SUBSTRATE MOISTURE AND TEMPERATURE EFFECTS ON LIMESTONE REACTION RATE

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Executive Summary

Lime reaction rate in a container substrate is influenced by temperature and moisture, which are likely to vary between batches of substrate during both storage and crop production. The effects of temperature and moisture on the duration required to achieve a stable substrate-pH is useful information for companies blending media, as well as a key component for a lime reaction model.

We quantified the pH over time of a 70% peat + 30% perlite substrate under a range of different storage temperature and substrate moisture levels, following the addition of a horticultural dolomitic limestone. Limestone was screened to the fraction that passed through a 100 US mesh but was retained on a 200 US mesh. The lime sample was incorporated into the substrate at 2.85 g $CaCO_3$ equivalent (CCE) per liter. Lime reaction rate (quantified as change in substrate-pH) was evaluated under five temperature levels of 35, 46, 50, 69 and 92 ^{o}F and five substrate moisture levels of 20, 40, 60, 80 and 100% container capacity (1 container capacity equaled 500 mL H_2O/L of substrate).

Lime reaction rate increased with increasing substrate temperature and moisture level. The days required to reach a target substrate-pH value of 6.0, indicating near-complete lime reaction at this lime rate, varied from 7 days for the high temperature (69 and 92^{o}F) plus the high moisture (80 and 100% container capacity) treatments to 70 days with low temperature (35^{o}F) and low moisture (20% container capacity).

At a typical moisture level (40%) found in stored commercial media, the duration required to reach substrate-pH 6.0 at 35, 46, 50, 69 and 92^{o}F was 35, 28, 28, 14, and 14 days, respectively.

Introduction

Media companies aim to deliver a substrate with an acceptable pH near the beginning of the crop. Ideally, the pH of substrates would also not drift out of an acceptable pH range (around pH 6 to 6.4) during crop production. Some aspects of pH drift are related to grower management (including water alkalinity and fertilizer selection). However, lime can also continue to react over time during crop production, leading to a gradual pH increase.

Temperature and moisture vary during both storage and crop production, which can affect lime reaction rate. The effects of temperature and moisture on the duration required to achieve a stable substrate-pH would be useful information for companies blending media. This relationship is also needed to refine our LimeRRR pH model.

The objective of this study was to evaluate the influences of substrate temperature and moisture levels on substrate-pH over time when horticultural limestone was incorporated into a 70% peat + 30% perlite horticultural substrate.

Materials and Methods

The experiment was conducted from April 19 through July 5, 2006 (11 weeks). The design included 5 temperature levels, 5 substrate moisture levels and 3 replications for each moisture level (Table 1). In the split plot design, temperature was the whole plot, and moisture was the subplot. In each controlled-temperature room, the five moisture levels were complete randomized design with three replications. There was no replication for a specific temperature level.

A superfine dolomitic carbonate lime (99.5% $CaCO_3$ $MgCO_3$, National Lime and Stone, Findlay, Ohio) was screened to the fraction that passed through a 100 US mesh but was retained on a 200 US mesh (0.075-0.15 mm). The limestone was incorporated into a 70% peat/30% perlite (volume/volume) substrate (with no pre-plant nutrients charges, no initial water addition and no wetting agent) at a rate of 2.85 g CCE per liter of substrate. Lime rate was calculated based on a pH titration curve with reagent $CaCO_3$ for this substrate, whereby 2.85 g CCE was required to reach a final pH value of 6. The lime was therefore assumed to have near-complete reaction at pH 6, with no residual lime remaining. The peat source was baled Canadian sphagnum peat (Sun Gro Horticulture, Vancouver, Canada) with long fibers and little dust (Von Post scale 1-2; Puustjarvi and Robertson, 1975), which was air-dried before adding moisture.

1 L blended lime and substrate samples were placed into one-gallon (3.8 L) plastic bags. Deionized water was added to each plastic bag and mixed with the substrate to bring the appropriate moisture levels of 20, 40, 60, 80 and 100% container capacity, respectively, (Table 1).

The container capacity of the substrate was determined using a 4-inch (10-cm) diameter standard round pot (0.4 L volume). The pot was first filled with the substrate, then weighed. The filled pot was immersed into deionized water for saturation. Saturation occurred when all the pore space in the medium was occupied by water, without free water on the surface. The moisture level after the substrate finished draining following saturation was termed container capacity. The difference in weight (in grams) between the initial measurement and the last measurement after draining divided by the pot volume (L) was the container capacity (mL H_2O/L of substrate) which equaled 500 mL/L.

The open plastic bags with moisturized substrate were put in each of the five temperature controlled rooms. Each plastic bag represented one moisture level. Substrate-pH was measured at day 2, 7, 14, 21, 28, 35, 42, 49, 56, 70 and 77 using an Orion Model 620 pH meter. Each time when pH was measured, (a) 0.05 L of substrate was taken from each of the plastic bags and was brought to 100% container capacity by adding additional deionized water, (b) substrate-pH was then measured immediately, and (c) the moisture levels in the plastic bags were also monitored using a balance and adjusted to the original water level by adding deionized water if any water loss was noticed. [The graphs show preliminary data - data will be analyzed using SAS PROC GLM and NLIN to develop a response surface model over time].

Results

Lime reaction rate increased with increasing temperature and moisture level (Table 1, Figures 1-3).

By 2 days after mixing, substrate-pH ranged from 4.6 to 5.6 depending on temperature and moisture level. On days 7 and 14) the spread in substrate-pH from the cool, dry treatment to the warm, moist treatment was also around 1 pH unit. Temperature and moisture levels therefore had a big effect on initial reactivity.

By day 28, at all but the least favorable (cool, dry) conditions for lime reaction, substrate-pH was at least 6.0 and slower-reacting treatments had "caught up" to the fast-reacting conditions.

The longest duration required to reach pH 6 was 70 days at the lowest 35^{o}F temperature at 20% moisture level. In contrast, the fastest lime reaction occurred at 92^{o}F for high moisture substrate with its completion reaction in less than 7 days.

For the warm temperature and high moisture treatments, pH tended to drop slightly after week 4. In particularly, there was an unexplained drop in pH at the 69^{o}F treatment.

At 40% moisture, similar to moisture levels found in stored commercial media, the duration required to reach substrate-pH 6.0 at 35, 46, 50, 69 and 92 ^{o}F was 35, 28, 28, 14, and 14 days, respectively.

At 50^{o}F, the duration required to reach substrate-pH 6.0 for the moisture treatments 20, 40, 60, 80 and 100% container capacity were 42, 28, 21, 14, and 14 days, respectively.

Literature Cited

Puustjarvi, V. and R.A. Robertson. 1975. Physical and chemical properties, p. 23-38. In: D.W. Robinson and J.G.D. Lamb (eds.). Peat in horticulture. Academic Press, London.

Table 1. Experimental design (5 temperature zone x 5 moisture level x 3 replications per moisture level = 75 plots).

Temperature zone (^oF)	Actual mean temperature ± 95 C.I. (^oF)	Five moisture levels (% container capacity)	Corresponding mL H_2O /L substrate
35	35.33 ± 0.05	20	100
46	45.93 ± 0.04	40	200
50	50.06 ± 0.07	60	300
69	69.08 ± 0.02	80	400
92	91.97 ± 0.02	100	500

Table 2. Number of days to approximately reach complete reaction. NLS limestone sample was incorporated into the substrate at the rate of 2.85g CCE/L. The rate was obtained based on a pH titration curve for this substrate so that the lime could have a complete reaction with an approximate pH value of 6.0.

Moisture (container capacity %)	mL H_2O/L substrate	Observed no. of days to complete reaction				
		35 ^oF	46 ^oF	50 ^oF	68 ^oF	92 ^oF
20	100	70.0	46.7	44.3	25.7	21.0
40	200	39.7	30.3	28.0	18.7	14.0
60	300	28.0	21.0	21.0	11.7	11.7
80	400	21.0	14.0	16.3	7.0	7.0
100	500	21.0	14.0	14.0	7.0	7.0

Figure 1. Response surface showing substrate-pH on day 2, 7, 28, and 70 at five temperature and moisture levels.

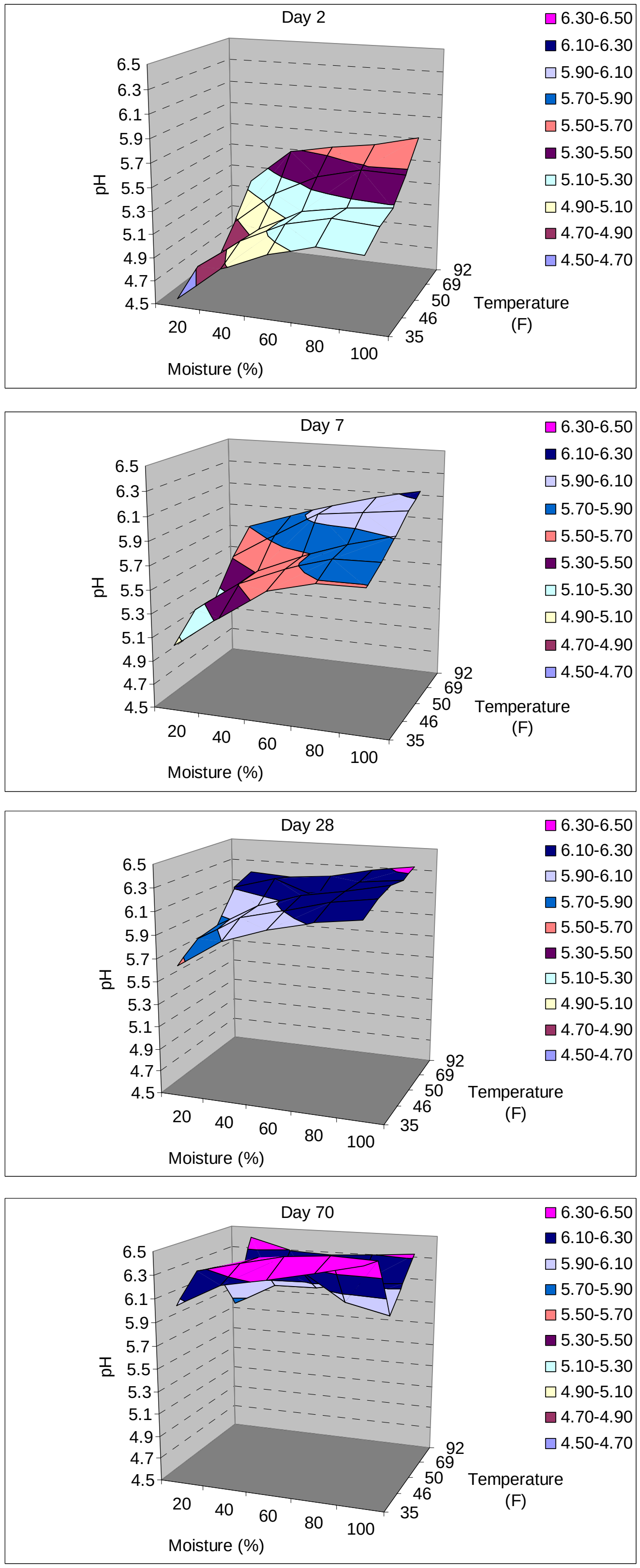

Figure. 2. Substrate-pH changes over time organized by temperature treatment at five moisture levels (% of container capacity).

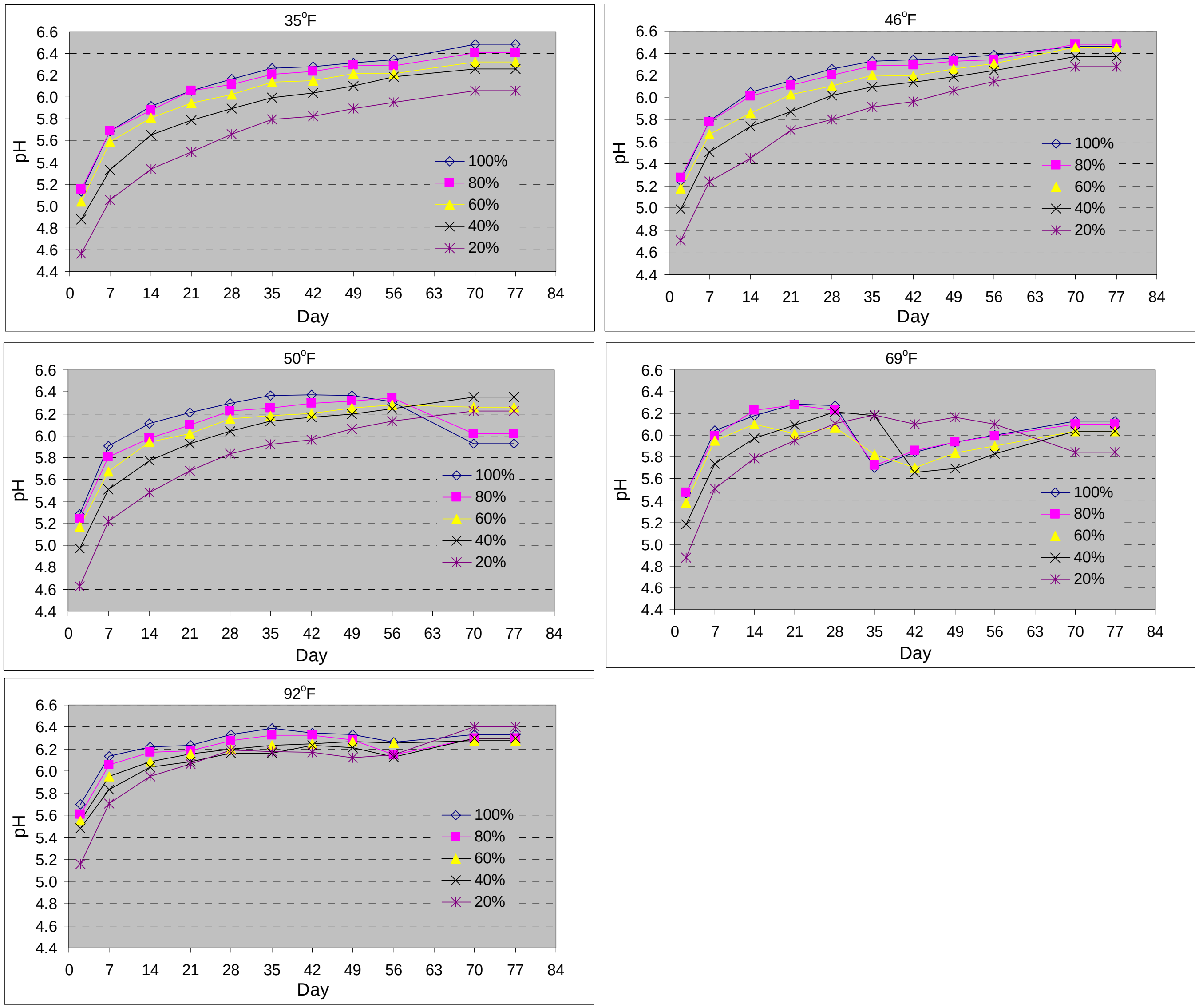

Figure 3. Substrate-pH changes over time organized by moisture level. Moisture level is expressed as % of container capacity, where one container capacity equaled 500 mL water per liter of substrate.