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AMMONIA VOLATILIZATION LOSSES FROM APPLIED UREA IN FLOODED ALKALI SOILS

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ABSTRACT

A laboratory study was conducted to evaluate the effect of different factors on ammonia volatilization losses in flooded alkali soils (ESP 26 & 82). Incubation studies in these soils showed that the losses were largely governed by pH/alkalinity of the system. The duration of presubmergence decreased the cumulative ammonia volatilization losses from 19.2 to 13.5 per cent in ESP 26 soil and 22.5 to 16.0 per cent in ESP 82 soil at 0, 5 and 10 cm floodwater depths, respectively. Flooding of the soil decreased the soil pH resulting in lower losses from 23.9 to 16.9 per cent in ESP 26 soil and 27.8 to 19.3 per cent in ESP 26 soil and 27.8 to 19.3 per cent in ESP 82 soil. The cumulative ammonia losses were maximum in the control treatment followed by Dhaincha straw, FYM, Rice husk and Wheat straw, varied from 8.1 to 16.9 per cent in ESP 26 soil and 9.0 to 20.5 per cent in ESP 82 soil, respectively. The floodwater NH_4^+, pH and $CO_3^{''}$ + $HCO_3^{'}$ in all the experiments followed the same trend in which the losses occurred.

KEY WORDS : Ammonia volatilization losses, floodwater NH_4^+-N, pH and $CO_3^{''} + HCO_3^{'}$, incubation studies, sodic soils, urea

Urea is gaining an important place among the solid nitrogenous fertilizers in world markets. In India, about 85 per cent of total N consumed is only in the form of urea. When urea or urea containing fertilizer is applied on soil surface, it gets hydrolyzed through enzymatic conversion from amide to ammonium and one or more inorganic carbon forms. In alkali soils, the soil pH is high due to the presence of Na^+ on the exchange complex and urea further increases the alkalinity during the hydrolysis due to formation of $NH4^+$ ions. During their reclamation, they are cropped to rice and wheat in the initial years (Ponnamperuma, 1978 ; Swarup, 1987, 1988).

Ammonia volatilization losses may occur whenever free ammonia is present near the soil surface. The quantities of ammonia lost are highly variable depending on such factors as rate, type and method of nitrogen fertilizer application, organic matter and environmental factors including temperature, moisture and wind. Studies in highly alkali soils are limited and indicate extensive losses in them. Information on these aspects in sodic soils is meagre. Therefore, the present experiments were conducted in the laboratory to study the influence of various soil factors on ammonia volatilization losses from applied urea under submerged conditions at two levels of sodicity (ESP 26 and 82).

MATERIALS AND METHODS

The soils used in this study were collected from experimental farm and Gudha Research Farm of the Central Soil Salinity Research Institute, Karnal. The important physico-chemical properties are given in Table 1.

The method of measuring the ammonia volatilization losses consisted of device similar to that used by Fenn and Kissel (1973). Two hundred

Table 1. Initial physico-chemical properties

Characteristics	Soil I	Soil II
pH (1:2 Soil : Water)	9.0	10.2
EC (1 : 2 Soil : Water) (dS/m)	0.44	3.20
Organic Carbon (%)	0.26	0.20
CaCO3 (%)	1.31	2.10
ESP	26.00	82.00
CEC (c mol (p^+) Kg^{-1})	9.80	9.40
Clay Content (%)	20.50	17.20
Texture	Loam	Loam
Saturation Percentage	32.76	34.08

g of the each soil was uniformly packed in plexiglass columns (5.5 cm diameter and 35 cm in length) fixed on a plastic disc with the help of araldite. The columns were compacted to 1.4 mg m^{-3} bulk density and then brought to approximate to field capacity or waterlogging (1 : 2 soil : water). Incoming air was passed through 2 lit. of 1M H_2SO_4 to remove ambient NH_3 then passed through 4 lit. of distilled water before entering the system. The humid air was subsequently passed over the soil kept in the column with the help of air compressor. Compressed air flew through the system at a rate of 304 cm^3 air cm^{-2} soil surface min^{-1} or 7 dm^3 min^{-1} $column^{-1}$. The volatilized ammonia was absorbed in 50 ml of 2 per cent boric acid containing mixed indicator (bromocresol green + methyl red). The losses were measured at an intervals of 2,4,6,8,10 and 14 days. The details of each experiment are as follows : (i) To study the effect of floodwater depth, columns were slowly filled from the base until standing water layers of 0, 5 and 10 cm were estabilished over the soil kept in the column. After allowing the suspension to settle down, urea at the rate of 100 mg N per kg soil was applied by broadcasting into floodwater ; (ii) In the duration of presubmergence experiment, soils were submerged for 0, 3 and 6 days prior to N fertilization. Urea-N at the rate of 100 ppm was applied into the floodwater. (iii) To study the influence of different moisture regimes on ammonia losses, the soils were brought to field capacity, saturation and flooding stages. Urea - N was applied at a similar rate to the flooded soil i.e. 100 ppm.

(iv) In the experiment with volatilization of ammonia from organic sources (Dhaincha straw, FYM, Rice husk and Wheat straw), dried and ground (<2mm) plant material was added at 1% (1gm in 100gm soil). Control columns, without addition of any plant material, were also maintained. Nitrogenous fertilizer (Urea-N) was applied at the rate of 100 ppm to the floodwater.

All the treatments were run in triplicate and compared with controls i.e. which did not received any fertilizer N. The boric acid was back titrated with 0.01 N H_2SO_4 to measure the amount of ammonia volatilized. For measuring floodwater pH, NH_4^+-N and CO3'' + HCO_3, separate columns were run simultaneously. The floodwater pH was determined by portable pH meter while NH_4^+-N concentration using Onken and Sunderman (1977) method. The total alkalinity (CO_3'' + HCO_3') of floodwater was determined following standard procedure.

RESULTS AND DISCUSSION

Although, a similar type of trend was observed in ESP 26 soil with respect to ammonia losses, floodwater pH, NH_4^+-N and CO_3'' + HCO_3' contents but their values were loss as compared to ESP 82 soil. Therefore, the results have been expressed in detail for ESP 82 soil only.

Effect of duration of presubmergence

The duration of presubmergence decreased the amount of ammonia volatilization losses at all time intervals. At 6 days, 8.25, 7.50 and 6.05 per cent of the applied N was lost at 0,3 and 6 days prior to submergence, respectively (Fig.1). The cumlative ammonia volatilization losses decreased from 19.2 to 13.5 per cent in ESP 26 soil and 22.5 to 16.05 per cent in ESP 82 soil, respectively. Therefore, higher ammonia losses at 0 day in comparison to different periods of presubmergence were due to decrease in soil pH, ESP, urea hydrolysis and increase in CO_2 pressure thereby, creating a most favourable environment for low ammonia volatilization losses. Katyal and Gadalla (1990) and Kumar *et al.* (1995) reported that the rate of urea hydrolysis slowed down with the duration of presubmergence.

The floodwater NH_4^+-N, pH and CO_3'' + HCO_3' increased from 2 to 6 days and then came down in subsequent days (Table 2). The floodwater pH was related to CO_2 concentration and HCO_3' activity. Thus, high bicarbonates in a system with

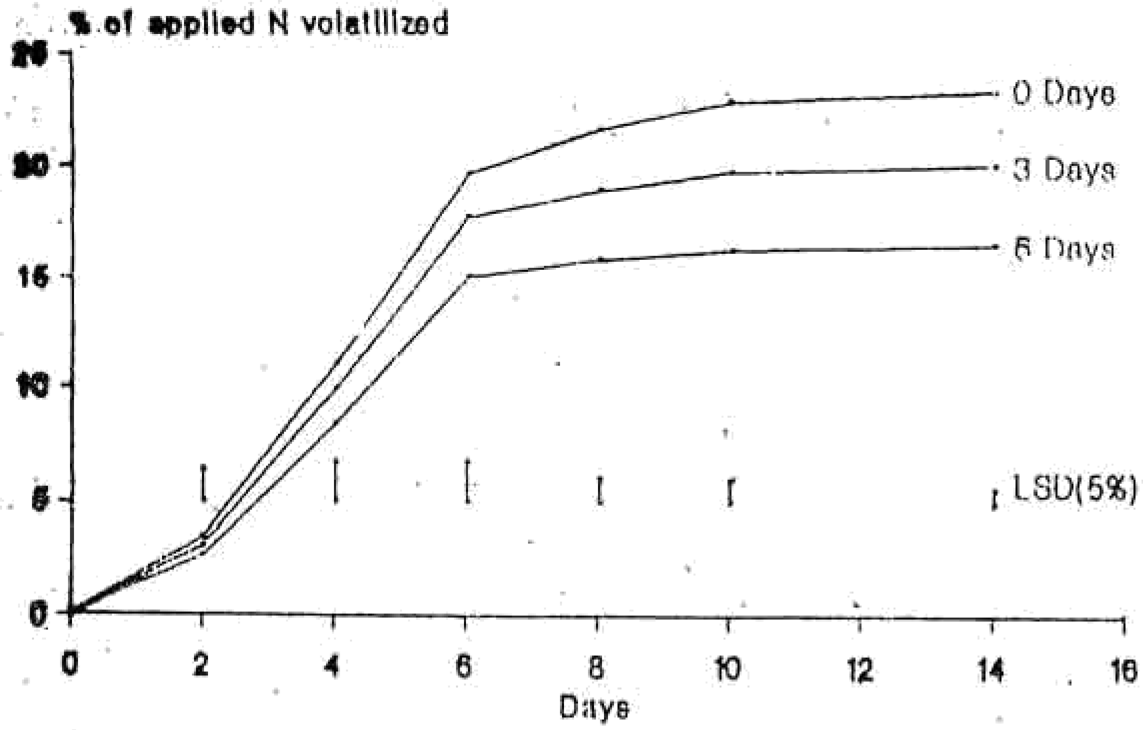

Fig.1. Periodical changes in cumulative ammonia volatilization losses with duration of presubmergence from alkali soil

constant removal of CO_2 may greatly increase the pH which ultimately affect ammonia volatilization losses.

Effect of depth of flooding

Increasing the depth of standing water decreased the amount of ammonia lost at all time intervals in both the soils. The ammonia volatilization losses increased upto 6 days and then decreased at all floodwater depths. The cumulative losses were 18.9, 14.7 and 13.8 per cent in ESP 26 soil and 22.2, 16.1 and 14.8 per cent in ESP 82 soil at 0, 5, 10 cm floodwater depths, respectively (Fig. 2). The higher ammonia losses at 0 cm standing water depth were due to moderate availability of moisture which increases the activity of urease enzyme. With increasing depth of standing water, the rate of urea hydrolysis becomes slow and ultimately, the ammonia was lost at a slower rate. The losses were less in the beginning which may be attributed to the delay in the hydrolysis of urea. The highest loss of ammonia occurred during first week at all floodwater depths, irrespective of the soil. Thereafter, it gradually decreased during subsequent weeks and amounted to a maximum of 3.4 per cent of the applied urea. Ammonia volatilization from submerged soils typically ceases about 7 to 14 days after fertilizer application depending upon the N sources, method of application and management.

Table 2. Effect of duration of presubmergence on periodic changes of floodwater NH_4^+-N, pH and $CO_3^{''}$+ $HCO_3^{'}$

Presubmergence period (Days)	Days					
	2	4	6	8	10	14
	Floodwater MH_4^+-N (ppm)					
0	3.2	4.9	5.4	2.8	0.9	0.4
3	2.8	3.8	4.2	2.4	0.6	0.3
6	2.4	3.7	3.9	2.0	0.4	0.3
LSD (0.05)	0.4	0.7	1.0	0.3	NS	NS
	Floodwater pH					
0	10.3	10.4	10.6	10.2	10.3	10.2
3	10.2	10.4	10.4	10.2	10.1	10.1
6	10.1	10.2	10.3	10.1	10.1	10.1
LSD (0.05)	0.1	0.2	0.1	NS	0.1	NS
	Floodwater $CO_3^{''}$+$HCO_3^{'}$ (me/l)					
0	4.5	5.8	6.1	3.9	1.6	1.5
3	4.1	5.4	5.8	3.6	1.5	1.5
6	4.0	5.3	5.6	3.4	1.3	1.4
LSD (0.05)	0.3	0.3	0.2	0.2	NS	NS

The floodwater NH_4^+-N and $CO_3^{''}$ + $HCO_3^{'}$ increased upto 6 days and then decreased (Table 3). When NH_4^+-N ions are present on soil exchange complex, an equilibrium NH_4^+ + OH^- ----- H_2O + NH_3 exists in the soil solution. Increasing the soil

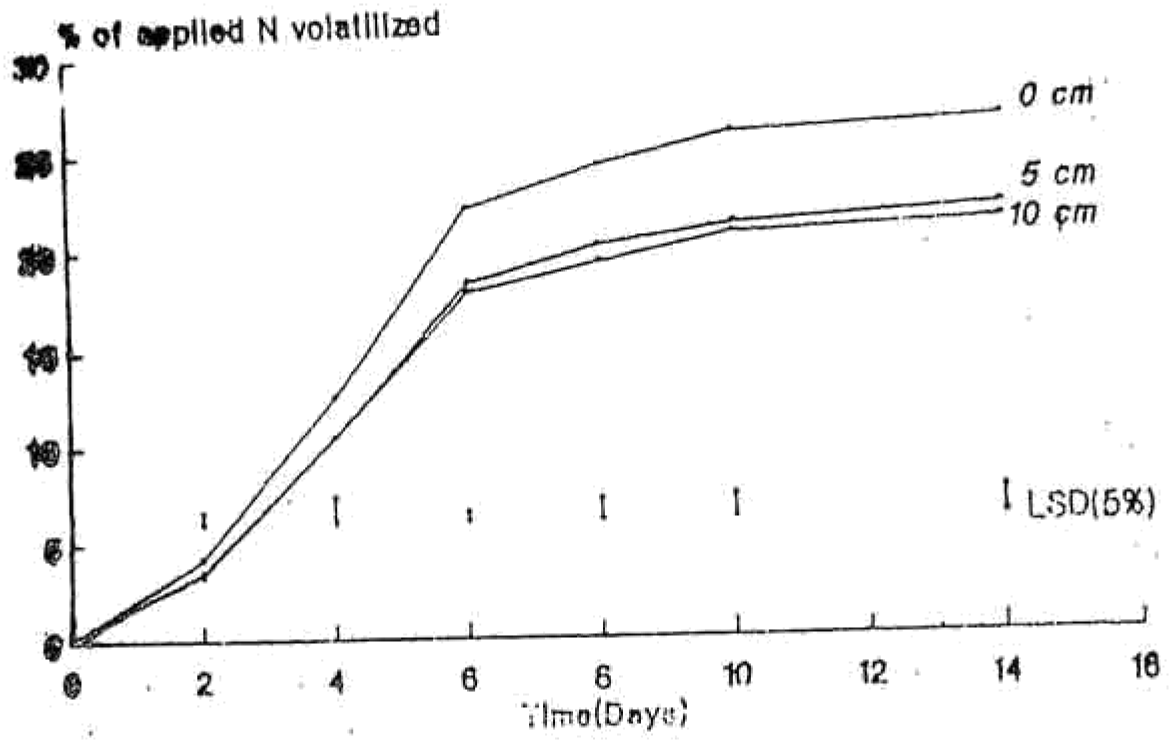

Fig.2. Periodical changes in cumulative ammonia volatilization losses with depth of flooding from alkali soil

pH causes an increase in the activity of both NH_4^+ and OH^- ions, thus driving the equilibrium to the right and increases the ammonia losses. The concentration of NH_4^+-N in the floodwater was inversely related to the depth of standing water in both the soils. The lower concentration of NH_4^+-N in 5 and 10 cm floodwater depths as compared to 0 cm floodwater depth was due to dilution of NH_4^+-N concentration. The floodwater pH also increase by 0.2 to 0.3 units in all the treatments from 2 to 6 days and then came down in subsequent days (Table 3).

Table 3. Effect of floodwater depth on periodic changes of floodwater NH_4^+- N, pH and CO_3 ''+HCO_3' content

Depth (cm)	Days					
	2	4	6	8	10	14
	Floodwater MH_4^+-N (ppm)					
0	2.8	5.2	6.6	2.6	1.2	0.7
5	2.1	4.7	5.9	2.0	1.0	0.5
10	2.0	4.6	5.4	1.8	1.0	0.5
LSD (0.05)	0.5	0.4	0.6	0.6	0.1	NS
	Floodwater pH					
0	10.3	10.4	10.6	10.2	10.2	10.2
5	10.2	10.3	10.5	10.3	10.3	10.3
6	10.2	10.3	10.4	10.2	10.3	10.3
LSD (0.05)	0.1	0.1	0.1	NS	NS	NS
	Floodwater CO_3 ''+HCO_3' (me/l)					
0	4.6	5.9	6.3	3.6	1.5	1.0
5	4.3	5.7	6.0	3.5	1.4	1.0
10	4.2	5.7	5.9	3.4	1.4	0.8
LSD (0.05)	0.2	0.2	0.3	0.1	NS	NS

Effect of moisture regimes

The ammonia losses from urea-N were maximal at field capacity, decreasing with the amount of water applied (Fig.3). The losses were reduced considerably from 23.9 to 16.9 per cent in ESP 26 soil and 27.8 to 19.3 per cent in ESP 82 soil on waterlogging due to reduction in pH (Table 4). Because Nitrogen is retained in the soil for a longer duration with increase in moisture content. Therefore, drying of the soil would lead to greater ammonia losses. But the moderate availability of moisture increases the activity of urease enzyme and thus helps in increasing the volatilization losses. Ponnamperuma (1978) suggested that the

Table 4. Effect of moisture saturation on cumulative ammonia volatilization losses and reaction coefficient

Treatment	N losses (%)		K (Day^{-1})	
	Soil I	Soil II	Soil I	Soil II
Field capacity	23.90	27.8	0.595	0.672
Saturation	21.80	23.6	0.485	0.538
Waterlogging	16.95	19.3	0.369	0.430
LSD (0.05%)	1.90	4.0		

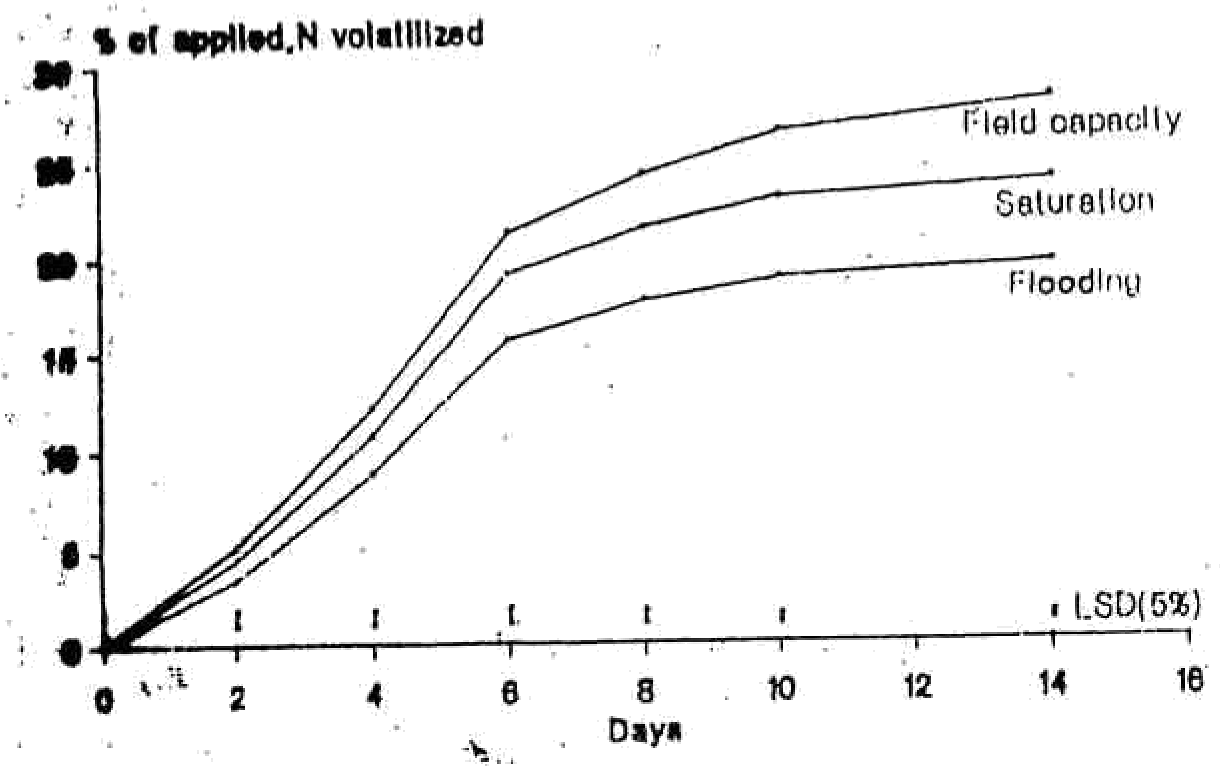

Fig.3. Periodical changes in cumulative ammonia volatilization losses with different moisture regimes from alkali soil

high bicarbonates in a system with constant removal of CO_2 may greatly increase the pH which can increase ammonia volatilization losses of surface applied fertilizer or of NH_4^+ concentration which diffuses into the water layer.

Effect of organic sources

Application of different organic materials decreased the ammonia volatilization losses significantly in both the soils from 2 to 14 days. However, their effect at 14 days was not found significant (Fig.4). The ammonia losses were significantly higher at all time intervals in the treatment where organic material was not applied. The cumulative ammonia losses decreased by 13.3, 20.8, 32.4 and 51.6 per cent in ESP 26 soil and 18.9, 31.9, 42.3 and 56.2 per cent in ESP 82 soil over control with the Dhaincha straw, FYM, Rice husk and Wheat straw, respectively. The reasons for decrease in ammonia volatilization losses in the presence of organic matter may be due to adsorption of NH_4^+ ion on organic matter surface which results in the reduction of NH_4^+ concentration in soil solution leading to less ammonia volatilization losses according to the following equation.

$$NH_4^+ \text{---------}> NH_3 + H^+$$

Sharma and Gupta (1989) observed that at lower rates of FYM application, urease activity is increased due to energy availability for micro-organism and at higher doses, the soil pH surrounding urea granules is lowered due to its application resulting in retardation of volatilization losses.

Floodwater NH_4^+-N and CO_3'' + HCO_3' increased upto 6 days and then decreased abruptly during 6-8 days (Table 5). The highest floodwater NH_{4+}-N and CO_3'' + HCO_3' concentration was found in the control treatment followed by Dhaincha straw,, FYM, Rice husk and wheat straw. The floodwater pH also increased from 0.2 to 0.3 units in all the treatments from 2 to 6 days and then came down in subsequent days. Following the hydrolysis of urea at soil water interface, the floodwater receives some of the NH_4^+ and CO_3^{-2} ions which are not adsorbed by the soil and becomes a weak NH_4HCO_3 solution. The HCO_3^- produces OH^- which further promotes ammonia volatilization losses as shown below :

$$HCO_3^- \text{------} CO_2 + OH^-$$

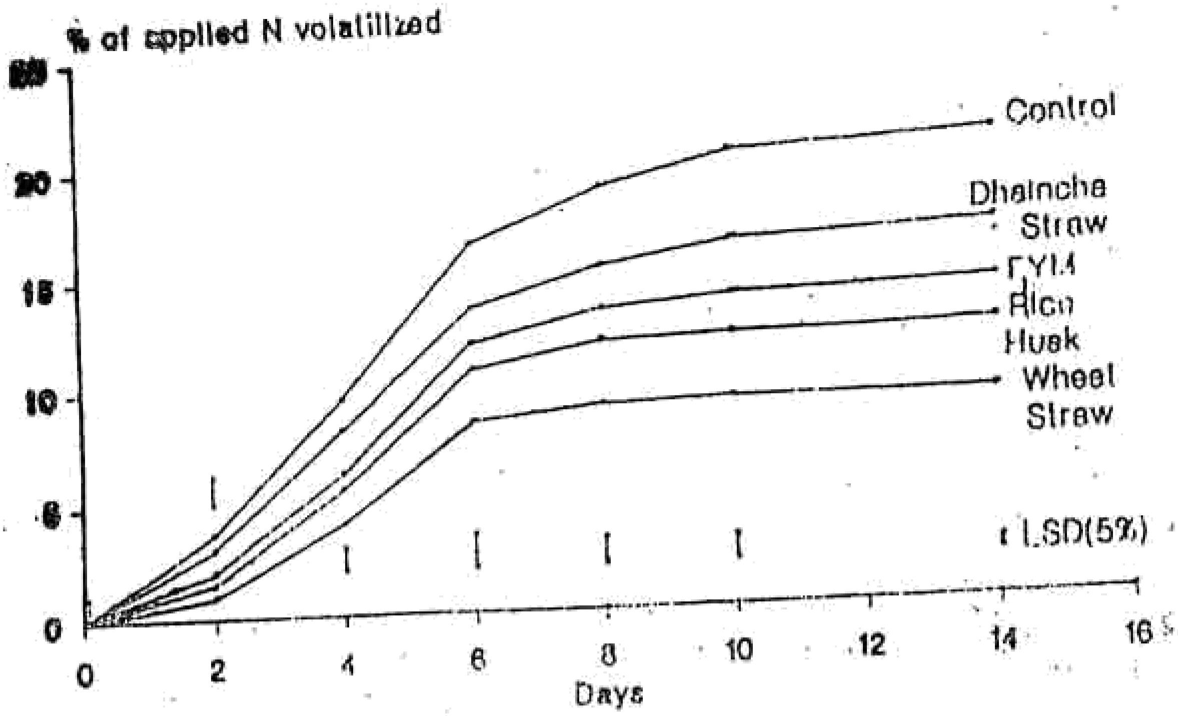

Fig.4. Periodical changes in cumulative ammonia volatilization losses with different organic sources from alkali soil

The OH^- ions act as proton acceptors and continuously promote the reaction :

NH_4^+ ------- $NH_3 + H^+$

The whole process leads to rise in the pH of the floodwater and then it slows down in subsequent days which ultimately affects floodwater pH.

Table 5. Periodic changes of floodwater NH_4^+-N, pH and CO_3 +HCO_3' with different organic matter

Treatments	Days					
	2	4	6	8	10	14
	Floodwater MH_4^+-N (ppm)					
Dhaincha Straw	2.5	4.3	5.4	3.2	1.8	0.4
FYM	2.1	3.7	4.5	2.1	1.3	0.3
Rice Husk	1.8	2.9	4 0	1.8	1.0	0.3
Wheat Straw	1.4	1.6	3.1	1.4	09	0.2
Control	3.0	4.5	5.7	3.6	2.1	0.4
LSD (0.05)	0.5	0.4	0.7	0.8	0.4	NS
	Floodwater pH					
Dhaincha Straw	10.3	10.4	10.4	10.3	10.3	10.3
FYM	10.3	10.4	10.5	10.4	10.4	10.2
Rice Husk	10.2	10.3	10.5	10.4	10.3	10.2
Wheat Straw	10.2	10.2	10.5	10.3	10.2	10.1
Control	10.3	10.5	10.5	10.3	10.3	10.2
LSD (0.05)	0.1	0.1	0.1	NS	NS	NS
	Floodwater CO_3 "+HCO_3' (me/l)					
Dhaincha Straw	4.0	4.4	4.8	3.0	1.5	0.7
FYM	3.5	3.3	4.2	2.7	1.1	0.5
Rice Husk	3.2	3.5	3.9	2.2	1.0	0.3
Wheat Straw	3.0	3.3	3.1	1.8	0.9	0.3
Control	5.0	6.0	6.2	4.0	2.0	1.5
LSD (0.05)	0.5	0.3	0.6	0.4	0.4	0.5

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