Proc. Fla. State Hort. Soc. 102:341-343. 1989.

MANAGEMENT OF HIGH pH HISTOSOLS FOR LETTUCE PRODUCTION

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Additional index words. manganese (Mn), phosphorus (P), sulfur (S), *Lactuca sativa*

Abstract. **One of the most widespread nutritional problems encountered in lettuce (*Lactuca sativa* L.) production on Histosols in south Florida is the ubiquitous high soil pH. This problem is usually manifested in the form Mn deficiency, and to some extent P deficiency, despite applications of these nutrients at levels normally considered to be adequate. Studies were conducted over several seasons to evaluate several pH management strategies as alternatives to the costly application of broadcast S. The first study was designed to evaluate broadcast versus banded S application with and without banded Mn. In the other experiments selected combinations of banded S, P, and Mn were evaluated. Lettuce responded to soil pH reduction when soil pH was higher than 6.5. It appeared that when soil pH was less than 6.5 the standard practice of applying Mn in the broadcast fertilizer was sufficient to avoid Mn deficiency in lettuce. Results indicated that band application of small rates of S may be a viable economic alternative to the more costly broadcast application. However, the data suggest that when P and Mn were applied in a band below the lettuce seeds there appeared to be no benefit from the addition of S.**

Over the past 15 years nutritional problems associated with high pH have been increasing in the Everglades Agricultural Area (EAA) (2). Most of the Histosols in the EAA overlay limestone bedrock and with continued cropping and continual soil subsidence carbonates are moved into the soil surface by mass flow and diffusion with soil water.

The major effect of high soil pH in the EAA is to reduce the availability of Mn and to some extent P. Alternatives found by researchers to address this problem included foliar application of Mn to crop foliage, direct application of Mn to the soil, and/or acidification of the soil by applying S (1, 9, 13, 14). However, evidence suggest that foliar sprays may not be as effective for correcting Mn deficiency on lettuce as they have been for other commodities (5). Furthermore, many growers prefer management strategies which focus on the prevention of nutrient deficiencies rather than correction of deficiencies, hence, soil application of S as a pH amendment and Mn as a nutrient is favored for lettuce.

The Soil Testing Laboratory at the EREC currently makes a Mn and S recommendation of 9 kg·ha^{-1} when soil pH is greater than 5.8 (10). Additionally, a S recommendation is made for lettuce when soil pH is greater than 6.1, and rates as high as 4480 kg·ha^{-1} are recommended when soil pH is greater than 6.8. However, the economic feasibility of broadcast S application is questionable. Recent work indicates that many organic soils are highly buffered against pH reductions (4). Furthermore, the benefits of pH reduction are short term because of the common practice of fallow flooding with carbonate enriched irrigation water each year.

Band application of low rates of S, an economical alternative to broadcast S application, is commonly practiced for sugarcane produced in the EAA (10). Recent work by Beverly (3), suggest that band application of S may be an economic pH management strategy for celery as well. However, band application of S has not been evaluated for lettuce. Additionally, growers are moving toward band application of P on the basis of recent studies which showed that P fertilizer rates required for optimal lettuce yields can be reduced by 66% when all the P required is banded (11). It is not known how this practice will effect pH management strategies for lettuce. Many P fertilizer sources are acid reacting and the concentration of P in a band near the lettuce seed may produce an effect similar to that of S. The objective of the studies reported herein were to evaluate several pH management strategies as alternatives to the costly application of broadcast sulfur. In the first study, broadcast versus banded S application with and without banded Mn was evaluated. In the other experiments selected combination of banded S, P, and Mn were evaluated.

Materials and Methods

Five field experiments were conducted to evaluate pH management strategies as alternatives to the standard practice of applying broadcast S. Experiments were conducted on Pahokee muck (eucic, hyperthermic Lithic Medisaprist), a Histosol having a depth of 90 to 130 cm over limestone bedrock. Planting and harvest times, and initial soil test data are shown in Table 1. Soil in plots received Zn and B at 9 and 2 kg·ha^{-1}, respectively. Lettuce was seeded in elevated double-row beds on 0.9 m centers and thinned at the 4 leaf stage to a 25 cm in row spacing to give an approximate plant population of 60,000 plants/ha. Heads were harvested from 6-m of each of 2 rows/bed and marketable yields were determined after grading according to standard marketing criteria. The oldest sound leaf from each of 10 plants was collected in each plot at the 6 to 8-leaf stage in experiments 3, 4, and 5. Plant material was dried at 60C for 48 hours and ground for analysis. After wet ashing (15), N and P were determined colorimetrically, and K, Ca, Mg, Fe, Zn, Mn, and Cu by atomic absorption spectrometery. Soil samples were taken before planting and 30 days after treatment application and analyzed as described previously (10). Data were analyzed using the appropriate statistical procedure (12).

Experiment 1 This study was conducted to compare broadcast and banded S with and without Mn with 'South Bay' lettuce. The entire plot area was fertilized broadcast with P at 190 kg·ha^{-1}, and K at 100 kg·ha^{-1}. The experimental design was a split-plot. The main plot treatments

Florida Agricultural Experiment Station Journal Series No. N-00158.

TABLE 1. Planting dates, harvest dates, and initial soil-test values for each experiment.

Experiment	Planting date	Harvest date	Soil-test pH	Soil-test P (ppm)
1	10 Oct.	27 Dec.	7.2	20
2	12 Feb.	22 Apr.	7.1	22
3	21 Nov.	19 Feb.	6.3	32
4	6 Nov.	19 Jan.	7.0	32
5	20 Feb.	27 Apr.	6.5	29

(Table 2) were arranged in a randomized complete block design with four replications. The subplot treatments were lettuce with and without additional Mn banded at 5 kg·ha⁻¹. Nutrients for all broadcast treatments were disked into the soil before planting. All banded treatments were applied 5 cm below the lettuce seeds in strips 8 cm wide at the time of planting.

Experiment 2 This experiment was split-plot design with 4 replications. The main plots were S at 0, and 105 kg·ha⁻¹ , P at 0, 25, and 50 kg·ha⁻¹ , and Mn at 0, 5, and 10 kg·ha⁻¹ applied in factorial combination. Nutrients were banded as described previously. The subplots were 2 lettuce cultivars (Ithaca and Minetto) randomized within the main plots. Because the soil-test index level of K was greater than the critical index value of 150 kg·ha⁻¹ (10), no K fertilizer was added.

Experiment 3 4, and 5 These experiments were randomized complete block designs with four replications. The treatments were S at 0, and 224 kg·ha⁻¹ , P at 0 and 50 kg·ha⁻¹, and Mn at 0 and 3 kg·ha⁻¹. Nutrients were banded as described previously. In experiments 3, 4, and 5, 150, 200, and 250 kg·ha⁻¹ K were applied, respectively.

Results and Discussion

Lettuce responded to pH management in experiments 1, 2, and 4 where soil pH was 7 or greater but did not respond to pH management in experiments 3 and 5 where soil pH was 6.5 or less (Table 1). Hence, it appears that the threshold soil pH where lettuce requires additional pH management is between 6.5 and 7.0 and below 6.5 the standard practice of applying 9 kg·ha⁻¹ Mn in the broadcast fertilizer is apparently sufficient to avoid Mn deficiency in lettuce.

The addition of S (treatments 3, 4, 5 and 6 compared to 1 and 2) significantly ($P<0.05$) increased lettuce yield in experiment 1 (Table 3). Differences between broadcast S at 2240 kg·ha⁻¹ and banded S at 224 kg·ha⁻¹ were not significant, indicating that band application of S may be a viable economic alternative to broadcast S application. Main effect responses to source of S and Mn application were not significant. There was, however, an indication ($P<0.07$) of an interaction between S application and band Mn application. Band applied Mn generally increased yield when S was not applied. A greater response to Mn was expected in this experiment, considering the large range in yield values observed. The lack of response appears to be that variability was great enough to obscure Mn treatment effects.

Experiments 2, 3, 4, and 5 were designed to compare the effect of various combinations of banded S, P, and Mn in an attempt to evaluate P management strategies under lettuce production systems where all the P fertilizer required is banded. Because there was no response to pH management in experiments 3 and 5, only the results of experiments 2 and 4 are discussed. First order interactions were significant in Experiment 2 (Fig. 1, 2, and 3). Gener-

TABLE 2. Main-plot treatment combinations in experiment 1.

No.	
1.	No S or Mn
2.	No S, 9 kg ha⁻¹ Mn broadcast
3.	S broadcast (2240 kg ha⁻¹), 9 kg ha⁻¹ Mn broadcast
4.	S banded (224 kg ha⁻¹), 9 kg ha⁻¹ Mn broadcast
5.	S (2240 kg ha⁻¹) and Mn broadcast as STM
6.	S (224 kg ha⁻¹) and Mn banded as STM, and 9 kg ha⁻¹ Mn in broadcast fertilizer.

[z]STM is 80% S and 5% Mn.

TABLE 3. Yield of crispheadlettuce as affected by treatment combinations in experiment 1.Main-plot treatment combinations in experiment 1.

Main-plot[z]	Banded Mn	Marketable yield (Mg ha⁻¹)
1	–	33.6
	+	32.6
2	–	35.1
	+	37.7
3	–	40.1
	+	40.6
4	–	37.1
	+	36.1
5	–	42.5
	+	41.5
6	–	38.1
	+	40.3
Orthognal comparison[y]		
S vs no S		0.01
Mn vs no Mn		NS
224 band Mn vs 2240 broadcast Mn		NS
S vs S + Mn		NS
S Rate by Source		NS
Mn vs no Mn band		0.07

[z]See Table 1 for main-plot treatment description.
[y]Not Significant (NS) when $P > 0.10$.

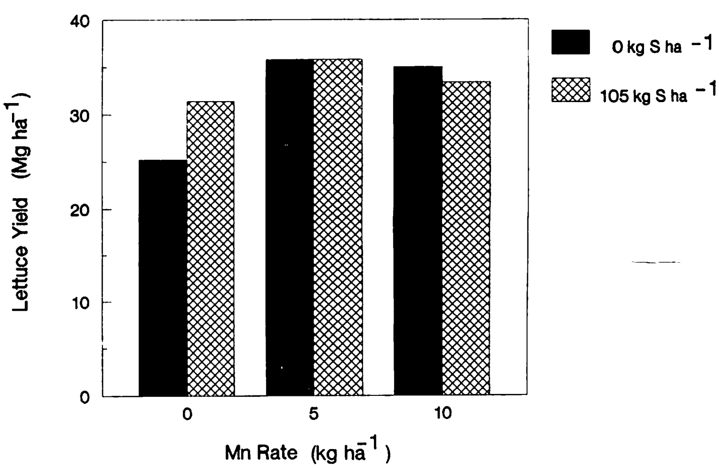

Fig. 1. Response of crisphead lettuce to S across three Mn rates.

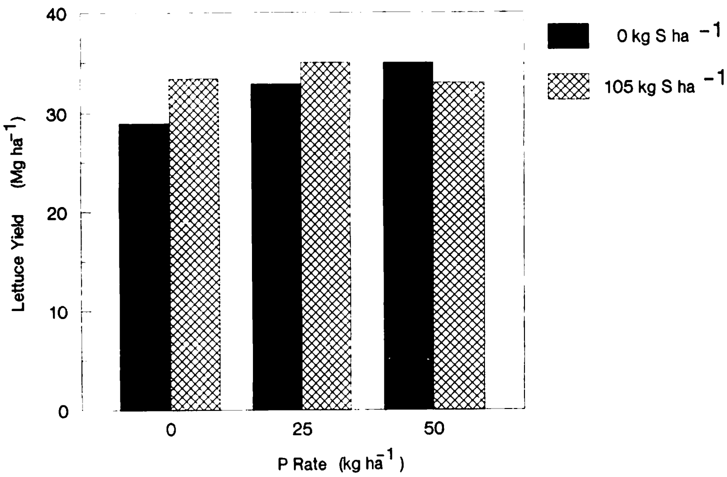

Fig. 2. Response of crisphead lettuce to S across three P rates.

ally, lettuce responded to S application only where Mn and P were not applied. However, lettuce did respond to 5 $kg \cdot ha^{-1}$ Mn at all P rates indicating that applying Mn in the P fertilizer band was beneficial under high pH conditions.

In experiment 4, results were similar to those obtained in Experiment 2, except that there was no yield response to S (Table 4). Experiment 4 was conducted during the winter when temperatures were cool and it possible that the microbial mediated oxidation of the S was too slow to provide a benefit to lettuce. The results of leaf analysis data from lettuce grown in Experiment 4 confirm that the major benefit of these treatments was to improve Mn and P availability (Table 4). Treatments had no effect on the concentrations of N, K, Ca, Mg, Fe, Zn, or B.

Results of Experiments 2 and 4 suggest that when P and Mn were banded 5 cm below the lettuce there was no need for the addition of S. Many P fertilizers, including triple superphoshate, are acid reacting and it is possible that concentration of P fertilizer in a band in the lettuce rooting zone causes pH reduction similar to that of banded S. Mortvedt and Kelsoe (8) found levels of extractable nutrients to be higher around banded type acid fertilizers than in untreated soil. In fact, monocalcium phosphate monohydrate, the primary constituent in triple superphosphate, reacts rapidly in the soil (6,7) whereas the oxidation of elemental S often proceeds slowly. It may be that the acidification caused by the banded P is more beneficial to a fast growing crop such as lettuce.

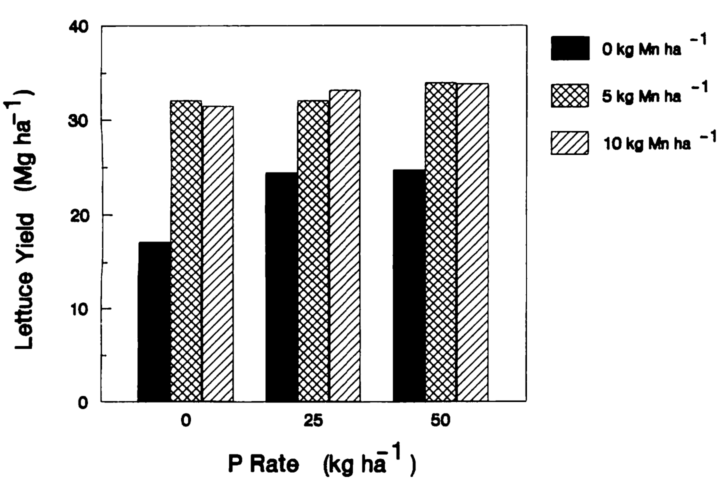

Fig. 3. Response of lettuce to Mn across three P rates.

Table 4. Yield of crisphead lettuce as affected by banded S, Mn, and P in experiment 4.

Treatment	Marketable yield ($Mg\ ha^{-1}$)	Lettuce leaf concentration P (%)	Mn (ppm)
Control	26.5	0.43	14
S	27.0	0.43	21
Mn	32.9	0.49	20
P	35.2	0.54	17
S + Mn	34.4	0.56	18
S + P	34.0	0.54	22
Mn + P	33.6	0.57	18
S + Mn + P	35.4	0.57	18
Sig.			
S	NS[z]	NS	NS
Mn	0.05	NS	0.05
P	0.01	0.05	NS
S*P	NS	0.08	0.05
S*Mn	NS	NS	NS
P*Mn	0.05	NS	NS

[z]Not Significant (NS) when $P > 0.10$.

Results indicate that banded S may be an economical alternative to broadcast S application when P fertilizers are applied broadcast. However, when P and Mn are banded for lettuce there appears to be no benefit to banded S.

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