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"Phosphorus deficiency in tropical dry bean production: an approach through foliar fertilization."

Summary

Phosphorus (P) deficiency is a primary constraint to bean (*Phaseolus vulgaris*) production in the tropics. We investigated the merit of foliar P fertilization (applied as commercial grade ammonium polyphosphate) as a way of circumventing soil P fixation and increasing the efficiency of P fertilization. In field studies in Brazil we determined the optimal concentration and timing of foliar P application. We found that different bean genotypes were differentially sensitive to foliar P damage. Foliar P fertilization significantly enhanced vegetative growth of beans grown in the field. In greenhouse studies under controlled fertility conditions we found that foliar P fertilization enhanced vegetative growth, particularly in marginal P conditions, by stimulating leaf area development. We conclude that foliar P fertilization is a promising new technology for marginal P soils of the tropics that warrants future investigation and development.

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Introduction

The common bean (*Phaseolus vulgaris*) is a significant food resource in the developing nations of the tropics and subtropics. A primary constraint on bean production in these regions is an inadequate supply of the essential plant nutrient, phosphorus (P). Many of the old, highly weathered soils characteristic of the humid tropics contain very little available P. For example, in tropical America over 80% of the total land area is deficient in P. Beans (and legumes in general) are particularly sensitive to P deficiency, since symbiotic nitrogen fixation by rhizobia in root nodules has a high P requirement. Conventional P fertilization is often ineffective in correcting P deficiency because of the ability of many tropical soils to chemically 'fix' applied P into forms that are unavailable to plants. Conventional P fertilization is also increasingly costly on account of dwindling P supplies and high energy costs.

An attractive alternative to conventional fertilization is foliar fertilization, a technique in which nutrient formulations (in this case, containing P) are applied directly to plant foliage as sprays. The foliarly-applied nutrients can be absorbed by shoot tissues and used to meet the plant's nutritional requirements. This technique would be of particular interest in the tropics, since it circumvents the problem of soil P fixation, and could thereby dramatically increase the efficiency of fertilizer utilization.

The objective of our research was to evaluate and develop foliar P fertilization as an efficient method of enhancing tropical bean production. Our research had two distinct components; a field component in Brazil under the direct supervision of Dr. Micheal Thung, a CIAT bean agronomist outposted at CNPAF/EMBRAPA, and a more physiological component conducted under controlled conditions at the Davis campus of the University of California. This report provides a brief summary of our studies and conclusions. Both field and greenhouse studies are still in progress as of this writing, and we have collected a large number of data that remain to be analyzed over the coming months. In

consequence this report does not represent our final conclusions, which will be made available to AID as published reports in scientific journals as reprints become available.

Field Studies in Brazil

The intention of our first field experiment was to identify the toxicity threshold of our foliar fertilizer formulation. The first season's planting of this experiment was abandoned because of unseasonal rain, but the second planting, in April of 1985, was carried through to completion under the supervision of Dr. Micheal Thung, our Brazilian collaborator. Nine concentrations of the fertilizer formulation (ammonium polyphosphate with L77 surfactant) were applied to P-deficient bean plants (cv EMP 84) at 4 different stages of ontogeny. At 4 times during the season plants were harvested for growth analysis, including leaf area, biomass, and biomass partitioning. Throughout crop development the toxicity of the foliar treatments was visually scored. At the end of the season the beans were harvested and subjected to conventional yield component analysis.

The toxicity threshold of the foliar treatment was between 6 and 12 % ammonium polyphosphate, much higher than anticipated. In fact, after the first application the concentration of the treatments was increased by a factor of 8 in order to obtain leaf burning. This is promising in that it means a significant quantity of P can be applied to the leaves without causing burning.

Statistical analysis of the yield data indicated that the foliar treatments did not significantly influence yield parameters, which may in part reflect the small number of replicates (4) and the great variability of field-grown *Phaseolus* plantings. However, foliar treatments did increases leaf area and plant dry weight at the final harvest.

In the 1986 growing season we characterized the genotypic variability of sensitivity to foliar fertilizer application. Based upon data from the first

experiment, we used an APP concentration of 10% applied early in vegetative growth to 300 genotypes in order to produce leaf damage. Ten days after the foliar treatment Dr. Thung visually scored the treated leaves for leaf damage on a 10 point scale. At maturity total seed yield was measured. Significant genotypic variation in response to foliar treatment was observed in each of the bean groups examined, and specific genotypes having the most extreme responses to foliar application were identified. Substantial variation in the relationship between leaf damage and subsequent yield reduction was also observed. In particular, elite black bean lines were able to withstand significant leaf damage without comparable yield reductions.

Our objective in the 1987 growing season was to conduct a detailed yield trial using the optimized treatment parameters (genotype, fertilizer concentration, application timing). Data from this experiment have not yet been analyzed. If significant effects on yield are obtained we plan to repeat the study and report our findings in an international scientific journal such as *Agronomy Journal*.

Physiological Work in California

Our initial efforts in Davis were directed towards the design and construction of an automated greenhouse sand-culture system capable of sustaining plant growth over extended periods at realistically low P concentrations. The maintenance of realistic P concentrations under controlled fertility conditions is a major technical obstacle to mechanistic studies of low P fertility. The computer-controlled system we developed, which is also applicable to mycorrhizal studies, represents an original contribution to the field of P fertility research and will be the subject of a technical report in an international scientific journal such as *Journal of Plant Nutrition*.

The sand culture system was fully functional in the fall of 1985, at which point we conducted the first greenhouse experiment. The objective of the first experiment was to determine the effects of foliar APP application on

vegetative growth over time. Our conclusion was that foliar APP application significantly enhanced vegetative growth of plants grown under limiting P conditions, despite the fact that our greenhouse plants had considerably more leaf damage following foliar treatment than field-grown plants exposed to the same APP concentration. Detailed gas exchange analysis of the leaves indicated that foliar APP application may have had some effect on the carbon assimilatory apparatus in the leaves.

During the 1986 growing season we conducted two detailed growth studies to determine if foliar APP application enhanced vegetative growth by stimulating carbon assimilation. Leaf photosynthesis, leaf initiation, and leaf area were measured over time in response to foliar APP application at three levels of soil P in the presence or absence of mycorrhizae. The effect of foliar treatment on leaf N, P, K, Ca, Mg, Fe, Zn, Al, and B content was determined. Carbon availability in the plant was monitored by analysis of starch and sugar levels in source and sink leaves at midday and predawn harvests. As of this writing we are just finishing all the sample analysis and are beginning to integrate the data. Visual evaluation and fresh weight data show that foliar APP treatment significantly enhanced plant growth under low P regimes. Foliar P application particularly enhanced leaf enlargement, which may have catalytically stimulated growth by increasing biomass partitioning to leaf area. Firm conclusions from these studies must await an integrated analysis of the data, which will occur over the next several months. We expect to submit a report of our findings to an international scientific journal such as *Crop Science*.

In the 1987 growing season we want to determine the effect of APP application during reproductive growth on yield parameters. As of this writing this experiment is in progress.