G.L. VELTHOF*, O. OENEMA*, J. POSTMUS** and W.H. PRINS*
Netherlands Fertilizer Institute NMI*/Institute for Soil Fertility**, Haren

In-situ field measurements of ammonia volatilization from urea and calcium ammonium nitrate applied to grassland [1)]

Metingen van NH_3-vervluchtiging uit ureum en kalkammonsalpeter op blijvend grasland

SUMMARY

Ammonia (NH_3) volatilization from urea and calcium ammonium nitrate (CAN) broadcast to permanent grassland on a heavy clay soil was measured in-situ, using a system of wind-tunnels. When CAN was applied virtually no NH_3 volatilized. More than half of the 12 measurements indicated a net influx of NH_3 from the atmosphere to CAN treated swards. Mean volatile N loss was -1.8 ± 6.0 per cent. Mean N loss through NH_3 volatilization from urea treated swards was 22.6 ± 15.6 per cent with a range of 6.5 to 60.4 per cent. Losses from urea were strongly related to N application rate and rainfall. The volatile N losses from urea and CAN treated swards agreed reasonably well with the difference in N efficiency of urea and CAN as measured in field experiments between 1954 and 1971. In recent experiments the N efficiency of urea was somewhat higher, however.

SAMENVATTING

Op blijvend grasland op een zware kleigrond is met behulp van windtunnels de NH_3-vervluchtiging uit ureum en kalkammonsalpeter (kas) gemeten. De totale N-gift varieerde van 150 tot 450 kg/ha/jaar, verdeeld over zes sneden. De meting van de NH_3-vervluchtiging startte meteen na bemesting en duurde steeds 6 à 10 dagen. Bij kas vervluchtigde er vrijwel geen NH_3. In meer dan de helft van de 12 meetperiodes werd geen vervluchtiging maar een netto influx van NH_3 van de atmosfeer naar de met kas bemeste graszode bepaald. Het gemiddelde N-verlies door NH_3-vervluchtiging was bij kas -1,8 ± 6,0 procent. Bij ureum was het gemiddelde verlies door NH_3-vervluchtiging 22,6 ± 15,6 procent, met een variatie van 6,5 tot 60,4 procent.
N-verliezen door NH_3-vervluchtiging bij ureum waren sterk gerelateerd aan de N-gift en regenval. De grootte van de N-verliezen door NH_3-vervluchtiging bij ureum en kas kwam goed overeen met het verschil in N-werking tussen ureum en kas, gemeten in graslandproeven in de periode 1954-1971. In recente proeven was het verschil tussen ureum en kas minder groot.

INTRODUCTION

Many field experiments have shown that urea is less efficient than calcium ammonium nitrate (CAN) as nitrogen (N) fertilizer for grassland (2). The low efficiency of urea has been attributed to N losses through ammonia (NH_3) volatilization.

When applied to grassland, urea hydrolyzes into ammonium (bi)carbonate generally within a few days. This process is accompanied by an increase in soil pH which, in turn, strongly favours NH_3 volatilization (5). Many other soil, environmental and management factors may also affect NH_3 volatilization from urea (3). In a field study Black et al. (1) found that ammoniacal N losses from pastures also depended on the method of measurement. Using three different methods, they found that after 4 days volatile N losses from urea applied at a rate of 100 kg N/ha ranged from 24 to 30 per cent.

In the literature the information about NH_3 volatilization from CAN is limited. Losses from CAN are probably low, because of the buffered near-neutral abrasion pH and the relatively low ammonium (NH_4^+) content.

The objective of the experiments described in this paper was the in-situ measurement of the NH_3 volatilization from urea and CAN broadcast to permanent grassland.

1) This paper is also published in the Proceedings of the XIIIth General Meeting of the European Grassland Federation, Banska Bystrica, Czechoslovakia, 1990.

METHODS

NH_3 volatilization from urea (46% N) and CAN (27% N) was simultaneously measured from two urea and two CAN treatments on a heavy clay soil during seven periods in 1989. The sward was six years old and consisted for over 90 per cent of *Lolium perenne L.*.

Herbage was mown six times a year to a stubble height of 4-5 cm. N fertilizers were applied in spring at T-sum 200-300, and subsequently after each cut, except the last one. The six N applications supplied 27, 20, 20, 13, 13 and 7 percent of the total annual amount, respectively. Annual application rates were 150, 300 and 450 kg N/ha. Phosphate and potassium were applied as recommended. The surface layer (0-5 cm) of the heavy clay soil contained 3.7 per cent organic carbon and had a pH (KCl) of 5.5.

Volatilization losses were measured, using a system of wind-tunnels as described by Lockyer (6). Each wind-tunnel covered an area of 0.5 x 2 m. Measurements started immediately after the plots (100 m^2) were mown, except in early spring, and fertilized with urea and CAN. The wind velocity in the tunnel was adjusted twice a day to the wind velocity measured in the field at 25 cm, the average height of the tunnel. The cumulative NH_3 flux with the incoming and outgoing air was determined during periods of 12 to 24 hours for one to two weeks. Two chemical traps with 20 ml 0.02 M H_3PO_4 were attached at the inlet and one at the outlet of the wind-tunnels. Air was drawn through the traps at a rate of 1.8 l per minute. The NH_3 collected in the traps was determined by a standard auto-analyzer technique using the indophenol blue method. The tunnels were replaced twice a day to minimize deviating conditions inside the tunnel.

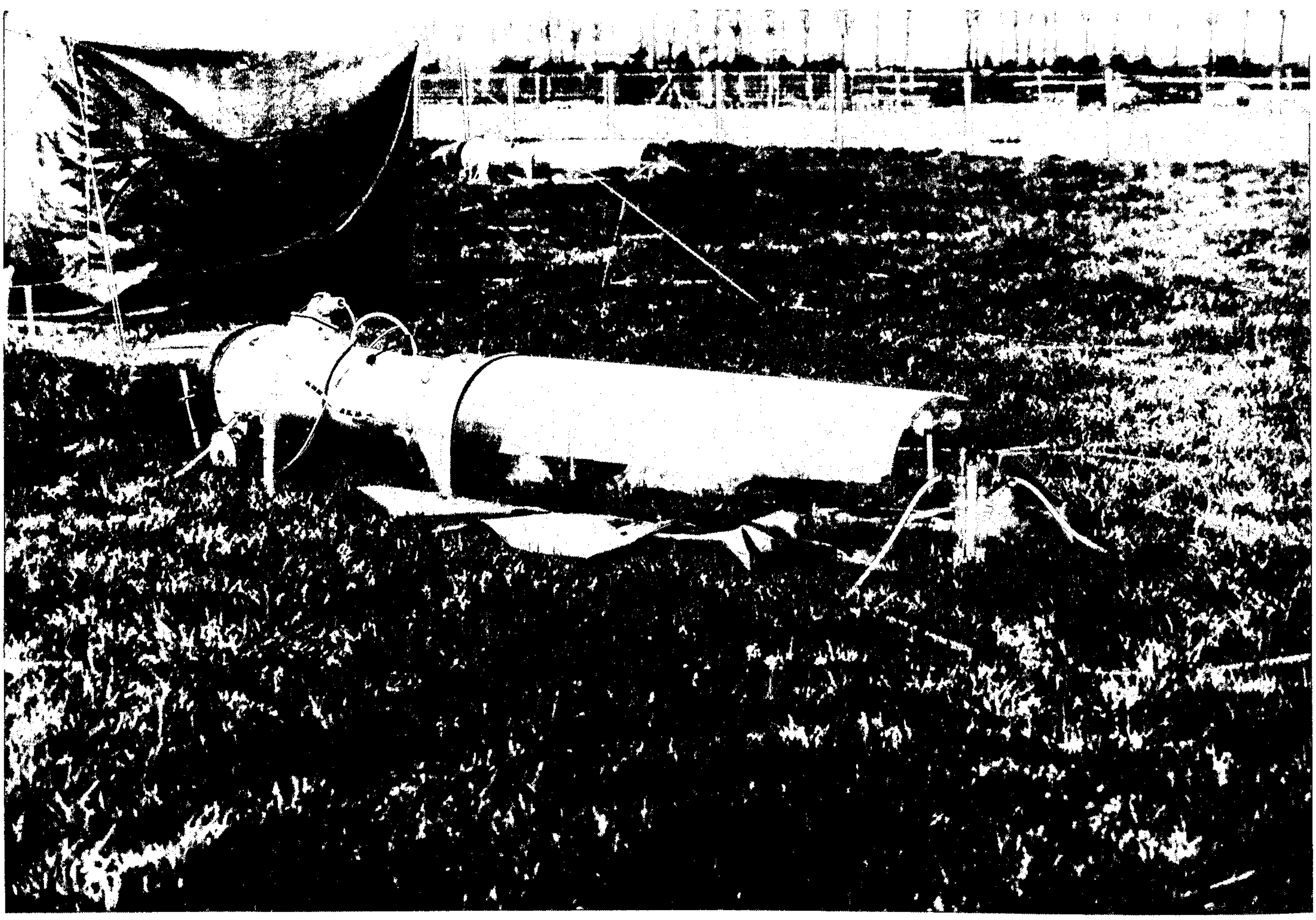
The range in NH_3 loss was measured once, during seven days in September, on four plots fertilized with 60 kg urea N/ha. The mean cumulative amount of volatilized NH_3 was 19.8 ± 4.2 kg/ha.

The N efficiency of urea and CAN was determined in a nearby field experiment, and in 1987 and 1988 in four experiments on permanent grassland on drained heavy clays and undrained sandy soils. Herbage N uptake was determined in plots (22 m^2) receiving 0, 150, 300, 450 and 600 kg N/ha/year, split over six cuts.

RESULTS AND DISCUSSION

Figure 1 shows the cumulative amount of volatilized NH_3 from urea and CAN treated swards in early spring. Volatilization from urea

Wind-tunnel
Windtunnel



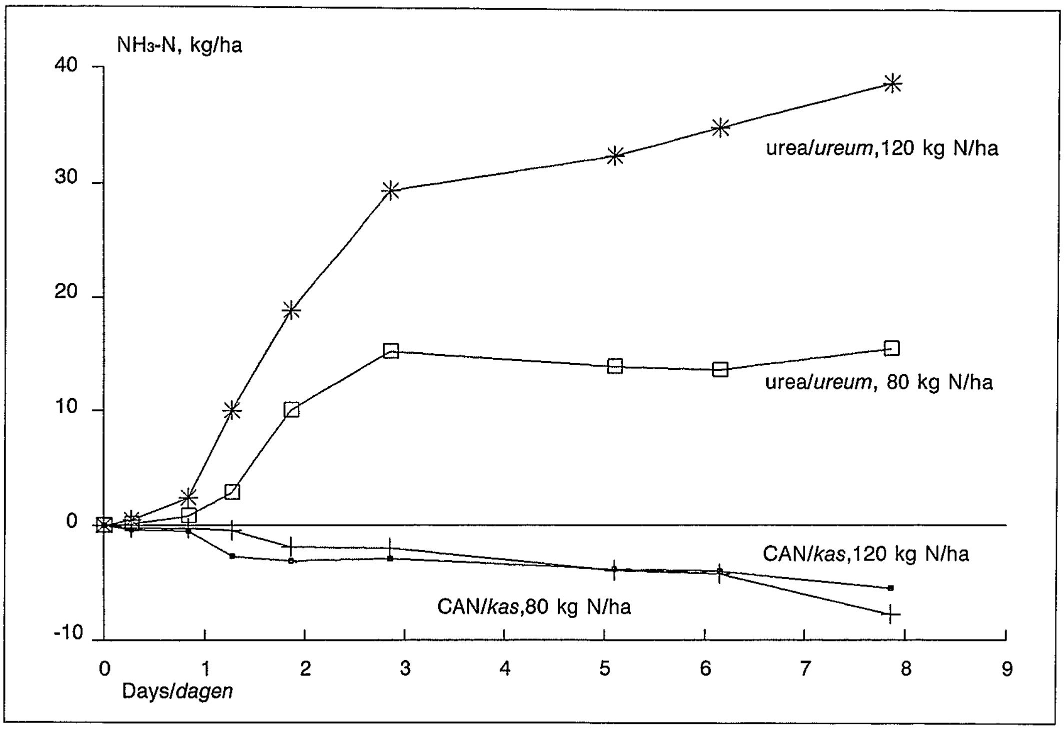


FIGURE 1. Cumulative NH_3 volatilization from CAN and urea broadcast to grassland at rates of 80 and 120 kg N/ha on 29 March 1989.
FIGUUR 1. Cumulatieve NH_3-vervluchtiging uit kas en ureum, na strooien op 29 maart 1989 op grasland, bij een gift van 80 en 120 kg N/ha.

treated swards was negligible during the first day after fertilization, reached a maximum during the next 1-3 days and decreased strongly after day 3. This sigmoid pattern is typical for soils supplied with urea and is related to the rate of the enzymatic hydrolysis of urea. At application rates of 80 and 120 kg urea N/ha, 19 and 32 per cent of the applied N volatilized, respectively (figure 1). Thus, the larger the N supply the larger the relative amount of NH_3 volatilization. With CAN an influx of NH_3 to the sward occurred. Also in some later measurement periods a net influx of NH_3 to CAN treated swards was observed; this will be explained later.

Figure 2 shows the cumulative NH_3-N losses from urea and CAN treated swards, during a wet period with 25 mm of rain within three days (Table 1).

Virtually no NH_3 volatilized from the urea treated sward except during the first day. The very high N loss during the first day is most

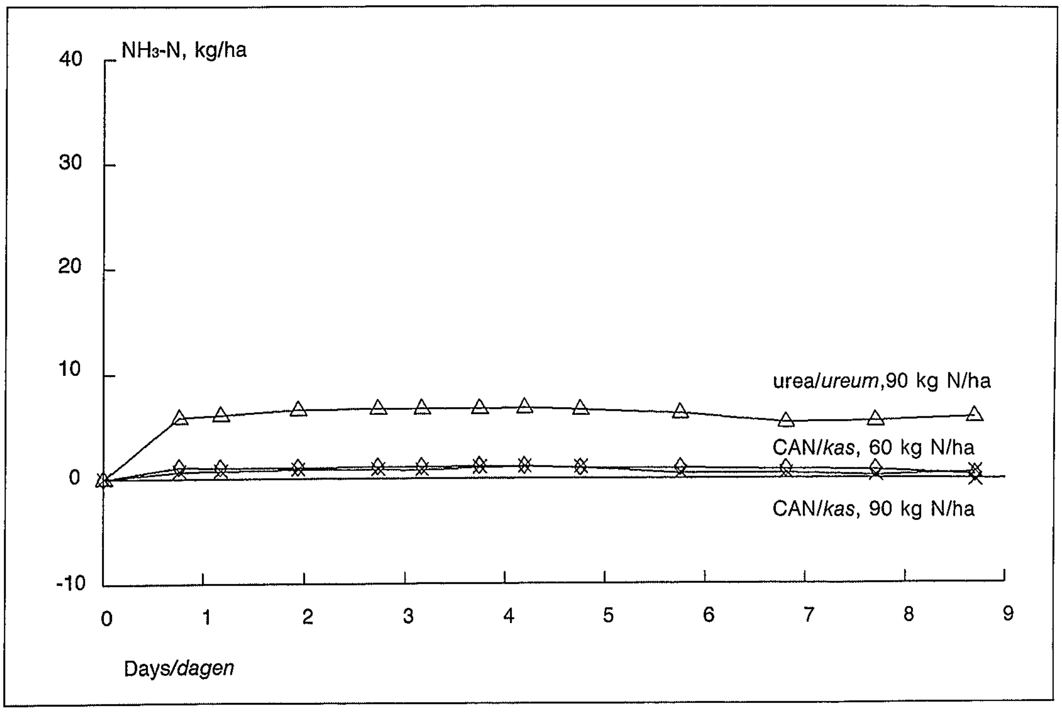


FIGURE 2. Cumulative NH_3 volatilization from CAN and urea broadcast to grassland at a rate of 90 kg N/ha on 28 June 1989. CAN also was applied at a rate of 60 kg N/ha.
FIGUUR 2. Cumulatieve NH_3-vervluchtiging uit kas en ureum, na strooien op 28 juni 1989 op grasland, bij een gift van 90 kg N/ha. Kas werd ook toegediend in een hoeveelheid van 60 kg N/ha.

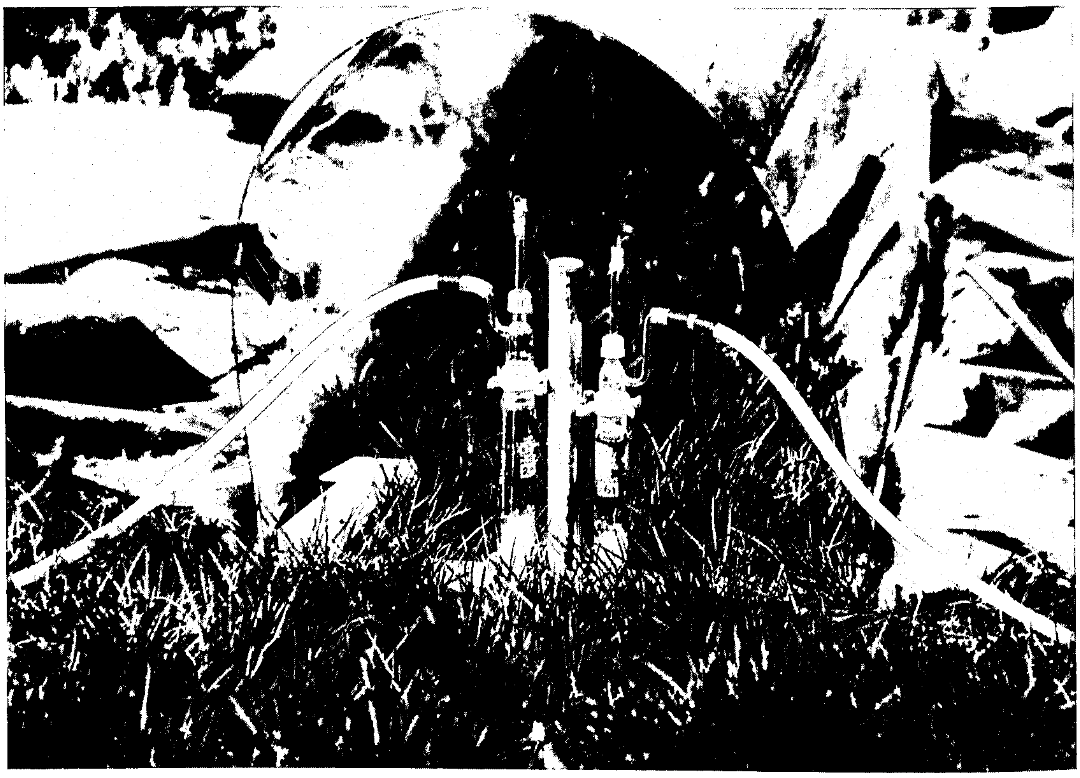
TABLE 1. Mean air temperature, total rainfall during 1, 3 and 5 days and cumulative NH_3 losses from CAN and urea, as a percentage of the amount of N applied, during 7 periods.
TABEL 1. Gemiddelde luchttemperatuur, totale regenval na 1, 3 en 5 dagen na bemesting en cumulatieve NH_3-verliezen uit kas en ureum als percentage van de toegediende hoeveelheid N, tijdens 7 periodes.

Period *periode*	Mean air temperature *gem. lucht-temperatuur* °C	Rainfall *regenval* mm			N kg/ha	NH_3-N loss *NH_3-N-verlies* %	
		day 1 *dag*	day 3 *dag*	day 5 *dag*		CAN *kas*	urea *ureum*
29/3 – 6/4	5.4	0.0	0.0	0.0	120	– 4.6	31.9
					80	– 9.7	19.4
7/4 – 17/4	8.3	0.0	0.5	5.5	80	– 0.8	15.3
					40	– 0.9	19.0
28/6 – 7/7	17.2	8.5	25.0	27.0	90	0.1	6.5
					60	0.6	.
10/7 – 20/7	14.4	0.0	0.0	1.0	60	–12.7	60.4
					30	– 6.2	36.5
22/8 – 30/8	14.3	0.0	4.0	14.0	60	1.0	19.9
					40	10.6	10.2
30/8 – 6/9	10.6	3.5	6.5	13.0	40	1.5	10.6
					20	– 0.2	8.2
6/9 – 13/9	15.6	0.0	0.0	0.0	60	.	33.0
mean/*gem.*						– 1.8	22.6
± sd.						± 6.0	± 15.6

likely a measuring error. The fact that hardly any NH_3 losses occurred is related to the rapid dispersion of urea in the soil by the heavy rain. This strongly limits the NH_3 concentration in the surface layer as well as subsequent NH_3 losses (4).

Table 1 summarizes the total amounts of volatilized NH_3 from urea and CAN for all periods. N losses through NH_3 volatilization from CAN were negligible, except during the fourth week of August when an extremely large amount of more than 10 per cent was lost.

In 7 of the 12 measurements an influx instead of an efflux of NH_3 to the CAN treated swards was measured. The influx of NH_3 to the sward suggests the absorption of atmospheric NH_3 by the sward. Absorption of NH_3 particularly occurred during periods with high NH_3 concen-



Two chemical traps at the inlet of the wind-tunnel
Voorkant van windtunnel met twee wasflesjes met zuur

trations in the atmosphere, associated with surface application of cattle slurry on adjacent pastures at distances up to 1.5 km. Harper et al. (4) reported NH_3 influx into a urea treated plant-soil system, especially around sunset and sunrise. These authors ascribed the absorption of NH_3 by plant and soil to 'N stress', i.e. low contents of soil mineral N and plant N.

Volatile NH_3 losses from urea ranged from 6.5 per cent in the wet first week of July up to 60.4 per cent in the dry third week of July (Table 1). Averaged over all periods and N rates, N loss through NH_3 volatilization from urea was 22.6 $\pm$ 15.6 per cent. This wide variation was mainly related to differences in N rate and rainfall. Differences in temperatures may also have contributed (3). The much larger loss from urea in comparison with CAN is in accordance with the lower N efficiency of urea. In a large number of field experiments on grassland between 1954 and 1971 Van Burg et al. (2) found that the N efficiency of urea varied from 75 to 85 per cent of that of CAN. This range of efficiencies agrees reasonably well with the difference in ammoniacal N losses between urea and CAN in 1989 (Table 1).

In the wet and cool years of 1987 and 1988, the mean N efficiency of urea was only 7 to 12 per cent less than that of CAN. In warm and dry 1989 the mean difference was only 6 per cent, much smaller than the difference in ammoniacal N loss (Table 1). This small difference is difficult to explain. A part, but not all, of this dissimilarity may be attributed to some differences in time of N application and, therefore, to the incidence of rainfall in the two experiments. We are, however, unable to satisfactorily explain the wide gap between ammoniacal N loss and N efficiency. The difference in mean N efficiency of urea obtained by Van Burg et al. (2) and that of this study also requires further study.

REFERENCES

1. Black AS, Sherlock RR, Cameron KC, Smith NP and Goh KM (1985) Comparison of three field methods for measuring ammonia volatilization from urea granules broadcast on to pasture. Journal of Soil Science 36, 271-280.
2. Burg PFJ van, Dilz K and Prins WH (1982) Agricultural value of various nitrogen fertilizers. Netherlands Nitrogen Technical Bulletin 13, 51 p.
3. Hargrove WL (1988) Soil, environmental, and management factors influencing ammonia volatilization under field conditions. In "Ammonia volatilization from urea fertilizers" (Ed. B.R. Bock and D.E. Kissel). (National Fertilizer Development Center, TVA, Muscle Shoals, Alabama). pp. 17-36.
4. Harper LA, Catchpoole VR, Davis R and Weir KL (1983) Ammonia volatilization: soil, plant and microclimate effects on diurnal and seasonal fluctuations. Agronomy Journal 75, 212-218.
5. Koelliker JK and Kissel DE (1988) Chemical equilibria affecting ammonia volatilization. In "Ammonia volatilization from urea fertilizers" (Ed. B.R. Bock and D.E. Kissel). (National Fertilizer Development Center, TVA, Muscle Shoals, Alabama). pp. 37-52.
6. Lockyer DR (1984) A system for the measurement in the field of losses of ammonia through volatilisation. Journal of the Science of Food and Agriculture 35, 837-848.