Pak. J. Agri. Sci.
24 (2) 129, 1987

AMMONIA VOLATILIZATION LOSSES FROM NITROGEN FERTILIZERS IN ALLUVIAL ALKALINE SOILS

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Ammonia volatilization losses of nitrogen from urea, sulphur coated urea, ammonium sulphate and ammonium nitrate in alluvial alkaline calcareous soil were measured under laboratory conditions. The results showed that ammonia volatilization loss from urea was 50 per cent higher than that from ammonium sulphate. Over a period of 49 days the loss of nitrogen as ammonia was about 30 and 20 per cent from urea and ammonium sulphate, respectively. Whereas NH_3 volatilization loss of nitrogen from sulphur coated urea was not detected undr these conditions.

Ammonia volatilization loss from urea was reduced to 7 per cent (about 77 per cent suppression) by amending the soil with straw of *Leptochloa fusca* (Kallar grass) or straw of *Oryza sativa* (rice) at 1 per cent of soil (W/W). The ammoniacal loss of nitrogen from urea could be reduced significantly by thiourea, phenol and hpdroquinone. Phenol was the most effective to reduce the volatilization of ammonia. Thiourea, hydroquinone and phenol suppressed NH_3 volatilization by about 50, 87 and 95 per cent for 112 days, respectively.

INTRODUCTION

Nitrogen is the leading nutrient in terms of tonnage for crop production. Most of the soils do not contain enough native nitrogen to sustain high production of crops. Modern agriculture, therefore, now relies heavily on the commercial nitrogen fertilizers for obtaining higher yields of crops. However, the efficiency of fertilizer nitrogen use by crops is low, with only 50 per cent of applied fertilizer nitrogen taken up by non-legume crops such as maize and wheat and only 30 to 40 per cent by paddy rice (Hardy *et al.*, 1975). Recent research (Mikkelsen and DeDatta, 1979; Vlek and Craswell, 1979; 1981) showed that this low efficiency is largely due to NH_3 volatilization which is encouraged by the high pH of soil. As the nitrogen fertilizers used in Pakistan contain their nitrogen as ammonical nitrogen or becomes ammoniacal upon hydrolysis and the soils are alkaline and calcareous the NH_3 volatilization losses might be very high.

The objective of this study was to obtain quantitative data on rate and extent of fertilizer nitrogen losses through volatilization in alluvial alkaline calcareous soil, and to develop a method for minimizing the ammoniacal loss of nitrogen.

MATERIALS AND METHODS

Direct measurement of NH_3 loss

The experimental apparatus for collecting NH_3 volatilized from the fertilized soil cosisted of an acid trap, water trap (humidifier), soil chamber (Erlenmeyer Flask) NH_3 collection vessel containing 50ml of 4% H_3BO_3 solution With bromcresol green and methyl red indicators (Matocha, 1976). An air compressor was used in moving the air across the sample surface.

As soon as the nitrogen was added to the soil, compressed air scrubbed through 0.5 N H_2SO_4 and then through water was passed into the flasks. This air had sufficient humidity to keep the moisture in the soil at a constant level. Air left the flasks (1.5 l/h) through the glass tubing and passed into the boric acid solution. Capillnry tubes were used at this point to equalize the pressure in the system. The NH_3 was trapped in the boric acid solution which was back titrated against standard H_2SO_4 (Jackson, 1958).

Laboratory exprriments were conducted on alluvial alkaline calcareous sandy loam soil (obtained from surface 30 cm) which was 10.2 % clay, 11.0% silt and 78.8% sand with pH 8.0, O.M. 0.83% and $CaCO_3$ 3.53%.

Fertilizers included in the study were $(NH_4)_2SO_4$, NH_4NO_3, urea and sulqhur coated urea.

Air dried samples of soil (500 g) were placed in 1l Erlenmeyer Flasks. The surface area of soil was 113.1 cm^2 in the flasks. The soil was moistened with enough water to bring the water content of sosl to 1/3 W.H.C. Nitrogen was applied to the furface of soil. The amount of N applied was equivallent to 120 kg/ha (on area basis). The measurements were made at room temperature (24 ± 2°C) except the effect of temperature on NH_3 volantilization.

The effect of plant residues, moisture content and chemicals on NH_3 losses from urea was studied as follows:

Effect of crop residue

Straw of *Leptochloa fusca* (Kallar grass; 0.57% N), Straw of *Oryza sativa* (rice; 0.59% N), straw of *Triticum aestivum* (wheat; 0.93% N), leaves of *Sasbania aculeata* (Jantar; 4.97% N), and leaves of *Gossypium hirsutum* (cotton; 2.41% N) were used as amendments at the rate of 1% of soil (w/w).

Effect of moisture content

Moisture levels maintained in the soil were : air dry, 2%, 5%, 10% and 15% on weight basis of air dry soil.

Effect of temperature

In order to study the effect of temperature on NH_3 volatilization, the experiment was done under controlled temperature conditions. Three temperatures (20 ± 1°C, 30 ± 1°C and 35 ± 1°C) were maintained for this study.

Effect of chemicals

Phenol, hydroquinone and thiourea were applied at rate to provide the chemical equivalent to 5% by weight of the urea added.

RESULTS AND DISCUSSION

The rate of volatilization of NH_3 from urea and $(NH_4)_2 SO_4$ after addition to soil in shown Fig. 1. Initially the volatilization of NH_3 from $(NH_4)_2 SO_4$ was higher which decreased gradually. While in urea no NH_3 volatilization occurred during the first day after application to soil. The self liming effect of the soluble urea increased the pH (Doak, 1952) and urea hydrolysis proceeded after the initial delay. Ammonia volatilization increased rapidly from urea after two days and this high loss rate continued through the sixth day and then the loss slowed during the second week. The cumulative loss of NH_3 (Fig, 2) was about 60 per cent higher in case of urea as compared to $(NH_4)_2 SO_4$, and the NH_3 loss from $NH_4 NO_3$ was half of $(NH_4)_2 SO_4$. No NH_3 loss was detected from sulphur coated urea under these experimental conditions.

Terman and Hunt (1964) hypothesized that in calcareous soils the chemical reaction between $(NH_4)_2 SO_4$ and $CaCO_3$ which results in the formation of sparingly soluble Ca SO_4 and unstable $(NH_4)_2$ CO_3 is expected to increase the rate of NH_3-N loss. The low solubility of $CaSO_4$ pushes the reaction to conpletion with the unstable $(NH_4)_2$ CO_3 decomposing further to NH_3, CO_2 and H_2O. Terman and Hunt (1964) suggest that NH_4-N losses would be considerably less from compounds such as NH_4 NO_3 which form no Ca-precipitate. Our results support this hypothesis. The biologically deqendant reaction of urea hydrolysts is slower and less affected initially by the presence of $CaCO_3$ or high soil pH (Gaster, 1964).

The residues of different plants had a marked effect on volatilization of NH_3 from urea (Fig. 3). The residues with low nitrogen content such as straw of *Leptochloa fusca* (Kallar grass) and straw of Oryza sativa (rice) reducted the NH_3-N loss considerably, Only 6-7 per cent NH_3-N was volatilized (about 77 per cent suppression in NH_3 loss) in the presence of Kallar grass and rice straw in about 7 weeks. Whereas residues with high nitrogen content like leaves of *Sasbania aculeata* (Jantar) increased the NH_3 volatilization loss to 55 per cent which was about double of that volatilized in unamended soil. These results contradict those reported by Rashid (Rashid 1977). In fact microbial population immobilize the available nitrogen during the decomposition of plant residues with low nitrogen content. The nitrogen demand of the microbes during decomposition is of obvious practical importance (Safigna *et al.*, 1982). Russel (1961) has pointed out that materials containing less than 1.2 per cent N, when rotting in the presence of NH_4 salts will cause some of the NH_3 to be taken up and converted into organic nitrogen compounds. If the material contains more than 1.8 per cent N, some of this nitrogen will be converted into NH_3 during the rotting process.

Moisture content of the soil affected the volatilization of NH_3 from urea (Fig. 4). Highest NH_3 loss was recorded, at 2 per cent moisture level. As the moisture content was increased from 2 per cent to 15 per cent the NH_3-N loss decreased from 45 per cent to 28 per cent in 20 days. Ammonia volatilization also occurred in air dry soil;5 per cent N volatilized in 20 days. The NH_3 loss from air dry soil was not observed by Volk (1959), probably duration of measurement was too short in his case. The loss of NH_3 at lower moisture contents are quite high in our experiment. Doak (1952) reported the hydrolysis of urea to be more rapid at moderate moisture content. Our results show that urea hydrolysed at low moisture content even in air dry soil by absorbing moisture from the air. At the lower moisture levels other transformations of nitrogen might be slow (Wahhab *et al.*, 1960) and this condition favoured NH_3 volatilization. Several workers (Fenn and Miyamoto, 1981; Vlek and Carter, 1983; Ferguson *et al.*, 1984. Bouwmeester *et al.*, 1985) observed reduction in NH_3 volatilization with increased rate of water application following urea application which was ascribed to the movement of urea deep into the soil and adsorption (Boumeester *et al.*, 1985). This explanation does not apply to our observations Under such condition the affinity of NH_3 for water and other transformations of N might be the reason of reduction in NH_3 volatilization with the increase of the initial moisture content in the soil. These points need confirmation.

Temperature affected the NH_3 volatilization from urea (Table 1). Ammonia volatilization was 23.6 per cent at 20 ± 1°C and 52.2 per cent at 35 ± 1°C. Hydrolysis of urea is temperature dependent (Doak, 1952; Broadbent *et al.*, 1958; Fisher and Parks, 1958). The optimum temerature for urea hydrolysis is reported to de 55°C (Van Slyke and Cullen, 1914) and accordingly the volatilization of NH_3 would also be increased with the increase in temperature.

Table 1. *Effect of temperature on NH_3 volatilization from urea in alluvial sandy loam alkaline soil (in 6 weeks)*

Temperature °C	NH_3 volatilized, %N
20 ± 1	23.6 ± 1.5
30 ± 1	38.3 ± 3.5
35 ± 1	52.2 ± 8.6
LSD $P<0.05=8.48$	$P<0.01=14.07$

The ammoniacal losses of nitrogen could be reduced significantly by thiourea, hydroquinone and phenol (Fig. 5). Phenol was most effective and thiourea least effective inhibitor of urease enzyme that hydrolyses urea. In 112 days the the loss of NH^3 observed was 15, 4 and 1.5 per cent in the presence of thiourea hydroquinone and phenol, respectively. The effect of urease inhibitors on the reduction of hydrolysis of urea in soils has been demonstrated by other workers (Kistiakowsky and Shaw, 1953; Bremner and Douglas, 1973; Malhi and Nyborg,

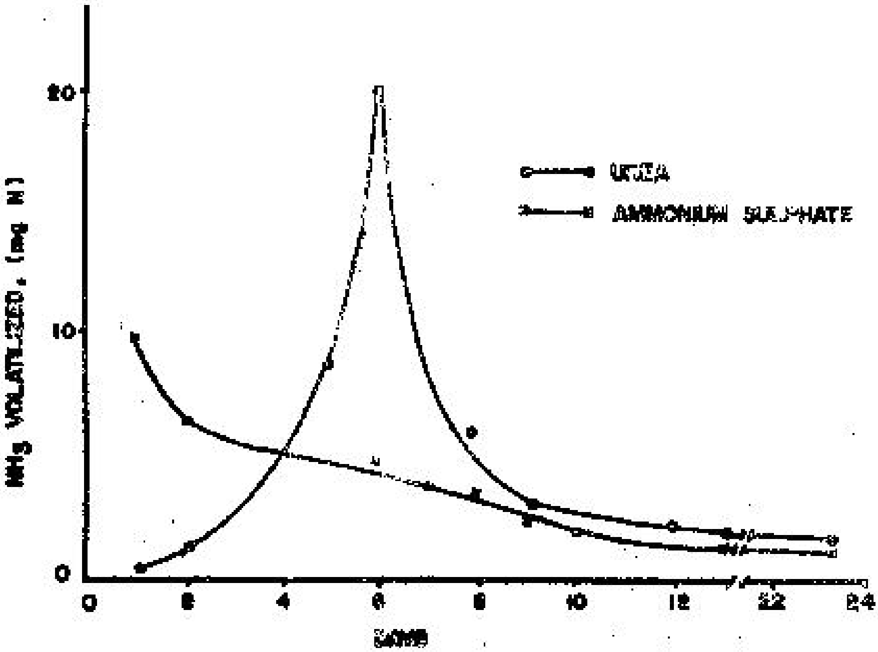

Fig. 1. Rate of volatilization of NH_3 from urea and ammonium sulphate.

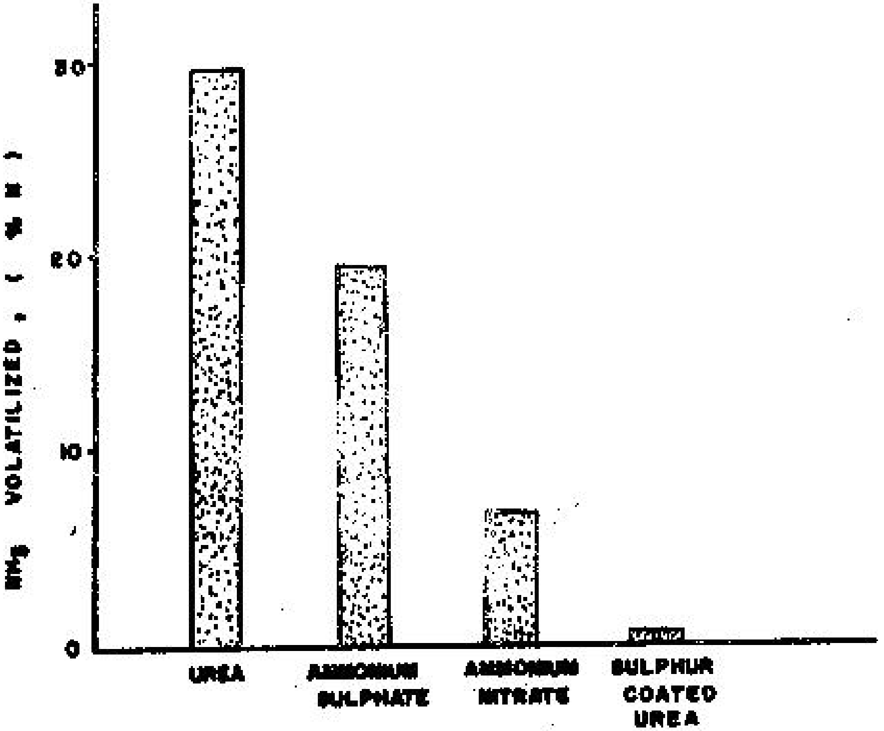

Fig. 2. Cumulative loss of NH_3 from N fertilizers (in six weeks

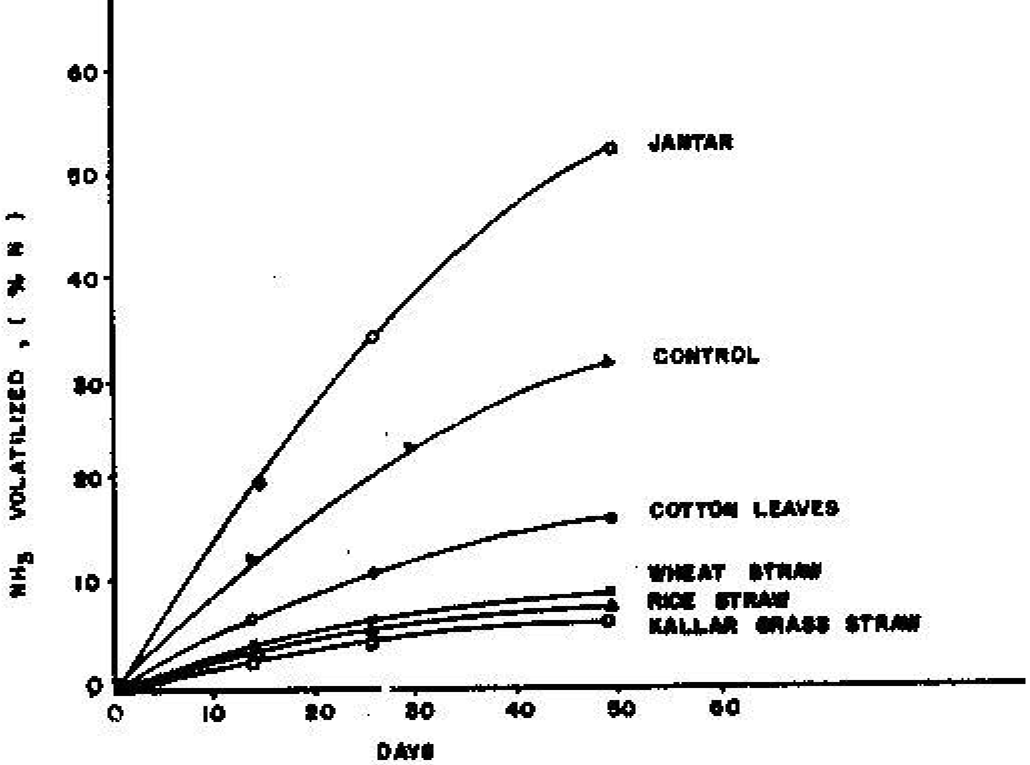

Fig. 3. Effect of plant residues on NH_3 volatilization from urea.

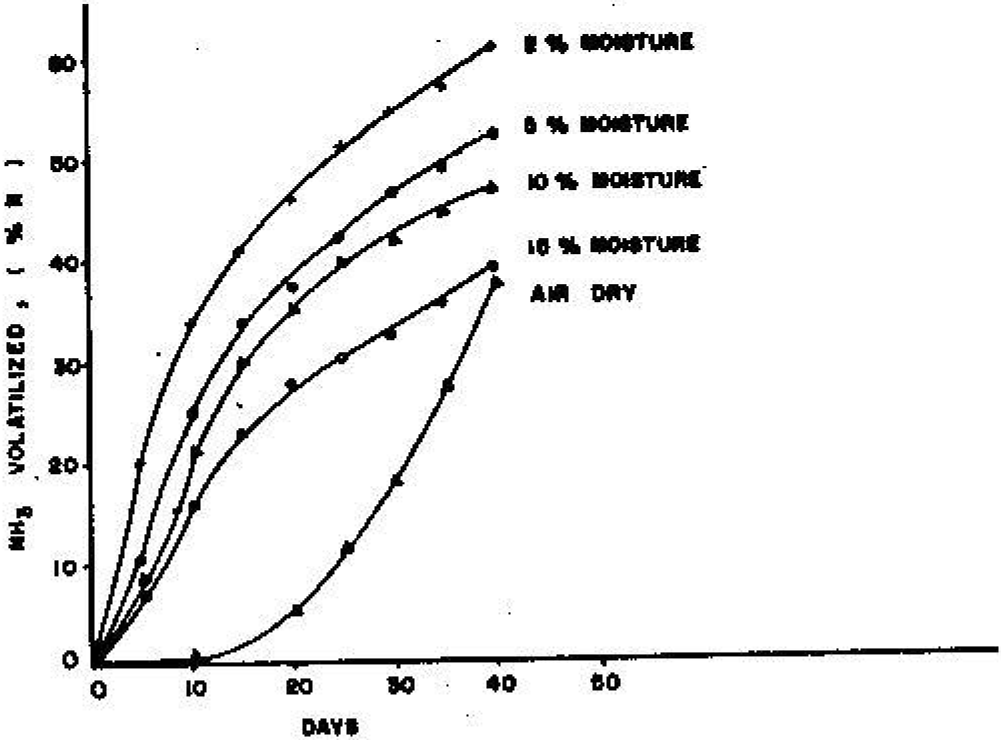

Fig. 4. Effect of moisture content on NH_3 volatilization from urea.

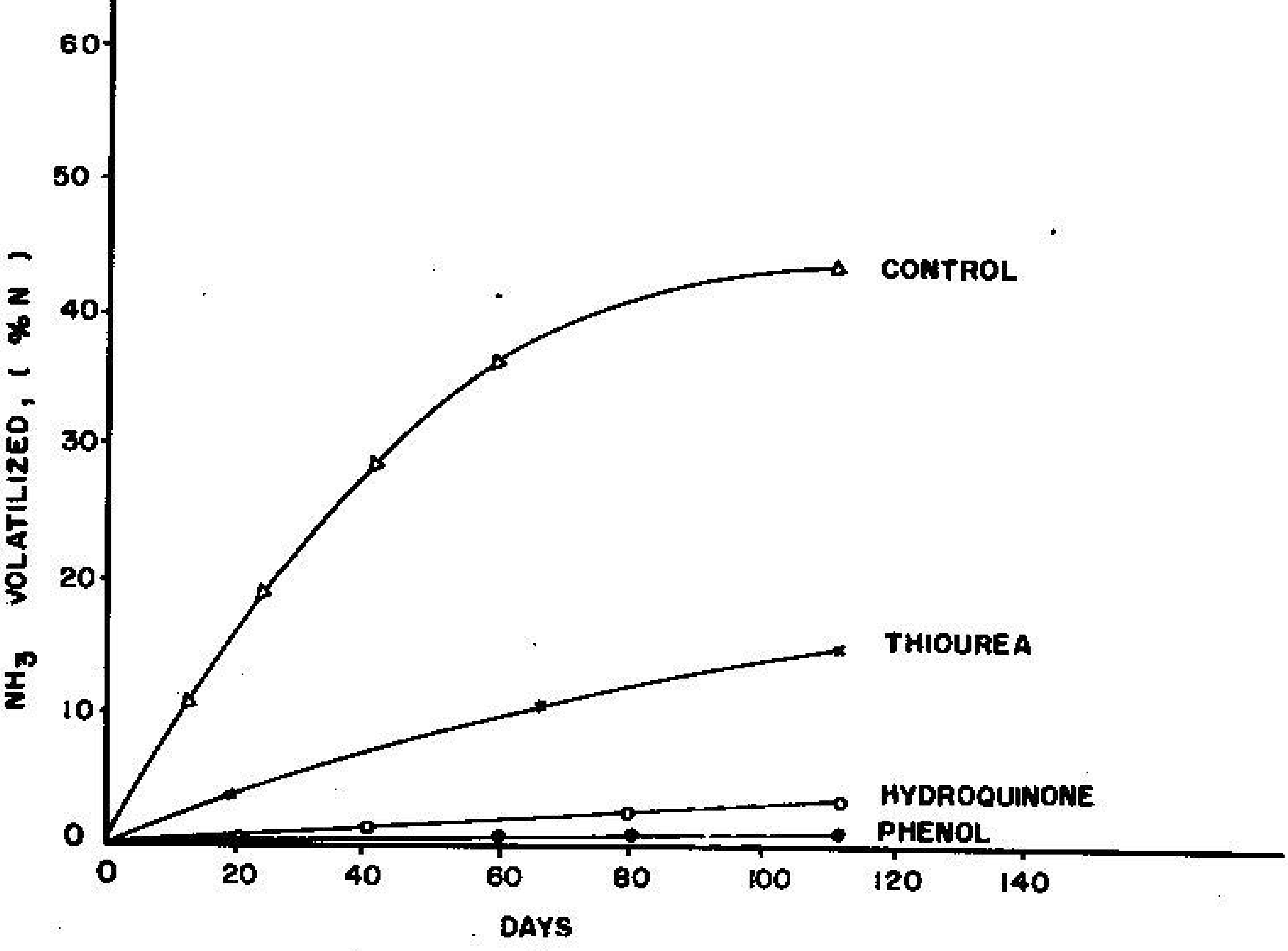

Fig. 5. Effect of phenol, hydroquinone and thiourea on NH$_3$ volatilization from urea.

1979; Byrnes *et al.*, 1983; Martens and Bremner, 1984; Magid and Mahi, 1986; Stupe and Monem, 1986; Fillery *et al.*, 1986). Thiourea has been shown to be inhibitor of urease (Kistiakowky and Shaw, 1953). Malhi and Nyborg (1979) observed supression of hydrolsis of urea with thiourea by about 50 per cent for one week and Rodger and Pruden (1984) observed no NH_3 loss from urea for 18 days by applying hydroquinone with urea. In our experiment thiourea, hydroqunone and phenol suppressed NH_3 volatilization (which follows hydrolysis of urea) by about 50, 87 and 95 per cent for 112 days, respectively. The high cost of these chemicals for field application warrants the development of economical and practical measures to control NH_3 volatilization from urea possibly through fertilizer modification and manipulation.

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