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The Fate of Urea in a Sphagnum Peat Medium as Affected by Lime Source and Rate

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Abstract. Sphagnum peat was blended with CaCO₃ or Ca(OH)₂ and incubated for 3 weeks at 20C to achieve a pH of ≈ 4.4, 5.4, 6.2, or 7.3. An unlimed control had an initial pH of 3.5. Urea was added to medium treatments at the rate of 125 µg urea-N/cm³. Samples were incubated at 20 ± 1.0C. Medium pH, urea-N, NO₂⁻-N, and NO₃⁻-N were measured immediately before urea addition (day 0) and 1, 2, 3, 4, 7, 14, 21, and 28 days after urea addition. Medium pH increased when urea was applied for all lime treatments. Medium pH remained at an elevated level, except for the two highest rates of C&CO₃, in which pH increased initially, then decreased. The rate of urea hydrolysis increased as lime rate increased. For both lime sources, urea was completely hydrolyzed within 4 days for the two highest lime rates, except for the highest rate of CaCO₃. Nitrite accumulation was evident in the highest lime rate for both lime sources. Nitrate formation was greater with CaCO₃ than with Ca(OH)₂.

Many ornamental crops respond unfavorably to ammoniacal N fertilizers, a phenomenon commonly referred to as ammonium toxicity (Barker and Mills, 1982; Bunt, 1976; Matkin and Chandler, 1957). Urea is classified as an ammoniacal form of N because it forms ammonium when hydrolyzed by the enzyme urease in soil (Bremner and Mulvaney, 1978).

Previous research suggests that urea can be more deleterious to plant growth than ammonium N sources (Bunt, 1976; Crater, 1973). Research using mineral soils indicated that the detrimental effects on crop growth associated with the use of urea may result from ammonia formation and volatilization (Bennett and Adams, 1970; Court et al., 1964a; Court et al., 1964b) and/or nitrite accumulation (Bingham et al., 1964; Morrill and Dawson, 1967). Both phenomena result from high medium pH conditions (pH > 7.0) associated with the hydrolysis of urea (Aleem

and Alexander, 1960; Alexander, 1977; Morrill and Dawson, 1967).

A great majority of potted floral crops and many containerized woody ornamental crops are grown in soilless potting media comprised mostly of peat. It has been shown that nitrification occurs very slowly in a peat-based medium (Matkin and Chandler, 1957; Elliot, 1984). Nitrification is an acidifying process. In the absence of nitrification, it might be expected that medium pH would increase as a result of the addition of urea. This change is of particular importance during the first few weeks of crop production, since high pH conditions can promote nitrite accumulation, ammonia loss, and decreased micronutrient availability. Plant growth can be severely retarded by nitrite, especially during the initial stages of crop growth (Bingham et al., 1964; Paul and Polle, 1965).

Little information is available presently regarding the N transformations and pH changes in a sphagnum peat medium following addition of urea. The aim of this research was to monitor the fate of urea and its effect on medium pH over a range of lime rates (medium pH levels) using two liming agents.

Materials and Methods

Medium treatment preparation. Baled sphagnum peat obtained from a peat bog near Manitoba, Ont., was used in this research. It was screened through a 1-cm²-mesh wire screen.

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Reagent grade CaCO_3 (Mallinckrodt Inc., Paris, Ky.) or Ca(OH)_2 (Fisher Scientific, Pittsburgh, Pa.) were used as lime sources. Calcium carbonate was mixed with peat at the rates of 2.12, 3.53, 4.94, or 6.36 $\text{kg}\cdot\text{m}^{-3}$ and Ca(OH)_2 was mixed at 1.41, 2.82, 3.81, or 4.95 $\text{kg}\cdot\text{m}^{-3}$. An unlimed control was also included.

After addition of lime, each medium treatment was moistened with sterile, distilled deionized water ($141 \text{ liters}\cdot\text{m}^{-3}$) and incubated for 3 weeks at $20 \pm 1\text{C}$ and 95% RH. After 3 weeks of incubation, pH values of 4.4, 5.4, 6.2, and 7.3 were obtained with each lime source for the previous lime rates. The unlimed control had an initial pH of 3.5.

Fertilizer treatment. Fifty-four 20-cm^3 samples of each medium were placed in 118-ml jars for pH determination and 236-ml glass jars for N determination. One-half the samples (27) were treated with a fertilizer solution either containing 500 $\mu\text{g}\cdot\text{ml}^{-1}$ N from urea or without urea. The fertilizer solution was formulated with (all $\text{g}\cdot\text{liter}^{-1}$) 0.77 K_2SO_4 , 0.233 K_2HPO_4 , 0.101 MgSO_4 , and 0.2 STEM (Soluble Trace Element Mix, W.R. Grace, Fogelsville, Pa.). Each 20-cm^3 sample received 5 ml of the appropriate fertilizer solution. Samples were gravimetrically determined to be at 80% water holding capacity (WHC). Treated samples were then incubated at $20 \pm 1\text{C}$ and 95% RH for 28 days.

Monitoring procedure. Sample pH was measured in saturated media extracts (Warncke, 1986). Urea-N (Mulvaney and Bremner, 1979), $\text{NO}_2^- \text{-N}$ (Keeney and Nelson, 1982), and $\text{NO}_3^- \text{-N}$ (Dick and Tabataba'i, 1979) content were determined from medium extracts. These substances were monitored immediately before fertilizer addition (day 0) and 1, 2, 3, 4, 7, 14, 21, and 28 days following the addition of fertilizer solution. There were three replications for each treatment for each sampling time.

Extraction procedure. Media extracts were obtained by adding 100 ml of a 10-mM calcium acetate solution containing 5 $\mu\text{g}\cdot\text{ml}^{-1}$ phenylmercuric acetate (urease inhibitor) to each 20-cm^3 medium sample. Samples were agitated for 30 min, then filtered using Whatman #42 filter paper. Each sample extract was cold-sterilized by filtration through a Gelman 0.20- μm metricel membrane filter (Gelman Inc., Ann Arbor, Mich.).

Statistical analysis. A completely randomized design was used and analysis of variance was conducted for all main effects and interactions. Regression analysis was conducted for urea content over time using the Statistical Analysis Systems package (SAS Institute, Cary, N.C.). All N data were calculated on a volume basis.

Results and Discussion

The addition of urea increased medium pH for all treatments within 4 days (Fig. 1). Medium pH values exceeded initial pH values for all treatments throughout the entire monitoring period, with the exception of the highest rate of CaCO_3 . The pH of medium treatments not supplemented with urea was stable during the entire 28-day monitoring period, with the exception of the medium with the highest rate of CaCO_3 , in which pH declined (data not shown). These data are in agreement with earlier work by Vetanovetz and Peterson (1987).

The effect of urea addition on medium pH was similar for lime sources (Fig. 2), except for the highest lime rates (initial medium pH). Medium pH significantly decreased in the CaCO_3 treatment relative to the Ca(OH)_2 treatment 14 days following urea addition.

The rate of lime amendment affected the rate of urea hydrolysis for both lime sources (Fig. 3). Statistical differences

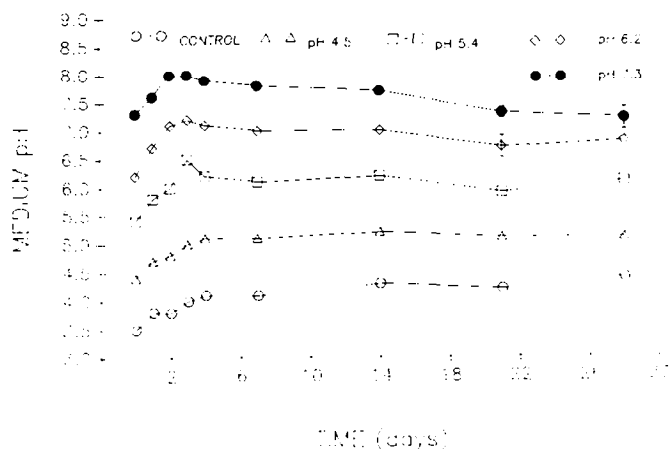


Fig. 1. Mean medium pH of sphagnum peat following addition of a fertilizer solution that supplied $125 \mu\text{g urea-N}/\text{cm}^3$. Data from both lime sources are included. Medium treatments consisted of CaCO_3 or Ca(OH)_2 additions to achieve an initial pH of 4.5, 5.4, 6.2, and 7.3, plus an unlimed control (pH = 3.5). Bars represent the SE of the mean ($n = 3$) when $\text{SE} > 0.1$.

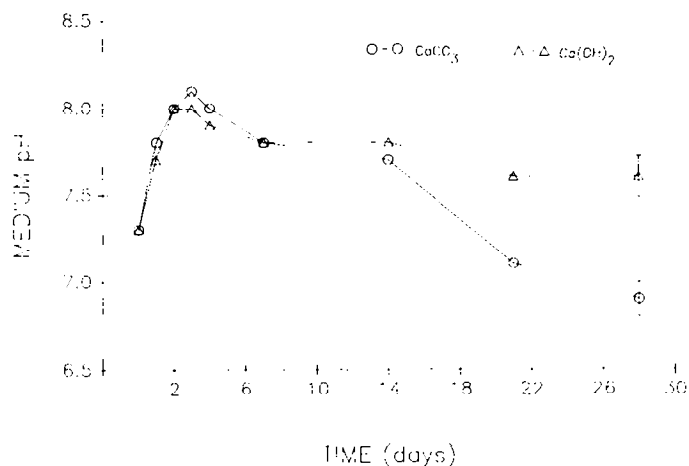


Fig. 2. Medium pH following the addition of $125 \mu\text{g urea-N}/\text{cm}^3$ for treatments having an initial pH of 7.3 using either CaCO_3 or Ca(OH)_2 as a lime source. Bars represent the SE of the mean ($n = 3$) when $\text{SE} > 0.1$.

among lime rates were significant, except between the two highest lime rates for both lime sources. Urea was found to be totally hydrolyzed 14 days after urea was added to the unlimed control. Urea hydrolysis was complete 7 days after addition of urea to medium treatments, having initial pH values of 4.4 and 5.4 and 4 days for treatments having an initial pH of 6.2 for both lime sources. Urea was completely hydrolyzed 4 days for medium treatments amended with the highest rate of Ca(OH)_2 (pH 7.3), whereas complete hydrolysis was evident 7 days after urea addition for medium treatments amended with the highest rate of CaCO_3 . More than 50% of the urea that was applied was hydrolyzed 2 days after application for all treatments, with the exception of the unlimed control treatment. While we expected that increasing the lime rate would increase urea hydrolysis, we did not expect that the two highest lime rates would be similar in affecting the hydrolysis of urea. When assaying urease activity in soils, samples are usually adjusted to a pH of 9.0, which is reported to be the optimum pH for ureolytic activity (Bremner and Mulvaney, 1978). It is possible that the increase in medium

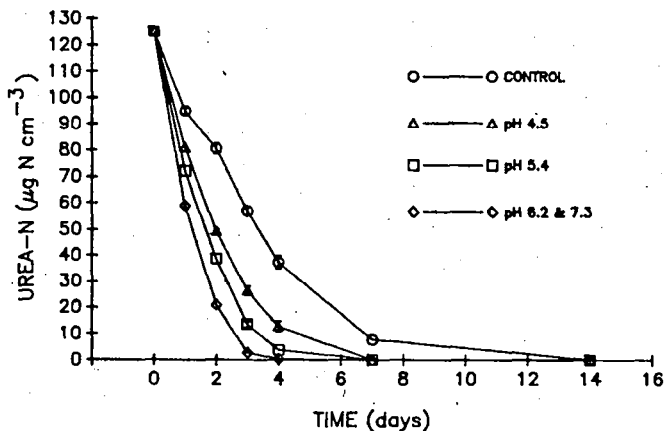


Fig. 3. Effect of lime rate on urea hydrolysis in sphagnum peat following the addition of 125 µg urea-N/cm³. Lime treatments had an initial pH of 3.5 (unlimed control), 4.5, 5.4, 6.2, and 7.3. Data for both CaCO₃ and Ca(OH)₂ treatments are included. Bars represent the SE of the mean (n = 3) when SE > 1.0.

Table 1. Mean urea content of peat 2 days after addition of 125 µg urea-N/cm³ of medium as affected by lime source at two values.

Initial medium pH	Medium urea-N (µg·cm ³)		Significance ^z
	CaCO ₃	Ca(OH) ₂	
6.2	27.2	16.0	***
7.3	26.6	13.5	***

^zF test performed on means between lime sources (rows).

***Significance at the 0.001 level.

pH from the urea hydrolysis itself brought the medium solution pH in a range close to "optimum", where hydrolysis was not affected significantly.

The rate of urea hydrolysis was similar for lime sources except for the two highest rates of lime 2 days following addition of urea. More urea was hydrolyzed at the two highest rates (initial pH 6.2 and 7.3) of Ca(OH)₂ than of CaCO₃ (Table 1). Similar trends were observed in earlier work (Vetanovetz and Peterson, 1987). While the practical significance of this effect is not clear, it suggests that carbonate may play a role in suppressing hydrolysis of urea (Kumar and Wagenet, 1984).

Increased additions of lime enhanced the accumulation of nitrite and formation of nitrate (Table 2). Nitrite levels were greatest for the highest rate of lime addition for both lime sources. The greatest amount of nitrite was found on day 21 in medium amended with the highest rate of CaCO₃. In this treatment, nitrite accounted for > 10% of the total N in the samples. Nitrite was not present in this treatment 28 days after the addition of urea. In contrast, nitrate levels had increased on day 28 relative to day 21, suggesting that nitrite was oxidized to nitrate. This decline in nitrite was not noted for the intermediate rate of CaCO₃ (pH 6.2). Perhaps, as ammonium was oxidized to nitrite, the pH decreased to a more desirable level for the *Nitrobacter* bacteria to oxidize nitrite to nitrate. The inhibition of growth of *Nitrobacter* by high pH levels in the presence of high ammonium levels is well-known (Aleem and Alexander, 1960; Alexander, 1977). Ultimately, 4 weeks after urea was applied, nitrate levels were more than eight times greater for the treatment receiving the highest rate of CaCO₃ (pH 7.3) than the treatment receiving the second highest rate of CaCO₃ (pH 6.2).

Calcium carbonate significantly enhanced nitrification com-

Table 2. Mean net nitrite and nitrate levels in a sphagnum peat medium following the addition of 125 µg urea-N/cm³ as affected by lime source and lime rate^{z,y}. Tukey's honestly significant difference (HSD = 0.05) is presented for mean comparisons within rows and columns.

Initial pH and lime source	Nitrite-N (mg·liter ⁻¹)				Nitrate-N (mg·liter ⁻¹)			
	Days				Days			
	14	21	28	HSD	14	21	28	HSD
CaCO₃								
5.4	0	0	0	0	0	1.0	1.0	0.1
6.2	0	0.3	1.3	0.8	0	1.6	7.7	1.9
7.3	2.8	13.0	0	3.0	1.2	6.0	58.1	43.0
HSD	1.7	2.5	0.7		0	1.6	42.9	
Ca(OH)₂								
5.4	0	0	0	0	0	0	1.1	0.1
6.2	0	0	0	0	0	1.0	1.4	0.4
7.3	0	2.0	5.4	7.5	0	2.3	3.1	0.8
HSD	0	2.1	7.2		0	0.6	0.7	
CaCO₃ vs. Ca(OH)₂								
Initial medium pH	14	21	28		14	21	28	
5.4	NS ^x	NS	NS		NS	**	NS	
6.2	NS	**	*		NS	NS	**	
7.3	*	*	NS		**	**	*	

^zNet nitrate levels were calculated by subtracting the mean medium nitrate level on day 0 from values generated for days 14, 21, and 28 for all treatments.

^yIncreased nitrite or nitrate levels were not found for unlimed control treatments and rate 1 for both lime sources.

^xComparisons were made between lime source within initial pH and day using F test.

NS,*,** Not significant or significant at α = 0.05 and 0.01, respectively.

pared to Ca(OH)₂. Nitrite was evident 14 days after urea addition for treatments receiving the highest rate of CaCO₃. Nitrate levels were more than 25 times higher for CaCO₃ than for Ca(OH)₂ at the highest lime rate on day 28. Nitrifying organisms may be stimulated by bicarbonate ions that originate from neutralizing acidity with carbonate. Schmidt (1982) indicated nitrifying bacteria use bicarbonate in solution as a carbon source for cell growth. The effect of differential quantities of Ca added in treatments between lime sources can be ruled out since Ca levels were comparable between sources for each lime rate.

The stimulation of nitrification from lime amendments is well-documented (Alexander, 1977; Dancer et al., 1973; Niemera and Wright, 1986). Nitrification was not evident for lime treatments having an initial pH of 4.5 and 5.4, and was very slow in medium treatments having an initial pH of 6.2. The initial pH of growing media used for the production of floral crops ranges within 5.5 and 6.5. Based on this information, it is doubtful whether the process of nitrification is very important in the production of floral crops having a short cropping schedule (Cox, 1985; Elliott, 1984).

This research demonstrates that problems arising from use of urea may not be entirely associated to ammonium toxicity, but rather to nitrite toxicity as well. A greater potential for nitrite toxicity would seem to occur if liming recommendations developed for potting media containing mineral field soil are applied to soilless, sphagnum peat-based potting media to achieve a pH range of 6.2-6.8 (Nelson, 1978). Under conditions where initial medium pH is high, further, more rapid, pH increases from urea hydrolysis may create an environment where nitrite

can accumulate and affect crop growth. More recent recommendations, based upon optimum nutrient availability in a soil-less medium, indicate that the initial medium pH should be in the range of 5.3-5.5 (Peterson, 1982). Adjusting medium pH to lower levels may offer benefits that appear to be important when urea-based fertilizers are to be used.

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