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Effect of Liming Rate on Nitrification in a Pine Bark Medium

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Abstract. **A 100% pine bark medium was amended with dolomitic lime at 0, 3, or 6 kg·m^{-3} and periodically fertilized with 210 ml of a nutrient solution containing 100 ppm N as $(NH_4)_2SO_4$. At the 3- and 6-kg lime treatments, medium solution NH_4-N concentrations decreased rapidly while NO_3-N concentrations increased. At 0 kg lime, the NH_4-N decrease was slower than at the 3- and 6-kg lime treatments and NO_3-N was not found. Similarly treated bark without plants was used to determine a NO_3-N accumulation rate (NAR). NAR was greatest at 6 kg of lime, except at the last 2 sampling dates, when NAR did not differ between 3 and 6 kg of lime. This lack of difference was attributed to a limiting NH_4-N supply at 6 kg of lime. In a 2nd experiment, NAR of bark treated with 6 kg of lime per m^3 and fertilized with 300 ppm NH_4-N was 3 times greater than with bark treated with 100 ppm NH_4-N, thus supporting the contention that, over time, the NH_4-N supply of the 100-ppm treatment limited nitrification. These results indicate that the stimulative influence of lime on nitrification is subject to medium pH and NH_4-N status that changes over time.**

Liming container media is a routine practice in the nursery industry. Liming increases medium pH, supplies Ca (and Mg in the case of dolomitic lime), and influences nutrient availability. An increased medium pH stimulates nitrification, the biological oxidation of NH_4^+ to NO_3^-. Thus, plant response to lime rate may be in part a response to the ionic form of N in the medium solution. Niemiera and Wright (7) treated pine bark with 6 kg of lime per m^3 and fertilized with $(NH_4)_2SO_4$ and found a depletion of NH_4-N and an accumulation of NO_3-N in the medium solution. Chrustic and Wright (1) treated pine bark with dolomitic lime in the range of 0 to 8 kg of lime per m^3 and reported that the 8-kg lime treatment had the lowest solution NH_4-N : NO_3-N ratio. This result was attributed to increased nitrifier populations and an increased adsorption of NH_4-N to bark particles. However, bark was fertilized with NH_4NO_3 in their experimentation, and the application of NO_3-N to the bark makes the influence of lime on nitrification difficult to discern. Niemiera and Wright (7) used a nitrification inhibitor in their experiment, and found the medium solution NH_4-N concentrations remained relatively high, indicating that NH_4-N depletion without NI was unequivocally a result of nitrification.

The ionic form of N has a significant influence on plant nutrient composition and growth (3, 4, 6). Chrustic and Wright (1) found that the growth of 3 woody genera was greatest at the 0 or 2 kg lime per m^3 bark treatments and attributed this response in part to a greater NH_4-N : NO_3-N ratio. Other researchers working with woody plants (5, 9) have shown a similar response to such a ratio. Growers of container-grown crops commonly fertilize with NH_4-N and amend their media with lime. However, lime rates vary greatly within the industry, depending on the species grown and grower preference. The purpose of this research was to determine how lime rates affect nitrification in a pine bark medium.

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Materials and Methods

Experiment 1. Pine bark used in this experiment was identical to bark described in a previous paper (7). Bark was moistened and amended with 0.58 kg of urea per m^3 to stimulate the establishment of nitrifier populations,and 1 kg of Micromax per m^3 (Sierra, Milpitas, Calif.). Bark then was treated with 0, 3, or 6 kg of dolomitic lime per m^3. This lime contained 51% $CaCO_3$, 40% $MgCO_3$, and had a $CaCO_3$ equivalent of 100. On 24 Jan. 1984, rooted cuttings of *Ilex crenata* Thunb. 'Convexa' were transplanted into 1-liter plastic containers and grown in a glasshouse with day/night temperatures of 24°/18°C. Irrigation techniques and method of medium solution extraction were the same as in experiment 2 of a previous paper (7). Containers were arranged in a randomized complete block design with 3 containers per treatment in each of 5 blocks. Medium solutions were analyzed for pH, NH_4-N, and NO_3-N using ion-selective electrodes.

A set of containers filled with amended pine bark but not containing plants was subjected to the same irrigation schedule and used for NO_3-N accumulation rate (NAR) determinations. Sufficient numbers of containers were prepared to allow for one container per treatment in each of 5 blocks to be periodically sampled.

Periodic determinations of NAR were made following the 2nd nutrient solution irrigation. Following irrigation, containers were allowed to drain for 1 hr, bark was stirred (to ensure uniformity of sampling), and a subsample of bark (about 50 cc) was removed. Containers with remaining bark were enclosed in a plastic bag and stored in an incubator at 25°C for 96 hr. The subsample was put into a PVC tube (2.5 × 15.2 cm) with one end covered with cheesecloth to retain bark during the leaching process. Distilled water (210 ml) was dripped onto bark-filled tubes at a rate of 70 ml·hr^{-1} and leachates collected (hour 0 N content). This process was repeated 96 hr later with another bark subsample from the same containers. After the leaching process, bark from each tube was dried and weighed. Leachates were anlayzed for NH_4-N and NO_3-N. The volume of leachate collected was multiplied by NH_4-N and NO_3-N concentrations to determine the total amounts of leachable NH_4-N and NO_3-N in the bark sample. The total then was divided by the weight of bark to arrive at an amount of N per grams of bark. The hour 0 amount of NO_3-N then was subtracted from the amount at hour 96 and the difference divided by 96 to get a NAR expressed as micrograms of NO_3-N per gram of bark per hour. Leachable NH_4-N was measured to give an indication of the relative amount of nitrifiable substrate on the bark at each NAR determination.

Experiment 2. NAR was determined every 6 days using bark treated with 6 kg of lime per m^3 and methodology as described previously. At days 42 and 48, some of the containers that had been fertilized prior to day 42 with 100 ppm NH_4-N were treated with 300 ppm NH_4-N. This experiment was conducted to determine if the NH_4-N supply of the 100 ppm N treatment limited nitrification over time.

Results and Discussion

Medium solution NH_4-N concentrations decreased over time in all treatments; however, the decrease occurred earlier, more rapidly, and to a greater extent in the 6-kg lime treatment compared to the 3-kg lime treatment (Fig. 1). Ammoniacal-N concentrations at 0 kg of lime declined gradually over time. Periods of increasing NO_3-N concentration in the medium solution coincided with the decline in NH_4-N. These periods occurred between days 29 and 70 and days 56 and 84 for the 6- and 3-kg lime treatments, respectively. Nitrate-N was not detected at any time in the 0-kg lime treatment.

Measurable NAR first occurred at days 41 and 84 for the 6- and 3-kg lime treatments, respectively, while NO_3-N accumulation did not occur at 0 kg of lime (Fig. 2). NAR was greatest at 6 kg of lime until day 84, after which there was no significant difference between NAR at 3 and 6 kg of lime. The stimulative effect of the 6-kg lime treatment on nitrification is in agreement with the fact that nitrifier growth and metabolism are pH dependent (2). Yet, similar NO_3-N concentrations were measured in the medium solution at the 3- and 6-kg treatments between days 70 and 145 (Fig. 1), and no differences in NAR occurred at the last 2 sampling dates in Expt. 2 between these treatments (Fig. 2). The reason for the lack of differences between treatments may be explained by a difference in substrate availability. Medium solution NH_4-N concentrations were generally lower during the period of considerable NO_3-N accumulation at 6 kg compared to the 3 kg lime treatment.

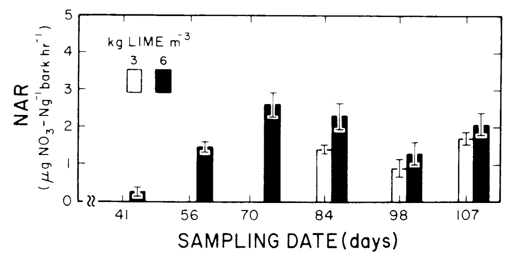

Fig. 2. Influence of lime rate on NAR. Bars indicate SE.

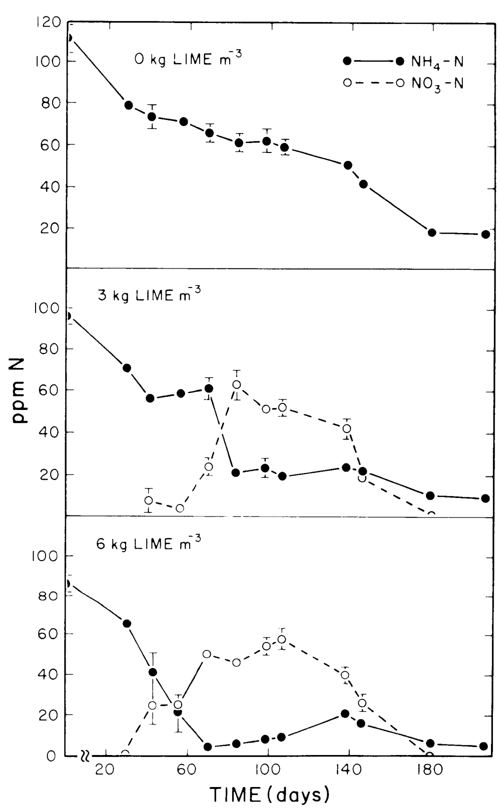

Fig. 1. Influence of lime rate on medium solution NH_4-N and NO_3-N concentrations. SE = 2.0 if bars are not indicated.

The amount of leachable NH_4-N per gram of bark at hour 0 beyond day 41 and the amount of this N remaining after 96 hr was inversely related to the liming rate (Table 1). Furthermore, only 10% of this hour 0 NH_4-N content remained after 96 hr beyond day 56. For example, the percentage of the hour 0 leachable N remaining after 96 hr at day 107 was 90%, 38%, and 12% for the 0-, 3-, and 6-kg lime treatments, respectively. Beyond day 70, the hour 0 leachable NH_4-N contents of bark at 6 kg of lime were significantly less than other treatments (Table 1). Thus, relatively low medium solution NH_4-N concentrations, relatively low hour 0 NH_4-N contents in the NAR determinations, and low amounts of this leachable NH_4-N remaining after 96 hr indicate that nitrifier activity at 6 kg of lime apparently was limited by a low NH_4-N supply. A nitrifier population exposed to a favorable pH and a limiting NH_4-N supply (as with the 6-kg lime treatment) could, over time, produce an amount of NO_3-N similar to that produced by a population exposed to a less favorable pH and a greater NH_4-N supply (as with the 3-kg lime treatment).

Experiment 2 was conducted to determine if the NH_4-N supply of the 100-ppm NH_4-N treatment limited nitrification over time. NAR of the 100-ppm N treatment increased until maximum values occurred at days 19 and 25, after which rates de-

Table 1. Influence of lime treatment on the amount of leachable NH_4-N measured at hour 0 and hour 96 during periodic NAR determinations.

Lime treatment (kg lime/m^3 bark)	Days 41	56	70	84	98	107	HSD[z]
	Hour 0 leachable NH_4-N (μg NH_4-N/g bark)						
0	290	356	362	363	386	324	89
3	275	279	324	292	303	235	64
6	265	278	206	163	142	123	68
HSD	55[y]	54	66	62	72	74	
	Leachable NH_4-N remaining after 96 hr (μg NH_4-N/g bark)						
0	295	376	362	364	341	291	93
3	280	278	305	275	195	87	57
6	260	264	22	17	13	14	49
HSD	55	90	47	54	51	46	

[z]Minimum significant difference within rows, HSD 0.05.
[y]Minimum significant difference within columns, HSD 0.05.

Table 2. Influence of N treatment on NAR and on the amounts of NH_4-N measured at hour 0 and hour 96 during periodic NAR determinations (Expt. 2).

Measurement	N treatment (ppm)	Days 1	7	13	19	25	31	37	43	49	HSD[z]
NAR (NO_3-N $\mu g \cdot g^{-1}$ bark·hr^{-1})	100	0.21	0.44	1.5	2.1	2.1	1.1	0.81	0.78	0.47	0.51
	300								2.3*[y]	1.7*	0.33
Hour 0 leachable NH_4-N (NH_4-N $\mu g \cdot g^{-1}$ bark)	100	229	159	174	141	92	58	42	31	28	21
	300								114*	104*	20
Leachable NH_4-N remaining after 96 hr (NH_4-N $\mu g \cdot g^{-1}$ bark)	100	208	122	150	99	17	7	8	4	3	17
	300								7	6	4

[z]Minimum significant difference within rows, HSD = 0.05.
[y]*Means significantly different within columns, *t* test = 0.05.

creased (Table 2). The hour 0 amount of leachable NH_4-N decreased from 229 μg of NH_4-N per gram of bark at day 1 to 28 μg of NH_4-N per gram at day 49 (Table 2). In association with this decrease, the amount of hour 0 NH_4-N remaining after 96 hr decreased from 208 μg of NH_4-N per gram of bark at day 1 to 17 μg of NH_4-N per gram of bark at day 25. Bark previously treated with 100 ppm of NH_4-N was treated with 300 ppm of NH_4-N at days 43 and 49. NAR increased at least 3-fold in response to the increased N supply. Bark of the 300-ppm N treatment contained at least 3 times the leachable NH_4-N at hour 0 as bark of the 100-ppm N treatment. The increased nitrifier activity was evidenced further by the fact that only 6% of the hour 0 leachable NH_4-N remained after 96 hr. Thus, results of Expt. 2 support the hypothesis that, over time, nitrifiers were limited by the N supply of the 100-ppm N treatment applied at 6-day intervals.

Medium solution pH decreased over time for all treatments (Fig. 3). Greater decreases in pH occurred during the period of rapid NO_3-N accumulation at 3 and 6 kg of lime compared to similar periods at 0 kg of lime. A similar result was found in previous work (7). Nitrification is pH-dependent, with maximum nitrification occurring at pH 7 to 8 (2). Since medium pH decreased over time, the influence of medium pH on nitrification was contingent on the prevailing pH.

This work has characterized the medium solution N and pH status of a pine bark medium treated with different rates of lime. Addition of lime stimulated nitrification; however, this influence varied over time, since medium pH and NH_4-N supply decreased over time. Thus nitrifier activity is subject to the dynamic nature of the medium solution and the influence of a particular lime rate on nitrification is dependent on the set of conditions that are prevalent at any one point in time.

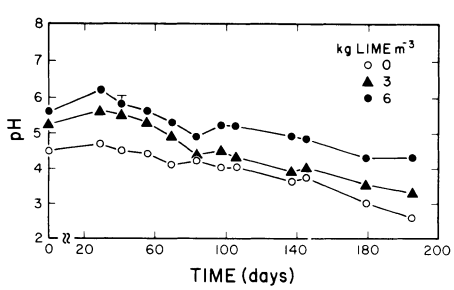

Fig. 3. Influence of lime rate on medium solution pH. SE = 0.2 if bars are not indicated.

The medium solution NH_4-N : NO_3-N ratio can have an influence on dry weight accumulation (3, 4, 6), and this influence is apparently species-specific. Nursery plants are sold on the basis of size, hence a ratio that maximizes growth would increase profits. Such a ratio could be effected by manipulating the amount of lime added to the medium. Chrustic and Wright (1) showed growth of azalea, holly, and juniper plants to be greater at 0 or 2 kg of lime per m^3 of bark than at higher rates of lime and attributed this growth response in part to the relatively high NH_4-N : NO_3-N ratio. A growth response to lime treatment may be in part a response to the ionic form of N as affected by nitrification and not a response to the increased pH or Ca availability. In agreement with this statement, Starr and Wright (8) showed no growth response to medium solution Ca concentrations >10 ppm.

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