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Ammonia Volatilization from Urea Applied to Salt-affected Soils under Flooded and Non-flooded Conditions

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Abstract

By conducting a soil incubation experiment, attempts have been made to assess ammonia losses from urea applied salt-affected rice soils under flooded and non-flooded conditions. Seven soils were treated with urea at 0 and 500 mg N kg⁻¹ soil and incubated at 30°C for different time intervals. The evolved ammonia was trapped in acid and was determined by steam distillation at the end of each incubation period. The results revealed that with increase in soil salinity, ammonia losses increased progressively under non-flooded conditions whereas a small increase was observed under flooded conditions. At low salinity level, significantly higher ammonia losses were obtained under flooded conditions as compared to non-flooded conditions but at higher salinity level the results were reversed. Average ammonia losses from the non-flooded soils were almost double as compared to the flooded soils.

Keywords: Ammonia volatilization, flooded and non-flooded conditions, salinity

Introduction

Soils of Pakistan are severely deficient in nitrogen (N) and use of large quantities of N fertilizers are inevitable for getting high crop yields. Presently, urea is a dominant N fertilizer in Pakistan. However, a significant portion of soil-applied urea-N is not taken up by plants and often lost into the environment. It may be lost from soil as a gas by two major mechanisms ammonia volatilization and denitrification. Losses of ammonia from various N fertilizer sources have been measured under field conditions (Keller and Mengel, 1936; Urban *et al.*, 1987). Their studies indicated that potential loss was greatest when the N source was urea. In a previous study ammonia volatilization losses from flooded soils have been reported to be larger than those from upland soil conditions (Blasco and Cornfield, 1966; Rajaratnam and Purushothaman, 1973). On the other hand Manguiat and Yoshida (1973) reported small ammonia volatilization losses from flooded soils.

Salinity has been reported a major factor to promote ammonia losses (Gandhi and Paliwal, 1976; McClung and Frankenberger, 1985). In Pakistan, about 6.3 million ha of land are affected to various degrees of salinity (Khan, 1993). Nitrogen is also a limiting factor in salt-affected soils (Saleem and Ahmed, 1988) and even a little higher doses of N fertilizer than for the normal soils are recommended to increase crop yields in these soils upto certain level of salinity (Yadav, 1988).

Since the efficiency of urea as N fertilizer in salt-affected soils is low, therefore, the present study was conducted to know the extent of ammonia losses from salt-affected rice soils of Pakistan following application of urea under flooded and non-flooded conditions.

Materials and Methods

Seven salt-affected soils (0-15 cm) collected from various districts in rice growing tract of Punjab were used in the study. The soils were dried and passed through a 2 mm

sieve before use. Properties of these are given in Table 1. To study ammonia volatilization losses from different salt-affected soils under flooded and non-flooded conditions. 50 g samples were taken in 250 mL erlenmeyer flasks and treated with solution of urea fertilizer at 0 and 500 mg N kg⁻¹ soil. For non-flooded soil conditions, additional water was added to bring soil moisture content to 80 percent field capacity whereas for flooded conditions, it was added upto 2 cm above the soil surface. The flasks were then fitted with an air device having an acid trap for absorption of ammonia (Bremner and Douglas, 1971) evolved on incubation of the soil samples. The device constituted of a rubber stopper having a hole in its centre fitted with a glass tube sealed from its lower end to the inside wall of a vial containing 5 mL of 0.25 M H₂SO₄. The bottom of the vial in the flask was about 1.5 cm above the surface of the soil or flood water in non-flooded and flooded condition, respectively. The lower end of the glass tube was about 5 mm above the surface of the acid in the vial and upper end was about 1 cm above the top of the stopper. The stoppered flasks were placed in an incubator maintained at 30 ± 2°C for 3, 7, 14, 21, 28 and 35 days. At the end of each incubation period the acid contents from the vials were collected separately and replaced with fresh acid for the next incubation period after adjusting moisture and water level according to the non-flooded and flooded conditions. Ammonia absorbed in acid was determined by steam distillation with 5 mL of 1 M NaOH (Bremner and Douglas, 1971).

Results and Discussion

Ammonia volatilization from Non-flooded soils: The results given in Table 2 showed that urea-N losses as ammonia ranged between 3.41-54.47 percent from non-flooded soils. In all the soils maximum losses occurred after 7 days and then decreased gradually. Ammonia losses increased

Table 1: Physico-chemical properties of soils used

Soil location	pH _s	EC _e	SAR ds/m	D.M. %	CaCO ₃ %	Sand %	Silt %	Clay %
Khanu harni, Lahore	7.97	4.36	23.0	1.16	3.5	38.2	28.0	33.8
Pepe pur, Gujranwala	7.78	5.23	17.7	0.92	2.0	49.6	23.8	26.6
Chak 642, Faisalabad	8.13	6.87	56.0	1.51	3.3	18.2	34.2	47.6
Ucha pind, Sheikhpura	8.02	8.37	42.8	0.64	0.3	29.7	43.3	27.0
Shah kot, Sheikhpura	8.35	9.54	38.6	0.82	2.5	37.7	28.4	33.9
Chak 216, Faisalabad	8.71	12.53	81.7	0.69	3.2	46.7	20.6	32.7
Khanu harni, Lahore	8.60	8.32	60.1	0.40	3.9	57.4	24.2	28.3

All the soils used were saline sodic; pH_s = pH of saturation paste; EC_e = Electrical conductivity of saturation extract; SAR = Sodium adsorption ratio; O.M. = Organic matter.

Table 2: Losses of urea-N as ammonia at different time intervals under non-flooded conditions.

Soil No.	Losses as NH ₃ -N (mg kg ⁻¹ soil) after							Mean	% loss
	3 d	7 d	10 d	14 d	21 d	28 d	35 d		
1	5.46	14.84	2.26	1.20	0.55	0.19	ND	3.5e	4.90
2	5.07	5.57	1.58	1.37	1.20	0.25	ND	2.4f	3.41
3	10.5	85.16	26.70	12.94	6.70	2.51	1.48	20.85c	29.20
4	5.33	33.30	12.19	8.84	8.14	2.42	0.60	10.11d	14.16
5	6.66	38.15	12.78	5.53	4.19	1.20	0.04	9.89d	13.85
6	32.93	96.20	62.71	33.81	22.54	15.62	8.55	38.91a	54.47
7	13.39	89.99	45.74	17.85	8.51	3.07	1.55	25.74b	36.02
Mean	11.33c	52.17a	23.42b	11.65c	7.47d	3.62e	1.75f		22.29

ND = Not detectable; Results are means of four replications; Mean with different letter in a row/column differ significantly according to DMRT ($p < 0.05$).

Table 3: Losses of urea-N as ammonia at different time intervals under non-flooded conditions.

Soil No.	Losses as NH ₃ -N (mg kg ⁻¹ soil) after:							Mean	% loss
	3 d	7 d	10 d	14 d	21 d	28 d	35 d		
1	2.35	21.40	12.42	10.39	3.43	0.40	ND	7.21d	10.08
2	1.63	20.59	11.23	9.18	7.32	1.28	0.08	7.33d	10.26
3	2.29	21.38	15.5	10.92	7.15	0.80	0.04	8.30c	11.62
4	2.20	14.43	12.57	10.49	8.60	1.37	0.05	7.10d	9.94
5	2.31	24.51	11.74	7.49	3.29	0.44	ND	7.11d	9.96
6	2.57	35.44	21.61	11.56	7.43	1.63	0.05	11.47a	16.06
7	2.32	30.81	18.64	15.08	9.27	0.85	0.04	11.06b	15.40
Mean	2.24e	24.09a	14.82b	10.73c	6.64d	0.97f	0.04g		11.9'0

ND = Not detectable; Results are means for four replications; Mean with different letter in a row/column differ significantly according to DMRT ($p < 0.05$).

sharply with increase in soil salinity (Table 1 and 2). It could be attributed to the fact that increase in soil salinity progressively decreases nitrification (Gandhi and Paliwal, 1976; McClung and Frankenberger, 1985), thereby more N remains in ammonium form in the soil which is subjected to ammonia volatilization. The losses were about 16 times in soil 6 (54.47%) having maximum pH, 8.71 and SAR, 81.7 as compared to soil 2 (3.41%) having minimum pH, 7.78 and SAR, 17.7 (Table 1 and 2). Ammonia volatilization increased markedly with increase in SAR of the soils (Fig. 1). It has been reported that the nature of cations on the exchange complex also effect ammonia volatilization from soil. Martin and Chapman (1951) observed higher ammonia losses from Na-saturated soils than those saturated with Ca and Mg presumably because of the higher pH values in Na-saturated soils. Similarly Sharma *et al.* (1992) reported that losses of ammonia increased with increasing exchangeable sodium percentage of the soil.

Therefore, relatively higher pH of salt affected soils due to high sodium on exchange complex was also one of the factors responsible for more ammonia losses. In the present study too, ammonia losses progressively increased with increase in pH or SAR of the soils and showed highly significant correlation with the pH ($r = 0.88^{**}$) and SAR ($r = 0.98^{**}$) of the soils (Table 4). Hence ammonia losses were more from soil 6 due to its high pH and SAR values. The average ammonia losses from all the seven soils were 22.29 percent (Table 2) which were comparable in magnitude to those reported by Ernst and Massey (1960) and Fenn and Kissel (1973) from alkaline soils (25% or more).

Ammonia Volatilization from Flooded Soils: The results given in Table 3 showed that losses of urea-N as ammonia ranged between 9.94 to 16.06 percent in flooded conditions. Maximum losses in all the soils occurred after seven days, and then decreased gradually. At the end of experiment (35

days) the losses were almost negligible. Average ammonia losses from all the seven soils were 11.9 per cent (Table 3). Losses were almost similar (about 10%) in soils 1,2,4 and 5 having SAR values, 17.7 to 42.8. Maximum loss 16.06 percent was observed in soil 6 having maximum SAR, 81.7 and pH 8.71. A significant correlation ($r = 0.85^*$) was found between ammonia losses and pH/SAR values of the soils (Table 4).

Table 4: Relationship of urea-N losses as NH₃ after 35 days with selected soil properties.

Soil property	Correlation coefficient (r) of urea-N losses as NH ₃ vs soil properties	
	Non-flooded Conditions	Flooded conditions
pH ₅	0.88 **	0.85 *
EC _e	0.79 *	0.63NS
SAR	0.98 **	0.85 *
O.M.	-0.28NS	-0.45NS
CaCO ₃	0.42NS	0.55NS

*, **Significatn at p<0.05, 0,01 level; NS Non-significant

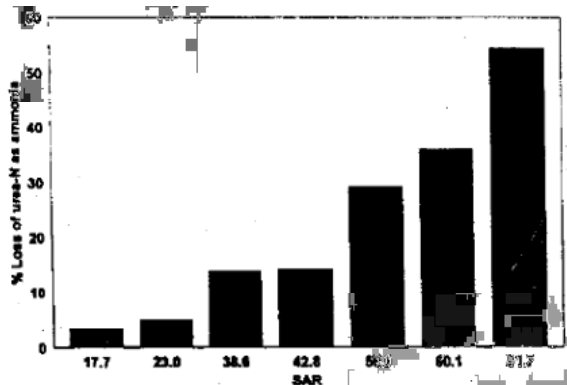


Fig. 1: Percent loss of urea-N as ammonia from non-flooded soils in relation to SAR

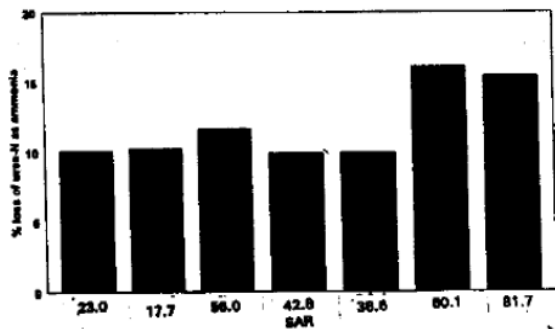
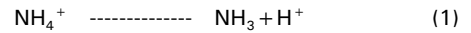


Fig. 2: Percent loss of urea-N as ammonia from flooded soils in relation to SAR

The important factors that influence ammonia volatilization from flooded soils are environmental and chemical in nature. Vlek *et al.* (1980) found that for three soils varying in cation exchange capacity (1 6.2-49.2 mg per 100 g) 50-60 percent of applied urea was found in the flood water which was subsequently hydrolyzed and 80 percent of it was found as ammonical N in the flood water. Conversion of NH₄₊ to aqueous NH₃ in solution is extremely rapid processes (Emerson *et al.*, 1960) and follows first order reaction kinetics. The equilibrium constant is such that appreciable amount of NH₃ can form only at pH>7.5.



The rate of ammonia volatilization from flooded soils is thus directly related to the concentration of aqueous ammonia, pH and temperature of flood water. Concentration of aqueous NH increases ten fold per unit increase in pH upto pH 9 (Vlek and Stumpe, 1978) and increases (approximately linearly with increase in temperature from 10-40°C (Beutier and Renon, 1978). While the reaction is going on, protons are released and there is a tendency for acidification, To keep the pH high enough for volatilization to continue the only proton acceptor present in appreciable amount in flood- water of calcareous soils is bicarbonate.



In addition to this urea upon hydrolysis creates a solution ideally suited for volatilization, i.e., the solution of high alkalinity and pH (Vlek and Stumpe, 1978). As all the soils included in the study were with pH greater than 7.5 (Table 1), contained bicarbonates due to their calcareous nature and were incubated at temperature 30°C, therefore, significant losses of NH₃ from all the soils even at low salinity level were observed under flooded conditions. These findings were similar to those of Vlek and Graswell (1979) and Sahrawat (1980).

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