AA knife spacing on NH_4-N persistence. However, irrigated corn grain yields were also obtained on the four soils in this report. Grain yields were significantly higher when AA was applied in 38 and 76 cm spacings compared to 152 cm on the coarse textured soil (Cass fsl) studied. There was no effect of AA knife spacing on corn grain yields when applied to fine textured soils. There may have been greater AA application losses when applied in the wide spacing (every other row) in coarse textured then in the fine textured soils. Yield data, therefore, indicated that AA can likely be successfully applied in every other row for irrigated corn without affecting grain yields.

Objectives

To evaluate the persistence of ammonium in the AA band as affected by concentration of applied AA and to compare AA application spacing on N distribution the soil profile after harvest.

Methods

Field experiments with center pivot irrigated corn were conducted on four soils in 1991 and 1992, (Cass fsl and Zook sicl in 1991; Hord sil and Sharpsburg sicl in 1992). Experiments had four AA rates plus a check (56, 112, 168 and 224 kg N ha^{-1}) applied in knife spacings of 38, 76 and 152 cm. Ammonium nitrate (AN) was applied at similar rates as a standard for comparison. Treatments were applied in 12 m long x 3 m wide plots with 0.72 m rows. All cultural practices of planting, herbicide and insecticide application and irrigation were conducted by the cooperating farmer. AA and AN treatments were applied immediately after planting. AA was knifed approximately 15-20 cm deep, parallel to the row with a field applicator calibrated at each knife outlet by weighing AA released in water at timed intervals. Soil samples were taken at 7.5 cm depth intervals to a depth of 37.5 cm in two replications with a hand probe guided by a steel template with 13 horizontal sampling locations 2.5 cm apart (Fig. 1). Samples were taken three times at 25 day intervals starting June 6, 1991, and four times in 1992, (May 18, May 26, June 4, June 22). Residual soil N was determined from composite samples taken after harvest in 1991 (Fig. 2).

Data was evaluated by fitting NH_4-N and NO_3-N concentrations in the band area to a normal distribution function. This model provided parameters "A" and "B" which are related to the height (A) and spread (B) of the distribution. Areas under the normal distribution curves were calculated and a first order kinetic model was fitted to the data ($N_t = N_o e^{kt}$) to determine the rate constant (k), of NH_4-N disappearence. Diffrences in the rate of NH_4-N disappearences were tested by evaluating homogeniety of slope for the linearized first order equation. Half life of the band was calculated as 0.693/k.

Results and Discussion

Cass and Zook Soils (1991)

The normal curve functions used to fit the NH_4-N and NO_3-N concentrations in the Cass and Zook soils is shown in Fig. 3. The analysis of variance for the A parameter (height of the distribution or maximum NH_4-N concentration) and B (width of the distribution) are shown in Table 1. It is readily apparent that the NH_4-N concentrations were significantly higher in the Cass than the Zook soil 25 days after AA application, especially at the higher application concentrations. The 37, 75 and 149 kg ha^{-1} knife application concentrations conform to the 38, 76 and 152 cm spacings, respectively, at the 224 kg ha^{-1} N rate (Table 2). However, while the concentration of NH_4-N was much higher in the band area in the Cass soil, the width of the band was much greater in the Zook soil (smaller B) especially at the wide spacing (high application concentration) for the first sampling (Table 3). To test persistence of the NH_4-N in the band the area under the normal curves (NH_4-N Index) was plotted as a function of time after N application (Fig. 4 and Table 4). Results indicate the rate of NH_4-N disappearance from the band area was significantly faster in the Cass than the Zook soils even through NH_4-N was moved horizontally to greater distances from the injection point in the Zook soil. It is believed that the Zook surface soil probably remained saturated with water, because of high clay content in the B horizon, which prevented rapid drainage. While this allowed NH_4-N to diffuse rapidly in the free soil water, lack of oxygen probably prevented as rapid nitrification as in the Cass soil. Calculated half-lives averaged 48 days for the Zook, compared to 18 days for the Cass soil. However, there was no evidence that increased AA concentration in the band area affected nitrification or disappearance of NH_4-N.

Hord and Sharpsburg Soils (1992)

Since much of the NH_4-N seemed to disappear from the injection area by 75 days in 1991, the soil sampling period was reduced in 1992 to 12, 19, 27 and 43 days after N application. Figure 5 shows that the peak concentration was higher in the Sharpsburg than the Hord soil probably because the band width was greater at high concentrations in the Hord soil. However, NH_4-N disappeared faster from the Sharpsburg soil, especially at high AA concentrations (Fig. 6 and Table 4).

Contrary to the findings in 1991, there was a significant effect of increasing concentration in delaying apparent nitrification in both soils in 1992 (Table 4). While NH_4-N half-life varied in the two soils, half-life was increased (on average across soils) from 14 days when applied in a 38 cm spacing to 66 days in a 152 cm spacing. Half-life was especially greater on the Hord (88 days) compared to the Sharpsburg (45 days) at the high application concentration (149 kg ha^{-1} knife or 224 kg N ha^{-1} applied in 152 cm spacing).

Results indicate that increasing knife spacing to every other row (152 cm) could potentially increase NH_4-N persistence to provide an NH_4-N presence throughout the growing season. A half-life of 66 days would indicate 25% of the applied N would be present in the ammonium form 132 days after application. This would provide at least equal if not better ability to delay nitrification compared to presently used nitrification inhibitors, which have reported half-lives from 20 to 30 days.

Residual Soil N Distribution (after harvest)

If fertilizer N could be maintained for a longer period of time in the NH_4-N form, leaching and denitrification losses should be theoretically reduced. Therefore, more carryover N should be maintained in the surface layers of the soil where it is generally more available than deeper in the soil profile. However, soil samples taken to a depth of 150 cm in the Cass and Zook soils indicated that AA spacing had no effect on residual NO_3-N or NH_4-N in 1991 (Fig. 7). A wet fall prevented taking soil samples in 1992.

Table 1. Analysis of variance on estimated model parameters(A and B) for the NH_4-N distributions in Cass and Zook soil (1991) and Hord and Sharpsburg soil (1992).†

Source of Variation	1991 df	1991 A	1991 B	1992 df	1992 A	1992 B
			Pr > F			
Soil (S)	1	.001	.03	1	.02	.49
Conc. (C)‡	3	.46	.33	3	.04	.68
Time (T)	2	.43	.62	3	.14	.32
C x S	3	.001	.08	3	.02	.01
S x T	2	.001	.17	3	.002	.12
C x T	6	.47	.49	9	.32	.56
S x C x T	6	.001	.01	9	.01	.30

† A and B are model parameters related to the height (A) and spread (B) of the NH_4-N and NO_3-N distributions as calculated from the normal curve model (Soil N distributions are shown in Fig. 3 and 5).
‡ Conc. (C) = Applied NH_3 concentration

Table 2. Rate equivalent N concentrations as a function of knife spacing.

N Rate	Knife spacing (cms) 38	76	152
kg N ha^{-1}	kg N ha^{-1} knife^{-1}		
0	0	0	0
56	9	19	37
112	19	37	75
168	28	56	112
224	37	75	149

Table 3. Means for estimated model parameters (A and B) as influenced by soil, concentration and time after N application.† Nebraska 1991-92.

Time‡	1991											
	Zook sicl						Cass fsl					
	AA Concentration kg ha^{-1} knife^{-1}											
	37		75		149		37		75		149	
	A	B	A	B	A	B	A	B	A	B	A	B
25	14	-.0151	19	-.0750	16	0.0849	25	-.0295	103	.4769	141	.3599
50	12	-.0600	13	0.0570	11	0.0610	4	0.1090	6	.2070	19	.1550
75	11	0.1090	11	0.0015	13	-.1200	5	-.0068	5	.1281	7	.1208
	1992											
	Sharpsburg sicl						Hord sil					
12	361	.6664	387	.6113	756	.3659	250	.7956	288	.5493	560	.4834
19	165	.6942	628	.6031	805	.4834	120	.6503	170	.3077	397	.5851
27	107	.4343	185	.8680	782	.4188	-	-	-	-	-	-
43	27	.2824	311	.3633	17	.0535	11	.1347	25	.6472	286	.4275

† A and B are model parameters related to the height (A) and spread (B) of the NH_4-N and NO_3-N distributions as calculated from the normal curve model (Soil N distributions are shown in Fig. 3 and 5).

‡ days after N application

Table 4. Analysis of covariance on NH_4-N Index data across soils to test for the equality of regression coefficients (Slope) on the linearized first order equation.†

Source of Variation	df	1991	1992
		Pr > F	
Intercepts			
Soil (S)†	1	.47	.33
Concentration (C)	3	.41	.05
S x C	3	.69	.02
Average Slope (Time)	1	.01	.01
S	1	.09	.21
C	3	.76	.01
S x C	3	.99	.01

† Cass and Zook soils (1991) and Hord and Sharpsburg soils (1992).

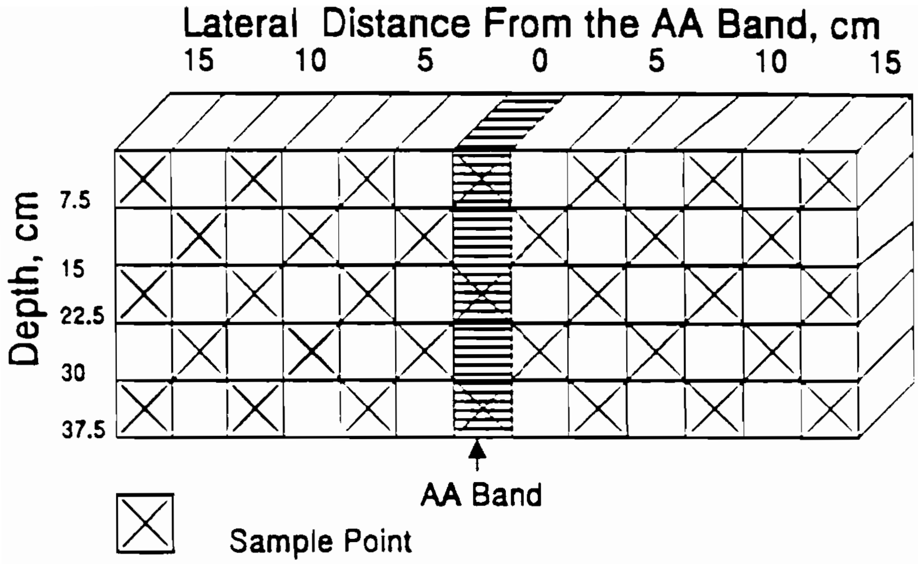

Fig. 1. Band sampling scheme illustrated on the template with 13 sampling locations 2.5 cm apart along the top axis.

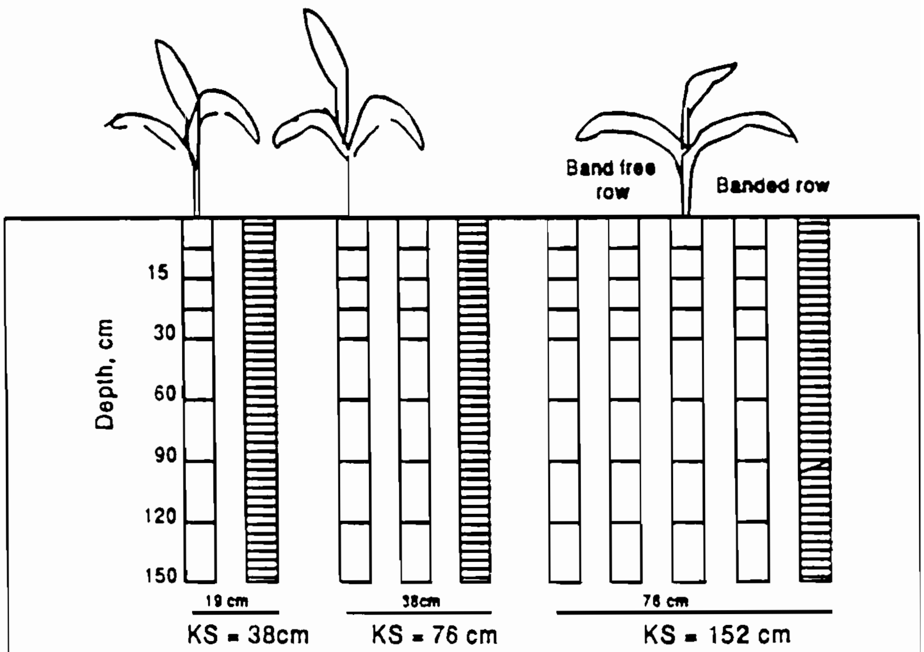

Fig. 2. Sampling for residual soil-N in the fall according to band spacing. The shaded area represents the AA band for the respective KS.

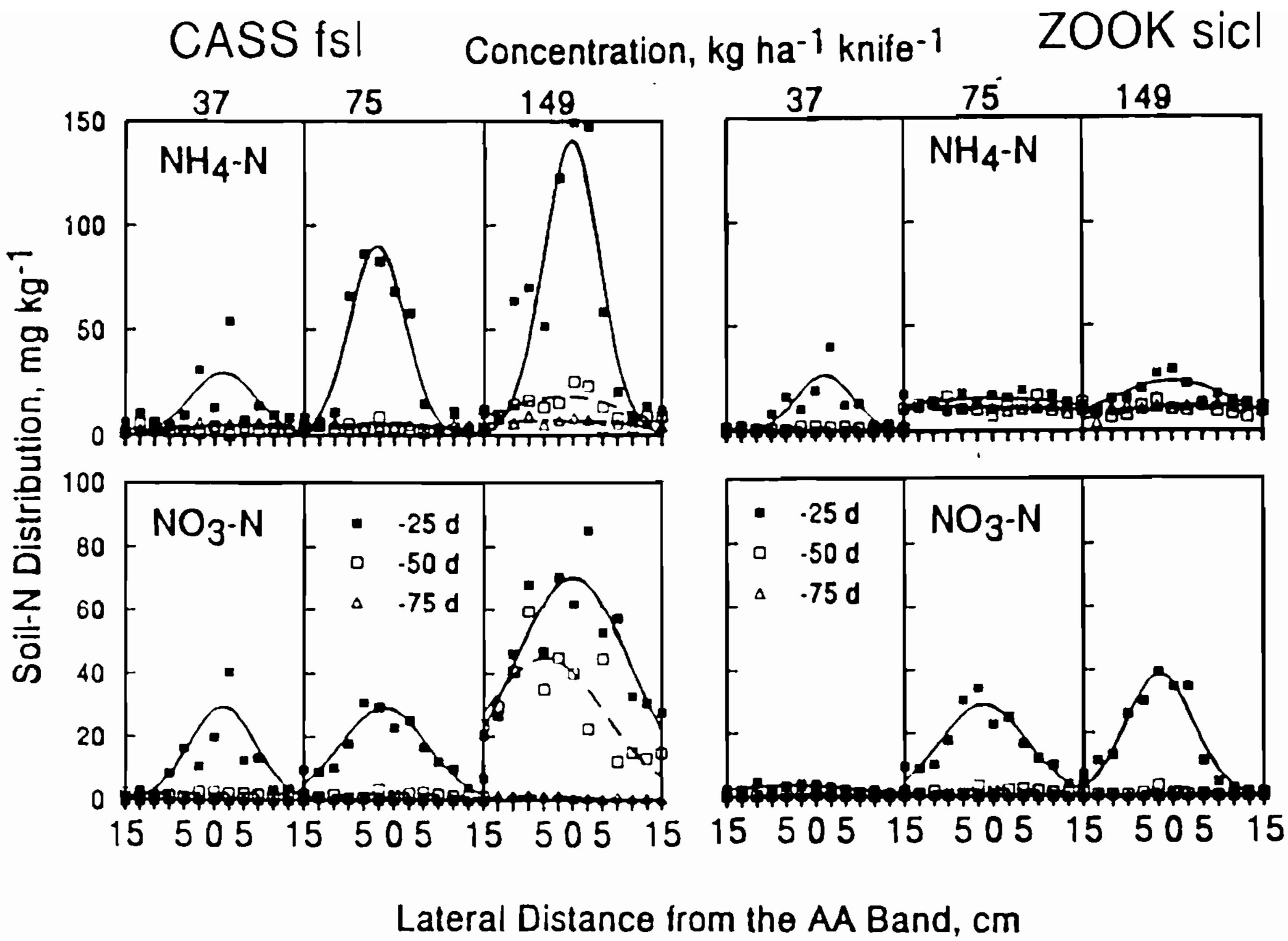

Fig. 3. Soil-N distribution in a Cass fsl and Zook sicl as affected by applied N concentration and different intervals from the time of N application. Nebraska 1991.

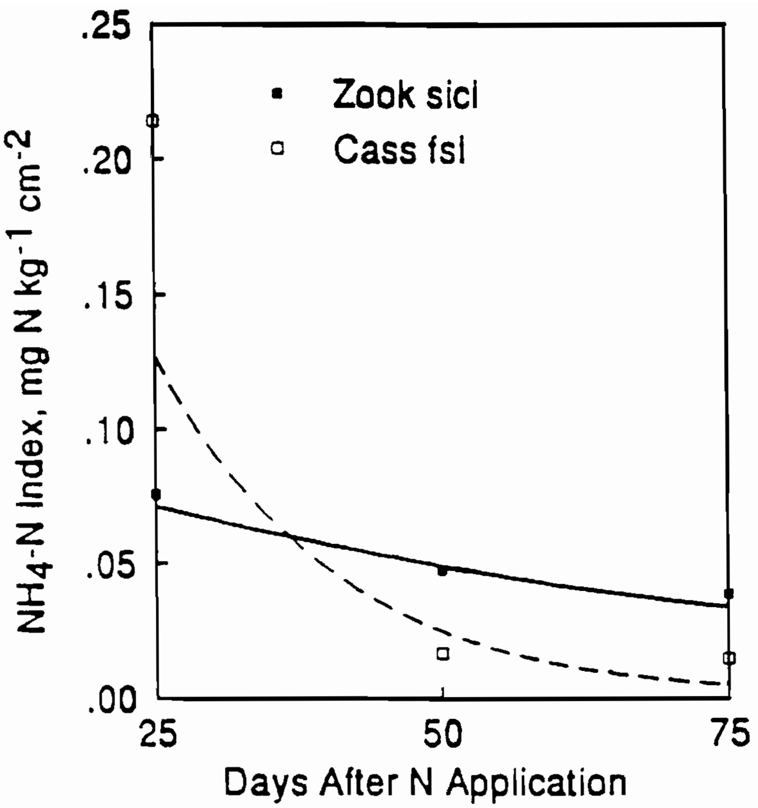

Fig. 4. The rate of change in the NH_4-N index with time after N applicatioon in a Zook sicl and Cass fsl soils averaged over concentration. Nebraska 1991.

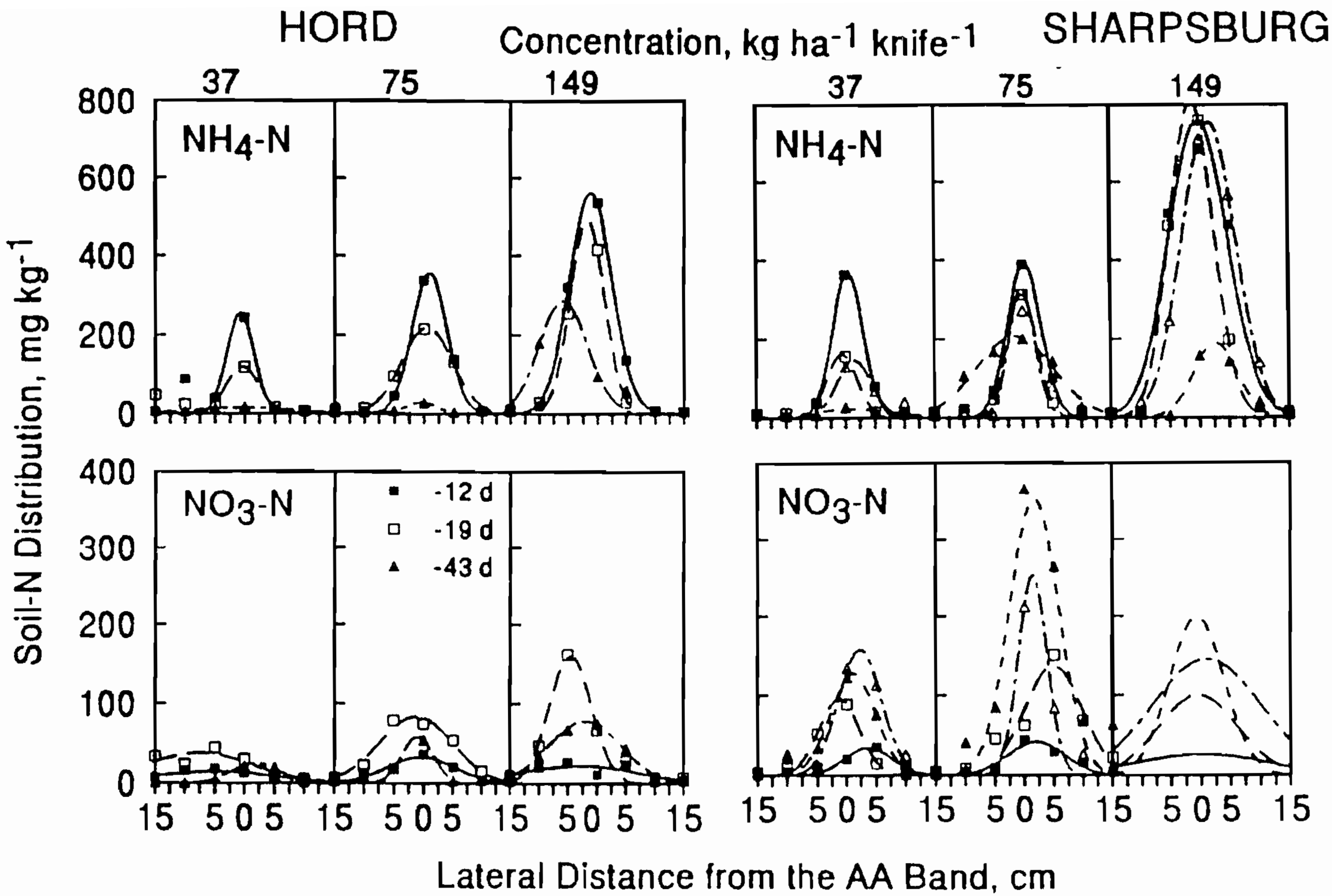

Fig. 5. Soil-N distribution in a Hord sil and Sharpsburg sicl as affected by applied N concentration and different intervals from the time of N application. Nebraska 1992.

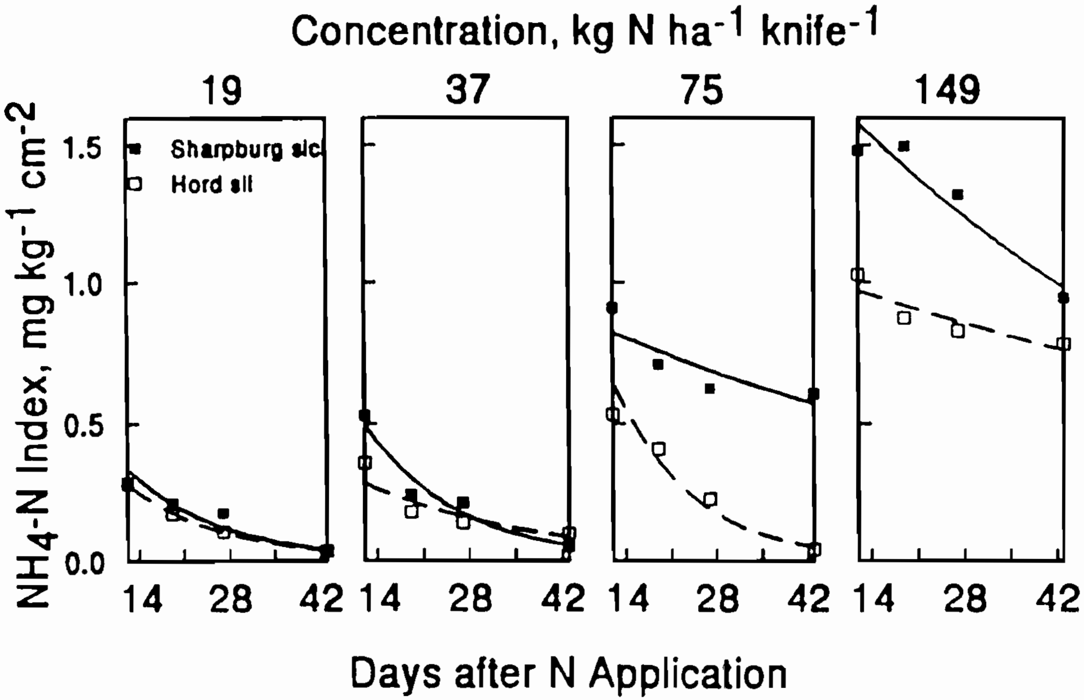

Fig. 6. The effect of concentration on NH_4-N index as a function of time after N application in a Sharpsburg sicl and Hord sil soils. Nebraska 1992.

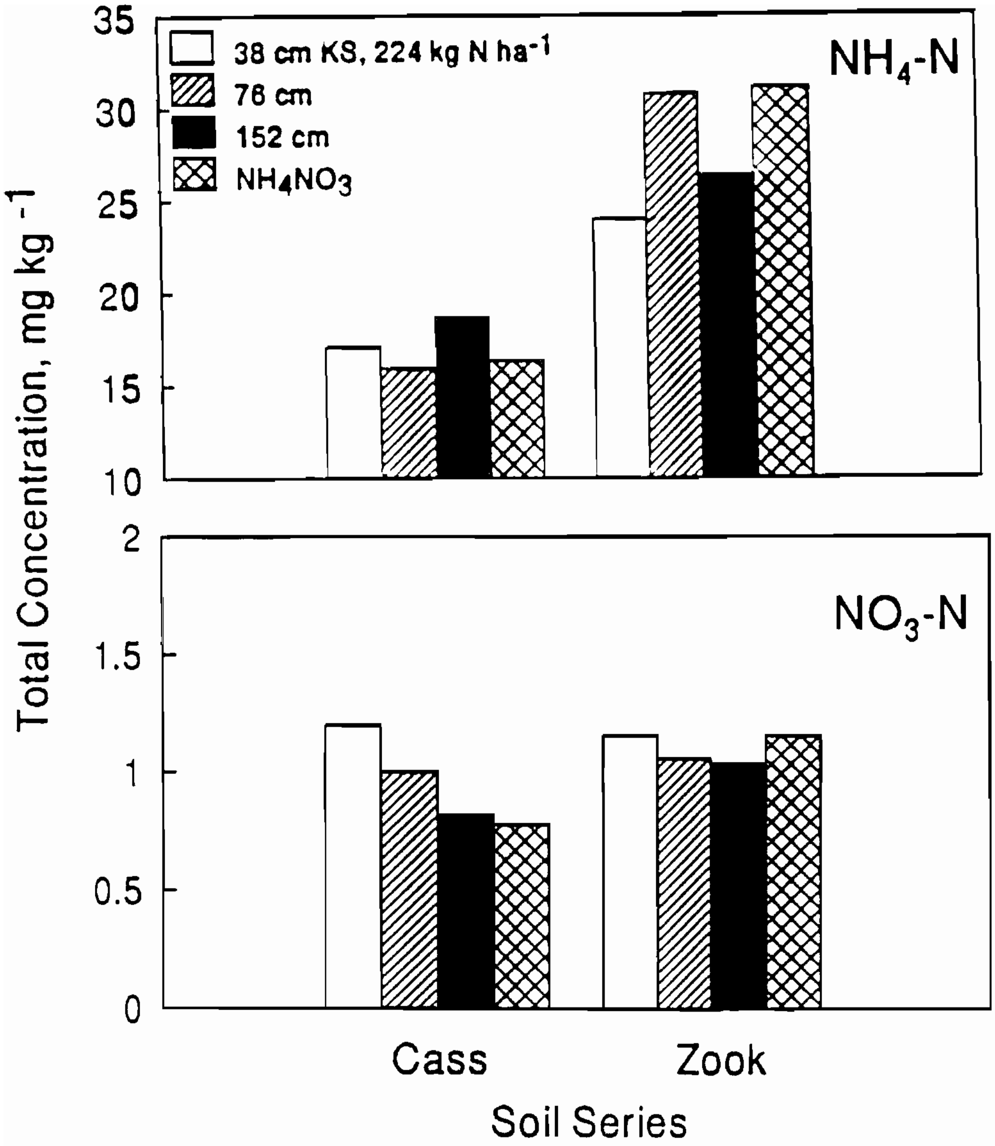

Fig. 7 Residual NH_4-N and NO_3-N as affected by anhydrous ammonia application spacing and NH_4NO_3 in Cass and Zook soils. Nebraska 1991.

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