Cooperative Extension Service
College of Tropical Agriculture and Human Resources
University of Hawai‘i at Mānoa

Soil and Crop Management
Sept. 2007
SCM-19

Phosphorus Fertilizer Management for Romaine Lettuce Grown in Fertile Volcanic Ash Soils of Hawai‘i

J. Deenik[1], R. Hamasaki[2], R. Shimabuku[3], and R. Uchida[4]
[1]Department of Tropical Plant and Soil Sciences; [2,3]Department of Plant and Environmental Protection Sciences,
[2]Kamuela Extension Office, [3]Kahului Extension Office; [4]Agricultural Diagnostic Service Center

Romaine lettuce is an important vegetable crop for farmers in the Waimea area of the island of Hawai‘i and in Kula on Maui. These areas are suited for this crop because they combine a favorable climate, characterized by warm sunny days and cool nights, with fertile volcanic ash soils. Given the dramatic rise in the cost of fertilizers since 2004, careful management of fertilizer inputs is an important part of growing a successful and profitable crop.

A soil test for phosphorus (P) is a useful tool farmers can use to determine whether their fields require P fertilizer or whether the soil contains a sufficient reserve of P for good crop growth. The soil P concentration associated with optimum growth is a critical piece of information that allows for the diagnosis of sufficiency or deficiency; this concentration is called the *soil P critical level*. The CTAHR Agricultural Diagnostic Service Center (ADSC) has used a general value of 85 ppm as the P critical level for all vegetable crops in light soils such as volcanic ash soils. Given results from field trials recently conducted in Waimea showing that the soil P critical level for head cabbage was 450 ppm (Deenik et al. 2006), we undertook field trials in Waimea and Kula to determine the soil P critical concentration for romaine lettuce production in volcanic ash soils.

Romaine lettuce production in Lālāmilo, Hawai‘i

Two field experiments

We conducted two field experiments to evaluate romaine lettuce yield response to increasing concentrations of soil P at the Lalamilo Research Station in Waimea, Hawai‘i, and the Kula Research Station on Maui. Climatic conditions and soil type are similar at both stations (Table 1). At the Lalamilo site we imposed four P treatments equivalent to 0, 30, 60, 120, and 240 lb P per acre arranged in a randomized complete block with four replicates. At the Kula site, five P treatments (0, 598, 2384, 3336, and 4765 lb P per acre) were imposed to ensure a wider range in target soil P concentrations at the high end (high quantities of P fertilizers are required in these volcanic ash soils to overcome their high P adsorption capacity). Phosphorus as triple superphosphate (TSP) was broadcast evenly across each plot and tilled in to a depth of 6 inches. Nitrogen, as urea, was broadcast with the TSP at 50 lb N per acre and sidedressed twice during the cropping cycle at 75 lb N

Published by the College of Tropical Agriculture and Human Resources (CTAHR) and issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Andrew G. Hashimoto, Director/Dean, Cooperative Extension Service/CTAHR, University of Hawai‘i at Mānoa, Honolulu, Hawai‘i 96822. An equal opportunity/affirmative action institution providing programs and services to the people of Hawai‘i without regard to race, sex, age, religion, color, national origin, ancestry, disability, marital status, arrest and court record, sexual orientation, or status as a covered veteran. CTAHR publications can be found on the Web site <http://www.ctahr.hawaii.edu/freepubs>.

per acre each time. Four-week-old lettuce seedlings (*Lactuca sativa* cv. Paris Island cos) were transplanted on September 26, 2006 at Lalamilo and on January 26, 2007 at Kula. Harvest was on November 5, 2006 at Lalamilo and March 27, 2007 at Kula. At harvest, 25 plants from each plot were cut at the soil surface and weighed. Two plants were randomly selected from each plot, carefully washed to remove soil, dried at 70°C for 72 hours, and analyzed for nutrient concentration at the ADSC. Composite soil samples (0–6 inches depth) were collected from each plot immediately before transplanting and at harvest and analyzed for pH, extractable P, and nutrient cations (K^+, Ca^{2+}, Mg^{2+}, Na^+) at the ADSC.

What we found

Romaine lettuce growth showed a strong response to increasing soil P concentrations at both experimental sites. There was a steep linear response in lettuce growth as soil P concentration increased to approximately 500 ppm[a] followed by a plateau in growth as soil P concentration increased to more than 1500 ppm (Fig. 1). The error bars associated with the points in Figure 1 show that there was considerable variability in soil P concentration in the plots that received higher P inputs. We used a non-linear regression technique to fit a linear-plateau equation[b] to estimate the soil P critical level shown in Figure 1.

This analysis indicated that the soil P critical concentration for romaine lettuce in the volcanic ash soils of Waimea and Kula is in the range of 446–644 ppm (545 ± 99 ppm). This means that we would expect lettuce to show a positive growth response to P fertilizer when soil P concentration is less than 550 ppm, but we would not expect a growth response when soil P concentration is greater than approximately 650 ppm. In other words, on fields where soil P concentration is greater than 650 ppm, the farmer can expect no added benefit to yield from P fertilizer applications.

Recommendation

Agricultural soils that are high in phosphorus, either because of their natural fertility or the accumulation of years of fertilizer P applications in excess of crop requirements, often do not need additional P to support good crop yields. In earlier on-farm trials with head cabbage in Waimea and Kula, we showed that soils with soil P concentrations above 450 ppm did not need more P fertilizer to obtain good yields (Deenik et al. 2006). Similarly, the results with Romaine lettuce provide a basis to propose a revised soil P critical concentration of 650 ppm for its production in the volcanic ash soils of Waimea and Kula. If soil analysis for P is 650 ppm or more, the ADSC will advise that additional P fertilizer application is not recommended for a Romaine lettuce crop.

Thus with the use of a soil test, Romaine lettuce farmers can determine when P fertilizers are necessary and apply them to reach the target of 650 ppm. When soils show higher P levels, farmers can save money by not applying P fertilizer and still be confident that their yields will remain high.

References

Deenik, J., R. Hamasaki, R. Shimabuko, S. Nakamoto, and R. Uchida. 2006. Phosphorus fertilizer management for head cabbage. University of Hawai‘i at Mānoa, College of Tropical Agriculture and Human Resources, publication SCM-16, 6 p. www.ctahr.hawaii.edu/oc/freepubs/pdf/SCM-16.pdf

Shuai, X.F., Z.J. Zhou, and R.S. Yost. 2003. Using segmented regression models to fit soil nutrient and soybean grain yield changes due to liming. Journal of Agricultural Biological and Environmental Statistics 8(2):240–252.

Acknowledgments

Our research was made possible through funds obtained from the Natural Resource Conservation Service (CESU Cooperative Agreement no. 68-3A75-4-72 Mod. 2) and the Office of Economic Development of Maui County (Grant Agreement no. G2279). We also thank Drs. G. Uehara, N.V. Hue, and R.S. Yost for their constructive comments.

[a]In the volcanic ash soils of Waimea and Kula, which are characterized by low bulk density (0.5 g/cm^3), 1 ppm is equal to approximately 1 lb per acre.

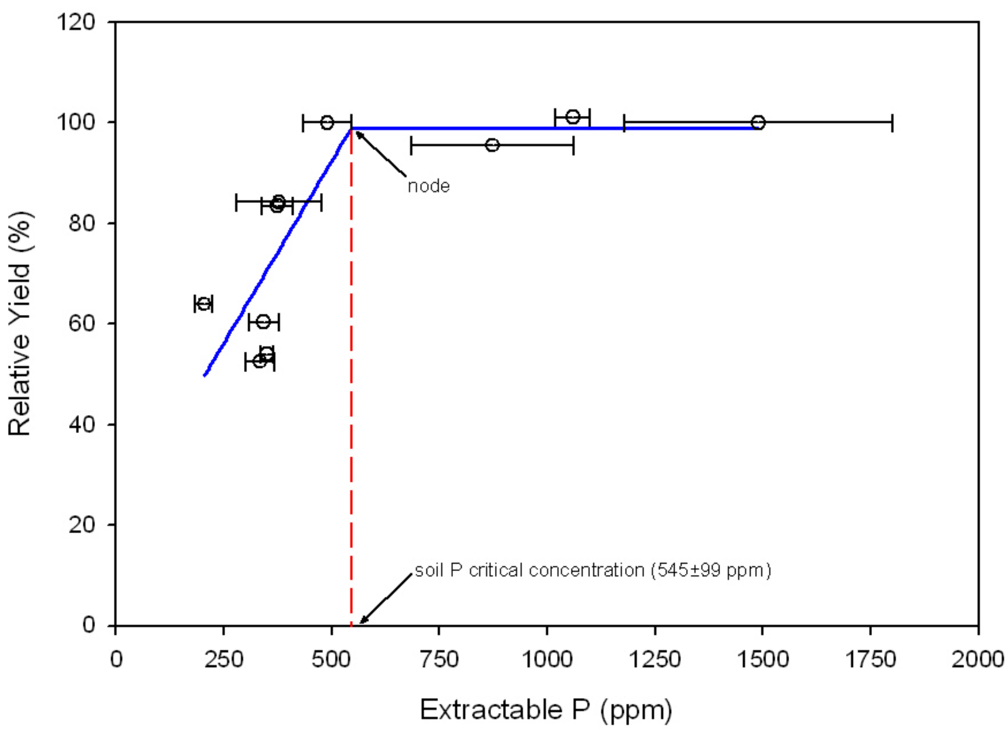
[b]The linear-plateau equation (Shuai et al. 2002) allows for simultaneous fitting of two linear equations, one characterizing the linear increase in growth as soil P increases and another associated with the yield plateau, to reveal the node, the point where the two equations meet. The X-coordinate associated with node corresponds to the soil P critical level. The fitting process also provides an estimate of the variability associated with predicted node expressed as a standard error.

Table 1. Selected climatic and soil data for the CTAHR Lalamilo and Kula Research Stations.

Station	Soil taxonomy	Soil texture	Elevation (feet)	Annual rainfall (inches)	Average temperature (°F)		Initial soil conditions	
					Min.	Max.	pH	P (ppm)
Lalamilo (Waimea series)	Medial, amorphic, isothermic	Silt Loam	2500	30	59	73	5.3 (±0.02)	354 (±12)
Kula (Kula series)	Humic Haplustands	Loam	3000	30	52	78	6.0 (±0.1)	133 (±3)

Numbers in parentheses are standard errors of the mean.

Figure 1. Romaine lettuce growth response to increasing soil P concentration in volcanic ash soils in Waimea and Kula.



Note: The data were fit with a linear-plateau equation (y = a + b*(if x<=node,x,node) using non-linear regression in SigmaPlot (version 8). Each point is a mean of four replicates, and the error bars represent the standard error of the mean.