Agrochimica, Vol. XLVI - N. 3-4 Maggio-Agosto 2002

Effect of nitrogen sources on ammonia volatilization, grain yield and soil nitrogen losses in no-till wheat in an Argentine soil

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INTRODUCTION. – Several factors affect loss of ammonia from nitrogen fertilizers; e.g.: i) soil properties; ii) crop management; iii) environmental factors and iv) fertilizer management (CLAY *et al.*, 1990; FOX and PIEKIELEK, 1993). Fertilizers applied to soil surfaces can lead to important losses of ammonia via volatilization (RICE and SMITH, 1984; WATSON *et al.*, 1994). The most frequent fertilization technology for no-till cropped wheat in Argentina and elsewhere is just broadcast urea on topsoil at tillering. Additionally, this cropping system enhances urease activity (KARLEN *et al.*, 1991; GRANT and LAFOND, 1994), and consequently, it is expected that ammonia volatilization losses should be high. Local experiments corroborated high ammonia losses (GARCIA *et al.*, 1996; SAINZ ROSAS *et al.*, 1997; PALMA *et al.*, 1998), and these data caused concern to farmers because of economical losses.

From the environmental point of view, increasing concentrations of ammonia in the atmosphere can cause aerosols formations, which are components of smog and acid rain. Therefore both economic and environmental viewpoints, much attention must be given to these losses. Different technological alternatives may reduce nitrogen volatilization losses, such as the use of other fertilizers rather than urea: nitrates or controlled release fertilizers (TRENKEL, 1997). The ammonia losses under field conditions vary between 1 and 50 % of nitrogen applied to the soil surface (GRANT *et al.*, 1996). These nitrogen losses can decrease crops yield, but several experiments with wheat in the Argentinean Pampas showed that yields are not related to the volatilization losses of several nitrogen fertilizers (ALVAREZ *et al.*, 2000).

Both ammonia volatilization and nitrification are differentially affected by ammonia concentrations. When the applied ammonia is lower than nitrogen critical concentration in soil only nitrification proceeds. However, when it is higher, occurs ammonia volatilization followed by nitrification (PRAVEEN and AGGARWALL, 1998). On the other hand, LADHA *et al.* (2000) found no residual effects of urea fertilization after 14 years of application. Even in some fields N balance was slightly negative. We hypothesize that ammonia volatilization from urea was compensated with higher apparent soil mineralization rate and then, even with high ammonia volatilization from urea, wheat yields were not affected. Our objective was to evaluate this hypothesis.

MATERIALS AND METHODS. – A field experiment with no-tilled wheat (cv. Cacique) was carried out near Chivilcoy (60° 30' W, 35° 30' S), Province of Buenos Aires, Argentina. The characteristics of the soil (a Typic Hapludoll) are shown in Table 1. Soil properties were measured as follows: pH (1:2.5 soil: water ratio); organic carbon (Walkley and Black); total N (Kjeldahl) extractable phosphorus (Bray and Kurtz); cationic exchangeable capacity and exchangeable Ca, Mg, Na and K (ammonium acetate extraction and atomic absorption determination) (PAGE *et al.*, 1982).

The soil was no tilled for four years, proceeding our experiment with corn as last crop. Sowing was carried out June 24 1996. Prior to seeding, all plots were fertilized with 150 kg ha^{-1} diammonium phosphate. Treatments consisted of control and three nitrogen sources: broadcast urea, dribbled UAN (30% N) and broadcast IBDU (isobutilidendiurea, particle size 2-3 mm). Nitrogen at 110 kg N ha^{-1} was applied August 16. Treatments were arranged in a randomized complete block design with three replicates. The experimental plots were of 30 m^2.

Volatilization was determined in cylinder chambers (0.15 m diameter and 0.20 m height) with non- disturbed soil samples (NOMMIK, 1973). The chambers were protected against rainfall. Evolved ammonia was trapped in polyurethane discs soaked in 12 ml of 1M sulphuric acid-glycerol solution 2:1 (v/v). Discs and the inner surface of the chambers were rinsed with 50 ml 2 M KCl, and the extract was removed. Ammonia concentration was determined using airstreams distillation (PAGE *et al.*, 1982) on days 1, 2, 3, 4, 5, 7, 9, 11, 14 and 21 after nitrogen fertilization.

At different times during wheat growth, four soil samples from each treatment were taken at intervals of 0.2 m to 0.6 m depth. Soil contents of nitrates (NO_3^-) and (NH_4^+) ammonium were determined by steam distillation (PAGE *et al.*, 1982). At tillering (August 27) and physiological maturity (December 12) 0.5 m^2 of plant material was collected in each experimental plot and dried at 70 °C. Nitrogen concentration was measured in aerial biomass (N_{sw}) and grains (N_g) by Kjeldahl method (NELSON and SOMMERS, 1973), consi-

TABLE 1. – *Soil average (n = 4) characteristics: carbon (C), total nitrogen (N), extractable phosphorus (P), exchangeable cations and cationic exchangeable capacity (CEC).*

Depth cm	pH	C	N	P	Ca	Mg	Na	K	CEC
		$g kg^{-1}$		$mg kg^{-1}$	$cmol_c kg^{-1}$				
0-20	5.7	16.3	1.81	10.1	10.5	2.6	0.5	1.6	17.4
20-40	6.5	9.2	1.03	6.8	9.7	2.7	0.6	1.4	16.2
40-60	6.7	5.8	0.66	4.8	8.0	3.0	0.6	1.1	14.9

dering $N_g + N_{sw}$ as N_v. The nitrogen from mineralization (N_m) was estimated as the difference between nitrogen accumulated in the crop at physiological maturity (N_r) and the changes in available nitrogen in the soil between sowing and harvest.-Nitrogen from soil and fertilizers (N_{s+f}) was taken into account (HUGGINS and PAN, 1993). Temperature was daily registered in the experimental site.

The data was subjected to a standard analysis of variance using ANOVA appropriate for a completely randomized block design and the Tukey test was used to compare means ($p < 0.05$) (SAS Inst., 1988). Results for different sampling days were analyzed separately.

RESULTS AND DISCUSSION. – a) *Volatilization losses.* – Figure 1 shows ammonia losses. Urea and UAN, had the greatest losses, while IBDU did not differ from the control treatment ($p < 0.05$). The losses of ammonia with urea and UAN were significantly different at the beginning of the experiment ($p < 0.05$). The urea treatment has peak ammonia volatilization the second day after fertilizer application, with volatilization decreasing by the fourth day, but ammonia losses were significantly higher compared with all treatments during all the experiment. The total losses at end of study from urea treatment were 24.8 kg N ha^{-1}, for UAN were 11.2 kg N ha^{-1} and for the control and IBDU treatments 6 kg N ha^{-1}. These values imply losses of 17.1%; 4.7% and 0.1% of the applied nitrogen from urea, UAN and IBDU, respectively. In the same crop and with no till system, in southern Pampean region, GARCÍA *et al.* (1996) found lower volatilization losses from urea and UAN. Our higher losses of ammonia can be attributed to the high registered temperature during this experiment, averaging 23°C in the studied period.

b) *Nitrogen evolution during crop cycle.* – Soil nitrate contents showed two extreme patterns (Figure 2): in the control decreased markedly during crop early stages, increased in spring (southern hemisphere) and fell again at harvest. In the IBDU treatment, nitrates remained fairly constant during the crop cycle. The treatments with UAN and urea were intermediate between both of them. The content of ammonia in soil showed small variations in all treatments (no data shown), with the exception of the IBDU treatment in which ammonium was higher during wheat grain filling stage (November). It reached 53.7 kg N-NH_4 ha^{-1} against 29.4 kg N-NH_4 ha^{-1} of urea treatment. The IBDU, evidently, did not release mineral nitrogen in the early stages of the crop.

Two months after fertilization we found neither variations in the mineral nitrogen in the soils or its accumulation in the crop (29/9). This behavior could be related to the initial immobilization of nitrogen in urea and UAN treatments. In a no-tillage system the stubble decomposes

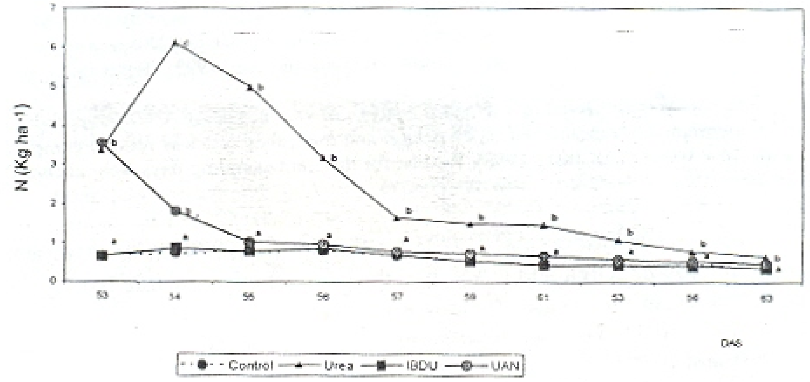

FIG. 1. Ammonia volatilization from different nitrogen fertilizers. DAS: days after sowing. For specific days, treatment means with different letters are significantly different at $p < 0.05$.

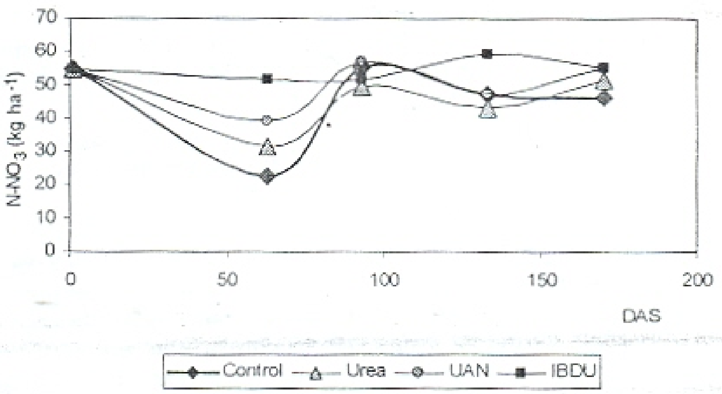

FIG. 2. – Effect of fertilization on nitrate evolution in soil. DAS: days after sowing.

slowly, which would increase the nitrogen immobilization (ANDREN *et al.*, 1993). Even in conventionally cropped wheat, SIERRA *et al.* (1986) found up to 45 % of immobilization one month after the fertilization.

c) *Apparent recovery of the applied nitrogen.* – At the end of tillering (August 27) the uptake of nitrogen was 37; 31; 35 and 30 kg N ha^{-1} for urea, UAN, IBDU and control treatments, respectively. This implies 13 to 19 % of total nitrogen uptake at harvest. The leaf nitrogen concentrations in this stage were 4.09% under urea and 3.49 % in the control, while for UAN and IBDU showed intermediate values. At this time the uptake of nitrogen from the fertilizers was low.

At physiological maturity (December 12), the accumulation of nitrogen of the fertilized treatments differed significantly from the control ($p = 0.01$). Total nitrogen accumulation at harvest is shown in Figure 3. In the urea treatment nitrogen accumulation was highest in straw. Protein content in grains was higher under urea and low in the control ($p = 0.0001$) (Table 2). This is important for farmers because several countries, among them Argentina, favor the wheat prices for protein content. Although slow nitrogen release fertilizer increased nitrates and ammonia at the last stages of wheat protein content in grains were lowest compared to urea. Yields were not different among the nitrogen sources ($p = 0.02$), as a yield increased 11.5; 16.6 y 15.9 kg grain kg^{-1} N for urea, UAN and IBDU, respectively.

Figure 4 shows the nitrogen accumulation at harvest. The N supply was the soil nitrates content at beginning of the experiment, the fertilizers and the nitrogen mineralized during the crop growth. The apparent nitrogen mineralization rates were 22; 17 and 16 g N kg^{-1} soil for urea, UAN and IBDU respectively, during the 6 months crop period. However, this estimation is a simplification, as the mineralized nitrogen is the result of the budget between nitrogen leaching, volatilization, denitrification, immobilization, additions by rainfall, non symbiotic fixation and so on. Local results indicate the little relevance of the N lixiviation in rain-feed wheat (Rimski-Korsakov *et al.*, 2000). The efficiency of apparent nitrogen uptake (kg N uptake kg^{-1} N applied) was very high. This could be attributed to the fact that plants could take more nitrogen in fertilized treatments because they have deeper or more efficient root systems (Goss *et al.*, 1993). Taking those limitations into account, we estimate that the quantity of nitrogen released from the soil surpassed in general the nitrogen lost via ammonia volatilization. For urea, apparent nitrogen mineralization compensated nitrogen volatilization and, in spite of the high losses, the wheat yield was not affected.

Conclusions. – Losses of ammonia via volatilization varied according to the nitrogen source. The highest volatilization rate was found with urea, but this loss did not affect the wheat yields. The nitrogen exported from the crop was similar in all fertilized treatments and appa-

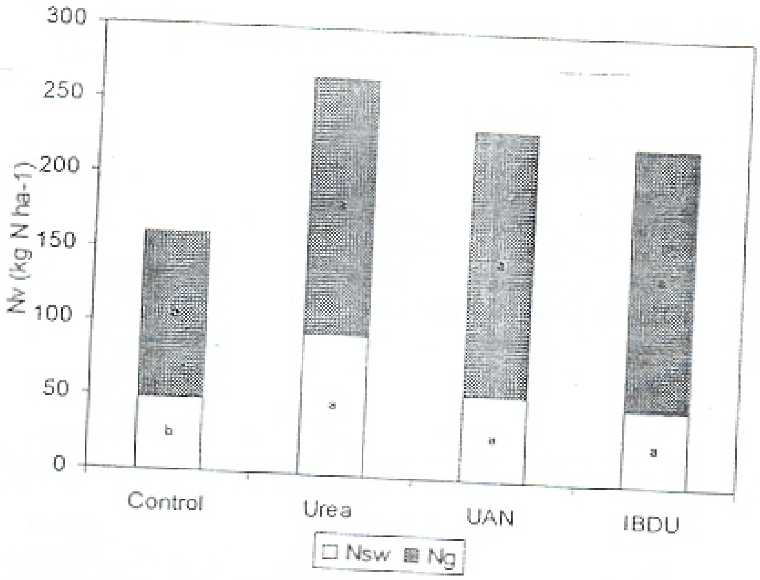

FIG. 3. – Wheat nitrogen uptake as grain (N_g) and straw (NSW).

TABLE 2. – *Effect of different source nitrogen on grain protein contents and yields. Treatment means in a column followed by different letters are significantly different at* $p < 0.05$.

Treatments	Protein contents (%)	Yield (kg grains ha⁻¹)
Control	14.3 c	4880 b
Urea	17.6 a	6147 ab
UAN	16.6 b	6705 a
IBDU	16.6 b	6632 a

rently higher than the applied nitrogen rates. That means that the highest ammonia volatilization rate from urea was compensated with higher apparent soil mineralization rate. These phenomena could lead to the impoverishment of the soil native nitrogen.

ACKNOWLEDGEMENT. – This research was granted by UBACyT and CONICET.

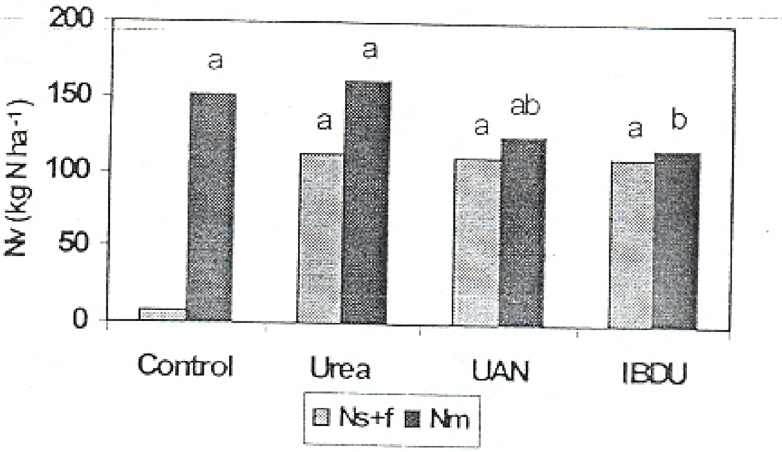

Fig. 4. – Nitrogen uptake by wheat (N_v) supplied from apparent mineralized nitrogen (N_m) and nitrogen availability (N_{s+f}).

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SUMMARY. – The ammonia losses under field conditions vary widely and these nitrogen losses can decrease crops yield. However, experiment with wheat in the Argentinean Pampas showed that yields are not related to the volatilization losses of several nitrogen fertilizers. We hypothesize that ammonia volatilization from urea was compensated with higher apparent soil mineralization rate and then, even with high ammonia volatilization from urea, wheat yields were not affected. We evaluated ammonia volatilization, apparent nitrogen mineralization, apparent nitrogen uptake efficiency, and their effects on wheat yields. The experiment was carried out with wheat grown in a no-till Typic Hapludoll, using urea, UAN and IBDU. Ammonia losses were 17.1% and 4.7% of N applied as urea and UAN, respectively; IBDU and control were low. Wheat yields were not affected by ammonia losses. The N uptake and N export was greater in fertilized treatments. For urea, the highest volatilization rate was compensated by the highest soil mineralization rate. From the sustainable agriculture point of view, the volatilization would be dangerous because the soil could tend to compensate that loss, thus impoverishing itself in native nitrogen.