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# COMPARATIVE RESPONSE TO LIMING OF VARIOUS NON-TRADITIONAL EXPORT CROPS GROWN IN ULTISOLS AND OXISOLS OF THE CARIBBEAN 1/

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## ABSTRACT

Non-traditional export crops were grown following a sequence in Ultisols and Oxisols which occur extensively throughout the Caribbean Region. The soils were limed to pH values ranging from less than 5.0 to more than 6.5. Green beans, cabbage, taniers and yams appeared to be quite sensitive to soil acidity factors. Tomato yields were not markedly affected until pH dropped to 4.6 with 45% Al saturation. Pigeonpeas barely responded to liming in Oxisols, but responded strongly in Ultisols. Soil acidity factors have no effect on yields of plantains on either groups of soils. Lime requirements should be based on exchangeable Al rather than on pH. Any program geared to increase crop production levels on acid soils of the Caribbean must be based on the use of complete technological packages of practices of which lime is an essential component.

## INTRODUCTION

The main thrust in pursuing the concepts relating to agriculture within the context of the Caribbean Basin Initiative is the effective utilization of the resources of each country to produce non-traditional export crops and to develop appropriate markets and marketing channels. These resources usually permit year-round production of crops. Intensive agricultural operations can take full advantage of the tropical environment and the available labor force to produce more food for export and concomitantly for domestic consumption.

An export-oriented agriculture will exert a marked effect on the internal economic activity of each country. It is a fact that each dollar of agricultural production at the farm level has a multiplier effect on the economy which is much larger than the industrial dollar. This is due to the fact that agriculture uses less foreign inputs and that a larger share of the income stays in the country. Agriculture is furthermore an important source of gainful employment in itself. Each farm job probably leads to the creation of additional jobs outside the farm. Experience indicates that most developed countries have an economically viable agriculture.

It is important, however, to use technologies that are suited to local circumstances in order to maximize the available resources. Only through the use of these technologies can crop yields be improved, inputs be cost-effective, and production for export within competitive markets feasible. Efficient production of the various non-traditional export crops depends, to a large extent, on the effective use and timely application of given packages of management practices in an integrated systems approach.

These technological packages must be crop-specific and site-specific. They must contain in each case all the elements that are essential for a profitable farm business. Major elements of these packages relate to the use of high-yielding, highly-pest resistant crop cultivars, proper tillage, irrigation and drainage, plant population density, pest control, judicious fertilization and liming acid soils.

Soil fertility problems associated with acid soils are diverse and complicated. In many cases liming is effective because it increases the supply, concentration and uptake of nutrients. Sometimes acid soil infertility problems seem to involve Ca deficiency. Other times they relate to Al, Mn, and Fe toxicities, to P mobilization and others (Fox et al., 1985; Lathwell, 1979).

The objective of this paper is to review the available results of liming experiments conducted under humid tropical conditions in Puerto Rico and to evaluate information that would be useful in developing soil management systems for the Caribbean Basin.

## The Soils

Experiments were established on three Ultisols and three Oxisols to study the effect of liming on the yield of various non-traditional export crops (Lugo-López and Rivera, 1977). Details of these experiments are described elsewhere (Abruña et al., 1974, 1983,1984; Lugo-López et al., 1959; Pérez-Escolar and Lugo-López, 1979; Rivera et al., 1985, 1985a,b,c; Vicente-Chandler et al, 1983). Varying amounts of hydrated lime were applied to plots of each soil (Table 1). These amounts were based on an estimate of the lime requirement of the soils and applied to achieve soil pH values ranging from less than 5.0 to more than 6.5. All of the limestone was applied before the first crop was planted and a series of successive crops was grown without further additions of lime.

The soil in all plots was sampled six months after liming and at reasonable intervals after planting each successive crop in the sequence. Generally, the two Oxisols were not as acid as the Ultisols and were much lower in exchangeable Al. The coarse-textured Bayamón loamy sand contained only very small quantities of exchangeable Ca and Mn. Because the CEC of the Bayamón soil was extremely low, only small amounts of lime were added and therefore the quantities of exchangeable bases increased only slightly. The Catalina clay, on the other hand, contained sizable quantities of exchangeable bases even without liming and these increased significantly upon liming because of the higher CEC and greater lime requirement.

In the Ultisols, however, both the exchangeable Ca + Mg and the exchangeable Al were high. As the rates of liming increased, exchangeable Al declined. Soil pH values increased only slightly.

## The Crops

The non-traditional export crops included in the experimental sequence were green beans, tomatoes, cabbage, plantains, taniers, yams and pigeonpeas.

Table 1. Some chemical properties of lime-treated Puerto Rico Oxisols and Ultisols. (Samples taken 6 months after lime application)

| Soil | Lime rate ($t/ha^{-1}$) | Sample depth (cm) | Soil pH | Exchangeable cations (me/100 gm) Ca + Mg | Al | Al Saturation (%) |
|---|---|---|---|---|---|---|
| | | | Oxisols | | | |
| Bayamón loamy sand | 0.00 | 0-15 | 5.1 | 0.7 | 0.1 | 13 |
| | | 15-30 | 5.1 | 0.6 | 0.2 | 25 |
| | 0.45 | 0-15 | 5.5 | 0.9 | 0.2 | 18 |
| | | 15-30 | 5.0 | 0.9 | 0.2 | 20 |
| | 0.76 | 0-15 | 5.4 | 0.9 | 0 | 0 |
| | | 15-30 | 5.1 | 0.8 | 0.2 | 20 |
| | 1.05 | 0-15 | 5.5 | 1.0 | 0 | 0 |
| | | 15-30 | 5.2 | 0.9 | 0.1 | 10 |
| | 1.92 | 0-15 | 6.0 | 1.2 | 0 | 0 |
| | | 15-30 | 5.5 | 1.0 | 0 | 0 |
| Catalina clay | 0.00 | 0-15 | 5.0 | 5.6 | 0 | 0 |
| | | 15-30 | 5.1 | 5.3 | 0 | 0 |
| | 0.45 | 0-15 | 5.1 | 5.3 | 0 | 0 |
| | | 15-30 | 5.1 | 5.2 | 0 | 0 |
| | 4.72 | 0-15 | 5.4 | 7.0 | 0 | 0 |
| | | 15-30 | 5.2 | 5.4 | 0 | 0 |
| | 7.30 | 0-15 | 5.4 | 7.4 | 0 | 0 |
| | | 15-30 | 5.2 | 5.4 | 0 | 0 |
| | 12.88 | 0-15 | 6.2 | 10.9 | 0 | 0 |
| | | 15-30 | 5.3 | 6.5 | 0 | 0 |
| Coto clay | 0.00 | 0-15 | 4.3 | 2.1 | 1.2 | 30 |
| | 0.45 | 0-15 | 4.5 | 2.4 | .0 | 25 |
| | | 0-15 | 4.7 | 3.2 | .6 | 15 |
| | | 0-15 | 5.3 | 4.0 | .2 | 5 |
| | | | Ultisols | | | |
| Los Guineos clay | 0.00 | 0-15 | 4.6 | 5.7 | 2.8 | 33 |
| | | 15-30 | 4.7 | 4.9 | 2.7 | 36 |
| | 0.45 | 0-15 | 4.6 | 5.3 | 2.8 | 35 |
| | | 15-30 | 4.7 | 5.5 | 2.6 | 32 |
| | 5.65 | 0-15 | 4.8 | 6.7 | 1.8 | 21 |
| | | 15-30 | 4.9 | 5.2 | 2.1 | 29 |
| | 8.73 | 0-15 | 5.4 | 8.4 | 0.2 | 2 |
| | | 15-30 | 5.2 | 7.4 | 0.5 | 6 |
| | 13.77 | 0-15 | 5.4 | 9.3 | 0 | 0 |
| | | 15-30 | 5.0 | 8.2 | 0.3 | 3 |
| Corozal clay | 0.00 | 0-15 | 4.7 | 12.3 | 4.1 | 25 |
| | | 15-30 | 4.5 | 9.5 | 11.8 | 55 |
| | 0.45 | 0-15 | 4.7 | 13.4 | 2.3 | 15 |
| | | 15-30 | 4.4 | 9.1 | 8.4 | 48 |
| | 1.22 | 0-15 | 4.9 | 15.0 | 1.7 | 10 |
| | | 15-30 | 4.5 | 9.1 | 12.4 | 58 |
| | 4.52 | 0-15 | 4.9 | 18.6 | 0.9 | 5 |
| | | 15-30 | 4.4 | 9.9 | 12.8 | 47 |
| | 9.81 | 0-15 | 5.5 | 20.5 | 0.3 | 1 |
| | | 15-30 | 4.6 | 13.2 | 8.9 | 41 |
| Humatas clay | 0.00 | 0-15 | 4.3 | 7.3 | 4.1 | 36 |
| | | 15-30 | 4.3 | 5.5 | 6.6 | 55 |
| | 0.45 | 0-15 | 4.9 | 7.6 | 3.1 | 29 |
| | | 15-30 | 4.4 | 6.1 | 4.3 | 41 |
| | 3.27 | 0-15 | 4.7 | 9.8 | 1.6 | 14 |
| | | 15-30 | 4.5 | 6.8 | 4.4 | 39 |
| | 5.45 | 0-15 | 4.9 | 12.0 | 0.9 | 7 |
| | | 15-30 | 4.4 | 6.1 | 4.7 | 44 |
| | 8.78 | 0-15 | 5.3 | 14.8 | 0 | 0 |
| | | 15-30 | 4.5 | 6.7 | 4.6 | 41 |

Green Beans: Green beans (cv. Bountiful) responded very strongly to liming on all soils. Yields increased with increasing soil pH to about 5.2 at which level these soils contained essentially no exchangeable Al. They also increased with increasing exchangeable soil base content to about 70% saturation based on CEC as determined with ammonium acetate at pH 7. Bean yields increased with decreasing exchangeable soil Al. The Ca content of the bean leaves increased and Mn decreased with increasing lime rates. Soil pH and exchangeable base and Al contents were effective criteria for liming these soils.

Tomatoes: Yields of cv Tropic were not markedly reduced by acidity in the Ultisols until the pH dropped to around 4.6 with 45 per cent Al saturation of the CEC, and no yield was obtained at about pH 4.1 and 80 per cent Al saturation. In the Oxisols, yields dropped steadily from 39.7 t $ha^{-1}$ when there was no exchangeable Al to 17.5 t $ha^{-1}$ at pH 4.4 and 45 per cent Al saturation. In all soils, yields were closely correlated with soil pH, exchangeable Al and Ca and the Al/Ca ratio.

Cabbage: Yields of cv Market Price, on all soils, responded strongly to liming, but the response was stronger on the Ultisols. All soil acidity factors correlated significantly with yields. On the Ultisols, yields increased with decreasing acidity up to pH 5.6. Only 50 per cent of maximum yield was obtained at 12 per cent Al saturation. Essentially no yields were obtained at pH values below 4.5 and 50 per cent Al saturation, a level of acidity common in Ultisols. About 50 per cent of maximum yield was obtained at pH 4.7 with 25 per cent Al saturation on the Oxisols compared to about 22 per cent of maximum yield obtained at this level of acidity on the Ultisols. Density of cabbage heads correlated positively with soil acidity on all soils. Soil acidity had no apparent effect on foliar composition of the basal leaves. The Ca content of the head leaves correlated negatively with soil acidity factors on the Ultisols. Basal leaves had a higher Ca content than head leaves and both a higher Ca and a lower P content on the Oxisols than on the Ultisols.

Plantains: Soil acidity factors had no effect on the yield components or foliar composition of plantains. In the Ultisols, yields averaged close to 30 t $ha^{-1}$ with about 40 fruits per bunch weighing 280 g each at soil pH's ranging from 4.1 to about 6,0, and exchangeable Al from nil to more than 70 per cent of the CEC. Chemical composition of the leaves was not affected by variations in soil acidity except for a tendency for Ca to decrease with increasing acidity. In the Oxisols, yields and yield components were similar when pH ranged from 4.25 to 5.25 and exchangeable Al from nil to 67 per cent of the CEC. In the Oxisols, leaves had more than four times the Mn content than those of plantains grown in Ultisols. The higher absolute Al values in the Ultisols and the higher Mn content in the Oxisols may be responsible for these differences. Plantains apparently can tolerate very high levels of both Al and Mn in the soil and take up Mn in quantities that will represent toxic levels to other crops.

Taniers: Yields of taniers on Ultisols decreased with increasing soil acidity from 16.3 t $ha^{-1}$ at pH 5.0 with 12 per cent saturation of the CEC with Al to 4.2 t $ha^{-1}$ at pH 4.2 and 70 per cent Al saturation. Much lower yields were obtained in Oxisols. These yields were lowered only at pH 4.5 and 34 per cent Al saturation of the soil CEC. Foliar composition of taniers was not affected by soil acidity, except that the Ca content was appreciably less at the highest acidity level on the Ultisols. For all soils combined, pH and per cent Al saturation of the soil CEC correlated very closely with yields. Overall yields were close to a maximum when the soil had a Ph of 5.2 and no exchangeable Al.

Yams: Yam cv. Smooth Statia responded strongly to variations in soil acidity in Ultisols. Yields decreased strongly as Al saturation of the effective CEC increased. Relative yields dropped to about 60 per cent of maximum when saturation was only about 10 per cent, and to 20 per cent of maximum when Al saturation was 50 per cent, a level common in the Ultisols of Puerto Rico. The high sensitivity of yams to soil acidity is shown by the fact that yields were sharply reduced when pH dropped from 5.6 to 5.1, a level at which most crops show little or no response to liming. Foliar composition was not affected by soil acidity except that Ca content decreased with decreasing soil pH and increasing Al saturation. Yields of a cultivar of the same species as Smooth Statia, known locally as Ñame de Palo, were not affected by soil acidity levels in Oxisols.

Pigeonpeas: Pigeonpeas barely responded in yield to soil acidity levels in Oxisols, but responded strongly to variations in soil acidity in the Ultisols. Yields increased from almost nil at pH 4 and 80 per cent Al saturation, to more than 8 t $ha^{-1}$ about pH 6.0 with no exchangeable Al. Yields increased with increasing soil pH, decreasing exchangeable Al, and increasing Al/Ca ratio. Yields were higher when the pH was about 6.0, exchangeable Al less than 20 per cent, and exchangeable Al/Ca ratio less than 1.0. Soil acidity did not affect leaf composition, except that Ca content decreased with increasing acidity and correlated well with yields, ranging from about 0.5 per cent with lowest yields to more than 1 per cent with the highest yields. Numbers of nodules per plant were not affected by acidity factors, except at the highest level of acidity, at which no nodules were found.

## DISCUSSION

There are great differences in response to lime among soils of the humid tropics of the Caribbean Basin such as Ultisols and Oxisols. In general, however, liming is an essential component of soil management systems. Many tropical crops may be tolerant of soil acidity but few are immune to all the factors of acid soil infertility. The evidence presented in this paper reveals that green beans, cabbage, taniers and yams are quite sensitive to soil acidity factors. In the case of tomatoes yields are not markedly reduced until the pH drops to 4.6 with 45 per cent Al saturation. At pH 4.1 and 80 per cent Al saturation no yields can be obtained. Pigeonpeas barely respond to liming in Oxisols, but respond strongly in Ultisols. Soil acidity factors have no effect on yield of plantains grown in Oxisols and Ultisols.

Relatively low rates of lime are usually adequate for maximum crop production. In some cases lime seems to be effectively mainly as a source of Ca and Mg as nutrients. It appears as though the level of Al in solution at a given soil pH is rather low in the highly weathered Ultisols and

Oxisols of Puerto Rico. They are usually highly resistant to pH changes above 5.5. Soil pH as such is not a very dependable criterion of lime needs in these soils. Lime requirements should be based on exchangeable Al rather than on pH.

Any program geared to increase production levels of non-traditional export crops as well as other crops in the Caribbean Basin will necessarily have to include liming as an essential component of technological packages of practices of most crops in acid soils.

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