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Influence of Surface Applied Lime and Gypsum on Subsoil Acidity, Extractable Ca and Nutrient Accumulation in Avocado (*Persea Americana* Mill.)

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ABSTRACT

A long-term liming experiment was conducted on a red Oxisol, to establish the amounts of lime and gypsum needed to attain and maintain a desirable soil Ca and pH status. Treatments applied at the beginning of the experiment in 1983 and repeated in 1987, were: 0, 1, 6, 9 and 12 t lime ha^{-1}, 3 t gypsum ha^{-1}, and lime plus gypsum (3 + 3, 4.5 + 4.5 and 6 + 6 t ha^{-1}). Soil samples were collected every six months and analyzed for pH, extractable K, Ca, Mg and available P. Leaf samples of avocado trees, which were planted in 1985, were analyzed for N, P, K, Ca, Mg and Mn. A soil pH (H_2O) of 5.6 and Ca level 880 mg kg^{-1} soil, were attained in the surface soil with the single lime treatment of 121 ha^{-1}15 cm^{-1}, After 3 years, soil pH leveled out and after 5 years it increased again after reimposing treatments. In the subsoil, pH started to decline after 3 years. Mixing lime and gypsum had a greater effect on the movement of Ca into the subsoil where Ca increased by 300% at the highest rate of lime and gypsum. Lime and gypsum applications resulted in a significant increase in the Ca content of avocado leaves, but a reduction in K content of up to 30% at the highest rate of lime. No significant treatment effects were found on the leaf N, P, Mg and Mn content. This study showed increases in soil pH within 2 years due to lime while lime requirement methods underestimated the amounts of lime to be applied to reach a target pH.

INTRODUCTION

Soil acidity is a major growth-limiting factor for crops grown in the southeastern and northeastern sub tropical areas of South Africa (Fouché, 1986). Crop yields may be reduced in acid soils due to high soluble Al or Mn or low plant available Ca (Clark, 1984; Foy, 1984). Besides, subsoil acidity limits root development, thereby reducing plant uptake of moisture and nutrients (Blue & Dantzman, 1976; Rechcigl *et al.,* 1985a). In acid soils, avocado suffers from nutrient imbalances and Ca deficiency which result in poor fruit quality (Fouché, 1983; Bezuidenhout & Voster, 1991). Liming of soils to attain a desirable pH and Ca status is believed to be an essential practice of avocado management (Barnard, 1989; Barnard & Mentz, 1992). There is need to determine the optimum growing conditions for avocado production, specifically in relation to soil pH and uptake of Ca and other nutrient elements. Therefore, the objectives of this study were to determine the influence of lime and lime + gypsum on chemical changes in the soil profile and on the uptake of Ca and other nutrient elements by avocado.

MATERIALS AND METHODS

The study was conducted at Westfalia Estates, Tzaneen, in the sub tropical region of eastern South Africa. The soil is classified as a Hutton form, Balmoral series in the South African Binomial system. Selected initial chemical properties of the soil are given in Table 1. Prior to the experiment, the site had been under Eucalyptus forest. The treatments applied at the start of the experiment in January 1983, were: Control; lime (6 t ha^{-1}; 9 t ha^{-1}; 12 t ha^{-1}); gypsum (3 t ha^{-1}); and lime + gypsum (3+3t ha^{-1}; 4.5+4.5t ha^{-1}; 6+6t ha^{-1}). Each treatment was replicated three times in a randomized block design. Individual treatment plots measured 2 m x 2 m and each plot consisted of a single tree planted at a later stage.

The calcium content of the agricultural lime and gypsum used in the experiment, were respectively 32.8% and 16.4% calcium. Lime and gypsum were applied at the beginning of the experiment in January 1983 and repeated again the middle of 1987. Both materials were broadcast on ploughed land divided into blocks of 2 m^2 and immediately incorporated into the top 15 cm of the soil by cultivation with hand hoes. Random soil samples from 0-15 cm and 15-30 cm depths were collected every six months from each treatment plot for the duration of the experiment. Soil analyses were conducted on a composite soil sample from each plot. Soil reaction was measured in water at a soil: solution ratio of 1:2.5. Calcium, Mg, K and P were extracted with a solution of 0.025 M HCl + 0.03 M NH_4F (Bray 1 method). Calcium, Mg and K were determined on the extract by atomic absorption Spectrometry and P by Auto-Analyser.

Table 1
Selected initial chemical properties of soil on experimental site

Chemical Properties	*Soil Depth (cm)*	
	0–15	*15–30*
pH (1 : 2,5)		
Water	4,60	4,40
1M KCl	4,20	4,10
Exch. cations cmol(+) kg^{-1}		
Ca	1,22	1,16
Mg	0,39	0,40
K	0,19	0,12
Al + H	2,44	3,22
C E C cmol (+) kg^{-1}	12,00	11,20
S value %	18,00	15,50
Lime requirement (SMP) (t ha^{-1} pH 6,0)	5,20	5,00
Available P(mg kg^{-1})	5,00	3,80
Fe & Al amorphous oxides	20%	20%

Two years after the application of lime and gypsum, avocado *(Persea Americana* Mill.) trees were planted in the plots. Trees received a basic blanket application of phosphate and potassium chloride. Starting 3 years after planting, leaf samples were collected every six months for tissue analysis. A composite sample from each treatment was ashed and then dissolved in HCl. Nitrogen and P were determined by auto-analyser and Ca, Mg, K, and Mn by Atomic Absorption. The data were statistically analysed by analysis of variance using Statgraphics program and treatment means were compared using the t-test.

RESULTS AND DISCUSSION

Soil analysis

In this study, soil analysis showed considerably more variation than plant analysis. Overall, Ca, K and P showed the greatest variation followed by Mg and pH (H_2O) of the 0 to 15 cm layer. Consequently, statistical analyses of these data obtained in some years were very meaningful.

Figure 1 shows pH fluctuations in the field over a period of 66 months. Soil pH of the 0 to 15 cm samples taken 24 months after the application of treatments, were, respectively, 4.6 and 5.5 in the control and 12 t lime ha^{-1} of the lime treatments (Figure la). In the single gypsum and lime + gypsum (6 + 6t ha^{-1}) treatments the soil pH was 5.3 and 5.2 respectively (Figure 1b). Thus soil pH in the top soil had been increased by almost 1 pH unit in the 12 t ha^{-1} lime amended soil. From the 24th to 42nd month the soil pH remained constant for a while, most probably because of a buffer effect by amorphous components (Fouché, 1986). After repeating the treatments during the 42nd month the pH started to increase again. It was clear that the soil pH of the single gypsum treatment did not differ much from the control for the first 18 months where after a sharp increase occurred. The effect of the treatments on subsoil pH (Figures 1c & d) was less and this was to be expected. Soil pH of subsoil samples taken 24 months after the application of the treatments were respectively 4.5, 5.4 and 5.0 in the control, 12 t lime ha^{-1} and lime + gypsum (6 + 6 t ha^{-1}) treatments (Figures 1c & d). These values remained more or less constant with a slight decrease of pH after 42 months and at the same time a slight increase of pH on the gypsum and gypsum + lime treatments.

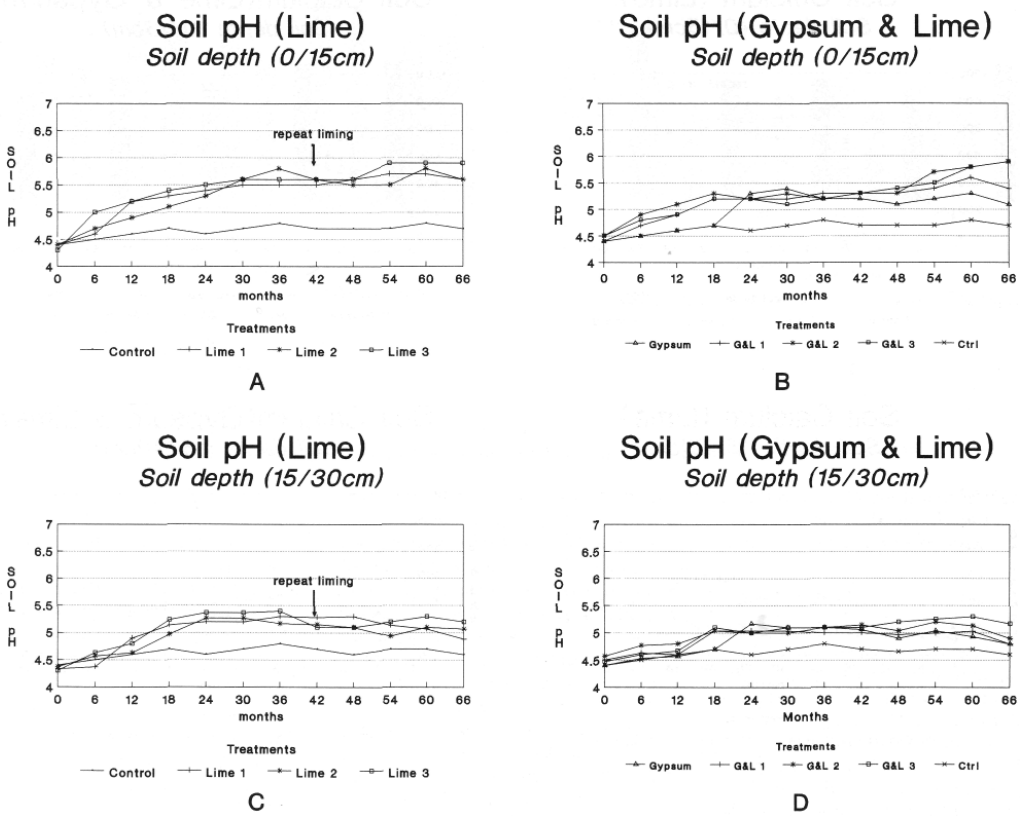

Figure 1

Soil pH (H_2O) at 0/15 cm and 15/30 cm depth for the different lime and lime + gypsum treatments. (ctrl – control; G & L – gypsum + lime)

Like many studies by other investigators on similar tropical soils, the effect of lime on soil pH is not as high as would be expected. The soil is clearly highly buffered so that the SMP-lime requirement method (Shoemaker *et al,* 1962) seems to underestimate the amount of lime required to attain a target pH of 6.0. In this study, the lime requirement of the soil as determined by the Shoemaker method to reach a pH of 6.0 was 5.2 t ha^{-1}. The highest soil pH reached after 2.5 years was about 5.6 using 12 t lime ha^{-1}. Comparable data from Andepts studied by Rixon & Sherman (1962) showed a lime requirement of 74 t $CaCO_3$ ha^{-1} to raise the soil pH 3 units from pH 4 to 7. The soil pH data also show that mixing lime with gypsum did not increase soil pH rapidly, but instead, after 24 months, suppressed it. Soil pH of the 0-15 cm samples taken 24 months after application of treatments was 5.5 and 5.2 in the lime alone (12t ha^{-1}) and lime + gypsum (6 + 6t ha^{-1}) treatments, respectively. This effect of the reduction in soil pH has been attributed to the addition of salts, e.g. gypsum (Alcordo & Rechcigl, 1993; Rechcigl, *et al,* 1988; Shainberg *et al,* 1989). More soluble Al was released into the soil solution causing a decrease in soil pH and having a buffer effect on the neutralization curve (Figures 1b & d) (Fouché, 1979). Interesting is the increase of pH on the single gypsum treatment to 5.3 and 5.1 in the top and subsoil after 24 months. This can be explained by a leaching effect in which soluble Al + H were leached from the soil by irrigation and rain.

Treatment effects of lime, and lime + gypsum amendments on extractable Ca are shown in Figure 2. Soil samples taken in the surface 0-15 cm after 24 months, had extractable Ca levels that ranged from a low of 237 mg kg^{-1} (control) to a high of 1030 mg kg^{-1} for the lime + gypsum (6 + 6 t ha^{-1}) (Figure 2b). The increase in the Ca level after 24 months was statistically significant ($p = 0.05$) at all lime and lime + gypsum rates. In the subsoil after 24 months, the Ca level was 200 mg kg^{-1} when no lime or gypsum was applied and 389 mg kg^{-1} for highest rate of lime and 542 mg kg^{-1} at the highest rate of lime + gypsum. This resulted in an increase of Ca level in the subsoil by almost 200% and 300% at the highest rate of lime and lime + gypsum (Figures 2c & d). Therefore, substantial movement of Ca into the subsoil occurred. It is interesting to note that the Ca control in the top soil steadily increased for 24 months and then remained constant (Figure 2a) while in the subsoil the Ca content increased for 18 months and then steadily declined (Figure 2c) to *ca* 200 mg kg^{-1}. However, for the lime + gypsum treatments after 24 months the Ca content decreased in the top soil (Figure 2b) while the Ca content in the subsoil remained at 400 mg kg^{-1}. Evidently, the Ca from the top soil had moved into the subsoil with the lime + gypsum treatments while with the lime only this had not occurred. Lime and gypsum resulted in greater movement of Ca than lime alone. This result is consistent with those reported by Hoyt & Drought (1990) and Farina & Channon (1988). Except during the first six months after the application of treatments, the extractable Ca levels in the soil appeared to be sufficient for optimal plant growth.

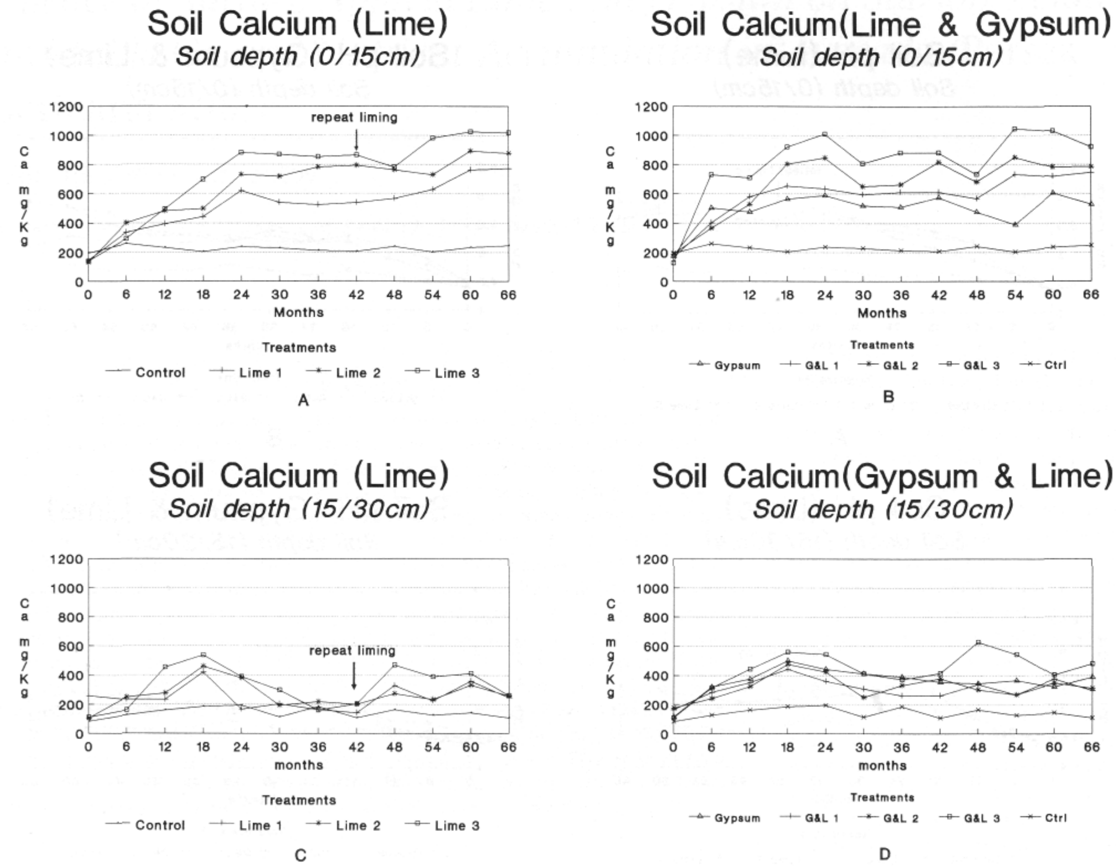

Figure 2

Extractable Ca of the soil at 0/15 cm and 15/30 cm depths for the different lime and lime + gypsum treatments. (ctrl – control; G & L – gypsum + lime)

With time, the level of Mg in the surface and subsoil remained relatively constant (data not shown). In all the soil samples, the extractable K was far below the critical level of 125 mg kg^{-1} for clay soils. In this study, extractable K values averaged 100 mg kg^{-1} soil in the surface and 30 mg kg^{-1} in the subsoil (data not shown). Similarly, P was deficient in all soil samples in all the years. Available P values averaged less than 5 mg kg^{-1} soil compared to the expected sufficiency level of most crops of 15 mg P kg^{-1} with the Bray 1 method. There were no statistical differences among treatments.

Plant analysis

Changes in pH of this magnitude, (more than 0.5 units in the top 0-15 cm), can have a remarkable effect on nutrient availability. For example, the availability of Mn and P are highly pH-dependent (Foy, 1984).

The Ca content of leaves of three-year avocado plants was significantly ($p = 0.05$) higher at lime and lime + gypsum rates > 9t ha^{-1} than with no lime or 6t lime ha^{-1} (Table 2). The Ca content of avocado leaves increased in most of the lime and lime + gypsum levels from 1988 to 1989 (Figure 3a). This trend in the data is consistent with the increase in extractable Ca of especially the subsoil during the same period (Figure 2). Roots probably obtained Ca below the 30 cm depth where the Ca levels were lower than in the surface. Magnesium showed no significant difference between the treatments.

A significant ($p < 0.05$) decrease in K content of avocado occurred at all lime and gypsum rates (Figure 3b). In 1988, the K content was 1.18% at zero-lime and 0.85% at the highest rate of lime (Table 3). This effect could be attributed to nutrient imbalances (Mortvedt & Khasawneh, 1986). The dominating effect of Ca over K is one good reason for determining the correct amounts and balances in the soil. There were no significant treatment effects on the N and P contents of the avocado.

Table 2
Treatment effects on concentration of nutrient elements in young avocados 30 months after planting.

Treatments	*Concentration of elements in leaves* %				
	P	*K*	*Ca*	*Mg*	*Mn*
Control	0,12	1,18	0,82	0,27	0,018
Lime (6 t ha^{-1})	0,10	0,61	0,93	0,32	0,019
Lime (9 t ha^{-1})	0,11	0,87	1,29	0,37	0,027
Lime (12 t ha^{-1})	0,10	0,85	1,09	0,30	0,026
Gypsum (3 t ha^{-1})	0,10	0,63	1,00	0,27	0,027
Lime + gypsum (3 + 3 t ha^{-1})	0,11	0,70	1,50	0,34	0.029
Lime + gypsum (4,5 + 4,5 t ha^{-1})	0,11	0,88	1,13	0,30	0,030
Lime + gypsum (6 + 6 t ha^{-1})	0,11	0,70	1,01	0,28	0,032
LSD (0,05)	ns	0,13	0,17	ns	ns

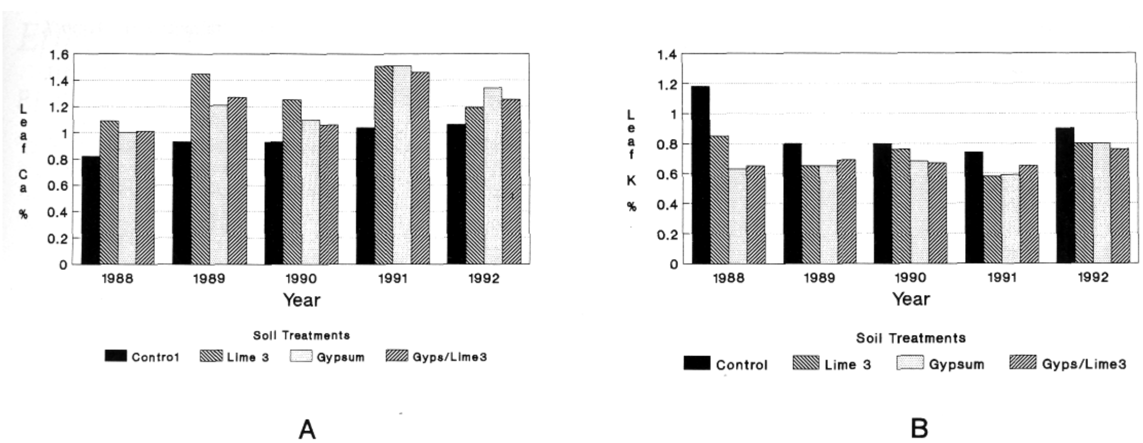

Figure 3
Avocado leaf-Ca (A) and leaf-K (B) for different lime and lime + gypsum treatments during 1988 to 1992.

Higher values of Mn content were obtained at all rates of lime and gypsum when compared to the control. However, this was not statistically significant. Soil extractable micronutrients e.g. Fe and Mn were not measured so that it cannot be determined if toxic amounts of these elements were present.

CONCLUSIONS

Like many other reported studies on similar soils, this investigation has shown that the effect of lime alone on soil pH is not as high and as rapid as would be expected. High rates of lime 6-12 t ha^{-1} and lime + gypsum (6 + 6 t ha^{-1}) decreased soil acidity and increased the Ca level in the subsoil, but these favourable conditions do not last longer than 3 years after application of treatments. A combination of "lime and gypsum" was more effective in increasing subsoil Ca. The lime requirement method used, underestimated the amount of lime to be applied on a subtropical soil to reach a required pH. Leaf Ca of young avocado trees increases significantly with lime treatment while a decrease in leaf K is found.

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