FERTILIZING EXPERIMENTS WITH ANHYDROUS AMMONIA AT KOTKANIEMI

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Abstract. On spring cereals and in fertilization in connection with the sowing of winter cereals the effectiveness of ammonia is comparable to that of calcium ammonium nitrate. In tests that were arranged at Rikkihappo Oy's experimental farm Kotkaniemi it was established that anhydrous ammonia given in connection with spring cereal fertilization and autumn cereal earthing is equal to CAN in effect. 16 tests were carried out during a period of five years using placement fertilization the soil being silty clay in most cases. Differences did not occur in the grain yield, the 1000-grain number hl-weight or in the protein content of the grain crop. Urea proved to be less effective than the two other fertilizers.

The usage of anhydrous ammonia as a straight nitrogen fertilizer had a good start in the USA in the 1950's. This method of using nitrogen in an anhydrous form has also been investigated in many European countries, namely France, England, and Denmark (Anon. 1968). Especially in Denmark the usage of ammonia has increased rapidly, and in 1967—68 about 95 000 tons of anhydrous ammonia was used rapidly as a fertilizer (Anon. 1969), and the figure is still going up.

Anhydrous ammonia (NH_3) contains 82.2 % nitrogen (N). Ammonia is usually a gas but under sufficient pressure it is possible to keep it liquid. While the temperature varies from 0° to + 30° C the necessary pressure varies within 3.4 to 10.9 kg/cm². Owing to this, the ammonia storage and transport equipment have to meet certain requirements. When the ammonia is discharged from the application equipment it immediately turns into gas and gets fixed into the soil.

The only application method for ammonia is injection. In its effectiveness as a fertilizer ammonia has proved to be equal to other nitrogen fertilizers (SALONEN 1967, COOKE 1968, JANSSON 1966, VAN BURG 1969). The equipment necessary for storage and injection, however, requires more capital than is needed in the use of bagged goods. How profitable the usage of ammonia is greatly depends on the distance of transportation, the kind of soil on the farm, the climatic conditions and the size of the farm (BUCHNER 1966).

Ammonia is not a suitable fertilizer for grassland (VAN BURG 1966, VAN BURG et al. 1967). In connection with the injection the roots of the plants are damaged and earthing

can seldom be carried out properly. Nor is ammonia suitable for winter cereals in spring because it may uproot the plants in connection with the injection (VAN BURG et al. 1967). Autumn injection is often too risky in Western Europe because of larger N-losses in mild and wet winters. Under certain conditions, however, autumn application might be successful (VAN BURG 1969).

In Finland anhydrous ammonia has been used only in experiments. Fertilizing experiments with ammonia have been carried out on the Kotkaniemi experimental farm at Vihti, the total number of experiments being sixteen during five years, 1966—70. The experiments have been made with spring and winter cereals. The experiments have been carried out with a Danish Marsk Stig apparatus which is easy to use and has a satisfactory injection accuracy. When the experiments were started the tank of the machine was replaced by gas bottles filled with ammonia in order to perform fertilization to a depth of 15 cm and make the ammonia fix perfectly into the soil. The working of the cultivator at the back of the machine is weak.

The precipitations and the mean temperatures of the test years (1965—70) are given in Table 1.

Table 1. Climatic conditions at Vihti during the growing seasons 1965—70.

Precipitation per month in mm.

	V	VI	VII	VIII	IX	Total
1965	8.3	18.1	106.9	90.0	65.0	288.3
1966	15.1	40.7	74.9	28.3	77.7	236.7
1967	51.9	21.8	27.8	142.1	53.3	296.9
1968	70.5	30.6	67.1	111.4	74.4	354.0
1969	21.6	15.5	45.3	40.1	95.9	218.4
1970	26.4	20.3	130.4	34.1	61.8	273.0
Mean value	32.3	24.5	75.4	74.3	71.3	277.8

Mean temperature per month in °C

	V	VI	VII	VIII	IX	Mean value (V—IX)
1965	7.7	16.0	14.6	13.4	11.6	12.66
1966	9.4	17.9	17.9	13.8	7.9	13.38
1967	10.1	14.7	17.6	15.2	10.5	13.62
1968	7.4	16.2	14.5	15.3	10.0	12.68
1969	8.7	15.3	16.2	15.2	9.6	13.00
1970	9.3	16.2	16.0	14.4	9.2	13.00
Mean value	8.8	16.0	16.1	14.5	9.8	13.04

Table 2. Experiment with anhydrous ammonia on winter cereals in the years 1966—70.

Test in 1966—67. Soil type silty clay. Soil analysis in 1967: pH 5.8, Ca 2 500, P 4.5 and K 220 mg/l. Fertilization in connection with seed-bed preparation 500 kg/ha compound fertilizer (15—25—10). Test made with Pekka rye and Nisu wheat. Size of test plot: wheat 5 × 30 m, rye 5 × 25 m. 2 replicates in both experiments.

Test in 1967—68. Soil type sandy and silty clay. Soil analysis in 1967: pH 5.8, Ca 2 100, P 10.0 and K 315 mg/l. Fertilization in connection with seed-bed preparation 1 000 kg/ha compound fertilizer (15—20—15). Test made with Pekka rye. Size of test plot 5 × 25 m. 3 replicates.
Test in 1968—69. Soil type silty sandy clay. Soil analysis in 1967: pH 5.7, Ca 2 430, P 4.0 and K 290 mg/l. Fertilization in connection with seed-bed preparation 800 kg/ha PK-fertilizer (2—17—15). Test made with Linna wheat. Size of test plot 5 × 50 m. 4 replicates.

Test in 1969—70. Soil type loam. Soil analysis in 1967: pH 5.8, Ca 2 770, P 2.0 and K 100 mg/l. Fertilization in connection with seed-bed preparation 800 kg/ha PK-fertilizer (2—17—15). Test made with Pekka rye. Size of test plot 7.5 × 40 m. 4 replicates.

The following table of experiments conforms with the year 1969. In 1966—68 the amount of nitrogen (N) given to the crop was 150 kg/ha, in 1969 162 kg/ha, in 1970 164 kg/ha.

Treatment	Average grain yield											
	Wheat (2 experiments)		Rye (3 experiments)		Average (wheat + rye)		Lodging %		Hl-weight kg		1 000 g.w. g	
	kg/ha	rel.	kg/ha	rel.	kg/ha	rel.	Wheat	Rye	Wheat	Rye	Wheat	Rye
1. PK-fertilizer (2—17—15) 800 kg/ha in autumn + nitrogen in calcium ammonium nitrate in spring	3 290	100	2 930	100	3 070	100	0	84	80.4	72.7	36.6	25.5
2. » + nitrogen in calc. amm. nitrate ½ in autumn, ½ in spring	3 360	102	3 070	105	3 180	104	0	81	80.7	73.2	35.8	24.3
3. » + ½ of nitrogen in autumn as ammonia, ½ in spring as calc. amm. nitrate	3 120	95	3 010	103	3 050	99	0	77	80.2	73.1	36.9	24.8
4. » + nitrogen as calc. amm. nitrate in autumn	3 240	98	2 990	102	3 090	101	0	76	80.6	73.8	36.5	27.1
5. » + nitrogen as ammonia in autumn	3 420	104	3 050	104	3 190	104	0	77	80.6	73.5	35.8	23.9

F-value (wheat + rye) = 1.26
$s_{\bar{x}}$ = 1.92 %

Results

The results of the experiments are given in Tables 2—6. Used in autumn on winter wheat and rye ammonia proved (Table 2) to have a fertilizing effectiveness as good as

that of calcium ammonium nitrate or even better, similarly on spring wheat and barley (Table 3). No differences can be seen in the hl-weights, in the 1 000 grain weights or in the crude protein. When comparing ammonia, calcium ammonium nitrate and urea

Table 3. Experiment with anhydrous ammonia on spring cereals in 1966—69.

Test in 1966—67. Soil type silty clay — fine sand. Soil analysis in 1967: pH 6.2, Ca 2060, P 11.0 and K 200 mg/l. Phosphorus — potassium fertilization corresponds to 500 kg/ha compound fertilizer (15—25—10). Fertilizers given 15 October 1966 through drilling, 24 May 1967 through broadcasting before tillage. Test made with Svenno wheat. Size of test plot 5 × 50 m. 3 replicates.

Test in 1967—68. Soil type silty sandy clay. Soil analysis in 1967: pH 5.9, Ca 3150, P 2.3 and K 215 mg/l. Fertilization 1200 kg/ha compound fertilizer (15—20—15). Fertilizers 20 September 1967 through drilling, 31 May 1968 through broadcasting before tillage. Test made with Otra barley. Size of test plot 10 × 50 m. 4 replicates.

Test in 1968—69. Soil type silty clay. Soil analysis in 1967: pH 5.8, Ca 2500, P 5.6 and K 340 mg/l. Fertilization 800 kg/ha PK-fertilizer (2—17—15). Fertilizers 8 October 1968 through drilling, 7 May 1969 through broadcasting before tillage. Test made with Pomo barley. Size of test plot 5 × 50 m. 4 replicates.

The following table of experiments conforms with the year 1969. In 1967 the amount of nitrogen given to the crop was 150 kg N/ha, in 1968 the figure was 180 kg N/ha.

Treatment	Grain yield barley + wheat average		Lodging-% barley + wheat	Hl-weight kg		1000 g.w. g		Protein % barley + wheat
	kg/ha	rel.	average	barley	wheat	barley	wheat	average
1. PK-fertilizer (2—17—15) in autumn + 156 kg N/ha calcium ammonium nitrate in spring	3 510	100	26	68.1	83.7	37.9	36.2	12.52
2. » + 78 kg N/ha in ammonia, autumn + 78 kg N/ha in calc. amm. nitr. in spring	3 800	108	28	68.8	83.9	37.2	35.7	11.85
3. » + 78 kg N/ha in ammonia, autumn + 78 kg N/ha in ammonia, spring	3 870	110	25	68.8	83.8	41.2	34.6	11.82
4. » + 156 kg N/ha in ammonia, autumn	3 860	110	28	70.5	84.1	42.0	35.7	11.15
5. » + 156 kg N/ha in calc. amm. nitr. in autumn	3 590	102	22	69.6	84.5	41.3	36.0	11.07

F-value (Grain yield) = 0.82

$s_{\bar{x}}$ = 4.96 %

Table 4. Comparison between anhydrous ammonia, calcium ammonium nitrate and urea on spring cereals in 1966—69.
Wheat: Soil type sandy clay. Soil analysis in 1967: pH 5.9, Ca 2400, P 4.0 and K 190 mg/l. Fertilization in spring with PK-fertilizer (2—17—10) 800 kg/ha, nitrogen in different forms in 1966 75 kg/ha (calcium ammonium nitrate 2 % and urea 6 % too large compared with ammonia), 1967 137 kg/ha, 1969 90 kg/ha, 1969 87 kg/ha. Test made with Svenno. Size of test plot 10 × 120 m. 2 replicates.

Barley: Soil type silty clay. Soil analysis in 1967: pH 5.8, Ca 2300, P 3.0 and K 215 mg/l. Fertilization in spring PK-fertilizer (2—17—15) 800 kg/ha, nitrogen in different forms in 1966—67 100 kg/ha and in 1968 95 kg/ha. Test made in 1966—67 with Balder and in 1968 Otra barley. Size of test plot 7.5 × 65 m. 2 replicates.

Treatment	Grain yield									
	1966		1967		1968		1969		Average	
	kg/ha	rel.	kg/ha	rel.	kg/ha	rel.	kg/ha	rel.	kg/ha	rel.
Wheat										
1. No nitrogen	2 000	100	2 160	100	1 300	100	1 470	100	1 730	100
2. Ammonia, drilling	2 250	113	3 540	164	2 960	228	2 540	172	2 820	163
3. Calcium ammonium nitrate, drilling	2 410	121	3 590	166	3 250	250	2 610	177	2 970	172
4. Urea, drilling	1 790	90	3 490	162	3 110	239	2 190	149	2 650	153
Barley										
1. No nitrogen	300	100	1 520	100	1 110	100			980	100
2. Ammonia, drilling	2 200	733	3 030	199	3 120	280			2 780	284
3. Calcium ammonium nitrate, drilling	2 000	667	2 670	176	2 830	255			2 500	255
4. Urea, drilling	1 060	353	2 320	153	3 010	271			2 130	217
5. Calcium ammonium nitrate, broadcast	1 510	503	2 400	158	2 990	269			2 300	234
	In 1966		In 1967		In 1968		In 1969			
Grain yields, wheat:	$F = 2.50$		$F = 11.62^{**}$		$F = 46.83^{***}$		$F = 20.75^{*}$			
	$s_{\bar{x}} = 8.38\ \%$		$s_{\bar{x}} = 6.36\ \%$		$s_{\bar{x}} = 5.00\ \%$		$s_{\bar{x}} = 5.18\ \%$			
Grain yields, barley:	$F = 53.30^{**}$		$F = 6.57$		$F = 0.62$					
(Treatments 2—5)	$s_{\bar{x}} = 4.14\ \%$		$s_{\bar{x}} = 4.80\ \%$		$s_{\bar{x}} = 5.10\ \%$					

(Tables 4 and 5) on wheat, ammonia gave a 5 % and urea an 11 % lower yield than calcium ammonium nitrate. On barley ammonia gave an 11 % higher yield than calcium ammonium nitrate and urea a 15 % weaker yield than calcium ammonium nitrate. Especially in 1966 urea gave a poor yield. As to the components, such as falling number

Table 5. Comparison between effects of anhydrous ammonia, calcium ammonium nitrate and urea on spring cereals in 1966—69. The results are average values: wheat 4 years (years 1966—69), barley 3 years (years 1966—68).

Treatment	Grain yield		Lodging	Hl-weight	1000 g.w.	Falling	Protein	pH	
	kg/ha	rel.	%	kg	g	number*)	%**)	1966	1969
Wheat									
1. No nitrogen	1 730	100	0	79.2	34.4	248	11.47	5.60	5.90
2. Ammonia, drilling	2 820	163	30.5	78.4	36.3	243	12.97	5.65	5.85
3. Calcium ammonium nitrate, drilling	2 970	172	31.2	78.1	36.5	278	13.85	5.80	5.95
4. Urea, drilling	2 650	153	26.2	78.9	36.0	271	13.72	5.80	5.85
Barley									
1. No nitrogen	980	100	0	63	38.0		11.50		
2. Ammonia, drilling	2 780	284	20.0	63.2	40.0		10.70		
3. Calcium ammonium nitrate, drilling	2 500	255	12.5	62.6	39.7		10.40		
4. Urea, placement	2 130	217	7.5	62.8	38.6		11.25		
5. Calcium ammonium nitrate, broadcas	2 300	234	6.7	61.7	38.1		11.10		

*) years 1968—69
**) only in 1968

and protein content, having an effect on the crop quality there are no differences between different fertilizers, nor are there any differences in the changes of the soil pH.

The crop yields obtained with pea-oats shown in Table 6 are the same in the cases of ammonia and compound fertilizer and additional nitrogen given in spring.

Table 6. Experiment with anhydrous ammonia on pea-oats mixture. Soil type clayey sand and silt. Soil analysis in 1967: pH 6.4, Ca 1 600, P 24.0 and K 470 mg/l. In spring 500 kg compound fertilizer (15—25—10) by drilling + 200 kg/ha calcium nitrate by broadcasting on shoots. Test made with pea-oats mixture (Pendek + Kalle). Size of test plot 5 × 30 m. 4 replicates.

Treatment	Grain yield		Lodging
	kg/ha	rel.	%
1. 75 kg N/ha as NH_3 previous autumn	3 059	100	95
2. Only spring fertilization	3 037	99	95

Test plot was so heavily fertilized in spring (500 kg/ha compound fertilizer (15—20—15) + 200 kg/ha calcium nitrate) that ammonia used in autumn did not have an increasing effect on the crop.

F-value = 0.05

$S_{\bar{x}}$ = 9.70%

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SELOSTUS

NESTEMÄISEN AMMONIAKIN LANNOITUSKOKEIDEN TULOKSIA

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Kevätviljojen lannoituksessa sekä syysviljojen kylvömuokkauksen yhteydessä annettavassa lannoituksessa on nestemäinen ammoniakki osoittautunut Rikkihappo Oy:n Kotkaniemen koetilalla vaikutukseltaan kalkkiammonsalpietarin veroiseksi. Viitenä vuotena on järjestetty sijoituslannoitusta käyttäen 16 koetta maalajin ollessa useimmissa kokeissa hiesusavea. Eroavuutta ei ole esiintynyt jyväsadon määrässä, 1000-jyvän ja hehtolitran painossa eikä jyväsadon valkuaispitoisuudessa. Urea osoittautui vaikutukseltaan molempia lannoitteita huonommaksi.