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Liming Reactions in Sphagnum Peat-based Growing Media

Barbara J. Williams[1], John C. Peterson[2], and James D. Utzinger[3]
Department of Horticulture, The Ohio State University, Columbus, OH 43210

Additional index words. dolomite, pH, perlite, vermiculite

Abstract. **Spagnum peat, perlite, vermiculite, and six media formulated (by volume) from these constituents (2:1, 1:1, 1:2 peat : perlite; 2:1, 1:1, 1:2 peat : vermiculite) were limed with 0, 0.9, 1.8, 2.7. 3.6, 5.4, 7.2, and 9.0 kg·m^{-3} dolomite [$CaMg(CO_3)_2$]. Media were wet to container capacity with distilled/deionized (d/d) water, incubated at 25° ±3°C, and pH determined at day 0, 2, 5, 7, 14, 28, 56, and 84. Liming reactions in mixes could not be predicted from reactions occurring in sphagnum peat, perlite, and vermiculite constituents alone. Although sphagnum peat made the major contribution to liming reactions, both perlite and vermiculite were found to contribute to liming responses of media in which they were incorporated. The major portion of pH change due to incorporation of pulverized dolomite in peat-based media occurred within 2 days. Change in pH was complete within 14 days.**

Much research has been aimed at assessing the physical properties of various soilless container media (2, 5, 7, 11, 15) and the impact of these physical conditions on plant growth (2, 5). Less research has been directed toward study of the chemical environment for plant growth in soilless mixes. Much of this work has involved investigation of chemical relationships in bark-based rather than peat-based media (1, 3, 6, 9, 16, 18).

Chemical reactions in organic media are different from those in mineral soils and soil-based media. Knowledge gained from studying soils cannot be extrapolated to these media. Knowledge of cation exchange capacity (CEC) in peat-based media cannot be used to predict liming reactions in the way that it can be with soils because of:

1) *Differences in types of CEC in soils and in peat-based media*. Mineral soils have cation exchange capacities largely due to permanent charge with little pH-dependent charge. The pH-dependent CEC of peat in its natural state may be as low as 50 meq/100 g. After liming to pH 5.5, values >100 meq/100 g are obtained and CEC, may be ≥130 meq/100 g at pH 7.0 (4, 12).

2) *Standard methodologies for laboratory determination of CEC*. Most soil testing laboratories employ saturation/extraction methods that were developed to measure the pH-independent CEC of mineral soils. Using these methods on peat-based media does not give a measurement of CEC with any real relationship to liming responses and capacities of these media to retain other cations. (8, 10, 13).

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[1]Research Associate.
[2]Associate Professor.
[3]Professor.

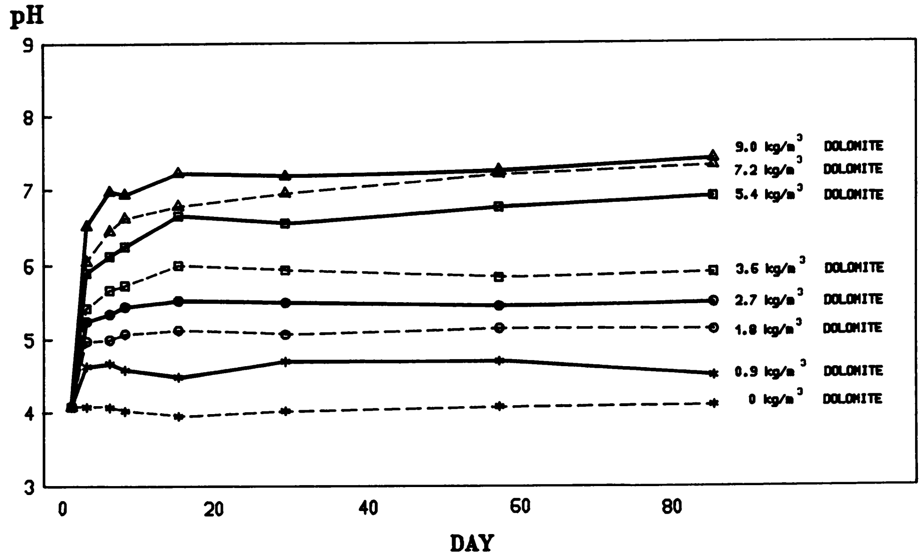

Fig. 1. pH response over time by lime rate for 2 peat : 1 perlite limed with dolomite.

Table 1. pH response curve slopes of regression equations of data for days 28 through 84[z].

Medium	Mean slope	Maximum slope
Peat	0.07	0.13
Perlite	0.05	0.11
Vermiculite	0.08	0.12
2 Peat : 1 perlite	0.08	0.18
1 peat : 1 perlite	0.10	0.14
1 peat : 2 perlite	0.05	0.09
2 peat : 1 vermiculite	0.08	0.22
1 peat : 1 vermiculite	0.05	0.08
1 peat : 2 vermiculite	0.10	0.13

[z]Slopes represent change in pH in 28 days.

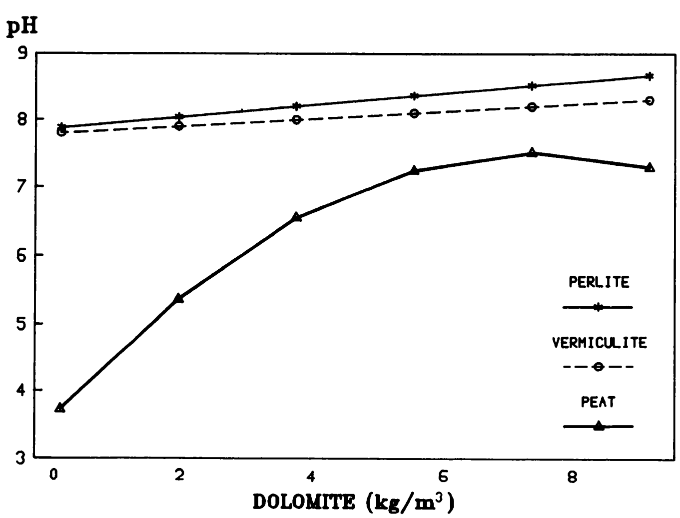

Fig. 2. Regression curves for responses of peat, perlite, and vermiculite to dolomite taken over day 28 through day 84. $\hat{Y}$ = pH, X = kg·m^{-3} dolomite. Regression equations are: perlite—$\hat{Y} = 7.878 + 0.051X$, $R^2 = 0.91$; vermiculite—$\hat{Y} = 7.802 + 0.027X$, $R^2 = 0.43$; peat—$\hat{Y} = 3.718 + 0.628X - 0.026X^2$, $R^2 = 0.99$

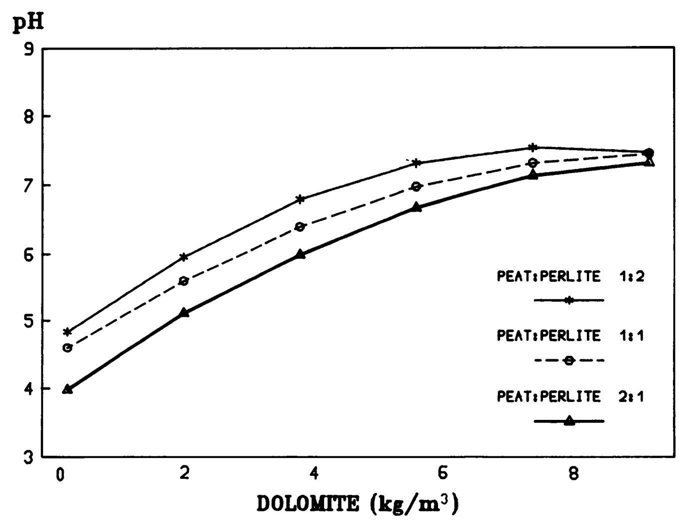

Fig. 3. Regression curves for response of 2:1, 1:1, and 1:2 peat : perlite to dolomite taken over day 28 through day 84. $\hat{Y}$ = pH, X = kg·m^{-3} dolomite. Regression equations are: 1:2 p:p—$\hat{Y} = 4.829 + 0.426X - 0.017X^2$, $R^2 = 0.97$; 1:1 p:p—$\hat{Y} = 4.596 + 0.377X - 0.013X^2$, $R^2 = 0.99$; 2:1 p:p—$\hat{Y} = 3.979 + 0.413X - 0.013X^2$, $R^2 = 0.99$.

Many factors combine to create a complex chemical system in the root environment of a plant growing in a container. It is important to evaluate these factors individually before evaluating interactions between various media components, fertilizer sources, water sources, liming materials, and the influence of plant roots themselves.

This research was undertaken to investigate pH responses to application of lime and a possible alternative to CEC for prediction of liming responses in peat-based growing mixes. The objectives were: a) to examine the nature of liming responses of peat, perlite, and vermiculite, and of media formulated from these constituents; b) to determine whether liming responses of peat-based media can be predicted from responses of media constituents; and c) to explore liming reactions of these media over time.

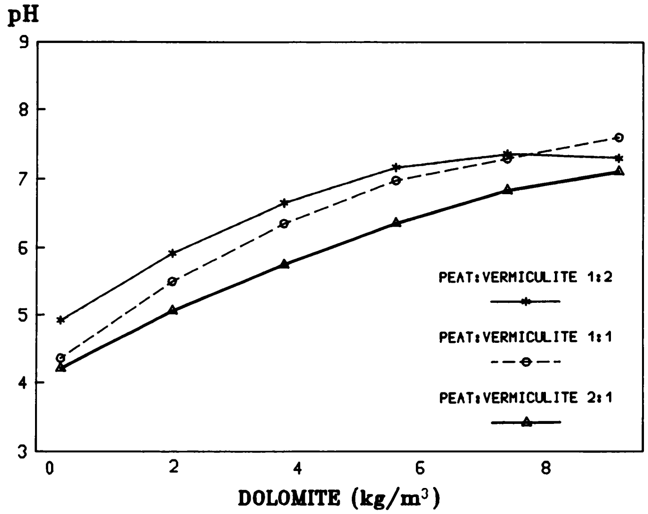

Fig. 4. Regression curves for response of 2:1, 1:1, and 1:2 peat : vermiculite to dolomite taken over day 28 through day 84. $\hat{Y}$ = pH, X = $kg \cdot m^{-3}$ dolomite. Regression equations are: 1:2 p:v—$\hat{Y} = 4.922 + 0.381X - 0.015X^2$, $R^2 = 0.99$; 1:1 p:v—$\hat{Y} = 4.364 + 0.425X - 0.015X^2$, $R^2 = 0.98$; 2:1 p:v—$\hat{Y} = 4.207 + 0.299X - 0.007X^2$, $R^2 = 0.99$.

Materials and Methods

Sphagnum peat, perlite, and vermiculite were evaluated individually and in six mixes. Mixes were (v/v) 2:1, 1:1, 1:2 peat : perlite (p:p) and 2:1, 1:1, 1:2 peat : vermiculite (p:v). Sphagnum peat with initial pH 3.6, coarse perlite with initial pH 7.4, and vermiculite, size 2/3/4, with initial pH 7.5 were used.

Media constituents were measured, combined, and mixed thoroughly. The nine media then were subdivided, and dolomite was added at the rates of 0.9, 1.8, 2.7, 3.6, 5.4, 7.2, 9.0 $kg \cdot m^{-3}$. In addition, unlimited samples of the nine media were prepared as controls. These rates were chosen to cover and extend beyond the range of recommended lime rates generally found in the literature (10).

The liming material was pulverized dolomite [$CaMg(CO_3)_2$] containing 20.8% Ca and 12.4% Mg. Dolomite was added to media in plastic bags, mixed thoroughly, wetted to container capacity (as determined by preliminary experimentation) with d/d water, and mixed again to assure even distribution of constituents and thorough wetting of media. The contents of each bag were distributed between 24 individual plastic cells with a volume of 6 cm^3. Individual cells were arranged randomly in flats, and flats were enclosed in plastic trash bags. All media were incubated at 25° ± 3°C in a controlled environment chamber.

For pH determination, a saturated paste was made with d/d water (17). After 1 hr of equilibration, pH was determined using a pH/ion meter with a pH/reference electrode. Determinations of pH were made on day 0, 2, 5, 7, 14, 28, 56, and 84.

The experiment was divided into three studies due to the numbers of samples involved and time required for performance of large numbers of pH determinations. Each third of the samples was begun at weekly intervals, and each study was a 3 × 8 × 8 factorial with three replications. Data for each of the three studies were analyzed separately.

A split-split plot analysis was used, with media the main plot factor, dolomite the subplot factor, and time the sub-subplot factor. The major portion of data analysis involved regression techniques. In all instances, both linear and quadratic equations were tested for statistical significance.

Using regression curves for peat, perlite, and vermiculite, a computer program was written to determine whether liming responses of media can be predicted from responses of limed media constituents alone. Theoretical equations were determined by using the equations for pH responses of peat and perlite, and of peat and vermiculite alone and weighting them in ratios of 2:1, 1:1, and 1:2 to determine if the calculated response curves approached the actual response curves of the peat-based media. Media constituents had been combined by volume. In order to determine if consideration of mass as well as volume was helpful in predicting liming responses, theoretical response curves also were calculated using mass of constituents as a weighting factor.

Results and Discussion

Precision. The largest SD for pH measurement was ±0.15 pH units. Standard deviation averaged ±0.09 pH units for media, ±0.13 units for dolomite, and ±0.11 units for time.

Response over time. Fig. 1 shows media pH responses to dolomite rates for 2:1 p:p over time. The illustrated responses are representative of the types of responses seen in all media used in this experiment. Response over time for all nine media represents a period of equilibration during the first 14 days, followed by relatively stable pH values over the remaining 70 days of the experiment. The major pH change occurred within the first 2 days in all media.

Liming responses to dolomite in this research were essentially completed within 14 days, rather than in months, as is common in mineral soils. The dolomite used would be considered "pulverized" according to the classification system of Schollenber-

Table 2. Pulverized dolomite amendments needed to achieve various incremental pH levels for media formulated from sphagnum peat, perlite, and vermiculite ($kg \cdot m^{-3}$), calculated from regression equations.

	Medium						
pH	Spahgnum peat	2 peat : 1 perlite	1 peat : 1 perlite	1 peat : 2 perlite	2 peat : 1 vermiculite	1 peat : 1 vermiculite	1 peat : 2 vermiculite
5.0	1.34	1.61	0.65	0.24	1.66	0.95	
5.5	1.96	2.53	1.58	1.01	2.88	1.78	0.95
6.0	2.68	3.57	2.62	1.84	4.25	2.73	1.93
6.5	3.48	4.85	3.80	2.91	5.80	3.89	3.21
7.0	4.76	6.60	5.53	4.22	7.88	5.50	4.70

Table 3. Comparisons of actual with theoretical weighted response curves for combinations of sphagnum peat and perlite limed with dolomite.

Ratio	Equation[z]	Basis
Peat	$\hat{Y} = 3.7183 + 0.6284X - 0.0260X^2$	Actual
2:1 p:p	$\hat{Y} = 3.9789 + 0.4126X - 0.0127X^2$	Actual
	$\hat{Y} = 5.1048 + 0.4360X - 0.0173X^2$	Weighted by volume[y]
	$\hat{Y} = 5.9503 + 0.3188X - 0.0121X^2$	Weighted by mass[x]
1:1 p:p	$\hat{Y} = 4.5964 + 0.3768X - 0.0125X^2$	Actual
	$\hat{Y} = 5.7981 + 0.3399X - 0.0130X^2$	Weighted by volume
	$\hat{Y} = 6.6234 + 0.2254X - 0.0078X^2$	Weighted by mass
1:2 p:p	$\hat{Y} = 4.8285 + 0.4261X - 0.0167X^2$	Actual
	$\hat{Y} = 6.4913 + 0.2437X - 0.0087X^2$	Weighted by volume
	$\hat{Y} = 7.1393 + 0.1538X - 0.0046X^2$	Weighted by mass
Perlite	$\hat{Y} = 7.8779 + 0.0514X$	Actual

[z]$\hat{Y}$ = pH, X = $kg \cdot m^{-3}$ dolomite.

[y]Formulae for actual pH response of peat and perlite weighted by volumes combined in mixes.

[x]Formulae for actual pH response of peat and perlite weighted by masses combined in mixes.

ger and Salter (14). For purposes of comparison, dolomite of this degree of fineness achieved 60% efficiency in 3 months and 85% efficiency in 1 year when incorporated to plow depth in Ohio agricultural soils.

The more rapid liming reactions found in peat-based media under conditions of this research could be due to continuous presence of water, rather than cyclic wetting and drying as in field soil; continuous temperatures of 25° ± 3°C, rather than typical field soil temperatures with cyclic cooling and warming; and more even distribution throughout the substrate than is possible with incorporation of liming materials in field soils. Dolomitic limestone of pulverized or finer grades probably should be used for liming sphagnum peat-based growing media in order to accelerate liming action. In addition, whenever practical, media should be moistened to initiate liming reaction at least 2 days before crops are established, since most of the response occurs within 2 days.

Removal of time factor. Regression equations were calculated for each dolomite level–medium combination using data from days 28, 56, and 84, because readings indicated equilibration during the first days after liming. The independent variable was time and the dependent variable was pH. The regression equation slopes for data of days 28 through 84 are shown in Table 1. The grand mean of slopes for all nine media was +0.08. Since this value was less than the SD for measurement of pH over time (±0.11), pH levels between days 28 and 84 were taken as levels achieved due to dolomite additions and exclusive of time.

Responses due to dolomite rate. Regression equations representing these pH responses to dolomite with time removed are shown in Figs. 2–4. Sphagnum peat and the six peat-based media had curvilinear responses, whereas the best-fitting curves were linear for perlite and vermiculite. The curvilinear relationship between dolomite and pH for peat-based media shows a greater amount of dolomite was required to effect an incremental increase in pH as pH increased, which can be explained by the pH-dependent nature of charges on the organic colloids. As increasing numbers of exchange sites became calcium/magnesium-saturated, increasingly higher numbers of Ca^{++}/Mg^{++} ions were required to dissociate H^+ ions into the media solution.

Calculations of amounts of pulverized dolomite needed to achieve various incremental pH levels (Table 2) were made using regression equations representing curves in Figs. 2–4. The calculated additions of dolomite serve only to demonstrate differences between media containing differing proportions of materials and cannot be considered as liming recommendations.

Prediction of media liming responses from media constituent responses. Table 3 compares actual with calculated weighted response curves for combinations of sphagnum peat with perlite limed with dolomite. Values for $\hat{Y}$ and intercepts represent pH levels, and X represents $kg \cdot m^{-3}$ dolomite. Results when the three media were limed were very different from the predictions for combinations of peat with perlite, both by volume and by mass.

It is apparent that liming responses of peat and perlite and peat and vermiculite combinations cannot be predicted solely from the pH responses of the media constituents. Both perlite and vermiculite contribute to these responses. However, weighting by volume gives disproportionately heavy influence to perlite/vermiculite and discounts the influence of peat. Use of mass rather than volume ratios further accentuates these trends and is not useful in generating predictive response curves.

This research has focused on a small number of possible considerations related to hydrogen ion concentration in organic potting media. Further research is needed to examine liming responses of media formulated with peat and vermiculite from various geographical locations, as well as with other organic and inorganic constituents. Effect of fertilizer applications in combination with liming, and the influences of microorganisms and of plant roots on the the complex pH-related chemical systems in growing media need study.

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Longevity of Pistachio Pollen Determined by in Vitro Germination

Vito S. Polito and Juvenal G. Luza
Department of Pomology, University of California, Davis, California 95616

Additional index words. *Pistacia vera*

Abstract. **Pistachio (*Pistacia vera* L.) pollen was examined for capacity to germinate in vitro 2 days after anthesis and at intervals of time after storage at ambient laboratory conditions or at −20°C. In 1986, fresh pollen of each of four clones examined had high germination percentages on a range of sucrose and agar concentrations. After 1 week at room temperature, germination percentages were <6%. However, when the same week-old pollen was treated to effect gradual hydration at high humidity prior to being placed on the germination medium, germination increased to >80% for 'Peters' pollen and 10.4% to 63.8% for the three other clones. In 1987, similar results were obtained for 'Peters' pollen, where pollen hydrated at high humidity had germination rates at least 50% that of fresh pollen when stored up to 18 days at ambient laboratory temperature and humidity. Pollen stored at −20° showed more exacting in vitro germination requirements than fresh pollen, particularly as time in storage increased. 'Peters' pollen retained germination levels comparable to fresh pollen after 4 months at −20°, but, by 12 months, germination percentages had fallen sharply.**

As part of our research program on pollination and fruit set in pistachio, we have been investigating methods for evaluating pollen quality and longevity in storage. In order to evaluate the quality of pollen to be used in research or supplementary pollination programs and to determine the suitability of storage methods in preserving pollen, it is essential to have a reliable method of determining pollen quality. Assessment of pollen quality by its germination and growth in vitro is a useful method, but results, particularly negative results, must be interpreted cautiously: pollen may not germinate because it is inviable, or, it may be that the requirements of the pollen are not adequately met by the conditions of a particular germination assay. Obviously, these requirements vary greatly among species and must be determined for each (7). In addition, as the results presented here illustrate, even the same sample of pollen may respond differently to a given set of conditions as it ages or as it is subjected to stress conditions such as those encountered during storage.

Several researchers (1, 6, 8–10) have investigated in vitro germination methods as indicators of viability for fresh and stored pistachio pollen. Previous work on pollen of the male pistachio cultivars used in California (1) led to several conclusions: a) a medium containing 10% sucrose solidified with 1% agar promotes maximum in vitro germination, b) pollen viability is lost when pollen is held for 3 to 4 days at room temperature, and c) when pollen of 'Peters', the most widely used pollen cultivar in California (2), is stored in a freezer for 3 to 4 months, viability falls greatly. Previous results in our lab on in vitro germination behavior of walnut pollen (4, 5) led us to believe that re-evaluation of these conclusions may be appropriate using methods that were successful for walnut pollen, particularly controlled rehydration of pollen prior to incubation on agar-solidified medium.

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