Soil Test Calibration Evaluations for Phosphorus on Upland and Pima Cotton

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Abstract

Numerous field experiments were conducted at a wide range of sites in Arizona from 1988 through 1999 involving phosphate (P) fertilization of cotton (Gossypium spp.). A total of 21 site-years were used to study the effects of P on both Upland (G. hirsutum L.) and Pima (G. barbadense L.) varieties. The purpose of these experiments was to evaluate University of Arizona (UA) soil fertility guidelines with respect to soil test results ($NaHCO_3$ extractable P) and to possibly fine-tune or calibrate these guidelines in relation to soil test P, applied P, and yield for common Arizona soils used in cotton production. Results from these experiments, based on soil test information, plant measurements, and lint yield showed no significant difference (P£0.05) due to treatments for all the studies with the exception of one P study conducted in Graham County in 1998 and another P study conducted in Pinal County in 1999. The 1998 Graham County site had a preseason soil test value of 7.6 ppm $NaHCO_3$ extractable P. The 1999 Pinal County site had a preseason soil test value of 3.0 ppm $NaHCO_3$ extractable P. Analysis of yield results vs. soil P show that soil test P levels greater than 5 ppm are consistently sufficient for both Upland and Pima cotton. Yield results vs. applied P (lbs. P_2O_5/acre) for both Upland and Pima did not indicate a positive response over the rates of fertilization tested (20-160 lbs. P_2O_5/acre). Based on the results from these studies, the current UA soil fertility guidelines for P fertilization of cotton appear to be valid. Furthermore, the data indicates that the UA soil fertility guidelines may be further refined to provide the following categories: < 5 ppm = high probability of response to an added P fertilization; 6-10 ppm = medium probability of response to an added P fertilization; and > 10 ppm = low probability of response to an added P fertilization.

Introduction

Phosphorus (P) plays an important role in the energy metabolism of the plant cell and is required in large amounts by reproductive organs. Phosphorus can have a significant effect on boll development, size, and time to maturity (Marcus-Wyner and Rains, 1982). The amount of plant available P in solution is controlled by several factors such as pH and calcium carbonate ($CaCO_3$) concentrations. Soil pH has a large influence on plant available P. The desert soils of Arizona commonly used for crop production often exhibit a high soil pH, well above 7.5. These high pH and lightly weathered soil conditions allow for solution P to form insoluble complexes with various Ca species in solution. This can reduce concentrations of plant available P in solution. For soils rich in $CaCO_3$, the solubility of P may be controlled by solid phase dicalcium phosphate (Cole and Olsen, 1959) or by chemisorption of P on $CaCO_3$ with the formation of a surface complex of calcium carbonate-P with a well defined chemical composition (Samadi and Gilkes, 1999). Such soil conditions are known to be quite conducive to the fixation of broadcast applications of P fertilizer, rendering the fertilizer P largely unavailable to the crop (Silvertooth et. al., 1990). To minimize P adsorption and the precipitation of Ca-P minerals, banding the P fertilizer near the seedline has been proposed as a better cultural practice than simple broadcast methods to improve the chemical availability of P (Evans et al., 1970).

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The basic construct of soil fertility guidelines and recommendations should include nutrient studies in relation to soil and plant tissue analyses. These guidelines and nutrient management recommendations should be established through soil test and plant tissue correlation and calibration procedures. Soil test correlation can be described as the process of determining whether there is a relationship between plant uptake of a nutrient and/or yield with the amount of that nutrient extracted by a particular soil test (Corey, 1987). Different methods may be used to examine such a relationship. One example of a simple graphical method is the Cate-Nelson method (Cate and Nelson, 1965). This method plots percent relative yield against soil test values which can effectively provide a visual indication of the reliability of a specified soil test and its correlation to plant response or the uptake of a specific nutrient (Dahnke and Olson, 1990). In addition, this method also allows for the identification of a soil test critical level by dividing soil test levels into soils that are likely or unlikely to respond to an added fertilization. Once this analysis has been conducted and a good correlation exists between the soil test and plant response, calibration analysis should be performed.

Soil test calibration is the process of relating the soil test measurement in terms of crop response (Bray, 1936, 1937, 1944, 1945; Truog, 1930; Olson et al., 1958; Corey, 1987; Rouse, 1967). Soil test calibration should describe soil test results in easily understood terminology and simplify the process of making fertilizer recommendations by placing soils in response categories (Dahnke and Olson, 1990). These response categories cannot be used to predict yield, but can offer the probability that a response to fertilization will occur. Usually, three types of categories are used regarding soil test values: low, medium, and high. A low soil test value offers a high probability of response to added fertilization. A medium soil test value offers a medium probability of response from added fertilization and a high soil test value exhibits a low probability of getting a response.

Sodium bicarbonate ($NaHCO_3$) extractable levels of P >5 ppm are usually considered sufficient for cotton production in Arizona and the desert Southwest, and levels $\leq$ 5 ppm P are indicative of possible deficient levels (Silvertooth et al., 1991). However, fertilizer P is often applied under conditions with ($NaHCO_3$ extractable) levels of P > 5 ppm. Soil test levels less than 5 ppm P would be considered a low soil test category, while a soil test level above 5 ppm would constitute a medium or high soil test category or lower probability of response to fertilization. Past field experiments on cotton in Arizona have shown no significant response in lint yield to the addition of a P fertilizer with preseason $NaHCO_3$ extractable P levels ranging from 5 to 11 ppm (Silvertooth et al., 1989, 1990, 1991). However, there is a need for further calibration of soil test levels for P and cotton fertilization in the desert Southwest.

Materials and Methods

For the studies examined in this report, a comparison between a check (no fertilizer in question added) and that of a given fertilization treatment were commonly evaluated with all other nutrients provided at an adequate level. Evans (1987) discussed this aspect of soil test calibration as an essential ingredient for the development of soil test calibration and fertilizer recommendations. Following this approach allows us to analyze the validity of soil test information and its use in cotton crop fertility management for the soil types and production systems common to Arizona and the desert Southwest.

To study the effects of the addition of a specific nutrient (P), each location utilized a randomized complete block design during the 1989, 1990, 1997, 1998, and 1999 growing seasons. Treatments were replicated three to four times in all cases. The treatment plot sizes varied from 4 to 75 rows wide x 650 to 1250 feet long depending on the study location. All treatments used a banded application technique with rates ranging from 20-160 lbs. P_2O_5/acre. Some of the common fertilizer products used were ammonium polyphosphate (10-34-0) and monoammonium phosphate (11-52-0). Soil test levels for P were determined by $NaHCO_3$ extractable P (Olsen and Sommers, 1982). Soil samples were collected from the field prior to planting. Twenty-five to 30 samples were taken to a depth of 6-10 inches at various locations around the field and mixed thoroughly into a composite sample. Sub-samples were then taken from these composite samples for laboratory analysis.

Plant measurements were initiated at all sites early in the season to monitor crop growth and development. These measurements were taken within each plot at approximately 14-day intervals. Plant measurements included: plant height, number of mainstem nodes, number of flowers per 50 feet of row, percentage canopy closure, and the number of nodes from the top fresh flower to the terminal (NAWF). The purpose for these measurements was to detect any possible differences in plant growth and development that may have resulted from the fertilizer treatments and to evaluate growth in relation to established baselines for Arizona (Silvertooth and Norton, 1998). Plant tissue samples were also collected at several dates during the season in each experiment. Samples of both the leaf blade and petiole of the uppermost, fully developed leaf on a plant were taken from a random selection of 40-50 plants within each plot.

All plots were harvested by use of a two, four, or six-row mechanical picker (depending on location and equipment available) in the center rows of each plot to eliminate border effects.

All experimental yield data were subjected to analysis of variance procedures and LSD multiple comparison tests, as outlined by Gomez and Gomez (1984) and the SAS Institute (1996).

Results

The Cate-Nelson correlation method was performed on a the Upland and Pima data from all site-years to evaluate the visual indication of a soil test critical level for P when utilizing a $NaHCO_3$ extractable P soil test procedure (Figure 1). The point of intersection for the quadrants is between 4 and 6 ppm $NaHCO_3$ extractable P for the Upland graph. The Pima graph showed a slightly higher point of intersection between 6 and 7 ppm P. These critical levels fall in line with the current UA cotton fertility guidelines for soil test P (5 ppm P).

Lint yield vs. $NaHCO_3$ extractable P was plotted for both Upland and Pima varieties (Figure 2). There were a few lower yields associated with preseason soil test levels less than 5 ppm for the Upland sites. The graph for the Pima varieties showed that a range of yields were associated with preseason soil test values between 6 and 8 ppm. Neither of the graphs exhibited a clear pattern of response between lint yield and soil test P. However, there was a general increase in yield response with higher soil P levels.

Lint yield vs. applied P_2O_5 (lbs./acre) is presented for all Upland and Pima cases (Figure 3). The Pima plot exhibits perhaps a negative relationship as the rates of fertilizer P increased. Neither of the graphs showed any clearly recognizable pattern between lint yield and P applied.

Percent relative yield vs. $NaHCO_3$ extractable P is presented for all Upland and Pima cases (Figure 4). A distinct response pattern in terms of yield vs. soil test P levels was not apparent. The Upland figure reveals a somewhat random scatter of yields over a range of 3 to 12 ppm P soil test values with a few lower percent relative yields associated with soil test levels less than 4 ppm P. There were a few lower percent relative yields in the range between 6 and 7 ppm P for the Pima plot.

Percent relative yield vs. applied P_2O_5 (lbs./acre) was plotted for both Upland and Pima varieties (Figure 5). A consistent or distinct response pattern to P fertilizer was not evident. There were some lower percent relative yields corresponding with 0 applied P that can be associated with studies conducted on soils with 3.0 and 3.5 ppm levels of $NaHCO_3$ extractable P.

Out of the total 21 site-years evaluated, only two P studies showed a significant response to P fertilization. One 1998 Graham County site showed a significant increase in lint yield with a preseason soil test value of 7.6 ppm $NaHCO_3$ extractable P and an application of 30 lbs. P_2O_5 /acre. The only other site that showed significant differences due to treatments was a Pinal County site that had a preseason soil test value of 3.0 ppm $NaHCO_3$ extractable P and an application of 56 lbs. P_2O_5/acre. Based on these data, $NaHCO_3$ soil test levels greater than 5 ppm appear to be sufficient for cotton plants in typical Arizona production soils. Perhaps more study sites should be selected with soil test levels less than 5 ppm. However, it is important to indicate that soils of this nature are not at all common in Arizona cotton production areas. The current UA cotton soil fertility guidelines for P appear to be valid. Furthermore, it appears that three soil test level categories and or response categories can be constructed from the data: < 5 ppm $NaHCO_3$ extractable P = high probability of response to an added P fertilization; 6-10 ppm $NaHCO_3$ extractable P = a medium probability of response to an added P fertilization; and > 10 ppm $NaHCO_3$ extractable P = a low probability of response to an added P fertilization. This can have significant impact on

Arizona cotton production systems because growers may be able to reduce their P fertilizer inputs based on preseason soil tests.

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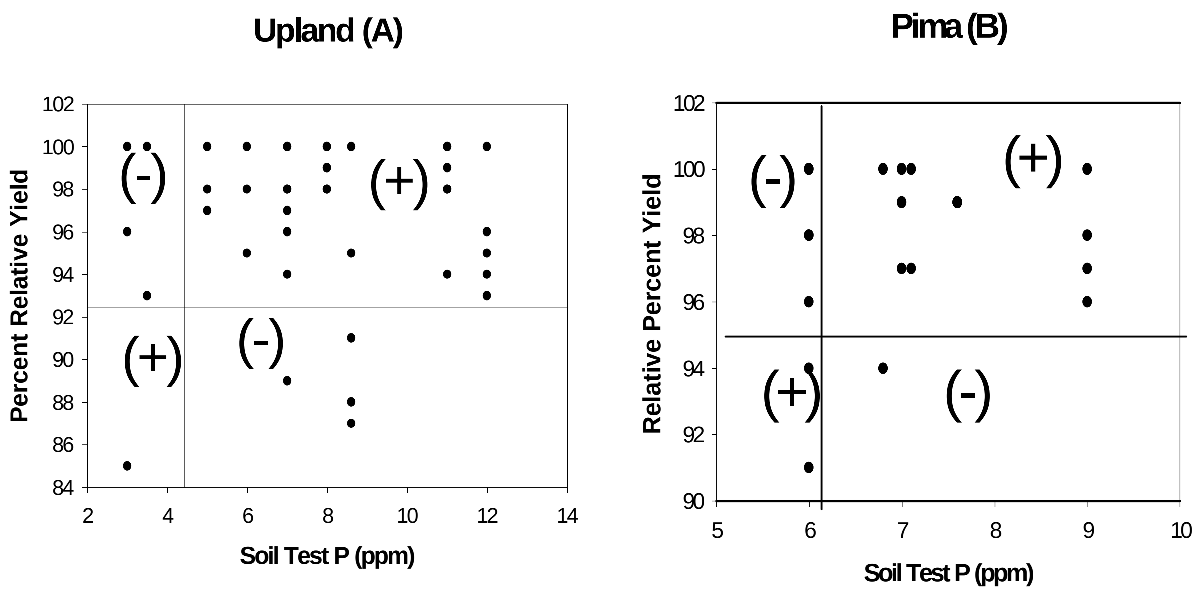

Figure 1. Cate-Nelson method, Upland (A) and Pima (B) varieties, AZ sites, 1988-1999.

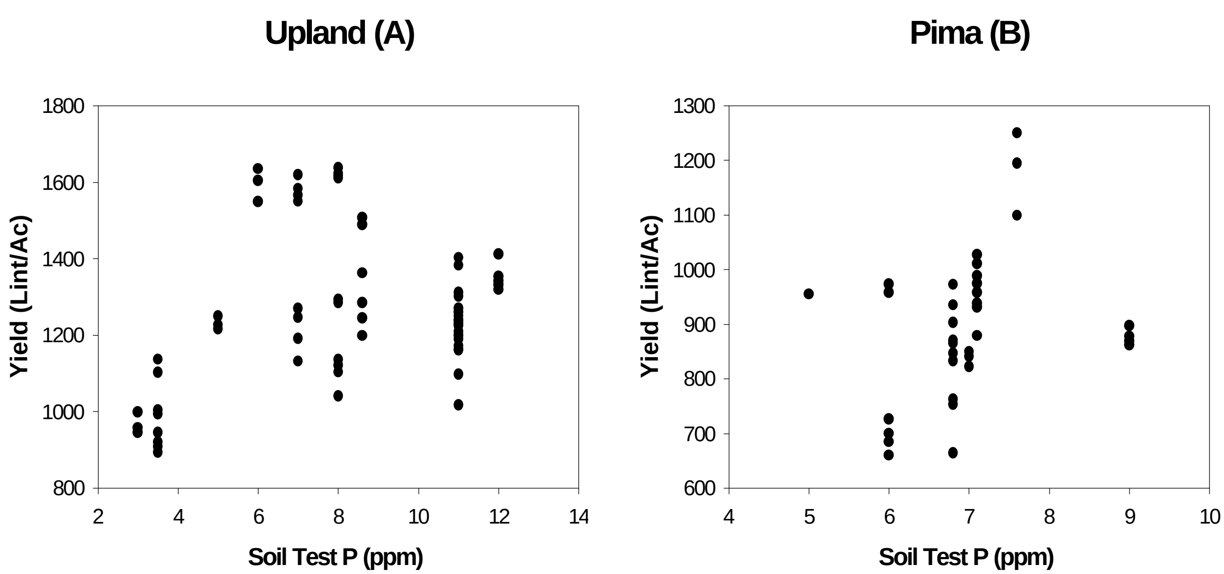

Figure 2. Lint yield vs. $NaHCO_3$ extractable P for Upland (A) and Pima (B), AZ sites, 1988-1999.

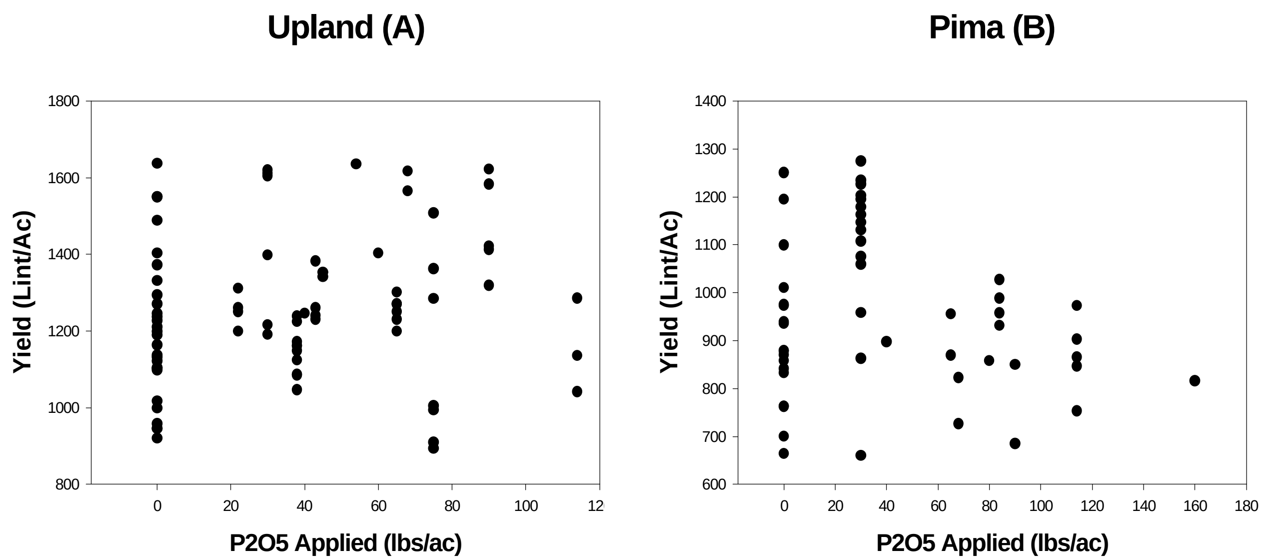

Figure 3. Lint yield vs. applied P_2O_5 (lbs./acre), Upland (A) and Pima (B) AZ sites, 1988-1999.

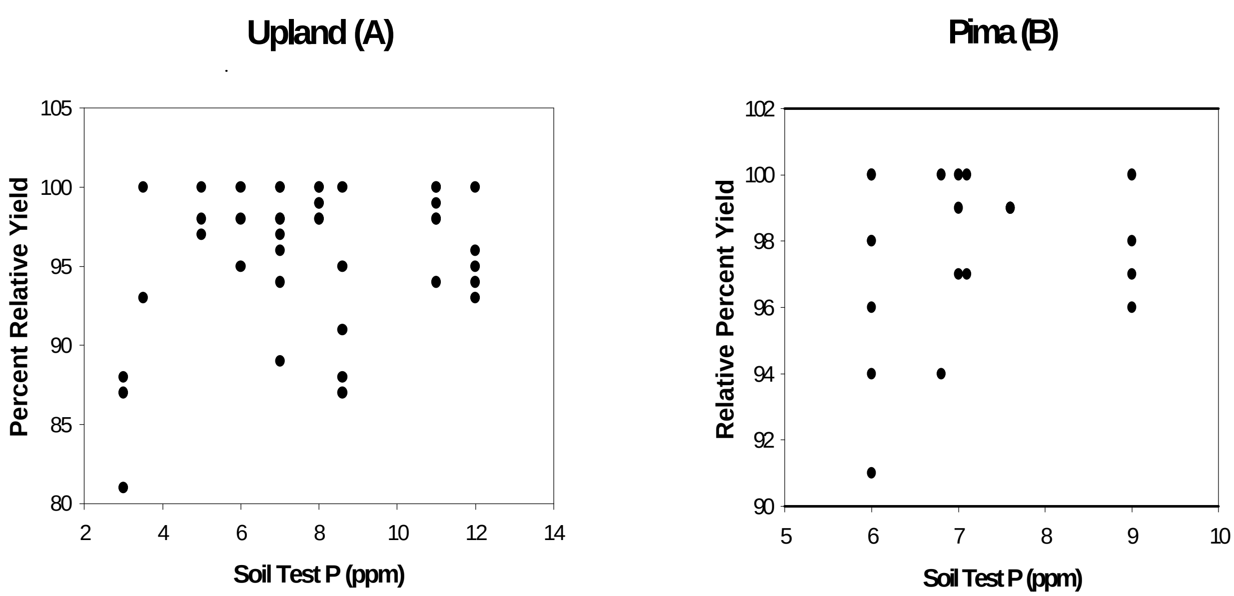

Figure 4. Percent relative yield vs. $NaHCO_3$ extractable P, Upland (A) and Pima (B), AZ sites, 1988-1999.

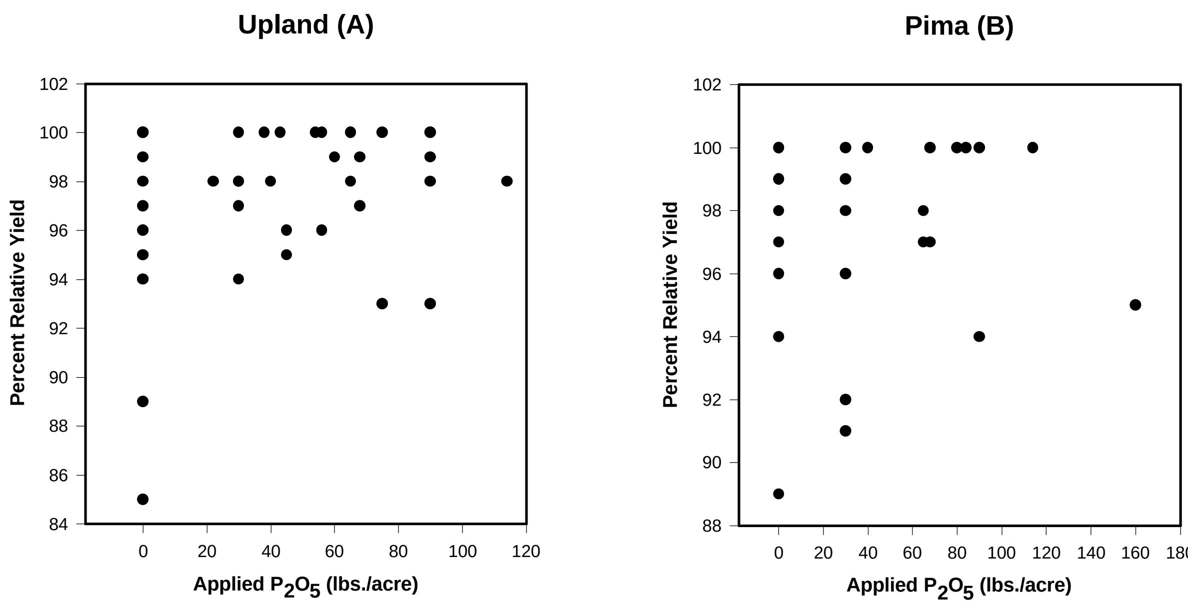

Figure 5. Percent relative yield vs. applied P_2O_5 (lbs./acre), Upland (A) and Pima (B), AZ sites, 1988-1999.