Fertilization Recommendations for Crisphead Lettuce Grown on Organic Soils in Florida

George Hochmuth, Ed Hanlon, Russell Nagata, George Snyder, and Tom Schueneman

Lettuce (Lactuca sativa L.) was planted on 14,000 acres in the 1990-91 season with about 80% of the crop grown in the Everglades Agricultural Area (EAA) (Fla. Agric. Statistics Serv., 1992). The value of the 1990-91 crop was $29.5 million which was about 2.0% of the total Florida vegetable crop value.

Crisphead lettuce made up about 5,000 acres of this lettuce acreage and the average crisphead lettuce yield is estimated to be 600 50-lb cartons per acre.

Crisphead lettuce is a moderately expensive crop to produce with costs for production, harvesting, and marketing averaging $3,400 per acre (Smith and Taylor, 1991). Fertilizer accounts for about 10% of the total preharvest costs for lettuce (Smith and Taylor, 1991).

During the last 15 years, considerable research has been conducted on lettuce fertilization on the organic soils of Florida with emphasis on the EAA. Optimum fertilization is important for maximizing yields and quality and for minimizing negative impacts to the environment resulting from overfertilization.

This publication presents the newly revised University of Florida recommendations for fertilization of crisphead lettuce on organic soils in Florida. Recommendations are based on field research and supersede those found in Bulletin 876 (Sanchez, 1990), Circular 806 (Hochmuth and Hanlon, 1989), and Circular 123C (Montelaro, 1977). Reviewing and updating fertilization recommendations is a continuing process.

ORGANIC SOILS

The organic (muck) farm lands in southern Florida originated from the drainage of marshes consisting largely of decomposing sawgrass. Upon decomposition of the organic matter, nutrients are released (mineralized), becoming available for plant uptake. Mineralization does not supply all of the nutrition required by lettuce. Lettuce is produced in southern Florida in the winter season. During the cool winter growing period, mineralization is not rapid.

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enough to supply adequate nutrients for a rapidly growing lettuce crop.

The soil pH of the EAA has increased with time (Beverly, 1984). As a result of increased soil pH, the availability of phosphorus and some micronutrients to lettuce plants is reduced. Fertilization is needed to provide the portion of the lettuce nutrient requirement rendered unavailable by high pH and to supply nutrients that are not in high enough supply from mineralization.

**SOIL TESTING**

The soil test calibration and fertilization recommendations outlined in this publication were developed using procedures of the University of Florida EREC Soil Testing Laboratory in Belle Glade, Florida. Recommendations for phosphorus (P) and potassium (K) are based on a soil test. Current methodologies use water as the extractant for P and 0.5N acetic acid for K (Sanchez, 1990). Soil testing provides an index to the portion of the crop nutrient requirements that can be supplied from the soil. Fertilizer is added to supplement the native fertility to obtain positive yield and quality responses. Although the recommendations in this publication are based on the above extractants, work is continuing to improve methodologies (Sanchez and Hanlon, 1990), especially in light of the increasing pH of these soils.

Soil testing benefits are related to the quality of the soil sample. Soil samples should reasonably represent the "production unit." The unit might vary in size from 10 to 40 acres, depending on the grower's understanding of soil uniformity. Areas not representative of the production unit such as shallow areas, borders near ditches or roadways, or areas varying from the predominant soil type should be sampled separately. These areas might need to be managed differently from the majority of the field.

**MACRONUTRIENTS**

**Nitrogen**

Several research reports outlined benefits of N application to crisphead lettuce (Beverly and Guzman, 1984; Guzman and Sanchez, 1986a; Sanchez et al., 1988a, b). The N recommendation for crisphead lettuce is to broadcast up to 50 lb N per acre in cool planting periods. N applications made after planting should be banded into moist soil during the cool period of the growing season or after leaching rains where the soil has been soaked or temporarily flooded.

Growers should avoid the temptation to overfertilize crisphead lettuce with N. Excess N can reduce head quality by lowering firmness or causing splitting. Bottom-rot might also be enhanced should warm, moist conditions occur after excess N application.

**Phosphorus**

Several studies have reported yield responses to P fertilization of crisphead lettuce grown on Florida organic soils (Guzman and Lucas, 1979; Lucas and Guzman, 1980; Beverly and Guzman, 1984; Sanchez et al., 1988a, b; Sanchez and Burdine, 1988; Guzman et al., 1989; Sanchez et al., 1990a, b; Nagata et al., 1992). A summary of the research results for broadcast P is presented in Figure 1. Data in Figure 1 show that lettuce response to P fertilization levels off between 300 and 400 lb P₂O₅ per acre. The same relative yield values corresponding to the same P fertilization rate have been plotted horizontally so
that no points are hidden. All relative yield values were calculated from reported marketable (not biomass) lettuce yields. Research literature from which data have been gathered to construct Figure 1 is cited in Table 1. A linear-plateau model (Dahnke and Olson, 1990; Cerrato and Blackmer, 1990) and a simple quadratic model were used to describe the data for response to P fertilization (Figure 2). The linear-plateau model showed that yield began to level off at 276 lb $P_2O_5$ per acre but the quadratic model did not maximize until 508 lb $P_2O_5$ per acre. Other research has shown that quadratic models tend to overestimate plant response to fertilization (Cerrato and Blackmer, 1990; Hochmuth et al., 1993). Upper and lower boundaries of lettuce response to P fertilization may be estimated using these two models. A value about equidistant between the linear-plateau shoulder and the quadratic maximum (i.e., 400 lb $P_2O_5$ per acre) represents a justifiable limit for response to broadcast P.

The critical soil-P index above which lettuce would not respond to fertilization with P was set at 27 (Sanchez, 1990). Figure 3 shows response of crisphead lettuce on unfertilized soil of varying P water indices from 22 experiments (Table 2). Figure 3 was constructed by plotting percent relative yield at zero added P versus the soil test index. A statistical method for grouping soils responsive to fertilization was proposed by Nelson and Anderson (1977). Graphical (Cate and Nelson, 1971) and statistical solutions were calculated for the data in Figure 3. The graphical solution showed that lettuce marketable yield was unlikely to respond to P fertilization of soils testing above a P water index of 15. A statistical solution showed that yield response was unlikely above a P water index of 12. The coefficient of determination for the statistical model was only 0.45, however, indicating that the initial P water index should not be used as the sole indicator for P fertilization.

Significant improvements in P efficiency and improved profitability result from band placement of P fertilizer (Guzman and Sanchez, 1987b). Recent research of Sanchez et al. (1990a), summarized in Figure 4, confirmed these results.

The new IFAS recommendations specify no more than 200 lb $P_2O_5$ (banded) per acre, depending on soil test results (Table 2). The P fertilizer should be placed in three-inch wide bands in the bed, two to

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**Table 1.** Listing of publications used in presentation of data in Figures 1 and 4 for responses to P fertilization of crisphead lettuce.

<table>
<thead>
<tr>
<th>Citation</th>
<th>Experiment</th>
<th>Soil P Index</th>
<th>Symbol</th>
<th>Max yield (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guzman and Lucas, 1979</td>
<td>Exp. 700</td>
<td>3</td>
<td>□</td>
<td>680</td>
</tr>
<tr>
<td></td>
<td>Exp. 701 (SE)</td>
<td>9</td>
<td>□</td>
<td>871</td>
</tr>
<tr>
<td></td>
<td>Exp. 701 (TP)</td>
<td>6</td>
<td>□</td>
<td>1138</td>
</tr>
<tr>
<td>Lucus and Guzman, 1980</td>
<td>Exp. 1</td>
<td>5</td>
<td>□</td>
<td>640</td>
</tr>
<tr>
<td>Beverly and Guzman, 1984</td>
<td>Exp. 1</td>
<td>4</td>
<td>△</td>
<td>794</td>
</tr>
<tr>
<td>Guzman et al., 1987</td>
<td>Exp. 1</td>
<td>6</td>
<td>□</td>
<td>806</td>
</tr>
<tr>
<td>Guzman et al., 1989</td>
<td>Exp. 1</td>
<td>9</td>
<td>□</td>
<td>834</td>
</tr>
<tr>
<td>Sanchez et al., 1990a</td>
<td>Exp. 1</td>
<td>2</td>
<td>□</td>
<td>804</td>
</tr>
<tr>
<td></td>
<td>Exp. 2</td>
<td>3</td>
<td>□</td>
<td>892</td>
</tr>
<tr>
<td></td>
<td>Exp. 3</td>
<td>4</td>
<td>□</td>
<td>1054</td>
</tr>
<tr>
<td></td>
<td>Exp. 4</td>
<td>5</td>
<td>□</td>
<td>804</td>
</tr>
<tr>
<td>Sanchez et al., 1990b</td>
<td>Exp. 1</td>
<td>28</td>
<td>□</td>
<td>840</td>
</tr>
<tr>
<td></td>
<td>Exp. 2</td>
<td>3</td>
<td>□</td>
<td>895</td>
</tr>
<tr>
<td></td>
<td>Exp. 4</td>
<td>6</td>
<td>□</td>
<td>1100</td>
</tr>
<tr>
<td>Nagata et al., 1992</td>
<td>Exp. 1</td>
<td>16</td>
<td>□</td>
<td>1055</td>
</tr>
<tr>
<td>Resain B., 1993</td>
<td>Exp. 1</td>
<td>4</td>
<td>□</td>
<td>820</td>
</tr>
<tr>
<td></td>
<td>Exp. 4</td>
<td>6</td>
<td>□</td>
<td>1055</td>
</tr>
<tr>
<td></td>
<td>Exp. 6</td>
<td>4</td>
<td>□</td>
<td>544</td>
</tr>
<tr>
<td></td>
<td>Exp. 8</td>
<td>8</td>
<td>□</td>
<td>695</td>
</tr>
<tr>
<td></td>
<td>Exp. 10</td>
<td>8</td>
<td>□</td>
<td>695</td>
</tr>
<tr>
<td></td>
<td>Exp. 12</td>
<td>8</td>
<td>□</td>
<td>900</td>
</tr>
</tbody>
</table>

Maximum yield from experiment in 55 lb cartons calculated from original data reported in referenced articles.

$P_2O_5$ index is obtained by water extraction procedure (Sanchez, 1990).
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Fig. 3. Relative lettuce yields from unfertilized treatments at indicated P water soil test index.

Fig. 4. Yield response of crisphead lettuce to rates of banded phosphorus.

Fig. 5. Yield response of crisphead lettuce to rates of broadcast potassium.

Potassium

Three inches below the lettuce rows. Banding liquid fertilizer is equivalent to, or slightly superior to banding granular fertilizers (Guzman et al., 1988; Sellers et al., 1988). Lettuce does not respond to supplemental P sidedressed during the growing season (Sanchez et al., 1990b).

Calcium, Magnesium, and Sulfur

Several responses to K fertilization have been documented (Guzman and Lucas, 1979; Beverly and Guzman, 1984; Guzman et al., 1987; Diaz et al., 1988; Guzman et al., 1989). A summary of research on lettuce response to K fertilization is presented in Figure 5. IFAS recommendations specify no more than 200 lb K₂O (broadcast) per acre, depending on the soil test (0.5N acetic acid) index value (Table 2). Potassium should be broadcast and incorporated into the bed before planting. Excessive application rates of K, especially banded applications, can cause soluble salt damage to lettuce plants.

Supplies of calcium (Ca), magnesium (Mg), and S from organic soils are usually adequate to meet crisphead lettuce nutrient requirements. These nutrients are supplied from the underlying limestone (during irrigation or flooding), from oxidation of the muck, from applied S (for soil acidification), or as a contaminant in fertilizers or certain pesticides.

Sometimes, Ca-related physiological disorders (e.g., tipburn) can occur. Research results on the relation of foliar- and soil-applied Ca to tipburn, cracked stem, and certain head disorders have been mixed (Guzman and Sanchez, 1987a), so no clear recommendation can be made. These disorders are usually not directly related to low soil Ca but rather to a temporary inability of the plant to translocate Ca to the young leaves in the lettuce head. A similar problem has been described for cabbage by Palzkill et al. (1976). Calcium moves in the transpiration stream of the plant, so Ca deficiency is related to the water status of the plant. Young leaves inside the lettuce head do not transpire as actively as wrapper leaves. Dry soil conditions, windy periods, excessive soluble salts, and high temperatures create transpirational demands in older leaves such that Ca movement to younger leaves is reduced thus increasing tipburn. Root pruning during cultivation also can lead to tipburn because young root tips (where Ca is preferentially absorbed) can be damaged. Excess fertilization with N (excessive growth rate) or K (increased soluble salts) can increase internal or external wrapper leaf tipburn.
MICRONUTRIENTS

There are only a few studies on micronutrient fertilization of crops on organic soils with emphasis on soil test calibration. Current micronutrient recommendations are for an apparent crop need, or are based on soil pH. Micronutrients can be broadcast before planting with the K fertilizer. Research has not evaluated banding of micronutrients. Banding of micronutrients might be more efficient than broadcasting, but rates might need to be reduced to prevent toxicities.

• **Manganese (Mn).** For pH below 5.7, no Mn is required (Forsee, 1940; Forsee, 1952; Forsee, 1954). For soils above 5.7, eight lb Mn per acre are recommended using sulfate or finely ground oxide sources.

• **Boron (B).** For crisphead lettuce, B should be added at 1.0 to 1.5 lb B per acre for each crop. This recommendation is based on apparent crop need and on the fact that B can leach from organic soils (Sanchez, 1990).

• **Copper (Cu).** Applications of 12 lb Cu and 4 lb Cu per acre for the first two crops, respectively, on virgin land are usually sufficient for succeeding crops (Forsee, 1940; Kretchmer and Forsee, 1964). No further Cu fertilization is required (Sanchez, 1990).

• **Zinc (Zn).** The recommendation is for 8 lb Zn per acre, based on apparent crop requirement (Sanchez, 1990).

• **Iron (Fe).** Deficiencies of Fe are rare in Florida vegetables grown on organic soils, and no general recommendation for Fe fertilizer exists.

FOLIAR MICRONUTRIENTS

Occasionally, micronutrient deficiencies appear in lettuce during cool or wet weather. However, some crops (even in fields with high pH) do not respond to soil-applied micronutrients. There appears to be some benefit to foliar application of some micronutrients (Beverly and Guzman, 1985). Recommendations for foliar micronutrient applications are in Table 3.

WATER MANAGEMENT

Irrigation and fertilization programs should be managed together for highest efficiencies and for minimizing nutrient movement. Water tables should not be maintained above that required to supply optimum moisture in the root zone. Overirrigation or excessive fluctuation of water table can lead to nutrient leaching. Water tables can be monitored with observation wells with graduated floats.

PLANT TISSUE ANALYSES

Analysis of lettuce leaves can provide information to help manage fertilizer more efficiently or to help diagnose a suspected deficiency. Interpretation of nutrient levels for crisphead lettuce are presented in Table 4.

LETTUCE FERTILIZATION RECOMMENDATIONS

• **Soil pH.** Target pH is 6.0. However, crop yield will not be sacrificed over a pH range from 5.0 to 6.5. At appreciably higher pHs, banding of P and foliar applications of needed micronutrients may be preferable to pH reduction attempts using S or other acid-forming amendments.

• **Nitrogen.** Broadcast up to 50 lb N per acre in cool planting periods.

• **Phosphorus.** Phosphorus recommendations are based upon a water extraction procedure. The maximum P recommendation (\(P_w < 3\) lb per acre) is for 200 lb \(P_2O_5\) per acre, banded (Table 2).
• **Potassium.** Potassium recommendations are based upon an acetic acid extraction procedure. The maximum K recommendation ($K_{OAC} < 50$ lb K per acre) is for $200$ lb $K_2O$ per acre, broadcast (Table 2).

**LITERATURE CITED**


Table 1. Calibration table and P and K fertilizer recommendations for crisphead lettuce on organic soils in Florida.

<table>
<thead>
<tr>
<th>Phosphorus (Water extractable P index)</th>
<th>≤3</th>
<th>6</th>
<th>9</th>
<th>12</th>
<th>15</th>
<th>18</th>
<th>21</th>
<th>24</th>
<th>≥27</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer (lb P₂O₅ banded per acre)</td>
<td>200</td>
<td>175</td>
<td>150</td>
<td>125</td>
<td>100</td>
<td>75</td>
<td>50</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Potassium (0.5N Acetic acid extractable K index)</td>
<td>&lt;50</td>
<td>80</td>
<td>110</td>
<td>140</td>
<td>&gt;170</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer (lb K₂O broadcast per acre)</td>
<td>200</td>
<td>140</td>
<td>80</td>
<td>50</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Recommendations for foliar application of micronutrients on Crisphead Lettuce (Sanchez, 1990).

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>lb Nutrient per acre (per application)</th>
<th>Number of applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn</td>
<td>1.0</td>
<td>2 to 4 weekly applications.</td>
</tr>
<tr>
<td>Zn</td>
<td>0.25</td>
<td>Twice weekly for two weeks.</td>
</tr>
<tr>
<td>Fe</td>
<td>0.25</td>
<td>Twice weekly for two weeks.</td>
</tr>
</tbody>
</table>
Table 4. Interpretation of plant tissue analyses values of crisphead lettuce.

<table>
<thead>
<tr>
<th>Plant Part</th>
<th>Sampling</th>
<th>Status</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
<th>B</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most recently matured leaf</td>
<td>8-leaf stage</td>
<td>Deficient (less than):</td>
<td>4.0</td>
<td>0.4</td>
<td>5.0</td>
<td>1.0</td>
<td>0.3</td>
<td>-</td>
<td>50</td>
<td>20</td>
<td>25</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adequate range:</td>
<td>4.0</td>
<td>0.4</td>
<td>5.0</td>
<td>1.0</td>
<td>0.3</td>
<td>0.3</td>
<td>50</td>
<td>20</td>
<td>25</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High (higher than):</td>
<td>5.0</td>
<td>0.6</td>
<td>7.0</td>
<td>2.0</td>
<td>0.5</td>
<td>0.8</td>
<td>150</td>
<td>40</td>
<td>50</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Wrapper leaf</td>
<td>Heads one-half size</td>
<td>Deficient (less than):</td>
<td>2.5</td>
<td>0.4</td>
<td>4.5</td>
<td>1.4</td>
<td>0.3</td>
<td>-</td>
<td>50</td>
<td>20</td>
<td>25</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adequate range:</td>
<td>2.5</td>
<td>0.4</td>
<td>4.5</td>
<td>1.4</td>
<td>0.3</td>
<td>0.3</td>
<td>50</td>
<td>20</td>
<td>25</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High (higher than):</td>
<td>4.0</td>
<td>0.6</td>
<td>8.0</td>
<td>2.0</td>
<td>0.7</td>
<td>0.8</td>
<td>150</td>
<td>40</td>
<td>50</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Wrapper leaf</td>
<td>Maturity</td>
<td>Deficient (less than):</td>
<td>2.0</td>
<td>0.25</td>
<td>2.5</td>
<td>1.4</td>
<td>0.3</td>
<td>-</td>
<td>50</td>
<td>20</td>
<td>25</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adequate range:</td>
<td>2.0</td>
<td>0.25</td>
<td>2.5</td>
<td>1.4</td>
<td>0.3</td>
<td>0.3</td>
<td>50</td>
<td>20</td>
<td>25</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High (higher than):</td>
<td>3.0</td>
<td>0.50</td>
<td>5.0</td>
<td>2.0</td>
<td>0.7</td>
<td>0.8</td>
<td>150</td>
<td>40</td>
<td>50</td>
<td>30</td>
<td>10</td>
</tr>
</tbody>
</table>

\(^{a}\)Values from Hochmuth et al.,1991.

\(^{b}\)Dry weight basis