SP153

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IFAS Extension

Fertilization Recommendations for Crisphead Lettuce Grown on Organic Soils in Florida[1]

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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.

SOIL pH

Early research demonstrated that a pH of about 6.0 was desirable for most vegetables (Lucas and Davis, 1961). The use of sulfur (S) to acidify organic soils with pH above 6.5 appears to have had merit for vegetables (Lucas and Davis, 1961; Burdine and Guzman, 1965a,b; Burdine and Guzman, 1968; Guzman and Sanchez, 1986a). However, organic soil is highly buffered against pH changes (Beverly and Anderson, 1986) such that up to 4000 lb per acre of S might be needed to reduce the pH from above 6.8 to 6.0 (Sanchez, 1990). Sulfur is expensive and the pH reduction is temporary so the economic benefit of S application must be weighed by the grower. Foliar applications of certain micronutrients and band placement of P and micronutrients might be more economically sound alternatives to S application for improving nutrient availability to plants (Beverly and Guzman, 1985).

MACRONUTRIENTS

Nitrogen

Several research reports outlined benefits of N application to crisphead lettuce (Beverly and Guzman, 1984; Guzman and Sanchez, 1986a; Sanchez et al., 1988 a, 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 P_2O_5 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.

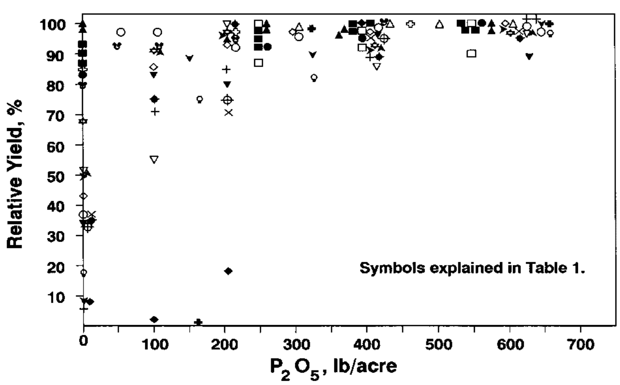

Fig. 1. Yield response of crisphead lettuce to rates of broadcast phosphorus.

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

Citation	Experiment	Soil P index[y]	Symbol	Max. yield (ctn/A)[z]
Guzman and Lucas, 1979	Expt. 700	3	□	660
	Expt. 701 (DS)	9	■	871
	Expt. 701 (TP)	9	▲	1128
Lucas and Guzman, 1980	Expt. 1	5	◇	840
Beverly and Guzman, 1984	Expt. 1	4	△	794
Guzman et al., 1987	Expt. 1	6	○	806
Guzman et al., 1989	Expt. 1	9	●	934
Sanchez et al., 1990a	Expt. 1	2	×	804
	Expt. 2	3	✡	982
	Expt. 3	4	▽	1054
	Expt. 4	5	▼	804
Sanchez et al., 1990b	Expt. 1	25	✙	640
	Expt. 2	3	✚	980
	Expt. 3	6	⋎	920
	Expt. 4	5	♀	1100
Nagata et al., 1992	Expt. 1	16	♉	1055
Rezaian B., 1993	Expt. 1	4	⊕	820
	Expt. 4	6	◆	1035
	Expt. 8	4	◆	545
	Expt. 10	8	∧	955
	Expt. 11	8	+	895
	Expt. 13	6	➤	990

[z]Maximum yield from experiment in 50-lb cartons calculated from original data reported in referenced articles. Guzman and Lucas, 1979, evaluated direct-seeded (DS) and transplanted (TP) crops.

[y]Soil P index is obtained by water extraction procedure (Sanchez, 1990).

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

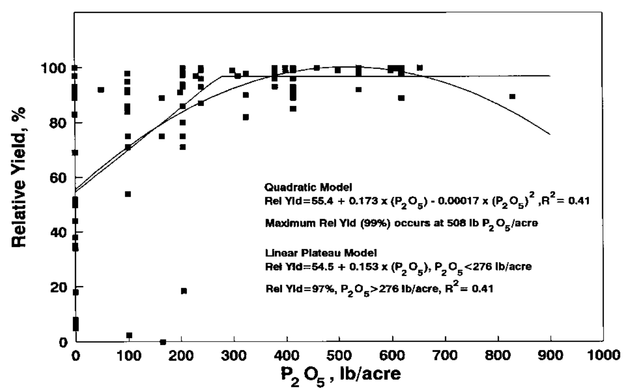

Fig.2. Relative yield of lettuce (from Fig. 1) as a function of P fertilization using the linear-plateau and simple quadratic models.

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

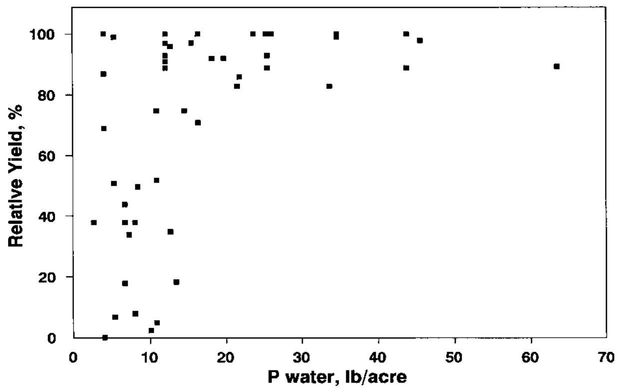

Fig. 3. Relative lettuce yields from unfertilized treatments at indicated P water soil test index.

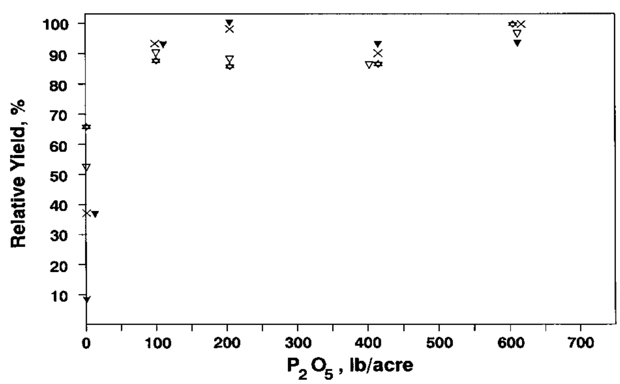

Fig. 4. Yield response of crisphead lettuce to rates of banded phosphorus.

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).

Potassium

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 K_2O (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.

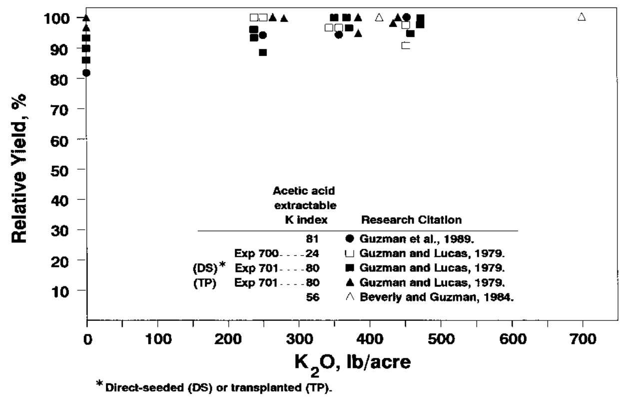

Fig. 5. Yield response of crisphead lettuce to rates of broadcast potassium.

Calcium, Magnesium, and Sulfur

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 on 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).

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Table 1.

Table 2. Calibration table and P and K fertilizer recommendations for crisphead lettuce on organic soils in Florida.

Phosphorus (Water extractable P index)								
≤3	6	9	12	15	18	21	24	≥27
Fertilizer (lb P_2O_5 banded per acre)								
200	175	150	125	100	75	50	25	0

Potassium (0.5N Acetic acid extractable K index)				
<50	80	110	140	>170
Fertilizer (lb K_2O broadcast per acre)				
200	140	80	50	0

Table 2.

Table 3. Recommendations for foliar application of micronutrients on Crisphead Lettuce (Sanchez, 1990).

Nutrient	lb Nutrient per acre (per application)	Number of applications
Mn	1.0	2 to 4 weekly applications.
Zn	0.25	Twice weekly for two weeks.
Fe	0.25	Twice weekly for two weeks.

Table 3.

Table 4. Interpretation of plant tissue analyses values of crisphead lettuce.

	Time of		%[y]						ppm[y]				
Plant Part	Sampling	Status[z]	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
Most recently matured leaf	8-leaf stage	Deficient (less than):	4.0	0.4	5.0	1.0	0.3	-	50	20	25	15	5
		Adequate range:	4.0	0.4	5.0	1.0	0.3	0.3	50	20	25	15	5
			5.0	0.6	7.0	2.0	0.5	0.8	150	40	50	30	10
		High (higher than):	5.0	0.6	7.0	2.0	0.5	-	150	40	50	30	10
Wrapper leaf	Heads one-half size	Deficient (less than):	2.5	0.4	4.5	1.4	0.3	-	50	20	25	15	5
		Adequate range:	2.5	0.4	4.5	1.4	0.3	0.3	50	20	25	15	5
			4.0	0.6	8.0	2.0	0.7	0.8	150	40	50	30	10
		High (higher than):	4.0	0.6	8.0	2.0	0.7	-	150	40	50	30	10
Wrapper leaf	Maturity	Deficient (less than):	2.0	0.25	2.5	1.4	0.3	-	50	20	25	15	5
		Adequate range:	2.0	0.25	2.5	1.4	0.3	0.3	50	20	25	15	5
			3.0	0.50	5.0	2.0	0.7	0.8	150	40	50	30	10
		High (higher than):	3.0	0.50	5.0	2.0	0.7	-	150	40	50	30	10

[z] Values from Hochmuth et al.,1991.

[y] Dry weight basis