SUMMARY

Various authors have emphasized acid soil infertility as a major limitation to sustainable crop production on Zimbabwean light-textured soils, particularly in the smallholder sector where the bulk of the country's groundnut crop is grown. Consequently, productivity of groundnut on these soils has declined, with pod yields averaging only 0.5 t ha^{-1}. Calcium (Ca) materials are universally used for ameliorating soil acidity, but their effectiveness depends on the soil type, and differs between the materials. Hence, the overall goal of this study was to examine the effects of soil acidity amelioration by four Ca-containing materials on vegetative and reproductive growth of groundnut so as to improve productivity on acid soils. The research questions that the study sought to answer were:

a) Which acid-soil infertility factors are limiting groundnut productivity on the acid sandy soils in Zimbabwe?
b) What are the effects of the Ca-source on soil pH and availability of the essential nutrients [Ca, magnesium (Mg), nitrogen (N), phosphorus (P) and potassium (K)] in the root and pod environments?
c) Do groundnut genotypes differ in their tolerance to acid soil infertility?
d) What are the effects of low pH *per se,* or the interactive effects of pH and availability of Ca on (i) germination, (ii) seedling survival, (iii) vegetative growth and (iv) reproductive growth of groundnut?
e) Can seed priming or pelleting with Ca provide sufficient Ca to ameliorate the effects of acidification in the sensitive seedling stage?

A field experiment was conducted over three seasons on acid soils at the Horticulture Research Station (HRC) and Makoholi Experiment Station (MES) to determine the direct and residual effects of application of calcitic lime (CL), dolomitic lime (DL), gypsum (G) and single superphosphate (SSP) on soil pH, nutrient status, growth and productivity of Spanish groundnut *cv.* Falcon. In addition, a greenhouse experiment was conducted at Harare Research Station with potted acid soil to monitor the chemical changes of the soil following application of the four Ca-containing materials and the resultant effects on groundnut productivity. In both the field and greenhouse experiments, the lime application rates were from 0 to 4000 kg ha^{-1}, while gypsum

application rates were from 0 to 3450 kg ha^{-1}, and those of SSP were from 0 to 250 kg ha^{-1}. The overall effects of CL and DL applied at 2000 or 4000 kg ha^{-1} were to increase soil pH, Ca and Mg content in both the pod and root zones. Leaf, and shell Ca and Mg concentrations were also influenced by application of CL and DL, whereas smaller effects were observed in kernels. Gypsum and SSP applications at 200 and 250 kg ha^{-1} respectively, had no significant effects on pH, Ca and Mg levels. However, when applied in equivalent amounts of Ca as CL or DL, gypsum improved the soil Ca status. Effects of the four ameliorants on the N, P and K levels in the soils and in plant material were generally neither significant nor consistent, making the interpretation of improved plant growth difficult. However, the concentrations of N and P were generally adequate both in the soils and in the plants. Application of CL or DL was more beneficial in improving crop growth and productivity compared to G or SSP and their combinations. However, G was the superior Ca-source in improving pod and kernel quality. The residual benefits of application of lime lasted for the duration of the field experiments despite the decline in soil pH over the seasons, and were manifested in improved plant stands, better growth, nodulation, productivity and quality of groundnut. By the end of the third season, the increases in cumulative kernel yields due to application of 4000 kg ha^{-1} lime over the control treatment were 110% at HRC, and 319% at MES. The study established that the most important factors limiting groundnut yields on the acid soils at HRC and MES were predominantly deficiencies of Ca and Mg, and low pH *per se.*

One way of increasing groundnut productivity on acid soil is to grow cultivars that are tolerant of soil acidity. Intra-species differences in plant tolerance to soil acidity have been observed for many crops. Some of the differences arise partly from different abilities in uptake and utilization of nutrients (Ca, Mg, P) whose availability is low under acidic conditions. Thus, another field experiment was conducted on an acid soil at MES to evaluate 12 advanced breeding lines and three commercial cultivars of groundnut on their tolerance to soil acidity. The groundnut genotypes showed significant differences in yield and nutrient utilization efficiency. Breeding lines 106/96 and 418/93 were the most efficient in nutrient uptake and nutrient use in acid soils with low fertility. They performed better than all the genotypes including the three commercial cultivars Jesa, Falcon and Teal.

Poor germination and seedling survival are among the factors that reduce crop yields. Because of their small size, plants are expected to be most vulnerable to soil acidity at early seedling growth stages. In groundnut, the pod growth and maturation occurs in the soil, which also exposes the developing pod to soil acidity. Thus, soil acidity is expected to adversely affect groundnut both in the root and pod environments. The greenhouse and growth chamber experiments conducted at the Hatfield Experimental Farm provided an opportunity for detailed studies on the basic effects of pH *per se* (pH 3.0 - 7.0) and its interaction with Ca (0 - 2000 μ*M* Ca) on germination, seedling survival, vegetative and reproductive growth of groundnut. The experiment on early seedling growth utilised potted sand that was watered with a nutrient solution containing various pH and Ca treatments. The experiment on reproductive growth involved the culture of attached gynophores in nutrient solutions containing the appropriate pH and Ca treatments. The results of this study indicated that low pH *per se* has a major detrimental impact on seedling survival, growth, pod formation, yield and quality of groundnut, but not on germination. The adverse effects of low pH were more pronounced in the absence of Ca, and became progressively less as the solution Ca concentrations increased. Significant delays in pod initiation and expansion were caused by low pH, with very little pod formation taking place at pH < 4.0. Although seeds were formed even at pH 3.0, normal embryos were only formed at pH 5.0 and above. Increasing the solution Ca concentration from 500 to 2000 μM had more effect on pod formation, yield and quality at pH 3.5 than at pH ≥ 5.0.

Since soil acidity adversely affects seedling survival and early growth, it is imperative to minimize these adverse effects by liming in order to increase crop productivity per unit area. For most resource-poor farmers, the cost of liming is beyond their reach. With these concerns in mind, experiments in growth chambers and in the field were conducted to determine the feasibility of counteracting the adverse effects of soil acidity on groundnut germination and seedling survival. The techniques examined were pelleting groundnut seeds with a Ca material (CL or G) or priming the seed with a solution containing Ca ($CaSO_4$, $CaCl_2$, $Ca(NO_3)_2$ or Calcimax). Significant reductions in seedling mortality were obtained with gypsum priming at Ca concentrations as low as 250 μM. The results of these experiments showed that groundnut establishment on acid soils can be significantly improved by pelleting seeds with small amounts of $CaCO_3$, or priming with $CaSO_4$.