Yield Responses and Nutrient Uptake of Broccoli as Affected by Lime Type and Fertilizer

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Abstract. In a 3-year study with broccoli (Brassica oleracea var. botrytis (L.) Mill. cv. Green Comet), NP or NPK fertilizer at rates of 56N–56P–0K, 56N–56P–56K, and 56N–112P–56K (kg·ha\(^{-1}\)) were banded in plots to which three types of lime had been applied —calcitic, calcitic with 3% Mg, or dolomitic. Fertilizer and lime controls were included. Previous liming had raised the soil pH from 5.3 to 7.2–7.4. Effects of lime on yields were greatest when no fertilizer was applied. Dolomitic lime was the most effective, increasing total yield by 49%, terminal weight by 54%, and hastening maturity. Fertilizer effects were most evident when no lime had been applied, with all fertilizer treatments increasing total yield, terminal and plant weight, and hastening maturity. Most changes occurred in the 56N–56P–OK treatment. Effects of lime when fertilizer was applied and effects of fertilizer when lime had been applied were less consistent. Lime alone, especially types containing Mg, increased leaf P, which generally followed the same trend as total yield. Calcitic lime increased leaf Ca and dolomitic lime increased leaf Mg over other lime treatments. Calcitic lime with 3% Mg increased leaf Ca, but not leaf Mg, compared to the check. All lime treatments decreased leaf Mn, B, and Zn. Fertilizer treatments usually increased leaf N and Mn. Phosphorus uptake was increased by either lime or fertilizer application. Regression analysis strongly suggested that P was the element most responsible for yield increases.

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Materials and Methods

Lime and fertilizer experiments with ‘Green Comet’ broccoli were carried out at the Horticultural Research Farm at Rock Springs, Pa. during 1985–1987. The soil type was Hagerstown silt loam (Typic Hapludalf). The statistical design was a split plot with three replications. The location of the plots in the field was changed each year to avoid planting broccoli in the same area in successive years.

Main plots consisted of three lime types — calcitic (38% Ca plus a trace of Mg), calcitic 3% Mg (a 3 calcitic : 1 dolomitic mixture), or dolomitic (21% Ca and 12% Mg), plus a control. The three lime types had been applied at 4.5 t·ha\(^{-1}\) in 1972, 1974, and 1978. They were broadcast evenly over each plot and incorporated with a rotovator. Soil samples were taken in the spring of each year from each lime plot and were analyzed for pH, Ca, and Mg (Dahnke, 1988).

Fertilizer treatments, consisting of NP or NPK at 56N–56P–OK, 56N–56P–56K, and 56N–112P–56K (kg·ha\(^{-1}\)), plus a control, made up the sub-plots. Urea (46% N), triple superphosphate (20% P), and muriate of potash (50% K) were the N, P, and K sources, respectively. Broccoli was seeded in 128-cell Todd planter flats (Speedling, Sun City, Fla.) in mid-June of each year using a 1 peat :1 vermiculite mixture. Seedlings were fertilized weekly with a complete soluble fertilizer (5 g of Millers 20N–20P–20K + micronutrients/liter at 1 liter/flat) starting 2 weeks after seeding and were acclimatized in a coldframe. Seedlings were transplanted mechanically into the field in late July in rows 0.9 m apart with 0.45 m between plants. The fertilizer treatments were applied in double bands 10 cm to each
side of the plants and 10 cm deep immediately after transplanting, using a tractor-mounted belt planter. Plots consisted of 12 plants, of which the center eight were used for data collection.

Leaf samples, consisting of the newest fully expanded leaf (petiole and blade) from six plants, were selected from each plot \( \approx 40 \) days after transplanting. They were cleaned by dipping in a detergent solution, followed by a tap water rinse and three successive distilled water rines, dried at 60°C, and ground to pass through a 1-mm screen. Samples were analyzed for eight elements: N using an AutoAnalyzer with manual digestion (Isaac and Johnson, 1976) and P, K, Ca, Mg, Mn, B, and Zn through the use of an ICP emission spectrometer (Dahlquist and Knoll, 1978).

Multiple, harvests were made starting = 50 days after transplanting. Terminal main heads and lateral side-shoots were harvested as they matured to determine total yield. Terminals were counted and weighed, laterals were weighed, and plants were cut at ground level and weighed after harvesting was complete. Effects on maturity were determined by calculating the percentage of terminal yield that was mature at the time of the first harvest (percent early terminal yield).

All growth response and leaf analysis data were subjected to an analysis of variance. Mean separation was determined by the Wailer–Duncan \( K \) ratio \( t \) test, where \( K = 100 \) was considered comparable to the 5% level. All field and leaf analysis data shown are means of 3 years. Regression analysis was used to determine the relationship between leaf elemental concentrations and total yield (SAS, 1985).

### Results and Discussion

**Soil analysis.** Means of results from 3 years (Table 1) showed that all liming treatments raised the pH similarly, although slightly more with the calcitic–3% Mg type. Soil Mg saturation was increased moderately by the calcitic–3% Mg type and markedly by the dolomitic. Soil Ca saturation was increased substantially by the calcitic and calcitic–3% Mg types and moderately by dolomitic lime.

**Growth responses.** There were lime x fertilizer interactions for yield responses (Table 2), but no significant year x lime, year x fertilizer, or year x lime x fertilizer interactions.

Effects of lime were greatest when no fertilizer was applied and varied with type. The calcitic type increased only plant weight, while the calcitic–3% Mg type increased terminal and plant weight and tended to hasten maturity. The dolomitic type, however, increased total yield by 49%, produced larger plants with terminals that were 54% heavier, and hastened maturity, with more than twice as many terminals ready at first harvest as when no lime was applied.

Similarly, fertilizer effects were most evident when no lime had been applied. All fertilizer treatments increased total yield, terminal and plant weight, and hastened maturity. The 56N–56P–56K and 56N–112P–56K treatments did not result in larger increases in total yield, terminal weight, or hastening of maturity than the 56N–56P–0K treatment.

Effects of lime when fertilizer was applied and effects of fertilizer when lime had been applied were less consistent. Lime had no effect on yield responses when 56N–56P–0K or 56N–56P–56K fertilizer treatments were applied and few effects when the 56N–112P–56K fertilizer treatment was applied. When lime had been applied, most fertilizer effects occurred only with the calcitic or calcitic–3% Mg types, where the 56N–56P–56K and 56N–112P–56K fertilizer treatments increased total yield, terminal weight, and usually plant weight, compared to the fertilizer control. However, when the dolomitic type was applied, the only effect fertilizer had was on plant weight, which was increased by all fertilizer treatments.

**Leaf analysis.** There were significant lime x fertilizer interactions for leaf K and Mn only.

Leaf N was not affected by lime when results were averaged across all fertilizer treatments (Table 3), but was increased by fertilizer application when results were averaged across all lime treatments, with the greatest increases occurring with the 56N–56P–56K and 56N–112P–56K treatments. However, when lime effects were compared in the control fertilizer treatment (data not shown), leaf N tended to increase with lime application, with values of 4.39%, 4.89%, 4.86%, and 5.12% for the control, calcitic, calcitic–3% Mg, and dolomitic lime applications, respectively. The level reached when only dolomitic lime was applied approached the level achieved by applying the 56N–56P–0K treatment alone (5.49%), indicating that liming, especially with dolomitic lime, and applying the 56N–56P–0K treatment, had similar effects on leaf N. Leaf N values among lime treatments were variable when fertilizer was applied.

Leaf Ca and Mg were affected differently by the lime types. Leaf Ca levels, which were related to the calcium content of the lime applied, were increased 32% by the calcitic lime type and 23% by the calcitic–3% Mg type, but were not increased significantly by the dolomitic type. The 56N–56P–0K treatment resulted in higher Ca levels than any other fertilizer treatment. Leaf Mg was doubled by the dolomitic type, but was not affected significantly by the calcitic or calcitic–3% Mg types. Leaf Mg levels were higher in the 56N–56P–0K fertilizer treatment than in the 56N–56P–56K treatment, probably because of an antagonism with the added K. Leaf B and Zn were decreased by all lime types, with calcitic being most effective in reducing Zn. The 56N–112P–56K fertilizer treatment increased leaf Zn over the control.

Although the lime x fertilizer interaction was not significant with leaf P, there are some important points that are apparent only when lime x fertilizer treatment effects are presented (Fig. 1). Leaf P was increased by lime (as much as 38% with the dolomitic type) when no fertilizer was applied. When fertilizer was applied, lime effects on leaf P were reduced since even the levels in the control lime treatment were increased. An earlier study conducted for 5 years in the same field (Smith, 1984) showed that all lime types, especially dolomitic, increased leaf P with sweet corn. Broccoli leaf P was increased by applying fertilizer and increased most by the 56N–112P–56K rate across all lime treatments. The 56N–56P–56K rate increased sweet corn leaf P further than the 56N–56P–0K rate only when the calcitic–3% Mg or dolomitic lime types were applied.

Broccoli leaf K was decreased by all lime types when neither fertilizer nor the 56N–56P–56K fertilizer rate was applied,
Table 2. Lime type and fertilizer effects on growth responses of ‘Green Comet’ broccoli (1985-1987).

| Lime type          | Fertilizer treatment | Total yield (t·ha⁻¹) | Terminal head wt (g/plant) | Plant wt (kg/plant) | Early terminal yield (%) |
|--------------------|----------------------|----------------------|---------------------------|---------------------|--------------------------|
|                    | 0N-0P-0K             | 56N-56P-0K           | 56N-56P-56K               | 56N-112P-56K        |                          |
| Control            | 3.79 Bb              | 5.24 Aa              | 6.03 Aa                   | 5.36 Ac             |                          |
| Calcitic           | 4.55 Bb              | 5.49 ABa             | 6.07 Aa                   | 5.87 Ab              |                          |
| Calcitic–3% Mg     | 4.64 Cb              | 5.49 BCa             | 6.41 ABa                  | 7.17 Aa             |                          |
| Dolomitic          | 5.65 Aa              | 6.37 Aa              | 5.94 Aa                   | 6.50 Aab            |                          |

Terminal head wt (g/plant)

| Lime type          | Fertilizer treatment | Control | Calcitic | Calcitic–3% Mg | Dolomitic |
|--------------------|----------------------|---------|----------|----------------|-----------|
| Control            |                      | 104 Bc  | 150 Aa   | 159 Aa         | 158 Ab    |
| Calcitic           |                      | 150 Aa  | 148 ABa  | 178 ABa        | 200 Aa    |
| Calcitic–3% Mg     |                      | 163 Aa  | 154 BCa  | 187 ABa        | 200 Aa    |
| Dolomitic          |                      | 172 Aa  | 179 Aa   | 156 Aa         | 172 Aab   |

Plant wt (kg/plant)

| Lime type          | Fertilizer treatment | Control | Calcitic | Calcitic–3% Mg | Dolomitic |
|--------------------|----------------------|---------|----------|----------------|-----------|
| Control            |                      | 0.51 Cb | 0.75 Ba  | 0.94 Aa       | 0.82 ABb  |
| Calcitic           |                      | 0.73 Ca | 0.86 Ba  | 0.97 Aa       | 0.99 Aa   |
| Calcitic–3% Mg     |                      | 0.75 Ba | 0.83 ABa | 1.04 ABa      | 1.07 Aa   |
| Dolomitic          |                      | 0.71 Ba | 0.95 Aa  | 0.97 Aa       | 1.01 Aa   |

Early terminal yield (%)

| Lime type          | Fertilizer treatment | Control | Calcitic | Calcitic–3% Mg | Dolomitic |
|--------------------|----------------------|---------|----------|----------------|-----------|
| Control            |                      | 43.1 Bb | 73.6 Aa  | 77.4 Aa        | 75.9 Aa   |
| Calcitic           |                      | 51.0 Ab | 77.2 Aa  | 77.4 Aa        | 75.9 Aa   |
| Calcitic–3% Mg     |                      | 69.3 Aab| 75.5 Aa  | 70.0 Aa        | 77.3 Aa   |
| Dolomitic          |                      | 89.6 Aa | 88.3 Aa  | 82.4 Aa        | 86.7 Aa   |

Mean separation within each treatment for each variable by the Wailer–Duncan K ratio t test, with K = 100. Uppercase letters denote fertilizer treatment effects. Lowercase letters denote lime type effects.

Table 3. Lime type and fertilizer effects on leaf analyses of ‘Green Comet’ broccoli (1985-1987).

| Treatment          | Element (%) | Element (µg·g⁻¹) |
|--------------------|-------------|------------------|
|                    | N           | Ca               | Mg               | B     | Zn    |
| Lime type          |             |                  |                  |       |       |
| Control            | 5.43 a      | 2.14 c           | 0.235 b          | 20.4 a| 41.0 a|
| Calcitic           | 5.44 a      | 2.83 a           | 0.224 b          | 15.8 b| 24.6 C|
| Calcitic–3% Mg     | 5.51 a      | 2.63 b           | 0.265 b          | 16.4 b| 27.2 b|
| Dolomitic          | 5.55 a      | 2.19 c           | 0.473 a          | 15.9 b| 28.7 b|
| Fertilizer rate    |             |                  |                  |       |       |
| 0N-0P-0K           | 4.81 c      | 2.44 b           | 0.295 ab         | 17.4 a| 28.9 b|
| 56N-56P-0K         | 5.45 b      | 2.59 a           | 0.313 a          | 16.9  ab| 30.1 ab|
| 56N-56P-56K        | 5.80 a      | 2.40 b           | 0.290 b          | 15.9 b| 30.3ab|
| 56N-112P–56K       | 5.87 a      | 2.37 b           | 0.299 ab         | 18.2 a| 33.3 a|

Mean separation within each lime type and each fertilizer treatment by the Wailer-Duncan K ratio t test, with K = 100. Uppercase letters denote fertilizer treatment effects. Lowercase letters denote lime type effects.

but was not affected by lime when the 56N-56P-0K or 56N-112P-56K fertilizer treatments were applied (data not shown). Leaf K was decreased by the 56N-56P-0K fertilizer rate with all lime types, except the calcitic–3% Mg type, which was probably a dilution effect because more growth occurred without supplying K.

Leaf Mn (Fig. 2) was related to the effectiveness of lime in reducing and fertilizer in increasing soil acidity. All three lime types reduced leaf Mn markedly, with proportionately greater reductions occurring when fertilizer was applied. Concurrently, leaf Mn usually increased when the 56N–56P–0K treatment was applied, with the largest increases occurring when no lime was applied. Addition of K usually increased leaf Mn further, which was probably due to the chloride contained in the KCl source (Palaniyandi and Smith, 1978).

Regression analysis was used to determine the relationship between leaf concentration and total yield. Each element was regressed against total yield, being tested for both linear and quadratic fits. In general, over the range of yields and concent-
Here, both liming with the dolomitic type and application of fertilizer increased yield, with much of the increase occurring with the 56N–56P–0K rate. Dolomitic lime had a similar nutritional effect to fertilizer application. Results from this study strongly suggest that increased P availability was the factor most responsible for the increases in yield, not increased N or Mg, or decreased Mn, availability. This result would explain the fact that fertilizer substituted for lime, and lime for fertilizer, in increasing yields.

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