EFFICIENT USE OF PHOSPHORUS FERTILIZER IN CALIFORNIA VEGETABLE PRODUCTION

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ABSTRACT
This project evaluated appropriate P management practices for lettuce production in the Salinas Valley of central California in light of elevated soil P levels from prior fertilization, and concerns over adverse water quality impacts. A field survey revealed that soil test P level (bicarbonate procedure) in soils in long-term vegetable rotations commonly exceed 70 mg kg^{-1}, both under conventional and organic management. Trials were conducted in 6 commercial lettuce fields in which the effect of preplant P fertilization (the typical grower practice) was compared to no P application; soil P levels ranged from 54-171 mg kg^{-1}. In only one of 6 fields was lettuce productivity improved with P application; the responsive field was the earliest spring planting, and had the lowest soil test P. Tissue analysis showed that P application in fields with high soil P levels barely influenced plant P uptake. Furthermore, currently suggested midrib PO_4-P sufficiency levels appear to be higher than necessary.

INTRODUCTION
Decades of heavy phosphorus fertilizer application to vegetable fields in the Salinas and Pajaro Valleys of central California have resulted in substantially increased soil P concentration. Soil test P levels (bicarbonate procedure) now frequently exceed 80 mg kg^{-1}. To put these soil test P levels in perspective, bicarbonate extractable soil P > 15-30 mg kg^{-1} is generally assumed to be sufficient for maximum yield of most agronomic crops (Reisenhauer, 1983). While there is evidence that certain vegetable crops (and particularly lettuce) have higher soil P sufficiency requirements (McPharlin et al., 1995, 1996; Diaz et al., 1988; Sanchez and El-Hout, 1995; Nagata et al., 1992), most research suggests that, even for the most P-sensitive vegetables, crop response to fertilization is unlikely if bicarbonate extractable soil P exceeds 40-60 mg kg^{-1}. However, many vegetable growers in these coastal valleys continue to routinely apply P to such fields. While this generally does not cause agronomic problems, it may be a significant contributor to the undesirably high P concentration found in the Salinas and Pajaro River systems. Parts of both watersheds have been listed by the California EPA as 'impaired' for soluble nutrients, based on the prevailing Federal water quality standards. This project was undertaken to reevaluate the current P management recommendations for lettuce production in light of this potentially serious environmental problem. Specific objectives were:

1) Develop efficient P fertilizer guidelines for coastal lettuce production
2) Document the relationship between soil characteristics, soil test P levels, and potential loss of P through in runoff.

METHODS

To determine the current P status of agricultural land in the Salinas and Pajaro Valleys, soil from 30 fields, most in long-term vegetable rotations, was collected in spring, 2002. The fields represented both conventionally- and organically-managed land. These soils will be used in a rainfall simulator assay to correlate soluble and sediment-bound P concentration of runoff water, and P concentration in leachate, with various soil test P procedures. The intent is to provide a simple system by which growers can rank their fields for P runoff potential, so that remedial actions can be targeted where they would do the most good.

Six trials were conducted in commercial lettuce fields in the Salinas Valley in 2002 evaluating whether P fertilization in fields with moderate or high soil test P levels actually affected crop productivity. The fields chosen varied from 54 – 171 mg kg^{-1} bicarbonate P (top 6 inches of soil, Table 1). Existing recommendations rank these field as moderate (fields 1 and 3) or high P availability (fields 2, 4, 5 and 6). In fields 3 and 5 the grower did not apply P fertilizer; we established 4 plots within each of these fields which received a preplant fertilization with 130 lb P_2O_5 / acre. In all other fields the growers applied preplant P, and we established 4 plots per field in which this P application was skipped. The experimental design in each field was randomized complete block, with each plot being three 80 inch-wide beds 200 feet long (field 3), or four 40 inch-wide beds 200 ft long (all other fields). All data were collected in the middle 100 feet of each plot, from the middle bed(s).

Table 1. Characteristics of the 2002 field trial sites.

Field	pH	Bicarbonate extractable soil P (mg kg^{-1})[z]	Lettuce type	P application rate (lb P_2O_5 / acre)	Planting date[y]
1	7.7	54	Head	59	April 3
2	7.6	124	Head	60	April 11
3	7.4	55	Romaine	130	May 11
4	7.4	72	Head	42	June 12
5	7.5	171	Head	130	July 15
6	7.3	78	Romaine	72	July 26

[x] top six inches of soil
[y] date of first water

Plant P status was monitored by biweekly sampling through the crop season, including at harvest. Plots with and without P fertilization were photographed on a biweekly basis with a digital infrared camera; from these images the percent of ground covered by the plant canopy was calculated to compare plant vigor between P treatments. Prior to commercial harvest, 30-40 whole plants per plot were selected at random and weighed to compare total plant biomass. Where practical, data on marketable yield and head size distribution was collected by working with the commercial harvest crew. Where that was not possible, randomly selected plants were trimmed to simulate commercial harvest, and the marketable yield of the treatments compared.

RESULTS AND DISCUSSION

The soils collected in the field survey ranged from 14 - 196 mg kg^{-1} bicarbonate extractable P, with an overall average of 78 mg kg^{-1} (Table 2). Both organically- and conventionally-managed fields were represented across the entire range of P concentrations, emphasizing that some growers in both management schemes have managed P fertility inefficiently. To put these numbers into context, soils from California's Sacramento Valley (which had roughly equivalent native soil P levels) that have been farmed for an equivalent period of time typically range from 10-25 mg kg^{-1} bicarbonate P. The difference reflects the higher application rates, and more frequent application, of P fertilizers in the coastal valleys. Despite these high soil test P values, many coastal vegetable growers continue to apply P before each crop regardless of soil test P level (as evidenced by the cooperating growers in the P fertilizer trials), and a substantial number also apply P in sidedressings.

Table 2. Bicarbonate extractable soil P (mg kg^{-1}) of survey fields.

Soil test range (mg kg-1 P)	Number of soils within range: Organic management	Conventional management
0-40	2	5
40-80	1	11
80-120	1	4
> 120	2	4
Ave	*97*	*74*

In the first field trial, planted in early April, a small but statistically significant response to preplant P was observed (Table 3). This was somewhat surprising, since the soil bicarbonate P level was 54 mg kg^{-1}, above the response threshold cited in most references. Early planting (cold soil temperature) was undoubtedly a factor, since P bioavailability is reduced at lower soil temperature. Field 2 was planted only a week later, but had substantially higher soil test P (124 mg kg^{-1}). As expected, production in plots in which preplant P was skipped was equivalent to the grower's standard P application. Fields 3 and 4 had intermediate soil test P levels, and neither showed significant crop response to P fertilization. Fields 5 and 6 also showed no crop response to P fertilization; not only did both fields have high soil test P, they were planted during mid-summer.

Table 3. Lettuce response to P fertilization.

Field	P treatment (lb P_2O_5 / acre)	% of plants marketable	Whole plant wt (lb)	Marketable plant wt (lb)	Boxes /acre
1	0	81^z	2.15^z	1.46^z	847^z
	59	87	2.29	1.56	751
2	0	93	2.42	1.58	1020
	60	95	2.52	1.57	1018
3	0		1.55	1.07	
	130		1.65	1.08	
4	0	84	2.56	1.66	
	42	83	2.64	1.70	
5	0	75	1.55	1.06	
	130	77	1.56	1.08	
6	0		1.21	0.90	
	72		1.17	0.88	

^{z} significantly different from the applied P treatment

In the first trial (the only responsive field) there was a consistent trend toward slightly smaller plants in the 0 P treatment, based on the infrared camera images. These differences were apparent at thinning, and were maintained throughout the growing season (Fig. 1). Preplant P apparently functioned mostly to maximize early seedling growth; once a substantial root system was established, the field soil had sufficient P availability to maximize crop growth, and all plots grew at a similar rate. This suggests that a low rate, at-planting P fertilizer application (a phosphoric acid overspray, for example) might provide the same crop response as a heavier preplant application. This would be environmentally desirable, since it would minimize further P loading in these soils.

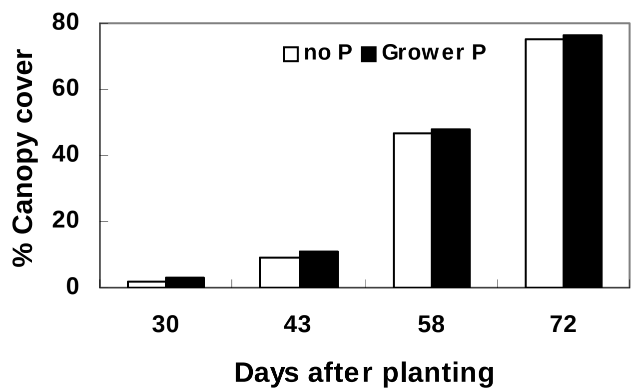

Fig. 1. Canopy development in field 1 as affected by P treatment.

P application had minimal impact on tissue P concentration in any field at any time in the cropping cycle (Table 4). Leaf P concentration was well above current sufficiency standards (Lorenz and Tyler, 1983) in both P treatments in all fields. This reinforces the conclusion that preplant P application is not an efficient practice in soils with moderate to high soil test P levels. In several non-responsive fields, mid-season midrib PO_4-P concentration in plots both with and without P was below commonly cited sufficiency levels (usually considered to be 2,000 – 3,000 mg kg^{-1}), suggesting that these standards need reevaluation.

In summary, soil P levels in the coastal vegetable production areas are high enough to potentially contribute to surface water quality problems. Continued P fertilization of high P soil is an inefficient practice, particularly for fields planted when soils are warm. Even for spring planted fields there may be a more environmentally benign, and more cost effective, approach than the conventional preplant application. Additional field trials will be conducted in 2003 to evaluate that potential.

Table 4. Effect of P fertilization on lettuce tissue P concentration.

Field	P treatment (lb P_2O_5 / acre)	At thinning % leaf P	At heading % leaf P	At heading mg kg^{-1} midrib PO_4-P	At harvest % leaf P
1	0	0.42	0.43	1370	0.64
	59	0.42	0.43	1250	0.66
2	0	0.35	0.48	1620	0.68
	60	0.35	0.51	1600	0.71
3	0	0.39	0.37	840	0.38
	130	0.41	0.40	830	0.42
4	0	0.50	0.51	3480	0.78
	42	0.50	0.53	3440	0.81
5	0	0.54	0.44	2480	0.55
	130	0.59	0.49	2760	0.59
6	0	0.54	0.56	1430	0.56
	72	0.52	0.56	1490	0.56

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