INTRODUCTION

Groundnut (*Arachis hypogaea* L.) has traditionally been one of the important crops of the smallholder-farming sector in Zimbabwe. As a protein source, it is an important component of the diet of the rural people. The demand for it by the oil expressing industry and confectioners also makes groundnut a cash crop of significance to the economy of Zimbabwe. The smallholder-farming sector produces more than 60% of the total crop (CSO, 2001). Spanish groundnut cultivars with a growing period of 100-130 days, depending on altitude, are largely grown. Some Valencia cultivars are also grown in the cooler, wetter areas (Hildebrand, 1996).

The bulk of the groundnut crop in Zimbabwe is produced on light textured soils ranging from coarse and fine sands to sandy clay loams. These soils are highly weathered, and have low Ca, Mg, P and Zn status (Grant, 1970; Mashiringwani, 1983; Tagwira *et al.,* 1993). In addition, the soils are usually acidic (Grant, 1970; Grant *et al.,* 1979, Mashiringwani, 1983), giving rise to high hydrogen ion (H^+) concentrations as well as toxicities of aluminium (Al) and manganese (Mn). Nyamangara & Mpofu (1996) reported considerable acidification rates in light textured soils in some communal areas in the high potential zones, with approximately 24% of arable soils becoming very strongly acidic over a ten-year period, and 56% of the soils needing to be limed. Recent surveys by the Chemistry and Soils Research Institute, Zimbabwe utilising the Diagnosis and Recommendation Integrated System (DRIS) programme showed that 69% of the sandy soils in eight communal areas had pH values between 4.2 and 4.5, with the majority of the soils having Al saturation levels exceeding 20% of the CEC (Mukurumbira, 1997; Dhliwayo *et al.*, 1998).

Despite the recent genetic and disease resistance improvements to the groundnut crop, its productivity has declined in the smallholder-farming sector, with pod yields averaging less than 500 kg ha^{-1} (CSO, 2001). Acid soil infertility in this farming sector could be a major contributing factor, and even if smallholder farmers are aware of the acidity status of their soils, their poor resource base is a major socioeconomic constraint that limits the extent to which they can invest in large amounts of liming materials. In view of this situation, practicable options for soil acidity amelioration are a prerequisite.

To overcome the constraints arising from acid soil infertility of the Zimbabwean sandveld soils, liming is advocated. Liming increases soil pH, neutralizes exchangeable Al and Mn toxicity, improves Ca and Mg supply, increases molybdenum (Mo) availability, decreases phosphorus (P) fixation, improves nitrogen efficiency and ensures optimal bacterial nitrogen fixation (Mendez & Kamprath, 1978; Sanchez & Uehara, 1980; Haynes, 1984). Mukurumbira & Dhliwayo (1996) showed that upon correction of soil pH through liming, a substantial increase in the N and P fertilizer use efficiency was achieved. Besides lime, other alternative ameliorants include wood ash (Clapham & Zibilske, 1992); animal wastes and green manures (Ahmad & Tan, 1986; Hue, 1992; Berek, *et al*., 1995; Materechera & Mkhabela, 2002); phosphate (Mongia *et al*., 1998) and gypsum (Shainberg *et al.,* 1989; Sumner, 1993; Carvalho & van Raij, 1997). On Zimbabwean soils, Grant (1967) observed that an annual cattle manure application of 3 to 6 t ha^{-1} progressively increased the cation exchange capacity, exchangeable bases and pH of a sandveld soil. Mugwira (1984) also documented substantial increases in soil pH due to application of cattle manure (1.29% N) at rates ranging from 10 to 80 t ha^{-1}.

Many studies have shown soil acidity amelioration to be of benefit to groundnut production (Snyman, 1972; Hartzog & Adams, 1973; Reid & Cox, 1973; Sullivan, Jones & Moore, 1974; Walker, 1975: Blamey & Chapman, 1982; Gani *et al.,* 1991). In general, results have shown that the benefit of soil amelioration, particularly with respect to kernel quality, has been due to improved calcium nutrition. Nonetheless, because of the many factors involved in acid soil infertility, coupled with the geocarpic nature of the crop, elucidation of the often unpredictable responses of groundnut to soil amelioration has been difficult (Blamey & Chapman, 1982).

SCOPE OF THESIS

The factors that constitute acid infertility and govern plant growth and yields in acid soils are complex. Low exchangeable soil Ca and Mg levels, low availability of P, K, Zn and Mo, and high H, Al and Mn levels in soil solution contribute in various degrees to the infertility problems of acid soils. The situation is further complicated by interactions of these factors with drought and with plant genotypes. At a given soil pH value, the limiting factor may vary with soil type; in a given acid soil, it may vary with plant species or cultivar (Awad *et al.,* 1976; Foy, 1984;

Fageria *et al.,* 1990; McCray & Sumner, 1990). It is therefore imperative to accurately identify the growth-limiting factor(s) in the particular soil, and then develop appropriate ameliorative strategies.

Since low soil pH stress and Ca deficiency are important components of the soil acidity constraints to groundnut growth in acid soils, the study will attempt to quantify the role of low pH *per se* and contributions of absolute Ca deficiency as well as pH x Ca interactions in regulating growth and productivity of groundnut.

Because the fruits of groundnut develop underground, they are just as vulnerable to direct effects of soil acidity as the roots are, thereby necessitating an assessment of the effects of acidity both in the podding (0 – 10 cm soil depth) and rooting (20 – 30 cm soil depth) environments of groundnut. It is reported in the literature that high Ca supply in the rooting environment inhibits Mg, P, K and Fe uptake, which may reduce these nutrients in the groundnut plant to deficiency levels. In the podding zone, high Ca also inhibits Mg, Zn and Mn uptake by the developing pods (Zharare, 1997). In addition, high Mg in the podding environment inhibits direct Ca and Zn uptake by pods, which results in poor pod filling. High concentrations of K and Mg in the pod zone can affect Ca uptake, thereby affecting groundnut fruit development, yield and quality (Alva *et al.,* 1989). The addition of different Ca-containing materials to soils not only changes various physico-chemical properties of soil, but also affects the availability of nutrients to plants. Caution is needed to avoid inducing deficiencies of other essential nutrients when applying Ca/Mg-containing materials to ameliorate soil acidity for groundnut production. This study will observe the reactions of the different types and amounts of liming materials with soils, as well as their effects on the nutrient status of the soils. There is a growing body of literature indicating that gypsum combined with lime is more effective in improving crop productivity than is lime alone when soils are acid (McLay *et al.,* 1994; Menzies *et al.*, 1994). This study will seek to elucidate the effectiveness of Ca-materials applied alone or in combination in improving groundnut performance in acid soils.

The overall goal of this study is to measure the effects of soil acidity amelioration on nutrient composition, growth, yield and quality of groundnut so as to come up with sound ameliorative strategies that would improve groundnut yields on acid soils. The study seeks to shed light on the nutrient interactions in the podding and rooting environments of groundnut. Hypotheses to be tested in the study are:

1. Groundnut yields on acid granite sands are limited by either (i) low pH *per se*, (ii) deficiencies of essential nutrients, particularly Ca, Mg or P or (iii) combinations of low pH and deficiencies of essential nutrients, and can be ameliorated to varying degrees by different Ca sources.
2. Because of the geocarpy of the groundnut plant in which the fruits mature underground, the crop is also susceptible to soil acidity in the podding environment, in addition to the rooting environment, and the direct effects of soil acidity in the podding environment can be observed.
3. Seed priming or pelleting with Ca can improve groundnut establishment under low pH stress.

The specific hypotheses and objectives are presented in detail for each experiment in the pertinent chapters.

RESEARCH METHODOLOGY

To assess the effect of judicious use of Ca-containing materials in ameliorating acid soil infertility constraints to groundnut growth, productivity and quality, several issues were investigated.

(a) What are the effects of the Ca-source on soil pH and availability of essential nutrients (Ca, Mg, N, P and K) in the rooting and podding environment of groundnut?

(b) Which components of acid soil infertility are most limiting to groundnut productivity on the acid sandy soils in Zimbabwe?

(c) 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) early growth and (iv) pod formation and development?

(d) Can seed priming or pelleting with Ca provide sufficient Ca to ameliorate the effects of acidification in the sensitive seedling stage?

(e) Do groundnut genotypes differ in their tolerance to acid soil infertility?

A three-year field experiment was conducted to determine the ameliorative effects of four Ca-sources on soil acidity, soil nutrient availability and plant nutrient composition, and on the vegetative and reproductive performance of groundnut on acid light textured soils of Zimbabwe. Residual effects of the ameliorants were assessed in seasons two and three. Pot experiments were also conducted for two seasons under glasshouse conditions at Harare Research station to examine the effects of Ca-source and Ca-rate on uptake of nutrients by groundnut in relation to both vegetative and reproductive performance in acid, light textured soils collected from communal areas. Soils were analysed for essential nutrients at the peak flower and physiological maturity stages from the pod zone (0 - 10 cm soil depth) and the root zone (20 - 30 cm soil depth). Samples of the youngest fully expanded leaves were also taken at peak flower and at physiological maturity stages, and analysed for essential nutrients. At maturity, samples of the groundnut shells and kernels were digested for chemical analysis. The four Ca-sources used in the study are calcitic lime (23% Ca), dolomitic lime (18% Ca), gypsum (20% Ca) and single superphosphate (12% Ca).

To investigate genotypic differences in tolerance to acid soil infertility, yield, soil and leaf nutrient composition, data was collected for fifteen groundnut cultivars and lines grown in a breeding experiment in the 1999/2000 season at Makoholi Experiment Station, Zimbabwe.

Greenhouse and growth chamber experiments were conducted at the Hatfield Experimental Farm, University of Pretoria to derive a better understanding of the relative importance of low pH *per se*, and Ca deficiency in limiting groundnut growth and productivity. The experiments investigated the effects of low pH *per se* and availability of Ca on germination, seedling survival, and vegetative and reproductive growth of groundnut. Studies on the effects of low pH and Ca on pod formation and development were conducted using a split medium technique whereby the roots were grown in sand culture and the pods in solution culture. Effects of seed priming and pelleting with Ca on germination and early seedling growth were investigated in growth chambers and in the field at the Hatfield Experimental Farm, University of Pretoria.