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Ammonia Volatilization from Nitrogen Sources Applied to Rice Fields: II. Floodwater Properties and Submerged Photosynthetic Biomass¹

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ABSTRACT

The effects of $(\text{NH}_4)_2\text{SO}_4$, urea, and urea amended with the urease inhibitor, phenyl phosphorodiamidate (PPD), on floodwater properties were studied concurrently as part of a field NH_3 volatilization study. In the $(\text{NH}_4)_2\text{SO}_4$ treatment the maximum concentration of ammoniacal-N in the floodwater ($\approx 50 \text{ g N m}^{-3}$) occurred immediately after its application to the floodwater. Thereafter, floodwater ammoniacal-N concentrations declined rapidly and were negligible 6 d after the application of $(\text{NH}_4)_2\text{SO}_4$. Ammoniacal-N concentrations in the urea treatment reached maxima of $\approx 12 \text{ g N m}^{-3}$, 3 to 5 d after urea was applied and then declined steadily to negligible concentrations in 7 d. Application of PPD (1% wt/wt) along with urea delayed the buildup of ammoniacal-N in floodwater until 5 to 7 d after N was applied although the maximum ammoniacal-N concentration in the floodwater was comparable to that obtained in the urea treatment. Floodwater pH displayed a marked diurnal pattern throughout the experiment in the urea-amended and background fields. In contrast, pH in the floodwater in the $(\text{NH}_4)_2\text{SO}_4$ -amended field was buffered at ≈ 8.00 for the first 2 d, probably because high concentrations of NH_4HCO_3 formed in floodwater. Diurnal fluctuations in pH prevailed after 3 d when ammoniacal-N concentrations had declined substantially. The partial pressures of NH_3 ($p\text{NH}_3$) in the floodwater in all treatments were synchronized with diurnal temperature and pH changes in the floodwater. The maximum $p\text{NH}_3$ in floodwater was similar in both the $(\text{NH}_4)_2\text{SO}_4$ - and urea-amended fields even though ammoniacal-N concentrations were initially significantly higher in the former. Total titratable alkalinity in floodwater increased after urea and urea/PPD were applied but declined following the application of $(\text{NH}_4)_2\text{SO}_4$. The initial levels of alkalinity in floodwater were double the content of alkalinity in irrigation water, and it is surmised that evaporation and/or respiration contributed significantly to alkalinity in the floodwater. Enumerations of algae present in the flooded soil showed the biomass to be small and dominated by non- N_2 -fixing blue-green algae (*Syanophyceae*). This biomass, however, was associated with marked diurnal fluctuations in floodwater pH, which coupled with the accumulated alkalinity, were the major factors contributing to the rapid NH_3 loss following the application of $(\text{NH}_4)_2\text{SO}_4$ and urea to the floodwater.

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THE ROLE OF FLOODWATER in the loss of fertilizer N from flooded soils has been emphasized in recent reviews (Vlek and Craswell, 1981; Craswell and Vlek, 1982). Attention has been largely focused on the effect of urea management on floodwater properties (Craswell et al., 1981; Cao et al., 1984) primarily because it was assumed that NH_3 loss was greater from urea than from NH_4^+ -N sources such as $(\text{NH}_4)_2\text{SO}_4$ or NH_4Cl .

Most laboratory and greenhouse studies show NH_3 volatilization to be negligible from $(\text{NH}_4)_2\text{SO}_4$ -amended floodwater (Fillery et al., 1984). In contrast several field studies conducted in the Philippines (Bouldin and Alimagno, 1976; Fillery and De Datta, 1986) show that appreciable NH_3 loss can occur when $(\text{NH}_4)_2\text{SO}_4$ is applied to floodwater 18 to 20 d after transplanting of rice seedlings.

The potential for high rates of NH_3 loss from $(\text{NH}_4)_2\text{SO}_4$ -amended floodwater does not appear to be restricted to Philippine conditions (Craswell et al., 1985). Similar high losses of ^{15}N have been detected following the application of $(\text{NH}_4)_2\text{SO}_4$ and urea in recently conducted field studies in other regions of Asia (Katyal et al., 1985; Vlek and Byrnes, 1986). Such findings contrast sharply with results obtained from simulated flooded soils conducted under greenhouse conditions. These show ^{15}N loss from $(\text{NH}_4)_2\text{SO}_4$ to be lower than from urea (Vlek and Craswell, 1979), primarily because NH_3 loss was lower from $(\text{NH}_4)_2\text{SO}_4$ -amended flooded soils (Vlek and Craswell, 1979; 1981). This apparent discrepancy in findings between field and greenhouse studies warrants evaluation.

Deionized or distilled water has generally been used to irrigate flooded soils in greenhouse or laboratory studies (Vlek and Stumpe, 1978; Vlek and Craswell, 1979). These water sources may resemble rainwater, the major source of floodwater for wet season rice crops

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grown in Asia. However, artesian or ponded water is chiefly used as irrigation sources in the dry season when higher rates of N fertilizer are applied to rice crops (Stangel, 1979). These water supplies are more likely to contain the alkalinity needed to buffer H^+ production during NH_3 volatilization from NH_4^+ -N sources (Vlek and Stumpe, 1978).

Ammonia volatilization from flooded soils is also strongly dependent on the pH values in floodwater (Vlek and Stumpe, 1978; Vlek and Craswell, 1981; Fillery et al., 1984). Diurnal cycles of photosynthesis and respiration largely influence pH in floodwater in field systems (Bouldin and Alimagno, 1976; Mikkelsen et al., 1978) irrespective of whether urea is applied to floodwater (Fillery et al., 1984). In contrast, the formation of NH_4HCO_3 during urea hydrolysis has been shown to buffer floodwater pH at about 8.0 in greenhouse studies (Vlek and Craswell, 1981). A decrease in pH values in floodwater has been detected after the application of $(NH_4)_2SO_4$ to flooded soils in greenhouse studies, presumably because the floodwater was poorly buffered (Vlek and Craswell, 1981). The effect of $(NH_4)_2SO_4$ on pH in field floodwater systems is unknown.

The sharply higher pH values in floodwater during the daytime in field systems, have been attributed to the photosynthetic activity of the algal biomass (Bouldin and Alimagno, 1976; Mikkelsen et al., 1978). Surprisingly, little is known about the composition or the extent of this biomass.

The objectives of this study were: (i) to evaluate, in the context of NH_3 volatilization, the effect that different N sources have on ammoniacal-N content, pH, and alkalinity in floodwater in fields irrigated with ponded water supplied from a major irrigation scheme; (ii) to characterize the composition of the algal biomass in flooded soils cultivated using traditional farmer practices; and (iii) to ascertain the effect of N fertilizers on the composition of this algal biomass, again in the context of NH_3 volatilization.

MATERIALS AND METHODS

Field Site and Layout

Details on the location of the experiment, soil used, and field layout are described in the companion paper (Fillery and De Datta, 1986). In brief, the experiment was conducted at the Maligaya Rice Research Training Center (MRRTC), Muñoz, Nueva Ecija, Philippines, on the Maligaya sicl. [Entic Pellusterts, pH 5.7; CEC 32.0 $cmol(+)kg^{-1}$].

Three circular fields (20-m radius) were constructed within an area of ≈ 2 ha, after the soil had been plowed, flooded, and puddled. Phosphorus ($13 kg P ha^{-1}$) and KCl ($25 kg K ha^{-1}$) were incorporated immediately before 20-d-old IR 56 rice seedlings were transplanted (0.2- by 0.2-m spacing).

The area was irrigated with water drawn from the Upper Pampanga River Integrated Irrigation System. The pH and alkalinity of the irrigation water ranged between pH 7.2 to 7.6 and 1.5 to 1.7 $mol [H^+] m^{-3}$, respectively.

Floodwater depth was maintained at 0.01 to 0.02 m for 4 d after transplanting of rice seedlings, when it was increased to 0.04 to 0.06 m. This depth was maintained for the duration of the study.

Fertilizer Treatments

Prilled urea, $(NH_4)_2SO_4$, and urea amended with phenyl phosphorodiamidate (PPD) (1% wt/wt) were applied to the

floodwater in the respective treatments, 18 d after transplanting (AT treatment) at a rate equivalent to $58 kg N ha^{-1}$.

Floodwater Sampling

Floodwater was sampled at the end of each NH_3 flux measurement using procedures described by Fillery et al. (1984). Nine floodwater samples were collected from each treatment in three sectors upwind of the central air sampling mast. Samples within each treatment were then grouped according to sector, floodwater bulked, mixed, and subsampled. An 0.018-L aliquot was treated with 0.002 L of a 50 $mg L^{-1}$ phenyl mercuric acetate solution to inhibit enzyme activity and then frozen. Ammonium-N analysis was performed using an autoanalyzer and the method described by Varley (1966). Another aliquot (0.020 L) of floodwater was titrated to pH 4.65 with 0.0005 M H_2SO_4 to determine total alkalinity: a digital pH meter and a titrator were used. Floodwater temperature was measured hourly from about 0600 to 2200 h by use of Cu-constantan thermocouples and an Omega digital trendicator.

Because of the marked diurnal fluctuations in many key floodwater parameters that influence NH_3 loss, data are presented for each day in relation to light and dark periods which represent 0600 to 1759 h and 1800 to 0559 h, respectively.

Algae Enumeration

Soil and water samples were taken for algae enumeration 28 d before transplanting, at transplanting, and 1 and 7 d after fertilizer application [18 and 25 days after transplanting (DT)]. Ten glass vials were pushed into the soil surface of each sampling area to an approximate depth of 0.1 m, then removed and stoppered from below. The floodwater and the top 0.005 m of soil of the 10 cores were combined. Distilled water was then added to the soil suspension to adjust the volume to a value equivalent to 10 times the surface area of 10 sample cores (10^{-1} dilution on a surface basis). After 30 min stirring, serial soil dilutions were made and 1 mL of 10^{-2} , 10^{-3} , 10^{-4} , 10^{-5} dilutions plated on solid media in Petri dishes. Petri dishes were incubated at laboratory temperature (22–30°C) under constant cold white fluorescent lamps for 21 d before colonies were identified and counted. Counts were expressed as number of colony-forming units (CFU) per m^2 . Two media were used: BG II medium (Stanier et al., 1971), without N and selective for N_2 -fixing blue-green algae (BGA), (*Syanophyceae*) and BG II medium, which is nonselective and permits the growth of BGA (*Syanophyceae*), unicellular green algae (*Chlorophyceae*), and diatoms (*Bacillariophyceae*). However, the latter medium does not permit a good growth of filamentous green algae. Each evaluation was the average of three measurements on three composite samples from 10 core samples. Statistical analyses were performed after logarithmic transformation of the data, according to Roger et al. (1977) and Roger and Reynaud (1978).

RESULTS AND DISCUSSION

Factors Affecting NH_3 Loss

Some of the differences in the pattern of NH_3 loss from urea and $(NH_4)_2SO_4$ -amended fields outlined in the companion paper (Fillery and De Datta, 1986) can be understood after considering the ammoniacal-N concentrations and the pNH_3 in the floodwater. The maximum concentration of ammoniacal-N ($\approx 50 g N m^{-3}$) in floodwater in the $(NH_4)_2SO_4$ treatment occurred soon after N application. Thereafter, ammoniacal-N concentrations declined sharply in this treatment (Fig. 1). Freney et al. (1981) also reported a rapid

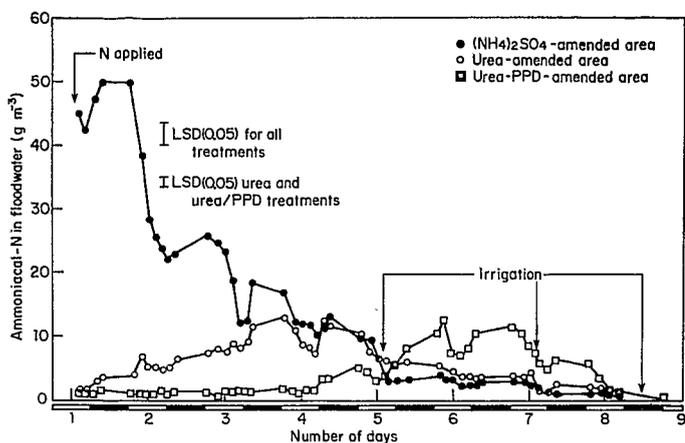


Fig. 1. Ammoniacal N in the floodwater after the application of urea, (NH₄)₂SO₄, and urea amended with PPD (1% wt/wt).

decrease in ammoniacal-N in floodwater after (NH₄)₂SO₄ was broadcast and incorporated into flooded Maahas clay [Andaqueitic Haplaquolls; pH 6.9, CEC 42.0 cmol(+)kg⁻¹]. In the urea treatment, ammoniacal-N concentrations reached maxima of ≈ 12 g N m⁻³, 3 to 5 d after N was applied (Fig. 1), the same period in which the highest NH₃ flux densities were recorded for this treatment (Fillery and De Datta, 1986). The delay in the buildup of ammoniacal-N in floodwater after urea application has been noted elsewhere (Fillery et al., 1984), and thus appears to be a characteristic of flooded soil systems with low urease activity in floodwater.

The elevated ammoniacal-N concentrations in floodwater after the application of (NH₄)₂SO₄ highlight the potential for NH₃ volatilization from this N source (Fig. 1). The rate of NH₃ loss is dependent on the partial pressure of NH₃ (pNH₃) in floodwater. The latter is affected by pH and temperature as well as by ammoniacal-N concentration (Bouwmeester and Vlek, 1981; Vlek and Craswell, 1981; Denmead et al., 1982). Although floodwater temperature was similar in both treatments (Fig. 2), floodwater pH was lower, initially,

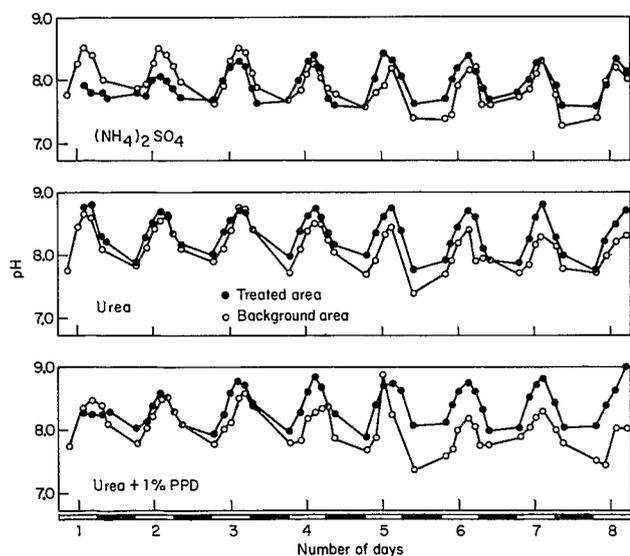


Fig. 3. Floodwater pH in N-amended and nonfertilized areas. LSD (0.05) is 0.19.

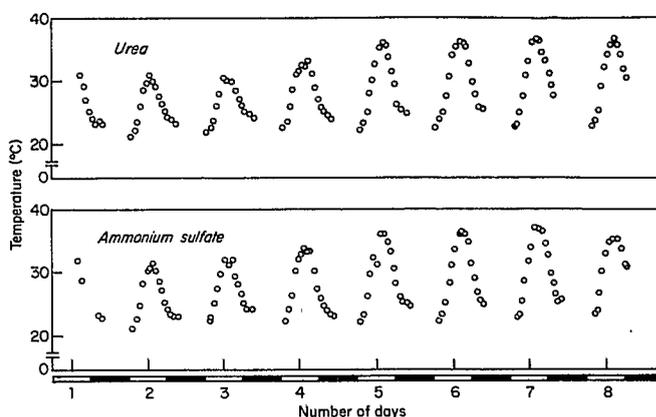


Fig. 2. Temperature in the floodwater in the urea and (NH₄)₂SO₄ amended fields.

in the (NH₄)₂SO₄-amended field (Fig. 3). As a result, the peak values of pNH₃ in the floodwater in the (NH₄)₂SO₄ treatment were only marginally higher than the comparable pNH₃ values obtained in the urea treatment (Fig. 4), even though the maximum ammoniacal-N concentrations were significantly lower in the latter treatment (Fig. 1).

Ammonia loss from the (NH₄)₂SO₄-amended field might have been substantially higher had the floodwater pH exhibited a diurnal fluctuation throughout. Therefore, it is pertinent to consider the cause(s) of the depression in floodwater pH during the first 2 d of the (NH₄)₂SO₄ experiment. Vlek and Craswell (1981) suggest that the reduction in pH often noted after the application of (NH₄)₂SO₄ to nonbuffered floodwater is the result of H⁺ ion accumulation during NH₃ volatilization. If this were the case in our study, pH in the floodwater should have decreased progressively with NH₃ loss and attained a neutral value. This did not occur. It is more probable that a weak NH₄HCO₃ solution formed immediately after the application of (NH₄)₂SO₄ and this buffered pH at about 8.0 (Vlek and Stumpe, 1978). The strength of this buffer should

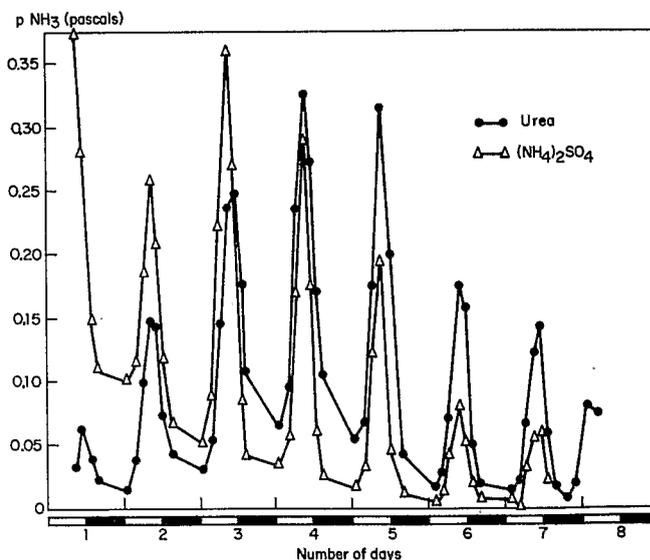


Fig. 4. Equilibrium vapor pressure of NH₃ (pNH₃) in the floodwater after the application of urea and (NH₄)₂SO₄.

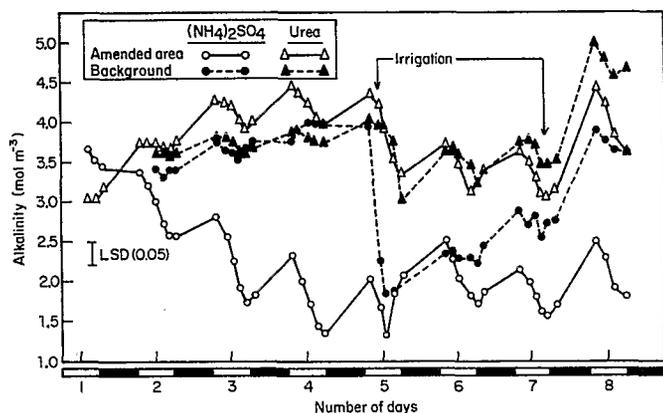


Fig. 5. Total titratable alkalinity in the floodwater in the N-amended and nonfertilized areas.

decrease concomitantly with the loss of ammoniacal-N from floodwater. Therefore, in time the floodwater pH should exhibit the same diurnal fluctuation noted in the untreated fields, as is apparent in the floodwater data obtained from the $(\text{NH}_4)_2\text{SO}_4$ -amended field (Fig. 3). Vlek and Craswell (1981) have also found NH_4HCO_3 to buffer floodwater pH at about 8.0 in a urea-amended system in which high concentrations of ammoniacal-N developed after rapid urea hydrolysis. Our urea study did not show this effect, primarily because ammoniacal-N concentrations remained low as a result of slow urea transformation.

Alkalinity in Floodwater

Total titratable alkalinity in floodwater initially ranged between 3 and 4 mol $(\text{H}^+) \text{m}^{-3}$ in all the fields, including the background areas (Fig. 5). However, the total titratable alkalinity declined sharply in the $(\text{NH}_4)_2\text{SO}_4$ treatment, presumably as a result of H^+ production during NH_3 volatilization. In comparison, the total titratable alkalinity increased in the urea-treated floodwater, and it would appear that HCO_3^- , produced during urea hydrolysis, maintained the alkalinity (Fig. 5). This confirms the finding of Vlek and Craswell (1981) that urea hydrolysis contributes to floodwater alkalinity. Assuming an average water depth of 5 cm at the time of fertilizer application, this level of alkalinity would have permitted an equivalent loss of approximately 42% of the applied N before the carbonate buffer was exhausted (Vlek and Stumpe, 1978). This value is in excellent agreement with the observed NH_3 loss of 36 and 38% (Fillery and De Datta, 1986).

The source of the alkalinity in the floodwater in the background areas and in the $(\text{NH}_4)_2\text{SO}_4$ -amended field has not been fully established. Irrigation water applied to the fields prior to the start of the experiment and during it contained $\approx 1.6 \text{ mol } (\text{H}^+) \text{m}^{-3}$ total titratable alkalinity; a typical level for river water (Vlek and Craswell, 1981). An evapotranspiration rate of 6 mm d^{-1} is common in flooded fields in the Philippines during the dry season (Tomar and O'Toole, 1980). To offset this, between 0.08 and 0.09 m of irrigation water would have been needed from 4 DT (when the floodwater depth was adjusted to a depth of 0.04 to 0.06 m) until the commencement of the NH_3 loss study (18 DT). This rate of addition of irrigation water could

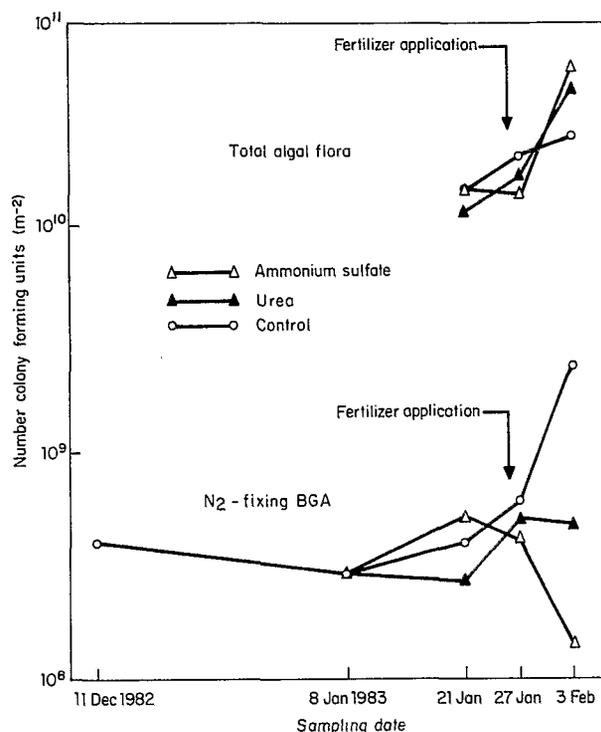
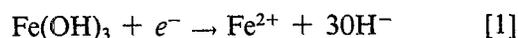


Fig. 6. Enumeration of algae on a selective medium for N_2 -fixing BGA and a nonselective medium.

theoretically have increased the content of alkalinity from ≈ 1.6 to $\approx 3.5 \text{ mol } (\text{H}^+) \text{m}^{-3}$, provided there was no loss of alkalinity from the floodwater. The latter value falls within the range of alkalinity values determined at the start of the NH_3 loss measurements.

Alternatively, biological processes, especially respiration, may have contributed additional alkalinity (HCO_3^-) to floodwater if OH^- were also produced as a result of the reduction of surface oxidized soil as shown in Eq. [1].



This explanation could account for the observed increase in alkalinity in floodwater at night, in the $(\text{NH}_4)_2\text{SO}_4$ -amended field, and the background areas adjacent to this field after irrigation on d 5 (Fig. 5). Floodwater in the background areas adjacent to the urea treatment showed only a slight decrease in alkalinity after irrigation on d 5 because the sampling points were not directly affected by irrigation water.

The increase in alkalinity in the floodwater, through either evaporation or other processes, highlights the likelihood that many flooded fields in Asia could contain adequate quantities of alkalinity to sustain modest rates of NH_3 loss from NH_4^+ -N, regardless of the quality of irrigation water applied at the time of fertilizer application. This point has not been considered in earlier discussions on the potential for NH_3 loss from different N sources.

Submerged Photosynthetic Biomass

The pronounced diurnal fluctuations in pH in the floodwater throughout the urea study and after 3 d in

Table 1. Relative abundance (%) of the dominant components of the algal florae enumerated on a selective medium for N₂-fixing BGA and a nonselective medium.

Algae	28 d before transplanting		At transplanting			13 d after transplanting			1 d after N application			7 d after N application		
	Control	Control	Control	AS†	Urea	Control	AS	Urea	Control	AS	Urea	Control	AS	Urea
%														
BG II medium without N														
Unicellular fixing	-	-	-	-	-	3	7	13	1	4	-	-	-	-
Anabaena	5	38	65	72	63	67	55	61	60	41	21	-	-	-
Nodularia	-	-	3	-	-	2	-	-	-	2	-	-	-	-
Nostoc	73	61	11	7	14	17	32	11	16	35	34	-	-	-
Scytonema	4	-	-	7	-	4	-	-	-	5	2	-	-	-
Calothrix	16	1	6	14	23	7	3	15	23	13	43	-	-	-
Fischerella	2	-	15	-	-	-	3	-	-	-	-	-	-	-
BG II medium														
Unicellular BGA	nd‡	nd	6	2	37	nd	nd	nd	-	1	2	-	-	-
Pseudonabaena	nd	nd	4	18	4	nd	nd	nd	5	4	3	-	-	-
L.P.P.O.	nd	nd	62	52	48	nd	nd	nd	68	81	71	-	-	-
N ₂ -fixing	nd	nd	3	6	-	nd	nd	nd	7	-	-	-	-	-
Unicellular green	nd	nd	-	-	-	nd	nd	nd	-	-	-	-	-	-
Diatoms	nd	nd	25	22	11	nd	nd	nd	20	14	24	-	-	-

† Ammonium sulfate.

‡ Not determined.

the (NH₄)₂SO₄-amended floodwater (Fig. 3) highlight the role of the submerged photosynthetic biomass, especially algae, in the NH₃ volatilization process in flooded fields. Indeed, the effect of the algae on pH in floodwater and the effect of floodwater alkalinity are probably the reasons for high rates of NH₃ loss from (NH₄)₂SO₄ obtained in field experiments (Fillery and De Datta, 1986) but not in laboratory or greenhouse experiments.

The number of N₂-fixing and total algal florae on the surface of the soil is shown in Fig. 6. The N₂-fixing florae were dominated by *Nostoc* sp. before plowing and puddling (Table 1). Land preparation reduced the number of N₂-fixing algae and induced a shift in the composition of the florae toward *Anabaena* sp. By 13 DT, *Anabaena* species were the dominant N₂-fixing species (Table 1). However, the total algal florae were dominated by non-N₂-fixing blue-green algae. Few unicellular green algae were observed, and diatoms represented only about 25% of the total CFU (Table 1). The application of N to the floodwater increased the total CFU, although the difference between treated and control plots was hardly significant because of the low accuracy of the plating method (Table 2). In contrast, the N₂-fixing florae were substantially lower in the N-amended areas, compared with the control, 7 d after N fertilizer was applied (Fig. 6). The difference between the control and the (NH₄)₂SO₄ treatment was significant at a level better than 95%, while the difference between the urea treatment and control had a level of significance better than 85%. This result is in agreement with previous observations which show an inhibitory effect of surface application of N fertilizer on N₂-fixing algae (Roger et al., 1980).

In general, our results of algal enumerations (2.0 – 4.0 × 10¹⁰ CFU m⁻²) indicate a relatively low algal biomass. For comparison, a total algae CFU count of 1.1 × 10¹² m⁻² in a rice field in Senegal corresponded to an algal biomass of about 4.6 Mg ha⁻¹ fresh weight (fw) (Roger and Reynaud, 1976). A rough calculation of the algal biomass was undertaken for the (NH₄)₂SO₄-treated area. Plate counts were multiplied by the vol-

Table 2. Confidence limits (95%) for the enumeration of algae 7 d after fertilization application.

Algal florae	Treatment	CFU/m ²		
		Lower limit	Mean	Upper limit
N ₂ -fixing	Background or control	3.7 × 10 ⁸	2.4 × 10 ⁹ a†	1.4 × 10 ¹⁰
N ₂ -fixing	(NH ₄) ₂ SO ₄	5.4 × 10 ⁷	1.4 × 10 ⁸ b	3.5 × 10 ⁹
N ₂ -fixing	Urea	8.6 × 10 ⁷	4.9 × 10 ⁸ ab	2.9 × 10 ⁹
Total	Control	0.9 × 10 ¹⁰	2.4 × 10 ¹⁰ a	6.7 × 10 ¹⁰
Total	(NH ₄) ₂ SO ₄	2.7 × 10 ¹⁰	4.0 × 10 ¹⁰ a	5.6 × 10 ¹⁰
Total	Urea	2.6 × 10 ¹⁰	3.8 × 10 ¹⁰ a	5.6 × 10 ¹⁰

† Means followed by a common letter are not significantly different at the 5% level by DMRT.

ume of each "count unit" according to the procedure outlined by Roger and Reynaud (1976). A value of only a few hundred kg fw ha⁻¹ of algae (lower and upper 5% confidence limits were 300 and 650 kg fw ha⁻¹, respectively) was obtained for the (NH₄)₂SO₄-treated area, 7 d after N application.

Despite the low value of this biomass, large fluctuations in pH in the floodwater had occurred (Fig. 3). This result indicates that large algal populations are not required to increase floodwater pH to levels that support rapid NH₃ loss from the flooded rice system.

Effect of PPD on Ammoniacal-N in Floodwater

Negligible concentrations of ammoniacal-N (Fig. 1) were detected in floodwater in the urea/PPD-amended field during the first 2 d of the experiment when NH₃ volatilization was not detected (Fillery and De Datta, 1986). However, ammoniacal-N concentrations in the floodwater increased rapidly after d 4 and reached a maximum of ≈ 12 g N m⁻³ on d 6 and 7 (Fig. 1). Ammonia fluxes from this treatment showed a similar trend (Fillery and De Datta, 1986).

These results indicate that PPD inhibited urease activity for up to 3 d in our field study. Comparable results have also been reported by Vlek et al. (1980) for flooded Crowley silt loam amended with urea + PPD (2% wt/wt). In contrast, recent research, also on the Crowley silt loam (Byrnes et al., 1983), has shown

PPD (1% wt/wt) to inhibit urease activity up to 11 d. Other studies (Fillery et al., 1986) show that PPD inhibits urease activity for only 1 d. Differences in urease activity and the rate of PPD degradation between flooded soils are probably important factors influencing the duration of inhibition of urease by PPD. Urease activity in soil is affected by a range of soil properties (Sahawrat, 1980) and is associated with the algal biomass in flooded soil (Vlek et al., 1980; Savant et al., 1986). Degradation of PPD has been shown to be highly dependent on pH and temperature (Austin et al., 1984).

Byrnes et al., (1983) reported that PPD can delay the increase in pH in floodwater which often accompanies the application of urea in pot studies (Vlek and Craswell, 1979). This phenomenon did not occur in our study primarily because the pH in floodwater was determined by diurnal cycles of photosynthesis and respiration (Fig. 4). Thus, the reduction in NH_3 loss from the field amended with urea/PPD compared with prilled urea, noted in the companion paper (Fillery and De Datta, 1986), was largely a function of the delay in the buildup of ammoniacal-N in the floodwater (Fig. 1).

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