THE EFFECT OF PELLETISED AND POWDERED LIME ON SOIL PH, CROP YIELD AND CROP QUALITY ON RICHARDS BAY KZN SOIL

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Abstract

In the 20th century, food security was constrained due to the increase in population and the pressure it placed on food demand. By 2050 further strain is going to be placed on food security as the population is anticipated to double. Land and natural resources are scarce, and soil acidity is a major concern in most parts of the world. A solution to treat acidic soil to increase its fertility to obtain better crop yields and quality is the treatment of lime together with gypsum. Lime is found in two forms pelletised and powdered; however, there lacks practical evidence to support; which is the best form to obtain optimised crop yields and crop quality. Therefore this study was conducted to determine the effect of each lime form together with gypsum on soil pH stabilisation, crop yield and crop quality on a peanut harvest. A quantitative research paradigm and an experimental research strategy were adopted. The pilot study found that the dosage range for pelletised lime being 3 tons/hectare plus 20%vol/lime gypsum and powdered lime was 5 tons/hectare plus 20%vol/lime gypsum. These dosage rates resulted in optimised crop yield and crop quality of peanuts. To ascertain the effects of elevated dosage rates the main study found the effect of both powdered and pelletised lime at two times and three times the optimised dosage range on soil pH stabilisation, crop yield and crop quality. Experimental error was minimised with the use of replicate samples, and a control (the untreated soil) was used as a reference.

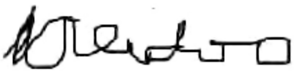
The optimum dosage range of pelletised lime resulted in a higher crop yield, and 100% of the crop met the quality standard as all peanuts yielded filled the shell cavity. However, the optimum dosage range for powdered lime resulted in a lower crop yield Furthermore, only 65% of the crop met the quality standard. It was found that less pelletised lime is required to stabilise soil pH than powdered lime over a period. Soil treated with pelletised lime had an increased crop yield and quality of peanuts over the use of powdered lime.

Despite the above findings, it was evident that overtreatment of both pelletised and powdered lime alone and together with gypsum did not result in a better crop yield or quality. The overtreatment of either pelletised lime or powdered lime and gypsum showed a decrease in crop yield and quality once the optimised dose was exceeded.

Consequently the overtreatment of either lime form or gypsum possibly had a toxic effect and inhibited crop yield and crop quality.

Declaration

I, Veloshni Naidoo hereby declare that this dissertation presents my own work, and that all the references, to the best of my knowledge, are correctly reported. This work has not been submitted for any other qualification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SIGNATURE OF MRS VELOSHNI NAIDOO

…08.05.2020……………………………………

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Chapter One - Introduction

This chapter provides insight into the background of the study, as well as an explanation of the problem statement. The aim and objectives of the study are subsequently set out in an attempt to resolve key aspects of the problem statement. This is followed by the hypothesis and scope of the study. A synopsis of the structure and flow of the study is then presented to demonstrate the research methodology that was adopted and applied to the problem.

1.1 Background and context of the study

Food security, according to Jones, Ngure, Pelto and Young (2013), Coates (2013), Hooker (2014) and Capone, Bilali, Debs, Cardone and Driouech (2014), is when individuals have access to adequate, nutritious and quality food. Porrka (2016) stated that during the 20th century, the world population doubled and concomitantly this placed pressure on food production to double. Of concern, is that by 2050, the population is said to double once again, adding further pressure on food production, which is already under strain to keep up with the demand. Qureshi, Dixon and Wood (2015) suggested that a proactive approach to agricultural research and development is needed to achieve zero hunger by 2050. As Porrka (2016) highlighted this would be a challenge as already 60% of the world's population is experiencing food insecurity due to strained resources. The proliferating world's population places constraints on water and land resources. These resources are the basic requirements for agricultural health and consequently needed for food security to exist.

Kunene and Fossey (2006) claimed that in Africa, livestock and agriculture are the primary sources of food production and income generation in rural farming. Therefore, Kumwenda, Waddington, Snapp, Jones and Blackie (1996) emphasised that an improvement needs to be made to agricultural productivity in Africa. Of concern, Mbow, Van Noordwijk, Luedeling, Neufeldt, Minang and Kowero (2014) pronounced that many parts of Africa already suffer from food insecurity and resource scarcity. According to Haywood (2013), rapid civil developments along the South African coastline have caused an influx of people, which has placed pressure on food production whilst depleting land resources. In addition, soils obtained in areas near dunes and wetlands are sensitive to environmental factors such as climate change. Richards Bay is a town on the northern coastline of KwaZulu-Natal (KZN) and is flanked by dune forests and wetlands. Consistent with this, Plaster (2007) and Mbow *et al*. (2014) stated that due to the variability of the climate, in the drier parts of Africa, soil quality is negatively affected, in turn, compromising their agricultural output.

Soil quality is especially important because it serves as a medium in which a plant can facilitate its growth. Furthermore, Mandal, Patra, Singh, Swarup and Mastro (2007) asserted that suitable soil quality is required to promote crop quality and production for both subsistence and commercial crops. Mbow *et al.* (2014) found that soil degradation is a concern for many parts of Africa. Soil degradation, according to Plaster (2007), is the loss of soil quality due to impacts from pollution and acidification of the soil. Similarly, Sanchez, Shepperd, Soul, Place, Buresh, Izac, Mokwunye, Kwesiga, Ndiritu and Woomer (1997) lauded that low soil fertility and soil degradation are contributing factors to the declining crop yields amongst small farmers in Sub-Saharan Africa.

The Department of Agriculture and the Fertiliser Society of South Africa advised that most crops need a neutral pH medium to grow. Slattery, Conventry and Slattery (2001) stated that the soil in Richards Bay is acidic. This acidity typically stunts root development, thus decreasing the uptake of water and nutrients such as phosphorus, calcium and magnesium. To address this concern, Coyne and Thompson (2006), Goto (2012) and Jones and Mallarino (2018) suggested that to combat the increased acidity in the soil; lime could be added to that soil.

Interestingly, calcium from lime enhances crop growth, as it establishes a medium for nutrients to be mobilised into the plant. In harmony, Burkhart and Collins (1942), Plaster (2007) and Goto (2012) revealed that during germination, a deficiency of calcium prevents the seeds from developing beyond the early seedling stage. Therefore, the addition of lime not only serves as an amendment to soil pH but as an additional source of calcium to the seedlings.

In light of these findings and according to Ritchey, Murdock, Ditsch, McGrath and Sikora (2016), lime is available in a pelletised form and a powdered form. Pelletised lime is a calcium carbonate compound which is bound by lignosulfonate and forms a granular shape while powdered lime is milled as calcium carbonate in a powdered form. Both these forms of lime are typically used in agriculture. Powdered lime is finer in particle size than pelletised lime. Murdock (1997), Anderson, Hart, Sullivan, Horneck, Pirelli and Christensen (2013) and Jones and Mallarino (2018) state that although pelletised lime is more expensive than powdered lime; it possesses an ease of application as it is not prone to becoming airborne.

Murdock (1997) found that even though the cost of pelletised lime is higher than powdered lime, the dosage of pelletised lime to powdered lime used at the end of the reaction time is lower. Therefore, less pelletised lime than powdered lime is needed to increase the pH of the soil to the desired level. Mallarino, Haq and Lawson (2017) confirmed that the neutralising ability of lime in acidic soil is dependent on the calcium carbonate ($CaCO_3$) equivalent also known as (CCE), and the fineness of the lime. However, there is little practical evidence to support this claim. Scott, Conyers, Fisher and Lill (1992) established that the capacity of limestone to increase pH was related to particle size. Furthermore, there was an initial exponential effect of lime on soil pH as particle size decreased. Thus, initially, powdered lime was seen to be more effective than pelletised lime and that the coarse particles in pelletised lime had a staggered reaction rate on soil pH. Jones and Mallarino (2018) are in agreement with this, and further found that particle size initially affects the pH neutralisation ability of lime; however, this effect is not sustainable and plateaus over a period of time. This suggests that the pelletised lime could be of a greater benefit in effectively neutralising the soil pH than powered lime. Despite research that has been conducted on the effectiveness of lime on the pH of the soil, there is a lack of research on the effect of different particle size of lime on soil pH over a period of time, as well as its impact on crop yield and quality. Furthermore, Qureshi, et al. (2015) mooted that an enhancement in agricultural research and development is needed as its one of the key pillars to food security. Thus, it can be inferred that there is a need for the development of sustainable farming and agricultural practices. Therefore the significance of this research is to use a practical approach to illustrate the impact of pelletised lime on crop yield and crop quality versus the traditionally used powdered lime.

1.2 Problem Statement

Scheepers (2014) stated that although Richards Bay has very acidic soil, it is also nutrient dense and that this soil can be very fertile if the acidic nature is managed appropriately. In the past, powdered lime was used to treat acidic soils. However, there were complaints that the lime was becoming airborne during application and transportation was difficult. Therefore, to address the above concern, pelletised lime was developed. According to Stevens and Dunn (2005), agricultural fertiliser dealers have reported an increase in the sales of pelletised lime to large scale farmers.

It was found that farmers preferred the ease of handling of the pelletised lime even though it was more expensive than the powdered lime. Ritchey *et al.* (2016) professed that pelletised and powdered limes each have their positive and negative attributes. However, there is a lack of practical evidence using these two lime forms in a field trial to measure the impact on soil pH neutralisation, crop yield and crop quality. Therefore, this study will outline the effectiveness of pelletised lime and powdered lime on soil pH neutralisation, crop yield and quality. This research hopes to aid farmers and the agricultural community with practical knowledge of these two lime forms. In addition, this research envisages providing the suitable dosage concentrations at which optimum crop yields and crop quality of peanuts is achieved using these two lime forms on Richards Bay soil.

1.3 Aim of the Study

The aim of this study is to evaluate the effectiveness of pelletised and powdered lime on soil pH, crop quality and crop yield of peanuts.

1.4 Objectives of the Study

The objectives of the study are:

- To treat the acidic soil obtained from Richards Bay with pelletised and powdered lime in order to monitor its pH neutralisation rate and stability.
- To determine the optimum dosage levels of pelletised and powdered lime to achieve maximum crop yield and crop quality of peanuts.

1.5 Scope of the Research

The study will be confined to the use of soil from Richards Bay, KZN. This soil will be used to demonstrate the effects of the pelletised and powdered lime in the ability to neutralise soil pH and the effect on crop quality and yield. The pelletised and powdered lime will be sourced from Idwala Carbonates.

1.6 Hypotheses

H_0 – pelletised lime is more effective on soil pH neutralisation, crop quality and crop yield of peanuts than powdered lime.

H_1– pelletised lime is not more effective on soil pH neutralisation, crop quality and crop yield of peanuts than powdered lime

1.7 Assumptions

Weather conditions do not affect the powdered and pelletised lime reaction capabilities. Seasonal changes will not affect the lime in its pH neutralisation ability of the acidic soil.

1.8 Delimitations

All soil samples will be exposed to the same levels of humidity, rain and temperature.

1.9 Overview of Research Methodology and Research Design

This study will be of an experimental (quantitative) nature. pH readings of the untreated soil, as well as the soil treated with the lime variants, will be taken seasonally. Once the optimum pH is reached, the peanuts will be planted. Crop quality of the peanuts cultivated will be ascertained on the fullness of the seeds in the shell. Crop yield will be ascertained by counting the peanuts yielded from the untreated soil and the soil treated with pelletised lime and powdered lime.

1.10 Structure of the Study

The study comprises of five chapters:

Chapter 1:

This chapter provided the background to the research. The problem statement, aim and objectives, as well as the rationale for the study were presented.

Chapter 2: Literature Review

This chapter will review books, journal articles and laboratory trials pertaining to aspects such as food security, global warming, acidic soil, peanuts, gypsum, forms of lime, pH of soil and its effects on crop yields and quality.

Chapter 3: Research Methodology

This chapter will define the laboratory methods, and conditions followed in obtaining data to meet the objectives.

Chapter 4: Results

This chapter will outline results obtained for crop yield, crop quality and pH reaction rate. The results will be presented in the form of tables and graphs.

Chapter 5: Conclusion and Recommendation

This chapter will reach a comparative conclusion to the effect of pelletised lime and powdered lime on soil pH neutralisation. The performance of pelletised lime and powdered lime will be established on peanut crop quality (fullness of the seed in the shell) and the crop yield of peanuts. Recommendations regarding the use of powdered and pelletised lime in obtaining good crop yields, crop quality and the management of acidic soil will be given to the farming community in Richards Bay.

Chapter Two - Literature Review

This chapter will outline the fundamentals and pillars of food security. Thereafter, the effects of global warming on food security will be discussed and the impact of product innovation on quality management in agriculture will be discussed. In addition, the impact of acidic soil on crop quality and crop yield will be presented, and the solutions available to treat these acidic soils will be ascertained.

2.1 Food Security

Food security as described by Berry, Dernini, Burlingame, Meybeck and Conforti (2015) as "the availability, at all times of adequate world food supply of basic foods to sustain the expansion of food consumption and to offset fluctuations in production and prices". Therefore "food security exists when individuals and households at all levels; nationally, regionally and globally at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Aborisade and Bach (2014) contended that food security is leaning on four pillars, that is, the availability of food, access to food, utilisation of food and stability of food supply.

2.1.1 Pillar 1: Availability of Food

Berry *et al. (*2015) professed that on a national level, the combination of commercial food production, domestic food production and food imports contribute to the availability of food. Hence, for the availability of food to be present within a food security system, each contributor must be committed to an optimised food production output. Aborisade and Bach (2014) submitted that the restricted availability of food forces an imbalance to a sustainable food security system. A factor according to them, which restricts food availability is an increase in population.

Furthermore, in recent years, increased urbanisation has placed constraints on land and contributed to an increase in soil pollution. Soil pollution is a result of an increase in urban air pollution levels and waste disposal, which affects the acid deposition of the soil. Consequently, the soil pollution will cause a decrease in crop yields and create a deficit in the availability of food (Lu, Song, Wang, Liu, Meng, Sweetman, Jenkins, Ferrier, Li, Luo and Wang 2015). According to Aborisade and Bach (2014), temperature changes, emission of greenhouse gases, the increase of carbon dioxide concentration and soil degradation will further decrease crop production yields. According to Doran and Zeiss (2000), natural resources such as water, land and soil quality are the basic requirements to ensure a successful agricultural output. Aborisade and Bach (2014) found that the availability, access to and quality of these resources are being negatively affected. Therefore, it can be gleaned from the factors discussed that food availability is at risk. The treatment of soil with agricultural products could assist in producing quality crops with an optimum yield. However, the mechanistic understanding and acceptable dosage levels of these products need to be present to ensure the conservation of the soil matrix for further agricultural use.

2.1.2 Pillar 2: Access to Food

Tusiime, Renard and Smets (2013) and Aborisade and Bach (2014) agreed that the availability of food alone does not result in individuals having access to it. A factor such as food price is directly related to access of food to the masses, and if prices are exorbitant, it forms a barrier to access. Therefore, coupled with high food prices, households must have sufficient income to ensure their buying power meets their daily dietary needs. According to Bold and Harris (2018), the rate of unemployment in South Africa is high, with approximately 66% of the population falling under the long-term unemployment category.

Furthermore, according to Mahadea and Kaseeram (2018), 34% of the qualified working class in South Africa are unemployed, and this is below global standards. In addition, youth unemployment is at an all-time high of 53%. Furthermore, jobs are being lost due to business closures within South Africa. Therefore, the average consumer’s income is constrained, placing their buying power at risk. According to Aborisade and Bach (2014), the factors that affect food prices are transport and the price of raw materials such as soil treatments and water. Batuo, Mlambo and Asongu

(2018) found that inflation is causing increases in product prices, and the cost of manufacturing is increasing.

Furthermore, they described South Africa as a country that is financially unstable. In addition, the gross domestic product (GDP) is declining further into the negative indexes since 2010. Due to the economic struggle, it is becoming more difficult for the masses of citizens to afford proper nutritious food. Baiphethi and Jacobs (2009) found subsistence farming as a solution to overcome the restricted access to food due to economic constraints in South Africa. However, individuals need to be aware of agricultural methods and products available to optimally produce crops to meet their daily dietary needs. Therefore, it can be said that the current increase in unemployment within South Africa cannot be ignored. Hence, this research not only hopes to assist the farming arena with practical evidence of soil amendment techniques to produce optimal crops but also to assist the unemployed masses of citizens to gain insight into the agricultural arena and assist them with knowledge so that they can potentially create an income from farming.

2.1.3 Pillar 3: Utilisation of Food

Misselhom, Aggarwal, Ericksen, Gregory, Phathanothai, Ingram and Wiebe (2012) submitted that in 2012, one billion individuals were starving while another one billion were malnourished. Similarly, Roberts (2008) claimed that there is a strong correlation between obesity and food insecurity from improper utilisation of food. Consequently, billions of people are overweight or obese, yet they are regarded as being malnourished. In response, Aborisade and Bach (2014) acknowledged that individuals may have access to and the availability of nutritious food but instead choose an unhealthy diet, which negatively affects proper utilisation within a food security system. Therefore, even when availability of food is present, an individual needs to make sure they choose the correct diet to provide their body with proper nutrition. For this to occur, individuals need to be knowledgeable about nutrition and the impact their dietary choices has on the body. In addition, the health of an individual plays a role in their utilisation of food. Therefore, the human body must allow for optimum absorption and metabolism of vitamins and nutrients. A condition like mal-absorption reduces the optimal utilisation of fats and carbohydrates in the human body. Therefore, adequate healthcare needs to be available within a successful food security system to ensure that the mechanism of the human body is processing food optimally to result in proper nutrition. Picchioni, Aleksandrowicz, Bruce, Cuevas, Dominiguez-Salas, Jia and Tak (2016) acknowledged that there is an intimate connection between agriculture, nutrition and health. In the past, the roles of the agricultural sector and healthcare have been treated as separate entities. However this mind-set is changing, the interrelation between these two entities and has forced a collaboration between them to ensure proper utilisation of food and for optimal quality crops to be produced to support human consumption demands. Therefore, for the human population to be fed and adequately nourished, an agricultural system needs to be supported by optimised and quality farming practices to produce food to at least meet the minimum dietary demand. This research, therefore, aims to enlighten the agricultural sector on products available to possibly assist in optimally producing quality crops.

2.1.4 Pillar 4: Stability of Food Supply

In accordance with Berry *et al.* (2015), to ensure stability within a food security system, quality food must be supplied at a constant rate meeting household demands. Aborisade and Bach (2014) professed that for stability to be met in a food security system, factors such as economic power, income of households and availability of food must be present within the food supply and demand chain. In addition, factors such as price volatility, conflicts in a country, epidemics and natural disasters negatively affect the stability of food security. However, a solution to the aforementioned problems can be minimised with proper agricultural education of producers, government and households which could encourage farming on a self-sustaining level. However, for ecological progress to be met, participation from government, producers and households must occur coherently. This will result in optimal agricultural output. As a result, crop wastage can be reduced; and more quality goods will be made available, thus ensuring sustainability.

Hanson (2013), Berry *et al. (*2015) and Owusu and Asumadu-Sarkodie (2016) affirmed that the sustainability of food supply could be viewed as the fifth pillar to food security. Sustainability is a precondition for the longevity of a food security system. For sustainability to occur, people need to be aware of their role and actions towards the conservation of the environment, natural resources and the impact of climate change. Consequently, the availability of food, preservation of biodiversity, economic and social sustainability will occur naturally. Furthermore, the accessibility of food to individuals will become evident. In addition, social and economic sustainability will positively attribute to proper utilisation of food. According to Berry *et al.* (2015), the interdependence of sustainability to food security and its effect on various sectors is depicted in Figure 2.1:

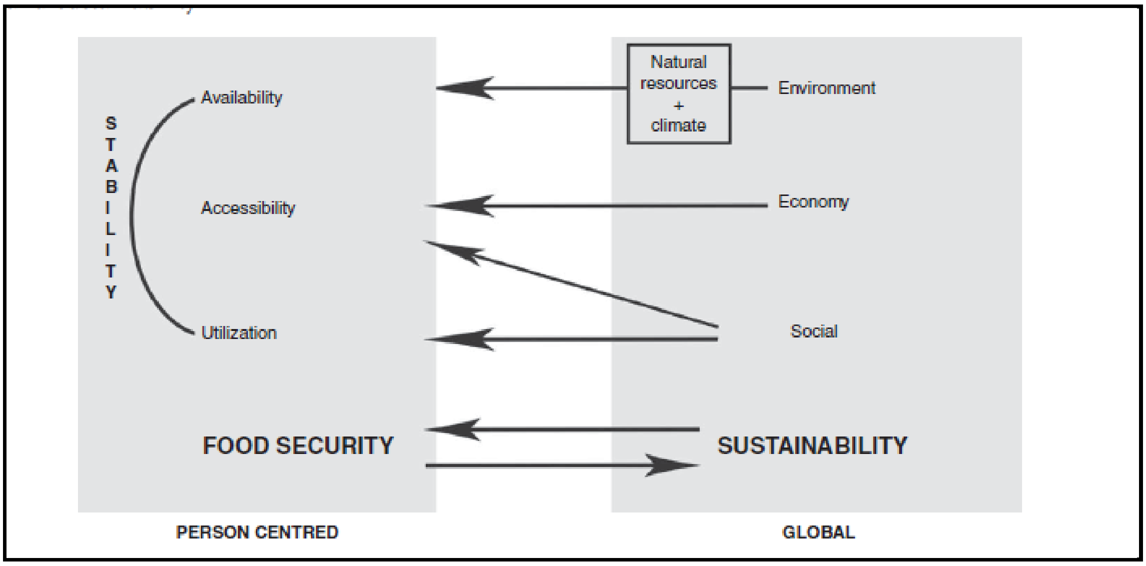

Figure 2.1 The interrelationships between food security and sustainability (Adopted from Berry *et al.* 2015)

From Figure 2.1 it can be seen that the relationship between natural resources, climate and the condition of the environment not only impacts on the sustainability of a global food security system but also has a ripple effect on every individual.

With the pillars of food security being discussed, it is evident that food security systems must inter-link with agricultural practices. Likewise Brown, Popp and Miller (2016) share the same ethos, stating that for optimised food security to occur an inextricable link to optimised agricultural practices is needed to eradicate world hunger, to ensure food security, eliminate malnutrition and to ensure agricultural sustainability. Similarly, Misselhom *et al.* (2012) claimed that optimum food production is needed to reduce global food insecurity. Therefore, to ensure the sustainability of food supply, the world's agricultural approach must be to produce food for an exponentially growing population coherently. Vaneck, Jones and Drinkwater (2016) acknowledge that the global aim of farming must be to enhance human nutrition and not jeopardise future agricultural productivity and this can only be done by responsible and sustainable agricultural practices. Therefore, there must be a long term vision of eradicating food insecurity where farming practices need to ensure the conservation of soil and resources. Hence, knowledge of sustainable farming practices amongst all stakeholders is required.

Capone *et al*. (2014) and Chauhan, Mahajan, Randhawa, Singh and Kang (2014) stated that the predicted growth of the world's population would place further pressures on agricultural systems. An innovative approach needs to occur in the agricultural arena to combat the effects of environmental stresses on agricultural output. Hence, this study will assist in bringing forth a new product which could assist in soil pH neutralisation thus transferring, knowledge onto the farming arena to achieving optimal crop quality and yield.

2.2 Product Innovation and the Link to Quality Management in Agriculture

Maistry, Hurreeram and Ramessur (2017) highlighted that there is a positive relationship between total quality management (TQM), innovation and performance. An optimised quality management system is required to enhance service delivery. Kormelinck and Bijman (2016) pronounced that an integrated quality solution is required in the agricultural sector so that food safety and quality standards are met. In response, Clancy and Moschini (2017) advocate that innovation of agricultural products contribute to precision farming to optimise crop quality and yield. However, for innovation to occur organisations, institutions and stakeholders must work together to ensure the production of optimised products that will allow opportunities for development in the farming arena. Padel, Vaarst and Zaralis (2017) submitted that innovation and agriculture are intertwined and this has been forced due to the effects of climate change and the lack of geographic resources. In addition, innovation assists in combating challenges like food security, climate change and conservation of natural resources and soil quality. As a result, Clancy and Moschini (2017) validate that innovation positively affects the ecosystem by enforcing advancements in farming management practices. Hence, for agricultural health to be obtained and maintained, product innovation is required. Therefore, this study will provide a comparison between an older soil pH amendment technique and a new one.

2.3 Global Warming and the Effects on Food Security

Global warming is a term used to describe the change in climatic conditions that is said to be induced by the increasing amounts of greenhouse gases emitted into the atmosphere. These gases consist of carbon dioxide, methane, nitrous oxide and halocarbons that trap heat near the earth's surface, (Kelly and Garnich, 2013).

Arndt, Farmer, Strzepek and Thurlow (2012) described the effects of climate change as pervasive and of serious concern in the world. Furthermore, Chauhan *et al.* (2014) and Aggarwal, Vyas, Thornton, Campbell and Kropff (2019) submitted that climate change would impact the productivity of agriculture significantly, and currently the livelihood of many countries is at risk due to the economic and social reliance on agricultural output. Wheeler and Von Braun (2013) mentioned that climate change negatively affects the progression of the global fight against hunger. This is because climate change negatively impacts crop productivity thus hindering food availability and affecting the progression of the global fight against hunger. Nelson, Van Der Mensbrugghe, Ahammad, Blanc, Calvin, Hasegawa, Havlik, Heyhoe, Kyle, Lotze-Campen and Von Lampe (2014) found the agricultural factors impacted by climate change, such as temperature, light availability to the plant and water quality affect the quality of agricultural produce.

Arndt *et al*. (2012) highlighted that there is an economic reliance on rain-fed agriculture, which makes developing countries vulnerable to climate change. Furthermore, the negative effects of climate change are said to be more prevalent in developing countries because food availability is already constrained. In addition, Chauhan *et al.* (2014) found that rainfall has become erratic. This resonates in Dai (2013) who found that insufficient rainfall has affected the land moisture level, which placed the livelihood of trees or woody plants at risk. In addition soil moisture, drought indices and precipitation-minus evaporation suggest a potential risk in the 21st century. Furthermore, insufficient rainfall and moisture loss are predicted to be widespread and severe in the next 30 to 90 years. Moreover Rosenzweig, Elliott, Deryng, Ruane, Müller, Arneth, Boote, Folberth, Glotter, Khabarov and Neumann (2014) confirmed that the drought experienced in 2012 resulted in a 25% reduction in maize growth in the United States. Chauhan *et al.* (2014) expressed that global surface air temperatures will increase by 4.0–5.8°C in the next few decades. In addition, Deryng, Conway, Ramankutty, Price and Warren (2014) illustrated that extreme heat stresses caused by global warming are projected to negatively impact on crop yield, thus making global food production insecure. In addition, impacts of extreme heat stress will result in a decrease in the yield of maize, spring wheat and soybean. Furthermore, Porter, Xie, Challinor, Cochrane, Howden, Iqbal, Lobell, Travasso, Field, Barros and Dokken (2014) claimed that the impact of global warming would negatively affect soil properties and result in soil erosion. There is a need to build resistance of soils to extreme heat stresses and rainfall variability. Furthermore, climate change will impact on the soil, carbon and nitrogen holding. Chauhan *et al.* (2014) expressed that climate change could cause more pests and insects, which will negatively affect crop survival rates. Rosenzweig *et al.* (2014) asserted that greenhouse gas emissions, global climate change and assumptions made about agricultural management expose agricultural security at risk. The impact of climate change and global warming on agriculture is illustrated in Figure 2.2.

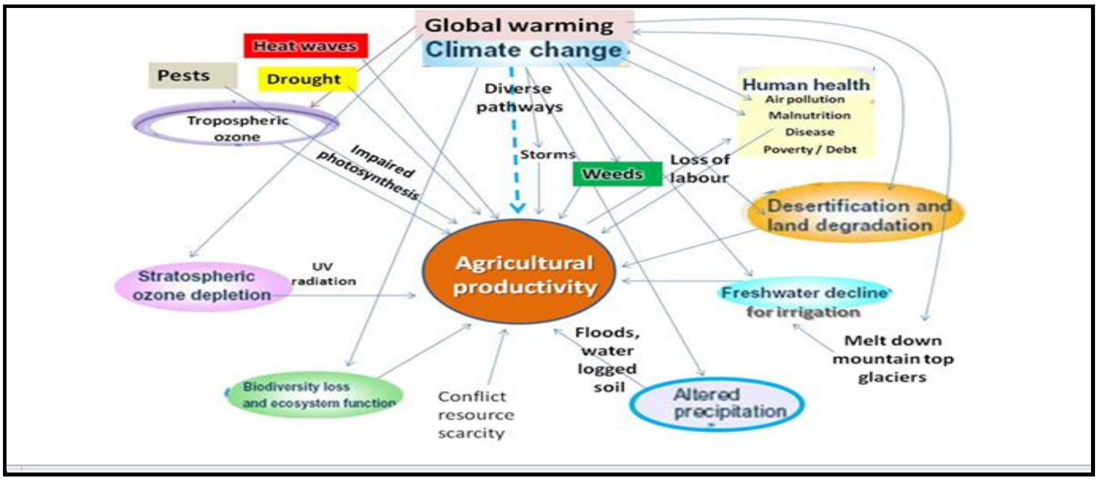

Figure 2.2 Impact of global warming on agriculture

(Sourced from www.climatechange foodsecurity.org 2017) (Accessed: 06 June 2017)

Figure 2.2 shows that global warming has a direct negative impact on agricultural productivity. Human health will be negatively affected due to air pollution and diseases of the human population which will result in a loss in labour and consequently, poverty and debt of the population.

Furthermore, according to Rosenzweig *et al*. (2014), due to global warming the quality of soil and natural resources will be further strained as pests, floods, melting of mountain top glaciers and water logged soils due to flooding and soil water deprivation due to droughts will be evident. The ecosystem is at risk due to the negative impact of global warming, placing the livelihoods of all living organisms at risk.

From the preceding section and Figure 2.2, it can be inferred that the effects of global warming, climate change and environmental pressures will negatively affect agricultural output and food security going forward. Therefore, this study hopes to assist in addressing soil quality issues by a comparative investigation of a newer soil amendment product to the older technique used in the hopes of increasing crop yield, crop quality and sustaining soil quality.

2.4 Soil Quality and Acidic Soil

Soil quality impacts on the nutrition of animals and humans and provides the functionality of the ecosystem (Harris, Karlen and Mulla, 1996). Holland, Bennett, Newton, White, McKenzie, George, Pakeman, Bailey, Fornara and Hayes (2018) and Holland, White, Glendining, Goulding and McGrath (2019) claimed that fertile soil is prudent in the ability to achieve food security. However, soil degradation, particularly soil acidity, is worsened by poor agricultural management. Similarly, Zornoza, Acosta, Bastida, Dominguez, Toledo and Faz (2015) claimed that poor management practices in agriculture and unsustainable land use negatively impact soil quality. Consequently, the ecosystem, agricultural productivity and human health are also negatively affected. Figure 2.3 depicts the interconnection between management practices and decision making on soil quality which affects agricultural productivity, human health and optimal functioning of the ecosystem.

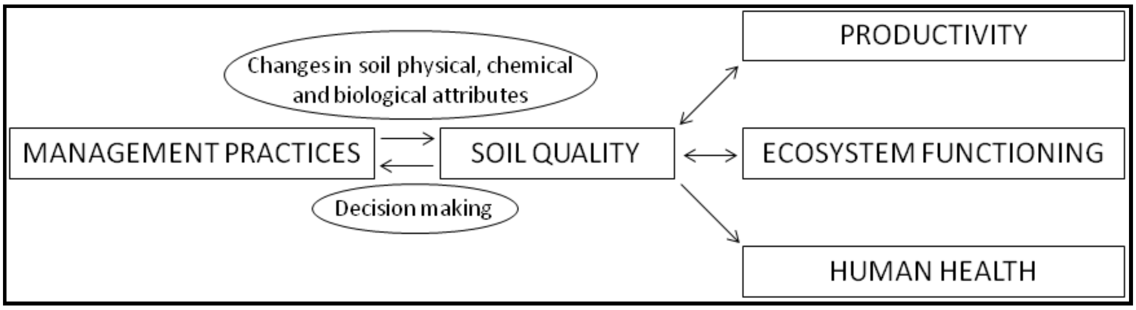

Figure 2.3 Interconnection between management practices, soil quality, productivity, environmental functions and soil health

(Adopted from Zornoza *et al*. 2015)

According to Zornoza *et al.* (2015), poor agricultural management decisions lead to exhausting nutrients and organic matter in the soil, which could lead to soil acidification. It can be seen in Figure 2.3 that if soil quality is compromised, human health and the ecosystem will be compromised. Therefore, soil quality issues, for example, soil acidity needs to be managed, and for this to occur the mechanism of soil acidity needs to be understood. According to Fageria and Nascente (2014), acidic soil is caused by the following:

- Leaching of bases in the soil;
- Acidic deposition from the atmosphere;
- Use of ammoniac fertilisers;
- Proton generation in the soil due to acid rain;
- Plant induced processes that affect soil structure through root penetration, water extraction, anchorage and exudation of compounds;
- Nitrogen fixation;
- Mineralisation of organic matter; and
- Reduction and oxidation of sulphates from pyrite contained in the soil.

Sime and Hill (2001) described soil pH as the concentration of hydrogen ions (H+) or the amount H^+ to hydroxyl (OH-) ions. Soil acidity is calculated by means of the pH scale: pH = - Log [H+]. Soil solutions containing equal concentrations of H^+ and OH^- ions are described as neutral and have a pH of 7.0. Where the concentration of H^+ ions is greater than that of the OH-, soils are said to be acidic and have pH values less than 7.0. When the concentrations of OH^- ions is greater than that of H+ ions soils are said to be alkaline and have pH values greater than 7.0. Bohn, Strawn and

O'Connor (2002) concluded that soil acidity is a concern as it affects approximately 30% of the world's soil.

Similarly, Behera and Shukla (2015) confirmed that a third of the world's soil is acidic with a pH < 6.5 and 50% of the acidic land still being used for growing unresponsive crops which are wasted. Ai, Liang, Sun, He, Tang, Yang, Zhou and Wang (2015) claimed that acidic soil is a non-productive environment; thus, previously these types of lands were abandoned. Therefore, due to the increase in the demand for agricultural produce, acidic lands need to be used now.

Soil acidification in terrestrial ecosystems has accelerated mainly due to nitrogen deposition from the burning of fossil fuels and use of nitrogen rich fertilisers (Penuelas, Poulter, Sardans, Ciais, Van Der Velde, Bopp, Boucher, Godderis, Hinsinger, Llusia, and Nardin, 2013). Similarly, Tian and Niu (2015) found that on a global level, the soil has been exposed to 50 kg ha^{-1} nitrogen (N) deposition in the period between 2000 and 2010. Hence, small additions of nitrogen can stimulate growth in plants; however, excessive loading results in nitrate loss and base cation reduction. The base cation [calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), sodium (Na^{+})] depletion contributes to soil acidification. Similarly, Simanský and Polláková (2014) found that organic matter in the soil is beneficial in limiting acidification. Furthermore, Lucas, Klaminder, Futter, Bishop, Egnell, Laudon and Hogberg (2011) and Tian and Niu (2015) found that the ammonium ion (NH^{4+}) and ammonia anion (NO^{3-}) from N-fertilisers have different impacts on acidification. Therefore, NH^{4+} ions can displace base cations Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} causing them to adhere to soil surface therefore, reducing their buffering against acidification. Moreover, when an NH^{4+} ion is absorbed by plant roots, an (H^{+}) ion will be released into the soil causing soil acidification. The NO^{3-} anions lead to the loss of metal cations by their leaching based on the charged ions in the soil solutions. Furthermore, a meta-analysis study revealed that nitrogen addition had reduced soil base cations.

In agreement Gazey and Davies (2009), Joris, Caires, Bini, Scharr and Haliski (2012), Liang, Pineros, Tian, Yao, Sun, Liu, Shaff, Coluccio, Kochian and Liao (2013) and Dixon, Strik, Fernandez-Salvador and DeVetter (2019) found that soil acidity decreased plant growth by causing deficiencies in the availability of the major plant nutrients such as phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg) and also the trace element molybdenum. Moreover, acidic soil causes toxicities of aluminium (Al), manganese (Mn) and hydrogen ions (H). Together with acidic soil, aluminium and low phosphorus contents are often coexistent severely inhibiting world crop production. Furthermore, acidity causes irregular distributions throughout the soil, thus plant roots are subjected to different levels of pH, aluminium toxicity, and phosphorus availability during their growth. Acidic soils contain a low concentration of cations and toxic levels of aluminium which negatively affect root growth, water absorption and nutrient uptake. Auxtero, Madiera and Parker (2012) also found that soil acidity from the hydrolysis of Al is a constraint on crop growth. Hydrolysis of Al in soil is normally found in soil of pH 5 and below, which are susceptible to hydrolytic by-products such as high concentrations of Al species of different bioavailability and bio-toxicity. In these acidic systems, the monomeric species, mainly Al^{+3}, Al $(OH)^{+2}$, and $Al(OH^{)+2}$ may form in the soil structure and limit root growth. In their abundance, many crops are negatively impacted by their phytotoxic effect. Thus due to the hindrance on the root growth, the plant is restricted to a particular soil volume and cannot penetrate other areas to make up for reduced nutrients and access to water. Hence, crop yields are reduced, causing vulnerability to agricultural security. Figure 2.4 shows the effect of soil pH on nutrient availability to a plant.

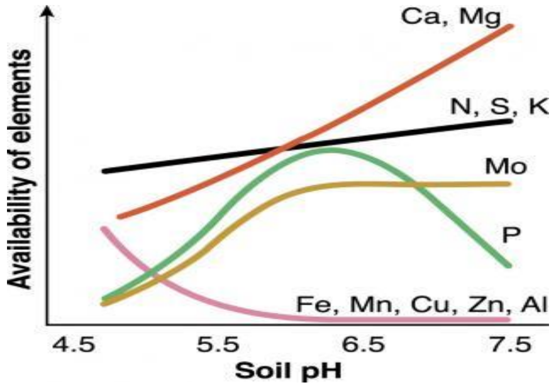

Figure 2.4 The relationship between soil pH and nutrient availability.

(Adopted from Gazey and Davies 2009)

Using Figure 2.4, it can be seen that when pH decreases the availability of key elements such as Ca^{2+}, Mg^{2+}, K^+ and Na^+ are hindered, which affects the nutrient availability to the plant. As pH rises the availability of (Ca^{2+}, Mg^{2+}, K^+, Na^+) increases and the availability of (Al, copper (Cu), zinc (Zn), Mn and iron (Fe)) decreases. By the availability of Al, Cu, Zn, Mn and Fe being reduced the root of the plant is not restricted; hence, creating a better mechanism for nutrient transfer to the plant.

Figure 2.5 Size of peanuts grown by a local farmer versus peanuts grown in acidic soil

The peanut on the right in Figure 2.5 was grown in acidic soil, at pH 4.7. The peanut on the left is from the local farmer who neutralises the acidic soil with lime. The size of the peanut grown in acidic soil was smaller than the peanut grown in controlled soil conditions.

Figure 2.6 Quality of peanuts grown by a local farmer versus peanuts grown in acidic soil

The peanut in Figure 2.6 on the top is from the local farmer who neutralises the acidic soil with the addition of lime, and the peanut at the bottom was grown in acidic soil, of pH 4.7. The quality and fullness of the shell of the peanut grown in acidic soil are inferior compared to the peanut grown by the farmer under controlled soil pH conditions. Therefore, it can be deduced that acidic soil does inhibit the growth of peanuts. Furthermore, the fullness of the shell, quality and size of the peanut is inhibited by acidic soil. In essence, acidic soil is not a productive medium for crop quality and crop yield; hence, this study will address the products available to control acidic soil adequately.

2.5 Soil Condition in Northern KZN, Richards Bay

Scheepers (2014) described Richards Bay as a sub-tropical climate with warm, wet summers. Therefore, the soils in this region are naturally acidic. Due to the acidic nature, the soil has low nutrient reserves, but it also has a high nutrient turnover, thus allowing for the soil to be a highly productive medium if properly treated. Therefore, this study made use of the acidic nature of Richards Bay soil and tested the effectiveness of selected products available in pH neutralisation.

2.6 Lime and its effects on acidic soil

Dracup and Belford (1993) claimed that acidic soil did not negatively impact crop yields, and the use of lime showed no benefits as crops of wheat and lupine grew optimally where the soil was most acidic. Furthermore, before lime application, surface soil pH was found to be between 4.3 and 4.9 at which crops grew best. However, Shazana, Shamshuddin, Fauziah and Syed Omar (2013) pronounced that acidic soils will have low productivity unless treated using appropriate products. In agreement, Shazana *et al.* (2013) and Anderson *et al.* (2013) confirmed that lime is an effective product to increase soil pH, precipitate active aluminium and iron. Anderson *et al*. (2013) described liming materials as providing necessary oxides, hydroxides, carbonates, and silicates of Ca and/or Mg to the soil. According to Ritchey *et al*. (2016), the most used form is agricultural lime which uses a carbonate as a basic medium. The anion in liming materials serves as a basic medium which reacts with soil acidity (H) to neutralise it. The effect of a carbonate limestone on acidic soil is shown in Figure 2.7.

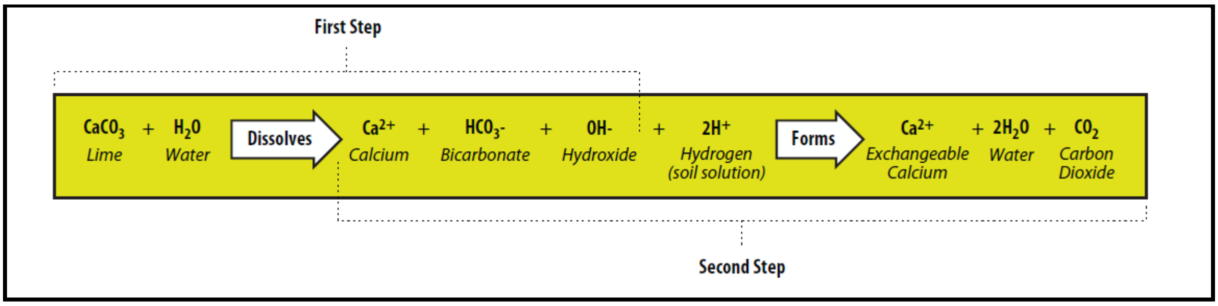

Figure 2.7 Reaction of lime on acidic soil

(Adopted from Ritchey *et al*. 2016)

According to Figure 2.7, the limestone dissolves to create calcium, bicarbonate, and hydroxide ions. The hydrogen ions combine with the hydroxide to form water. The decrease in the concentration of hydrogen ions will cause an increase in pH. Therefore, this reaction is important in understanding the mechanistic action of a carbonate lime and its effect on acidic soil. The impact of a carbonate lime on soil pH is shown in Figure 2.8.

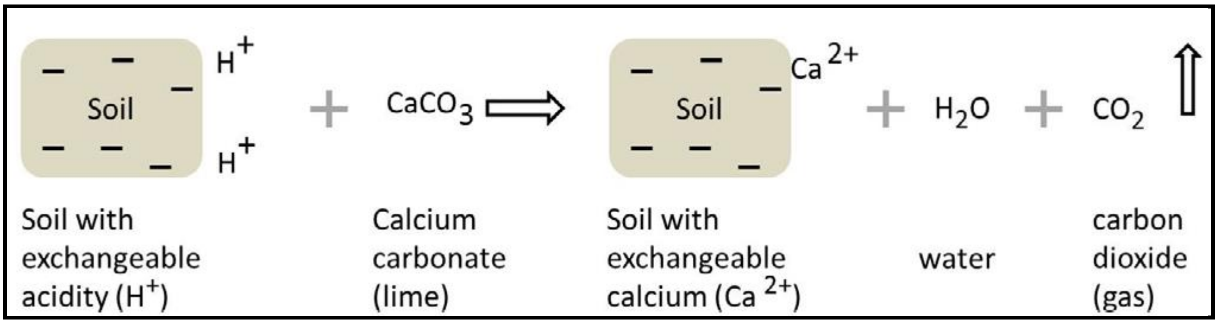

Figure 2.8 Reaction of acidic soil with lime to form water and carbon dioxide (Adopted from Anderson *et al.* 2013)

It can be deduced from Figure 2.8 that adding lime to acidic soil extracts the hydrogen (H^+) from the soil cation exchange capacity and replaces the H^+ with a basic cation such as calcium (Ca^{+2}) and this aids root development. Furthermore, the addition of lime assists in adjusting pH on acidic soils which is required for good crop yields, weed control and sustained soil health.

In their efforts, Holland *et al*. (2018) confirmed in Table 2.1 that liming impacts the soil nutrient process, the availability of minerals and restriction of toxic elements. As a result, lime not only decreases soil pH but assists in the biological and biochemical activity, mineralisation of organic elements, chemical absorption, precipitation reactions and facilitating uptake of nutrients within the plant and soil system. In addition, lime adds Ca and $CaCO_3$, which impacts on biological availability and facilitate the use of both cationic (Mg, K) and anionic (P) elements. As a result, the lime activates the soil buffering process by balancing the exchange of cations and the dissolution of Al^{3+}, Mn^{2+} and Fe^{3+}. Therefore, it can be seen that lime is a complex agent which impacts on a wide series of simultaneous effects and subsequent changes to soil chemistry. According to Shazana *et al.* (2013), lime affects soil pH but also has an effect on the soil nutrient exchangeability, consequently affecting the plant's health. The impact of lime in soil and nutrient activity is shown in Table 2.1.

Table 2.1 The impact of lime on soil macronutrients, trace elements and heavy metals

(Adapted from Holland *et al*. 2018)

Nutrient /Element	Effect on the soil exchange process
Phosphorus (P)	• Increased organic P mineralisation • Increased risk of P loss • Changes to the plant available P
Potassium (K)	• Increased K adsorption • Increased risk of K deficiency
Sulphur (S)	• Increased SO_4^{2-} mineralisation • Increased SO_4^{2-} immobilisation • Greater release of SO_4^{2-} and more risk of S loss
Calicum (Ca)	• Increased Ca in the soil solution
Trace Elements	• Increased adsorption of Boron(B), Copper(Cu), Cobalt(Co) and Zinc(Zn) • Increased Selenium(Se) availability
Heavy Metals	• Increased Cadmium(Cd) immobilisation • Increased plant uptake of Manganese(Mn), Cadmium(Cd), Nickel(Ni) and Lead (Pb) • Increased risk of heavy metal leaching

It can be seen in Table 2.1 that the addition of lime to soil affects soil macronutrient availability and positively affects the soil exchange process. Therefore, it can be deduced that lime not only adjusts soil pH but allows for better adsorption of nutrients in the soil and then to the plant, thereby increasing plant nutrient uptake and reducing nutrient deficiencies. Shazana *et al.* (2013) and Anderson *et al.* (2013) also reported that lime has the added benefit of improving calcium nutrition in crops, as well as neutralising the soil pH, which increases phosphorus availability. Haynes (1982) found that phosphorus (P) is often considered the most important nutrient for crops. Subsequently, Holland *et al.* (2018) found that lime can increase the availability of P due to mineralisation of the soil organic P and by the amelioration of (Al) toxicity which enhances root growth.

Similarly, Scanlan, Brennan and Sarre (2015) showed that where lime was applied, plant uptake of (P) increased. Even though phosphorus is low in acidic soil, the addition of phosphorus only (20 Kg ha^{-1}) resulted in only a marginally increased yield as opposed to adding lime as well. This proves that even when phosphorus is readily available in the soil if the pH is low, it will not allow for absorption of (P). Therefore, lime will not only raise the pH of the soil but will increase the availability and absorption of phosphorus. In an investigation conducted by Auxtero, Madiera and Parker (2012) application of lime significantly increased the activity and total concentration of (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) ions, as well as reduced the (Fe^{3+}, Cu^{2+},Mn^{2+} , Zn^{2+} and Al^{3+}) ions, and the soluble complexes of the Al in the soil solution. The activeness of the monomeric Al species was lower than the soils untreated with lime. Therefore, root growth will be jeopardised and nutrients will not efficiently reach the plant. Application of 2 ton $CaCO_3$ ha^{-1} corresponded with lowering the Al levels; however, not below the desired threshold. However an application of 6 ton $CaCO_3$ ha^{-1} showed a favourable outcome to balancing the total ion concentrations, thus resulting in optimal crop yields.

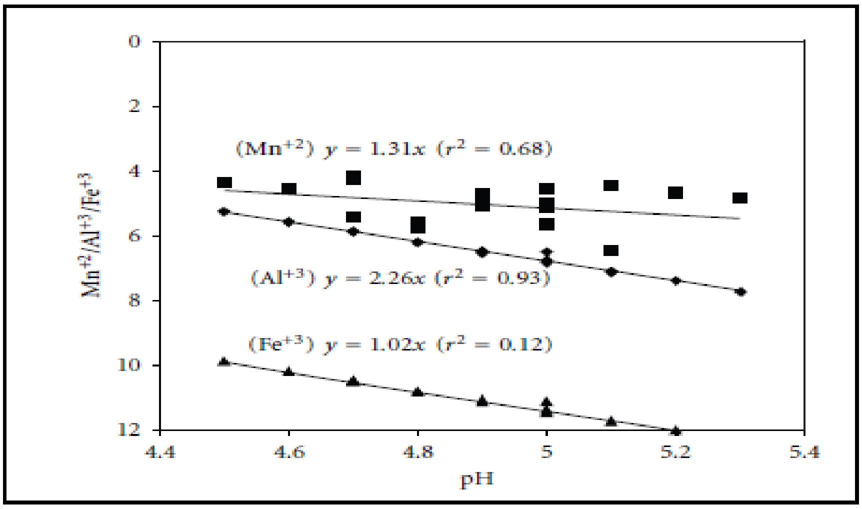

Figure 2.9 Concentration of Mn^{+2}, Fe^{+3}, and Al^{+3}(−log) in soil solution in relation to pH of limed soils

(Adopted from by Auxtero, Madiera and Parker 2012)

It can be seen in Figure 2.9 that the application of lime significantly reduced the Fe^{3+}, Mn^{2+} and Al^{3+} ions in the soil solution and therefore, reducing toxicity within the plant and allowing for optimum nutrient transfer. Van Zwieten, Rose, Herridge, Kimber, Rust, Cowie and Morris (2015) confirmed that acidic soils limit legume growth. An investigation was conducted in a sub-tropical field with the attempt of cultivating faba bean (*Vicia faba* L.) in conjunction with corn (*Zea mays*) subsequent to the treatment of compost and lime. The result was that the corn yield in the unfertilised areas showed no change from prior years. The fields where compost was added, also showed no positive impact on crop yield. However, with the addition of lime with the compost, yields of corn increased significantly. The faba bean displayed the highest yield values when lime was added with the compost. Therefore, the addition of lime to acidic soil improves crop yield. According to Fageria and Nascente (2014), liming is required in correcting pH, and it also shows a benefit to increasing agricultural productivity. Furthermore, lime improves symbiotic nitrogen fixation within the soil, stimulating root growth. With the enhancement of the root growth, uptake of nutrients and water to the plant is enhanced. The impact of lime on root growth stimulation is shown in Figure 2.10.

Figure 2.10 Root growth in upland rice from lime treated soil versus untreated soil at two time intervals.

(Adopted from Fageria and Nascente 2014)

It can be gleaned From Figure 2.10 that post lime treatment of 2.5 grams lime per kg (g/kg^{-1}) on the soil, the rice root was longer and thicker as opposed to when no lime was added to the soil. This proves that under these conditions, lime stimulates root growth. Holland *et al.* (2018) found that most crops require a neutral pH to grow optimally, which was illustrated in Figure 2.11.

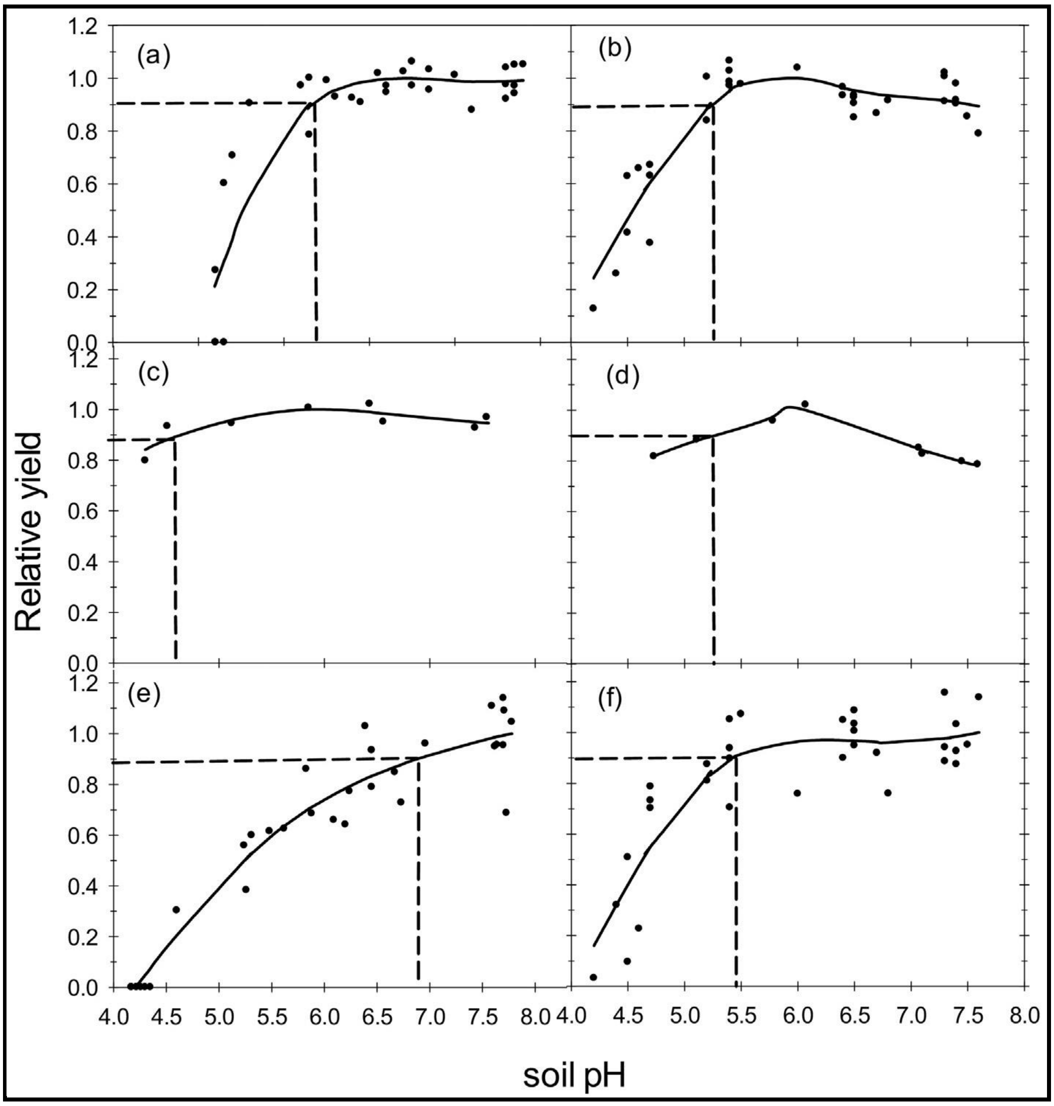

Figure 2.11 Crop yield-soil pH relationship

(a) Wheat A; (b) Wheat B; (c) Potatoes A; (d) Potatoes B; (e) Beans; (f) Oilseed rape

(Adopted from Holland *et al.* 2018)

It can be deduced from Figure 2.11 that the two wheat species together with the oilseed and beans showed a greater yield % at a higher pH, although a pH of > 8 could not show conclusive results. In addition, Holland *et al.* (2018) profess that the addition of lime to soil is important in restricting crop diseases which is soil-borne. Acidic soil tends to be more susceptible to crop diseases caused by fungi. This is because acidic soil affects nutrient availability, which changes the metabolic process within the plant, causing the defence mechanism to be compromised. The impact of lime on the soil processes and soil functioning is shown in Figure 2.12.

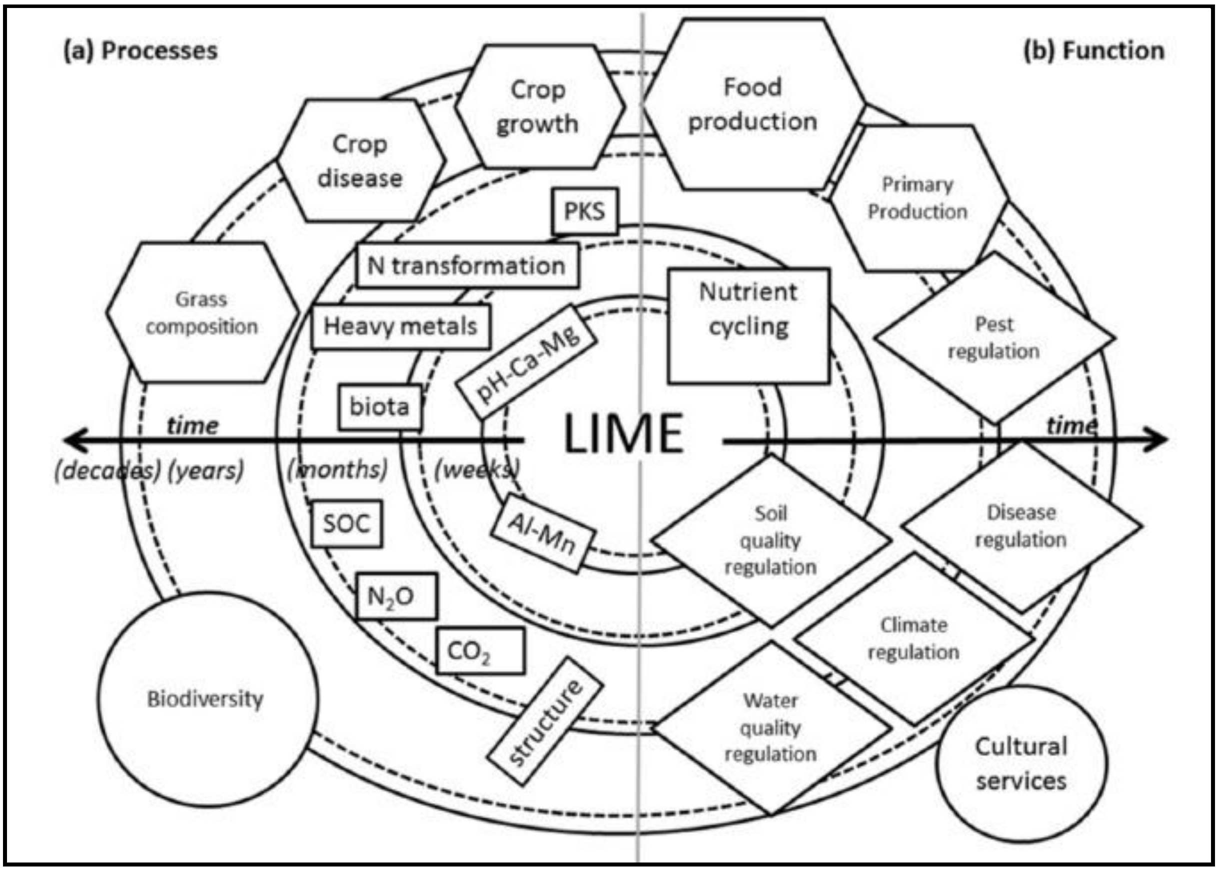

Figure 2.12 A qualitative framework of liming impacts for soils, crops and biodiversity with a chronological scale for (a) properties and processes, and (b) function (ecosystem services) within an agricultural ecosystem.

(Adopted from Holland *et al.* 2018*)*

It can be gleaned from the qualitative framework depicted in Figure 2.12, that liming has a significant impact on the functionality of soils and therefore affects crop growth and yield. Furthermore, the addition of lime enhances the physical process, as well as soil biology by impacting levels of phosphorus (P), potassium (K), sulphur (S), N transformations, heavy metals (HM), soil biota, soil organic carbon (SOC), nitrous oxide (N_2O), carbon dioxide (CO_2). Hence, the addition of lime to acidic soil enhances the soil ability to support plant growth. In addition, lime has an impact on disease control of crops and assists in achieving biodiversity, which inevitably impacts positively on the sustainability of the ecosystem. Kochian, Pineros, Liu and Magalhaes (2015) found that there is a need to understand acidic soil and the tolerance of varying crop species to it. In addition, a complementary strategy is needed to ensure sustainable agricultural production in acidic soils.

Moreover, Holland *et al.* (2018) confirmed that even though lime and its impact on acidic soil have been examined, a vast gap in knowledge remains. Therefore future research is needed to better illustrate the mechanistic understanding of lime on the soil at a process level and for a specific organism. Consequently, this study aimed to illustrate the impact of lime on acidic soil and pH neutralisation. The effect of lime on crop quality and yield of a single organism was, subsequently, ascertained.

2.7 Types of Lime

Ritchey *et al*. (2016) identified two types of limestone which can be used in the agricultural arena, namely calcites and dolomites. Calcite limestone is described as calcium carbonate, whereas a dolomitic limestone contains both calcium and magnesium carbonates. This study will make use of calcite limestone. The two forms of calcite limestone are pelletised and powdered.

2.7.1 Forms of Calcite Limestone

Calcite limestone can be found in two forms that is, granulated/pelletised calcium carbonate or a calcium carbonate powder.

Figure 2.13 Physical appearance of pelletised calcite lime

It can be seen in Figure 2.13 that pelletised lime is in the form of granules.

Figure 2.14 Physical appearance of powdered calcite lime

Powdered lime is an ultrafine powder as seen in Figure 2.14. Higgins, Morrison and Watson (2012) described pelletised lime as powdered lime fused into uniformly sized granules. Therefore, due to its granulated form spreading is more accurate, transportation easier, and with minimal dust exposure as opposed to the application of powdered lime, which due to its light weight, becomes airborne. Lignosulfonate serve as the binder in pelletised lime to create the granular form. The benefit of lignosulfonate is its ability to readily react with water. Theoretically, this should allow for pelletised lime to dissolve quickly and have an increased reaction rate on pH neutralisation. However, there is limited practical evidence currently on pelletised lime and its effects in comparison to powdered lime. Therefore, this research aimed to illustrate the effect of pelletised lime in comparison to powdered lime on acidic soil pH neutralisation and subsequently, the effect on crop yield and crop quality. To add on Mengel (2016) concluded that gypsum is required, in addition to lime, to enhance the effects of lime on soil, thus co-assisting in crop yield and quality.

2.8 Gypsum and its Role in Acidic Soil

Gypsum is a sulphate mineral containing calcium sulphate di-hydrate, with the chemical formula $CaSO_4\ 2H_2O$**.** Mengel (2016) claimed that gypsum is the resulting salt of a strong acid, which is illustrated in Figure 2.15:

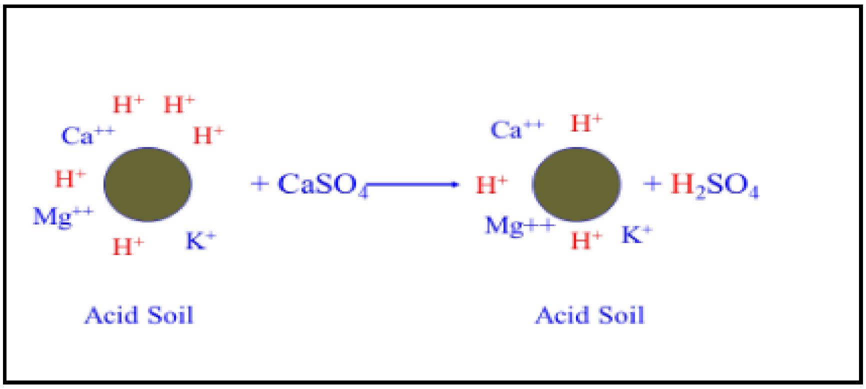

Figure 2.15 The reaction of gypsum on acidic soil

(Adopted from Mengel 2016)

It can be seen in Figure 2.15 that the acid dissolves to form (Ca^{+2}) and sulphate (SO_4^{-2}) in the soil solution. The calcium partially replaces the (H^+) ions resulting in sulphuric acid (H_2SO_4). When the reaction shown in Figure 2.15 occurs, there is no effect on soil pH, but gypsum offers the added calcium required for plant growth; however, neutralisation of the replaced exchangeable H^+ ions is needed. Hence, lime is added to adjust the pH. In an earlier study, Adams and Hartzog (1979) found that many months are needed for powdered lime to react with acidic soils; therefore, gypsum was added to peanut fields, in order to compensate for the calcium loss during this time. Anderson *et al*. (2013) maintain that calcium on its own does not affect soil pH. Even though gypsum contains calcium, the compound lacks a basic anion that is a carbonate, hydroxide, oxide, or silicate to affect soil pH. Hence, gypsum does not assist in soil pH neutralisation. With this said, both gypsum ($CaSO_4$ $2H_2O$) and a calcite lime ($CaCO_3$) is needed simultaneously in a soil matrix to combat acidity and to enhance mobility of nutrients within the plant Furthermore, gypsum acts as an additional calcium source, whilst the lime reacts to neutralise the soil.

Anderson *et al*. (2013) found that gypsum has the ability to reduce aluminium toxicity in acidic soils. Furthermore, the added benefit of gypsum is not only to supply calcium but also to supply sulphur to the soil and in turn to the plant. In addition, gypsum serves as a flocculating agent. Flocculation is the clumping/aggregation of soil particles which improves soil structure. Elements like (Ca^{2+}) and (Mg^{2+}) have more than one positive charge, and these elements hold the soil particles together in a stable form. A single charge ion like sodium (Na^+) causes the soil particles to separate. The flocculating power of calcium is the highest at 43 and magnesium is 27. Therefore, since gypsum is rich in calcium, its addition increases the flocculating power of the soil. If the soil has an inability to flocculate, this can cause soil erosion and nutrient loss due to particles not being held together. Poor flocculation contributes to poor infiltration, causing the soil to become water logged when it rains. It further causes cement-like distribution when the soil dries out, which makes it difficult for roots to penetrate through the soil due to crusting. In a study conducted by Anikwe, Eze and Ibudialo (2016) gypsum and lime were added to the soil, and the following results as shown in Table 2.2 were obtained.

Table 2.2 Results of adding gypsum and lime to acidic soil

(Adopted from Anikwe, Eze and Ibudialo 2016)

Treatment	pH (2013)	pH (2014)	Plant height (cm/plant) of cassava(2013)	Plant height (cm/plant) of cassava(2014)	Number of leaves per plant of cassava (2013)	Number of leaves per plant of cassava (2014)
Untreated soil	4.8	4.5	61.6	64	46.2	51.6
Lime 5000 kg/ha	5.7	5.4	61.9	66.0	48.2	56.4
Gypsum 2500 kg/ha	5.5	5.0	59.4	62.4	61.7	74
Lime 5000kg/ ha+ gypsum 2500 kg/ha	5.9	5.7	86.8	92.6	76	86.4

The results of the study in Table 2.2 proved that applying a combination of lime and gypsum to the soil positively influenced the growth and quality of the cassava. Anikwe, Eze and Ibudialo (2016) confirmed that due to the calcium (Ca) applied through the inherency of lime and gypsum, it encouraged flocculation in the soil particles; hence, allowing the soil to have a better nutrient uptake, enhanced infiltration, aeration, and increasing phosphorus availability. The application created an optimum pH range for plant growth. Furthermore, the study revealed that there was a reduction of aluminium (Al), manganese (Mn) and iron (Fe) toxicity. Therefore, the study concluded that lime and gypsum worked together as a catalyst to improve soil quality and in return, increasing the yield of the cassava. With this knowledge, it can be concluded that gypsum, together with lime, shows a more positive outcome in terms of crop yield than lime on its own. Hence, to effectively compare pelletised lime and powdered lime on crop yield and crop quality, gypsum was used. This will ensure that the comparisons of both forms of lime were monitored under optimal soil conditions.

2.9 Peanuts and their Response to Lime

Nwokolo and Smartt (1996) described peanuts (*Arachis hypogaea L)* as "one of nature's most nutritious seeds". Peanuts are one of the most universal crops harvested in nearly 100 countries. Peanuts are a popular and nutrient dense food, and thus, an understanding of its growth ability and quality in lime treated soils is needed (Nwokolo and Smartt, 1996).

According to Adams and Hartzog (1980), liming in acid soils of South Eastern United States of America has a history of improving peanut yields. In addition, Cope, Starling, Ivey and Mitchell (1984) found that peanut yields were reduced when lime was not addeda to the soil. Burkhart and Collins (1942) and Arnold (2014) concluded that calcium is the most limiting nutrient in the growth of peanuts. Calcium from lime is an active ingredient for soil treatment and enhances crop growth, as it establishes a medium for nutrients to be facilitated into the plant. Hence, decreased calcium levels in soil can reduce crop yield and peanut quality. Peanuts require high calcium concentration to ensure optimum germination rates. Therefore, calcium deficiency prevents the seedlings from developing beyond the early seedling stage. Calcium deficiency resulted in unfilled pods and increased rotting of the peanut in the pod. Thus peanut yield and quality decreased. Peanuts display their fruiting by exposure of a plant above ground, which continues below soil level where the fruit (the nut) develops. During the growth of the peanuts, the calcium is transported through the plant by the xylem, from the roots along the transpiration stream and is limited in the phloem tissue. Since the fruit, is underground it is unable to receive calcium from the plant. Hence, the fruit relies on the soil to make up for the deficit calcium. Therefore, it can be deduced that peanuts are reliant on calcium for its growth. According to Mengel (2016), lime and gypsum contain high levels of available calcium. Since this study is to conduct a comparative experiment between powdered and pelletised lime with the addition of gypsum and peanuts are reliant on calcium for its growth, peanuts will be used as the test species to monitor crop yield and crop quality.

2.10 Summary of the Chapter

This chapter identified that global warming has a significant impact on food security. Furthermore, acidic soil is also a major concern for optimised agricultural output. It also provided evidence that there are existing scientific gaps in knowledge in the farming arena to treating acidic soil sustainably and effectively. The addition of lime can assist in eradicating the issue of acidity in the soil. However, there lacks practical evidence on what form of lime is better suited for enhanced crop yield and crop quality.

Chapter Three – Research Design and Methodology

This chapter will outline the research design and methodological stance adopted in this study. The research paradigm, research approach and strategy used will be presented. Details of the apparatus and materials used will be given. The experimental-set up and procedure to the sampling of the soil and treatment will be presented. A pilot study will be conducted, which will deduce the optimised dosage range of pelletised lime and powdered lime together with gypsum that is needed for optimal peanut yield and peanut quality. Furthermore, the pilot study will show the pH neutralisation ability of pelletised lime, powdered lime and gypsum at various percentages. Validity and reliability of the quantitative work will be discussed.

3.1 Research Design

Research can be explained as the careful and systematic inquiry to which solutions to problems are found (Tan and Ko, 2004). With this said, there are six common types of research designs, which are case studies, experiments, surveys, correlation research, and casual comparative and historical research. It is recommended that each type of research needs to be examined for its strengths and weakness in obtaining the desired aim of a study and the researcher should use this knowledge to select the most appropriate design. This is supported by Arikunto (2006), who mentioned that experimental studies confirm the cause-effect relationship of the variables studied.

Similarly, Ary, Jacobs, Sorensen and Walker (2010) confirmed that experimental designs refer to the conceptual framework within which the experiment is conducted. Hence, the design needs to be appropriate for testing the hypothesis of the study. Therefore the design selected for this study was experimental as the aims are to provide a comparison between the effect of powdered and pelletised lime on soil pH neutralisation, crop yield and crop quality.

3.2 Research Methodology

According to Welman, Kruger and Mitchell (2005) and Berg and Latin (2008), various research methods create a basis for study. Examples of this are deductive reasoning, inductive reasoning, the scientific method of enquiry and critical thinking amongst others. Schutt and Check (2012) described deductive processes as being associated with quantitative research and inductive processes with qualitative research. Therefore, the basis for this study relied on observations and deductive reasoning (testing ideas against observations). Observation and deductive reasoning were integral to the initiation of this study. A comparative study between two lime forms was done to assist agricultural progression.

3.3 Methodological Paradigm to the Study

Singh and Naidoo (2012) stated that there are two techniques for conducting research; these are qualitative and quantitative. Qualitative research is when case studies, literature reviews and interviews are conducted to express the outcome of a research problem. In contrast, in quantitative techniques, numbers are used to create a comparative outcome of the research problem. Johnson and Christensen (2008) proclaimed that a quantitative approach tests “hypotheses with empirical data to see if they are supported”. Johnson and Christensen (2008) further maintaining that an experimental research strategy allows the researcher to change the independent variable and measure the dependent variable in order to “identify cause-and-effect relationships”.

According to Welman, Kruger and Mitchell (2005), experimental research involves a form of intervention on the units of analysis, which under normal conditions would not occur. The hypothesis is then expressed by the effect that the independent variable has on the dependent variable. It is this effect that is measured in experimental research. Hence, the extent of intervention (independent variable) is measured in accordance with the change it caused to the unit of analysis (dependent variable). This is illustrated in Figure 3.1.

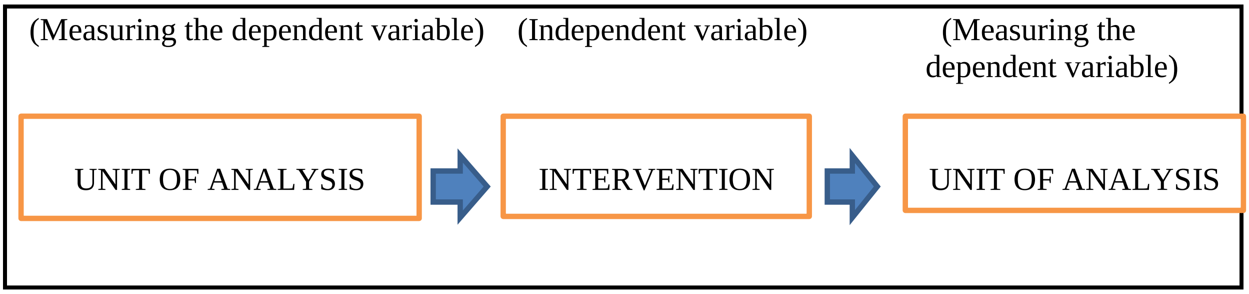

Figure 3.1 The effect of the independent variable (intervention) on the dependent variable (unit of analysis)

(Adopted from Welman, Kruger and Mitchell 2005)

As this study sought to provide a comparison between pelletised lime and powdered lime on soil pH neutralisation, crop yield and crop quality, a quantitative research design and an experimental research strategy were used. According to Ary *et al.* (2010), quantitative designs use a post-positive claim in the attempt to develop knowledge (determining the cause and effect relationship, testing specific variables and hypotheses) further using measurement and observation to test theories. Experiments on a pre-determined instrument are conducted to achieve this strategy of inquiry; hence, resulting in comparative statistical data. Therefore, this research used a pH meter to measure the soil pH pre and post lime addition. Sudijono (2005 cited in Creswell 2013) confirmed that the quantitative approach is primarily investigatory and uses a post-positive adaption to deduce knowledge, which is the cause and effect relationships, deductions of specific variables, use of measurements, observations and examinations of theories. The researcher should use one-group as a pre-test post-test methodology in quantitative designs, which involves three steps listed below (Ary *et al.* 2010).

- Administering a pre-test measuring the dependent variable
- Applying the experimental treatment X to the subject(s)
- Administering a post-test again measuring the dependent variable post-treatment

Once this is done, pre-test and post-test evaluations and differences should be evaluated. This is shown in Table 3.1.

Table 3.1 Design of Pre-Test and Post-Test

(Adopted from Ary *et al.* 2010)

Pre-test	Treatment	Post-test
Y I	X	Y 2

here :

X : Treatment

Y1 : Pre – test

Y2 : Post - test

The following design was adopted for this study using Table 3.1. Table 3.2 shows the design chosen to test the effect of powdered lime.

Table 3.2 Design of Pre-Test and Post-Test Powdered Lime Effect

Pre-test	Treatment	Post-Test
Original soil pH, crop yielded and crop quality	Powdered lime at different vol%	Soil pH , crop yielded and crop quality post treatment
Y1	X1	Y2,1

Using Table 3.2, the pre-test consists of monitoring soil pH of the untreated soil and determining the crop yield and crop quality resulting from the untreated soil. The post-test aimed to determine the effect on soil pH, crop yield and crop quality obtained from exposing the original soil to powdered lime at different vol%.

Table 3.3 shows the design chosen to test the effect of pelletised lime.

Table 3.3 Design of Pre-Test and Post-Test Pelletised Lime Effect

Pre-test	Treatment	Post-Test
Original soil pH, crop yielded and crop quality	Pelletised lime at different vol%	Soil pH , crop yielded and crop quality post treatment
Y1	X2	Y2,2

Using Table 3.3, the pre-test consists of monitoring soil pH of the untreated soil and determining the crop yield and crop quality resulting from the untreated soil. The post-test aim is to determine the effect on soil pH, crop yield and crop quality obtained from exposing the original soil to pelletised lime at different vol%.

Table 3.4 Design of Pre-Test and Post-Test Gypsum Effect

Pre-test	Treatment	Post-Test
Original soil pH, crop yielded and crop quality	Gypsum at different volume%	Soil pH , crop yielded and crop quality post treatment
Y1	X3	Y2,3

Table 3.4 shows the design chosen to test the effect of gypsum. Using Table 3.4, the pre-test consists of monitoring soil pH of the untreated soil and determining the crop yield and crop quality resulting from the untreated soil. The post-test aim is to

determine the effect on soil pH, crop yield and crop quality obtained from exposing the original soil to gypsum at different volume percent.

The proposed research design and methodology was adopted over a two-phase approach: Phase One – Pilot Study and Phase Two – Main Study.

3.4 Strategy Adopted for the Study

In accordance with the findings of Petersen (1994), in agricultural science, a fundamental tool for confirming or obtaining new data in research is to conduct a field experiment. The aim of this, according to Petersen (1994), is to develop new varieties or adding on information on current varieties to enhance yield ability, disease resistance and quality of crops. He further added that field experiments assist in the exploration of new technologies, new crops and new regions for agricultural output. In addition field studies are a requirement to enlighten farmers on newer products available with the support of practical evidence, thus enticing their participation in trying newer technologies and products. In addition, field studies assist with the understanding of what factors impact on crop production and allow flexibility in evaluating levels required for optimised crop yields and enhanced crop quality. Therefore, this study made use of a field study, which aimed to expose the crops and soils to environmental factors.

3.5 Experimental Error Measurement and Control

According to Petersen (1994), agronomy trials are examples of field studies. Examples of these trials extend to time, rate additions of soil amendment agents, plant density, tillage studies and pest and weed control studies, amongst others. In these studies, it is recommended that to measure and control experimental errors; the researcher should make use of replication techniques. Replication involves performing the same treatment methods and percentages on more than one plot at a time. Replication provides an estimate for experimental error as it provides an observation of several samples receiving the same treatment. Therefore variation amongst samples can be measured. Therefore, this study consisted of 10 replicate samples of each soil sample being treated with different concentrations of lime and crop growth enhancers (gypsum).

3.6 Materials and Methods

For both the pilot and main study, the following materials and instruments were used:

- pH Meter (HM Digital, PH2000 Waterproof Professional Series)
- 12cm planting pots
- Soil obtained from the Richards Bay Area
- Lime variants obtained from Idwala Industrial Holdings Pty(Ltd)
- Peanut seeds purchased from Bhagwan's Goods North Coast

3.7 Experimental Design

With reference to the OECD principle (2006), the experimental design for the pilot and main study was structured as follows:

- **Test Design**

The same species of peanuts were used for the entire study. To avoid overcrowding and to ensure adequate space was allowed for growth, a maximum plant density of three peanut seeds per $100cm^2$ pot was used. In the attempt to minimise variability, equal numbers of seeds were planted in each pot. A replicate as per OECD (2006) is defined as a pot; therefore, individual plants within a pot did not constitute as a replicate. A control group of the untreated soil was used in comparison to the treated soil to ensure that the effects observed were attributed to the test substance exposure (the lime variants and gypsum) on soil. The untreated soil was replicated in ten separate pots. Random assignments of test and control pots were examined to prevent bias.

The field rate of lime application was measured in tons/hectare. For this study representation of the application rate to the $100cm^2$ planting pot was as follows
1 ton/hectare represents $0.01grams/cm^2$.

- **Range- finding test**

A range finding exercise was performed in the pilot study to ascertain the dose-responsiveness of the lime variants and gypsum on the soil. This was done to ascertain a maximum concentration/application rate for optimum results to be used in the main study.

- **Test Conditions**

The following test conditions were followed in this study.

Table 3.5 Test conditions during preparation of the soil and duration of the study

Test	Condition
Testing facility	Natural environment
Test System	$100cm^2$ planting plastic pots
Original Soil Characteristics	Acidic soil of pH 4.6
Lime application rate	grams/ cm^2 converted to represent $tons/hectare^2$ of soil
Gypsum application rate	%volume of the lime variant
Method of lime application	Weighed and distributed by hand
Temperature Exposure	Environmental exposure
Light Exposure	Environmental exposure
Watering	20ml distilled water every second day after potting
Number of seeds per pot	Three

Test	Condition
Number of Replicate Pots	Ten
Duration of the test	Stage 1 : Original pH Readings ; Stage 2 : Every 3months until pH neutralisation is reached ; Stage 3: Planting of Peanuts until growth occurs

Eleven data collection techniques including action, case-study, content analysis, correlation, developmental, ethnography, experimental, ex-post de-facto, grounded, historical and observations are available (Singh and Naidoo, 2012). This study made use of experimental and observations.

According to Welman, Kruger and Mitchell (2005), there are two types of sampling techniques, namely probability and non-probability sampling. It is further explained that with probability sampling, the probability of every element is present in the sample can be determined. In non-probability sampling, the probability cannot be determined. This study used soil obtained from the Richards Bay area. Therefore with the replication of each soil sample, the probability in the sampling technique was able to be compared to the crop yield and crop quality obtained.

According to Baskin (1998), Buhler and Hoffman (1999) and the OECD principle, the test substance (pelletised lime and powdered lime) was incorporated into the soil surface, which ensures proper exposure to the lime and at an accurate dosage. Thereafter pH was monitored over seasonal exposure, and once the soil pH was neutralised, peanuts were planted.

3.8 Pilot Work

Yin (2013) found that a researcher should conduct a smaller scale study known as a pilot study so that possible constraints and issues can be outlined, further adding a practical approach to gaining knowledge into the targeted research area. Similarly, Johnson and Christensen (2012) confirmed that pilot studies increase the reliability, validity and practicability of the research. Therefore, a pilot study refines research procedures, thus clarifying the method to be conducted in the main study. Verifying the feasibility of the study on a larger scale will save costs and time. Preliminary work in the form of a pilot study was conducted to determine the feasibility of the methodology adopted for this research.

Table 3.6 shows the various dosage rates used for pelletised lime, powdered lime or gypsum to test its effect on soil pH stabilisation, crop quality and crop yield.

Table 3.6 Dosage rate of lime variants and gypsum on the soil

Powdered Lime (tons/hectare)			**Pelletised lime (tons/hectare)**			**Gypsum Only**		
3	4	5	3	4	5	10%vol	20%/vol	30%/vol

Table 3.7 shows the various dosage rates used of pelletised lime, powdered lime + 10%vol/lime gypsum to test its effect on soil pH stabilisation, crop quality and crop yield.

Table 3.7 Dosage rate of 10% gypsum in addition to the following lime variants

Powdered Lime(tons/hectare)			**Pelletised Lime(tons/hectare)**		
3	4	5	3	4	5

Table 3.8 shows the various dosage rates used of pelletised lime, powdered lime + 20%vol/lime gypsum to test its effect on soil pH stabilisation, crop quality and crop yield.

Table 3.8 Dosage rate of 20% gypsum in addition to the following lime variants

Powdered Lime(tons/hectare)			**Pelletised lime(tons/hectare)**		
3	4	5	3	4	5

Table 3.9 shows the various dosage rates used of pelletised lime, powdered lime + 30%vol/lime gypsum to test its effect on soil pH stabilisation, crop quality and crop yield.

Table 3.9 Dosage rate of 30% gypsum in addition to the following lime variants

Powdered Lime (tons/hectare)			**Pelletised Lime(tons/hectare)**		
3	4	5	3	4	5

The pH was examined before lime application, three months after application and six months after application until pH reached optimum for planting. Thereafter peanut growth yield and quality were monitored, and crop quality in terms of fullness of the peanut within the shell was examined. Table 3.10 shows the pH readings obtained after three months post pelletised or powdered lime and gypsum treatment at various dosage rates.

Table 3.10 pH readings after three months of treatments with lime variants and gypsum on the soil

Sample Number	Un-Treated Soil	Powdered Lime			Pelletised Lime			Gypsum Only		
		3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	10 % vol	20 % vol	30 % vol
1	4.6	5.1	5.7	6.3	5.3	6.2	7.9	4.6	4.7	4.6
2	4.6	5	5.8	6.3	5.3	6.4	7.6	4.7	4.7	4.8
3	4.6	5.2	5.8	6.1	5.3	6.5	8	4.5	4.8	4.6
4	4.6	5.3	5.7	6.2	5.3	6.6	7.5	4.6	4.6	4.7
5	4.6	4.9	5.6	6.4	5.5	6.2	7.5	4.8	4.6	4.5
6	4.6	5.2	5.7	6.2	5.4	6.2	7.6	4.6	4.8	4.6
7	4.6	5.2	5.4	6.3	5.6	6.3	7.6	4.7	4.6	4.7
8	4.6	5	5.5	6.6	5.3	6.6	7.5	4.5	4.7	4.7
9	4.6	5.1	5.6	6.2	5.4	6.2	7.8	4.6	4.5	4.8
10	4.6	5	5.5	6.4	5.2	6.4	7.9	4.6	4.6	4.6
Average pH	4.6	5.1	5.63	6.3	5.36	6.36	7.69	4.6	4.7	4.7

From Table 3.10 the results show that the 5 tons/hectare powdered lime and the 4 tons/hectare pelletised lime variant proved to be most effective in neutralising soil pH to around 7. The addition of gypsum showed no impact on the soil pH. However, due to research, the incorporation of gypsum proved positive in overall plant nutrition and yield; hence, the additions of gypsum at different percentage levels together with the lime forms were examined.

Table 3.11 shows the pH readings obtained after three months post pelletised lime or powdered lime + 10%vol/lime gypsum treatment at various dosage rates.

Table 3.11 pH readings after three months of treatments of lime variants and 10% gypsum on the soil

Sample Number	Powdered Lime + 10% Gypsum			Pelletised Lime + 10% Gypsum		
	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare
1	5.1	5.7	6.3	5.3	6.2	7.9
2	5	5.8	6.3	5.4	6.4	7.6
3	5.2	5.8	6.3	5.3	6.5	8
4	5.3	5.8	6.2	5.3	6.6	7.6
5	5.1	5.6	6.4	5.5	6.3	7.5
6	5.2	5.8	6.2	5.4	6.3	7.6
7	5.2	5.4	6.3	5.6	6.3	7.6
8	5	5.5	6.6	5.3	6.6	7.6
9	5.1	5.6	6.3	5.4	6.3	7.8
10	5	5.5	6.4	5.3	6.4	7.9
Average pH	5.12	5.65	6.33	5.38	6.39	7.71

From Table 3.11 with the addition of 10%gypsum and the powdered lime at 5 tons/hectare and pelletised lime at 4 tons/hectare showed most beneficial in neutralising soil pH within a three month period.

Table 3.12 shows the pH readings obtained after three months post pelletised lime or powdered lime + 20%vol/lime gypsum treatment at various dosage rates.

Table 3.12 pH readings after three months of treatments of lime variants and 20% gypsum on the soil

Sample Number	**Powdered Lime + 20% Gypsum**			**Pelletised Lime + 20% Gypsum**		
	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare
1	5.2	5.8	6.5	5.4	6.3	8
2	5.2	5.8	6.5	5.5	6.5	7.6
3	5.2	5.8	6.5	5.4	6.6	8
4	5.3	5.8	6.4	5.4	6.6	7.6
5	5.2	5.7	6.4	5.6	6.5	7.5
6	5.2	5.8	6.4	5.5	6.5	7.6
7	5.2	5.7	6.4	5.6	6.5	7.6
8	5.2	5.6	6.6	5.5	6.6	7.6
9	5.2	5.7	6.4	5.5	6.5	7.8
10	5.2	5.7	6.4	5.5	6.5	7.9
Average pH	5.21	5.74	6.45	5.49	6.51	7.72

From Table 3.12 with the addition of 20%gypsum with powdered lime at 5 tons/hectare and pelletised lime at 4 tons/hectare showed most beneficial in neutralising soil pH within a three month period.

Table 3.13 shows the pH readings obtained after three months post pelletised lime or powdered lime + 30%vol/lime gypsum treatment at various dosage rates.

Table 3.13 pH readings after three months of treatments of lime variants and 30% gypsum on the soil

Sample Number	Powdered Lime + 30% Gypsum			Pelletised Lime + 30% Gypsum		
	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare
1	5.3	5.9	6.6	5.5	6.4	8
2	5.3	5.9	6.5	5.5	6.6	7.7
3	5.3	5.9	6.6	5.5	6.7	8.1
4	5.3	5.9	6.5	5.5	6.6	7.7
5	5.3	5.8	6.5	5.6	6.6	7.7
6	5.4	5.8	6.5	5.5	6.6	7.6
7	5.3	5.8	6.5	5.6	6.6	7.7
8	5.3	5.7	6.6	5.5	6.7	7.7
9	5.3	5.8	6.5	5.6	6.6	7.8
10	5.3	5.8	6.5	5.6	6.6	7.9
Average pH	5.31	5.83	6.53	5.54	6.6	7.79

From Table 3.13 with the addition of 30% gypsum with powdered lime at 5 tons/hectare and pelletised lime at 4 tons/hectare showed most beneficial in neutralising soil pH within a three month period. A further three months was added to the test to accommodate seasonal changes.

Table 3.14 shows the pH readings obtained after six months post pelletised or powdered lime or gypsum at various dosage rates.

Table 3.14 pH readings after six months of treatments of lime variants and gypsum on the soil

Sample Number	**Un-treated Soil**	**Powdered Lime**			**Pelletised Lime**			**Gypsum Only**		
		3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	10 % vol	20 % vol	30 % vol
1	4.6	5.2	5.8	6.4	6.6	7.4	7.9	4.6	4.7	4.6
2	4.6	5.2	5.9	6.4	6.6	7.4	7.6	4.7	4.7	4.8
3	4.6	5.2	5.9	6.3	6.6	7.4	8	4.5	4.8	4.6
4	4.6	5.3	5.8	6.3	6.6	7.3	7.5	4.6	4.6	4.7
5	4.6	5.1	5.9	6.4	6.6	7.3	7.5	4.8	4.6	4.5
6	4.6	5.3	5.7	6.3	6.4	7.4	7.6	4.6	4.8	4.6
7	4.6	5.3	5.7	6.4	6.6	7.3	7.6	4.7	4.6	4.7
8	4.6	5.3	5.6	6.6	6.7	7.4	7.5	4.5	4.7	4.7
9	4.6	5.2	5.6	6.7	6.7	7.3	7.8	4.6	4.5	4.8
10	4.6	5.3	5.7	6.6	6.7	7.4	7.9	4.6	4.6	4.6
Average pH	4.6	5.24	5.76	6.44	6.61	7.36	7.69	4.62	4.66	4.66

From Table 3.14 after a six month period (lapse of two seasons) the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime showed most beneficial in neutralising soil pH within a 6month period and the 4 tons/hectare pelletised lime caused the soil to become basic. It was also noticed that the 5 tons/hectare pelletised lime addition caused the pH to drop over a further three month lapse in time marginally. Gypsum again showed no impact on soil pH.

Table 3.15 shows the pH readings obtained after six months post pelletised lime or powdered lime + 10%vol/lime gypsum treatment at various dosage rates.

Table 3.15 pH readings after six months of treatments of lime variants and 10% gypsum on the soil

Sample Number	**Powdered Lime + 10% Gypsum**			**Pelletised Lime + 10% Gypsum**		
	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare
1	5.3	5.9	6.5	6.7	7.4	7.9
2	5.3	6	6.5	6.7	7.4	7.6
3	5.3	5.9	6.4	6.6	7.4	8
4	5.3	5.9	6.4	6.7	7.3	7.5
5	5.2	5.9	6.4	6.6	7.3	7.5
6	5.3	5.8	6.4	6.5	7.4	7.6
7	5.3	5.8	6.4	6.6	7.3	7.6
8	5.3	5.9	6.7	6.7	7.4	7.5
9	5.4	5.8	6.7	6.7	7.3	7.8
10	5.3	5.9	6.6	6.7	7.4	7.9
Average pH	5.3	5.88	6.5	6.65	7.36	7.69

From Table 3.15 a six month period (lapse of two seasons) the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime showed most beneficial in neutralising soil pH within a six month period with the 10% addition of gypsum.

Table 3.16 shows the pH readings obtained after six months post pelletised lime or powdered lime + 20%vol/lime gypsum treatment at various dosage rates.

Table 3.16 pH readings after six months of treatments of lime variants and 20% gypsum on the soil

Sample Number	Powdered Lime + 20% Gypsum			Pelletised Lime + 20% Gypsum		
	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare
1	5.4	6	6.6	6.8	7.5	7.9
2	5.3	6	6.6	6.8	7.4	7.7
3	5.3	6	6.6	6.7	7.4	8
4	5.3	6	6.5	6.7	7.4	7.6
5	5.3	5.9	6.5	6.8	7.4	7.6
6	5.3	5.9	6.5	6.6	7.4	7.6
7	5.3	5.9	6.5	6.6	7.4	7.6
8	5.4	5.9	6.7	6.7	7.4	7.6
9	5.4	5.9	6.7	6.7	7.4	7.8
10	5.4	5.9	6.6	6.7	7.4	7.9
Average pH	5.34	5.94	6.58	6.71	7.41	7.73

From Table 3.16 after a six month period (lapse of two seasons) the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime showed most beneficial in neutralising soil pH within a 6month period with the 20% addition of gypsum.

Table 3.17 shows the pH readings obtained after six months post pelletised lime or powdered lime + 30%vol/lime gypsum treatment at various dosage rates.

Table 3.17 pH readings after six months of treatment of lime variants and 30% gypsum on the soil

Sample Number	Powdered Lime + 30% Gypsum			Pelletised Lime + 30% Gypsum		
	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare
1	5.4	6	6.6	6.8	7.5	7.9
2	5.3	6.2	6.6	6.8	7.4	7.7
3	5.3	6.1	6.7	6.7	7.4	8
4	5.3	6	6.5	6.7	7.4	7.7
5	5.3	5.9	6.6	6.9	7.4	7.6
6	5.4	5.9	6.6	6.6	7.4	7.7
7	5.4	5.9	6.5	6.6	7.4	7.6
8	5.4	5.9	6.7	6.7	7.4	7.7
9	5.4	5.9	6.7	6.7	7.5	7.8
10	5.4	5.9	6.6	6.7	7.4	7.9
Average pH	5.36	5.97	6.61	6.72	7.42	7.76

From Table 3.17 a six month period (lapse of two seasons) the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime showed most beneficial in neutralising soil pH within a six month period with the 30% addition of gypsum.

Once pH stabilisation was reached peanuts were planted in the untreated and soil treated with powdered lime, pelletised lime or gypsum. The following crop yield results as shown in Table 3.18 were obtained.

Table 3.18 Crop Yield and Quality of Peanuts grown after treatment of lime variants and gypsum on the soil

Sample Number	Untreated soil	Powdered Lime			Pelletised Lime			Gypsum Only		
		3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	10 % lime vol	20 % lime vol	30 % lime vol
1	0	0	2	3	4	0	0	0	1	1
2	0	1	2	3	4	0	0	0	1	0
3	0	0	2	3	4	0	0	0	0	0
4	0	1	2	3	4	1	0	0	0	0
5	0	1	2	3	4	0	0	0	1	0
6	0	1	2	3	4	1	0	0	0	0
7	0	0	2	3	4	1	0	0	0	1
8	0	0	2	3	4	0	0	0	0	0
9	0	0	2	3	4	0	0	0	0	0
10	0	0	2	3	4	0	0	0	0	0
Average Number Peanuts Grown	0	0.4	2	3	4	0.3	0	0	0.3	0.2
Quality / Visual Appearance of Peanuts grown		Peanut does not occupy the entire shell cavity	Does not occupy the entire shell	Does occupy the entire shell cavity	Does occupy the entire shell cavity	Does not occupy the entire shell cavity			Does not occupy the shell	Does not occupy the shell

From Table 3.18 it can be seen that 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime proved most beneficial in crop yield.

Once pH stabilisation was reached peanuts were planted in the soil treated with powdered lime or pelletised lime and 10%vol/lime gypsum. The following crop yield results as shown in Table 3.19 were obtained.

Table 3.19 Crop Yield and Quality of Peanuts grown after treatment of lime variants and 10% gypsum on the soil

Sample Number	**Powdered Lime + 10% Gypsum**			**Pelletised Lime + 10% Gypsum**		
	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare
1	1	1	2	2	0	0
2	0	1	1	2	0	0
3	1	1	2	2	0	0
4	1	1	1	2	0	0
5	1	1	2	2	0	0
6	0	1	2	2	0	0
7	1	1	1	2	0	0
8	1	1	2	2	0	0
9	0	1	2	2	0	0
10	1	2	2	3	0	0
Average Number of Peanuts Grown	0.7	1.1	1.7	2	0	0
Quality / Visual Appearance of Peanuts grown	Peanut does not occupy the entire shell cavity	Peanut does not occupy the entire shell	Peanut does not occupy the entire shell	Peanut does not occupy the entire shell	Peanut does not occupy the entire shell	Peanut does not occupy the entire shell

From Table 3.19 it can be seen that 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime proved most beneficial in crop yield.

Once pH stabilisation was reached peanuts were planted in the soil treated with powdered lime or pelletised lime and 20%vol/lime gypsum. The following crop yield results were obtained as shown in Table 3.20.

Table 3.20: Crop Yield and Quality of Peanuts grown after treatment of lime variants and 20% gypsum on the soil

Sample Number	**Powdered Lime + 20% Gypsum**			**Pelletised Lime + 20% Gypsum**		
	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare
1	1	3	4	6	0	0
2	1	3	5	6	0	0
3	1	3	4	5	1	0
4	1	3	5	6	0	0
5	1	3	4	6	0	0
6	1	3	4	5	1	0
7	1	3	5	6	0	0
8	1	3	4	5	1	0
9	1	3	5	6	0	0
10	1	3	5	6	0	0
Average Number of Peanuts Grown	1	3	4.5	5.7	0.3	0
Quality / Visual Appearance of Peanuts grown	Peanut does not occupy the entire shell cavity	Peanut does not occupy the entire shell	Peanut does occupy the entire shell cavity	Peanut does occupy the entire shell cavity	Peanut does not occupy the entire shell cavity	Peanut does not occupy the entire shell cavity

From Table 3.20 it can be seen that 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime proved most beneficial in crop yield.

Once pH stabilisation was reached peanuts were planted in the soil treated with powdered lime or pelletised lime and 30%vol/lime gypsum. The following crop yield results were obtained as shown in Table 3.21.

Table 3.21 Crop Yield and Quality of Peanuts grown after treatment of lime variants and 30% gypsum on the soil

Sample Number	Powdered Lime + 30% Gypsum			Pelletised Lime + 30% Gypsum		
	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare	3 tons/ hectare	4 tons/ hectare	5 tons/ hectare
1	1	3	3	4	0	0
2	1	2	3	5	0	0
3	1	2	4	5	1	0
4	1	2	3	5	0	0
5	1	3	3	5	0	0
6	1	3	3	5	0	0
7	1	2	3	5	0	0
8	1	3	3	4	0	0
9	1	2	3	5	0	0
10	1	3	3	5	0	0
Average Number of Peanuts Grown	1	2.5	3.1	4.8	0.1	0
Quality / Visual Appearance of Peanuts grown	Peanut does not occupy the entire shell cavity	Peanut does not occupy the entire shell	Peanut does not occupy the entire shell	Peanut does not occupy the entire shell	Peanut does not occupy the entire shell	

From Table 3.21 it can be seen that 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime proved most beneficial in crop yield.

In a comparison of Tables 3.18, 3.19, 3.20, 3.21, the highest number of peanuts yielded was at 5 tons/hectare + 20w/w% gypsum (4.5peanuts) and 3 tons/hectare pelletised lime + 20%w/w gypsum (5.7peanuts). This means that the optimum dosage range for pelletised lime is 3 tons/hectare + 20w/w% gypsum and for powdered lime, the optimum dosage range was 5 tons/hectare + 20%w/w gypsum. These optimum concentrations were used in the main study as a starting point to observe what would be the impact on pH stabilisation, crop yield and crop quality if these concentrations were exceeded.

3.9 The Main Study

The main study followed the same format as the pilot study. From the results deduced from the pilot study, the optimum ranges for pelletised and powdered lime together with gypsum was ascertained.

From the pilot study the optimum dosage range were concluded as follows:

5 tons/hectare powdered lime + 20% gypsum

3 tons/hectare pelletised lime + 20% gypsum

Using the optimum concentration range from the pilot study, the impact of adding lime and gypsum over the optimum concentration range in the main study was undertaken.

The main study examined the pH neutralisation rate and peanut growth of the following variants and concentrations.

Table 3.22 shows the dosage rates used of powdered lime, pelletised lime or gypsum to test their ability to neutralise soil pH, and its effect on crop quality and crop yield. The untreated soil will also be examined as a reference.

Table 3.22 Main study dosage rate of lime variants and gypsum on the soil

	Powdered Lime			**Pelletised Lime**			**Gypsum Only**		
Un-treated Soil	5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare	20% Lime vol	40% Lime vol	60% Lime vol

Table 3.23 shows the various dosage rates used of pelletised lime or powdered lime and 20%vol/lime gypsum to test its effect on soil pH stabilisation, crop quality and crop yield.

Table 3.23 Main study dosage rate of lime variants in addition to 20% lime volume gypsum

Powdered Lime			Pelletised Lime		
5 tons/hectare	10 tons/hectare	15 tons/hectare	3 tons/hectare	6 tons/hectare	9 tons/hectare

Table 3.24 shows the various dosage rates used of pelletised lime or powdered lime and 40%vol/lime gypsum to test its effect on soil pH stabilisation, crop quality and crop yield.

Table 3.24 Main study dosage rate of lime variants in addition to 40% lime volume gypsum

Powdered Lime			Pelletised Lime		
5 tons/hectare	10 tons/hectare	15 tons/hectare	3 tons/hectare	6 tons/hectare	9 tons/hectare

Table 3.25 shows the various dosage rates used of pelletised lime or powdered lime and 60%vol/lime gypsum to test its effect on soil pH stabilisation, crop quality and crop yield.

Table 3.25 Main study dosage rate of lime variants in addition to 60% lime volume gypsum

Powdered Lime			Pelletised Lime		
5 tons/hectare	10 tons/hectare	15 tons/hectare	3 tons/hectare	6 tons/hectare	9 tons/hectare

The pH neutralisation effect was examined before the lime application, three months after application and six months after application until pH reached optimum for planting. Thereafter, peanut yield and quality were calculated and examined.

3.10 Validity and Reliability of the Pilot and Main Study

Tierney (2008) mooted that for an experiment to confidently show an accurate cause-effect relationship between the independent and dependent variables, the confounding variables must be controlled. For this experiment that intent was to determine the effect of powdered and pelletised lime at different concentrations on acidic soil pH stabilisation, crop yield and crop quality. Standardised procedures in line with OECD were used to ensure the effects are caused by the independent variable and no other factors. Furthermore, all soil test substrates were exposed to the same environmental condition, thus increasing the validity of results obtained for the cause-effect relationship of the independent and dependent variable. Researcher bias was eliminated from the experiment as one researcher was used to conduct all experimental work and standard procedures consistently to all samples.

Campbell and Stanley (1963) found several factors that affect internal and external validity in experimental studies. They found that malfunctioning instrumentation was a major factor, which affects the changes in outcomes of experimental trials. All instrumentation and devices used in this experiment were satisfactorily calibrated and inspected prior to use to ensure accurate, reliable and valid results. Walker (2011) stated, with reference to reliability, experimental reliability is achieved by reproducibility and repeatability of tests. Therefore, this experiment made use of replicate samples. These considerations for reliability and validity were made for both the pilot and main study.

3.11 Data Analysis

O'Neil and Schutt (2013) considered data analysis for quantitative studies as critical analysis and interpretation of figures and numbers in the attempt to find a rationale behind the emergence of main findings. Statistical methods were used to analyse data to determine the validity of empirical research. The data collected were analysed using SPSS version 25.0 and GraphPad Prism 5. Inferential techniques included the use of ANOVA test values, which were interpreted using the p-values.

The data analysis techniques included the following:

- Presentation of the descriptive statistics with the mean and standard deviations

- Graphical presentations of the summarised data
- Trend analysis using linear regression models
- Comparison of data points
- Comparison of slopes

3.12 Summary of the Chapter

This chapter outlined the research design and experimental procedures undertaken in this study. It used the quantitative method of analysis and an experimental strategy. Results from the pilot study confirmed the optimum dosage range of pelletised and powdered lime variants together with % gypsum/lime volume as:

5 tons/hectare pelletised lime + 20% gypsum to lime volume

3 tons/hectare powdered lime + 20% gypsum to lime volume

The subsequent chapters will discuss the results of the study and advice on the direction for future application.

Chapter Four – Results and Discussions

This chapter presents the results and discusses the findings obtained from this study. The results will present the descriptive statistics in the form of graphs, cross tabulations and other figures for the quantitative data that was collected.

4.1 Results

This section will show the pH results obtained pre and post lime or gypsum treatment. The study will be conducted at three and six month intervals to accommodate seasonal changes. Once pH stabilisation is obtained, the crop yield and crop quality of the peanuts cultivated will be ascertained. Table 4.1 shows the pH readings obtained post lime and gypsum treatment after a three month period.

Table 4.1 pH readings after three months under following exposure limits to the soil

Sample	**Un-treated Soil**	**Powdered Lime**			**Pelletised Lime**			**Gypsum Only**		
		5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare	20% vol/ lime	40% vol/ lime	60% vol/ lime
1	4.6	6.2	8.2	8.4	5.4	8.6	8.8	4.6	4.7	4.6
2	4.6	6.3	8.3	8.5	5.3	8.6	8.9	4.7	4.7	4.7
3	4.6	6.2	8.4	8.6	5.4	8.7	8.8	4.6	4.7	4.7
4	4.6	6.3	8.4	8.5	5.4	8.6	8.9	4.7	4.6	4.7
5	4.6	6.3	8.4	8.6	5.4	8.6	8.9	4.7	4.7	4.6
6	4.6	6.1	8.3	8.6	5.4	8.7	8.8	4.7	4.7	4.7
7	4.6	6.4	8.3	8.6	5.5	8.7	8.8	4.6	4.7	4.6
8	4.6	6.4	8.3	8.6	5.4	8.7	8.9	4.7	4.6	4.6
9	4.6	6.3	8.4	8.5	5.4	8.7	8.9	4.6	4.6	4.7
10	4.6	6.3	8.4	8.5	5.3	8.7	8.8	4.7	4.6	4.7
Average pH	4.6	6.28	8.34	8.54	5.39	8.66	8.85	4.66	4.66	4.66

From Table 4.1 after a three month time lapse the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime showed most effective in neutralising soil pH. In comparison to pelletised lime, the powdered lime proved more effective in neutralising the pH. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no benefit in pH neutralisation, furthermore it increased the pH over the desired neutral state.

Table 4.2 shows the pH readings obtained post pelletised lime or powdered lime and 20%vol/lime gypsum treatment after a three month period.

Table 4.2 pH readings after three months under following lime exposure limits plus 20% gypsum added to the soil

Sample Number	Powdered Lime + 20% Gypsum			Pelletised Lime + 20% Gypsum		
	5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare
1	6.6	8.3	8.5	5.5	8.7	8.9
2	6.5	8.3	8.5	5.4	8.6	8.9
3	6.5	8.4	8.6	5.5	8.7	8.8
4	6.6	8.3	8.5	5.4	8.6	8.9
5	6.6	8.4	8.6	5.5	8.7	8.9
6	6.6	8.4	8.6	5.4	8.7	8.8
7	6.5	8.4	8.6	5.4	8.7	8.9
8	6.7	8.3	8.6	5.4	8.7	8.9
9	6.6	8.3	8.6	5.4	8.7	8.9
10	6.6	8.4	8.5	5.4	8.7	8.9
Average pH	6.58	8.35	8.56	5.43	8.68	8.88

From Table 4.2 after a three month time lapse the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime with the addition of 20%w/w gypsum showed most effective in neutralising soil pH. In comparison to pelletised lime, the powdered lime proved more effective in neutralising the pH. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no benefit in pH neutralisation, furthermore it increased the pH over the desired neutral state of 7.

Table 4.3 shows the pH readings obtained post pelletised lime or powdered lime and 40%vol/lime gypsum treatment after a three month period.

Table 4.3 pH readings after three months under following lime exposure limits plus 40% gypsum added to the soil

	Powdered Lime + 40% Gypsum			**Pelletised Lime + 40% Gypsum**		
Sample Number	5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare
1	6.8	8.2	8.6	5.4	8.8	8.9
2	6.8	8.1	8.6	5.5	8.6	8.8
3	6.6	8.2	8.6	5.5	8.8	8.9
4	6.8	8.2	8.6	5.6	8.7	8.9
5	6.6	8.1	8.7	5.3	8.7	8.9
6	6.6	8.2	8.7	5.5	8.7	8.9
7	6.7	8.2	8.6	5.6	8.8	8.9
8	6.7	8.2	8.7	5.5	8.8	8.9
9	6.7	8.2	8.6	5.4	8.8	8.9
10	6.7	8.2	8.7	5.4	8.7	8.9
Average pH	6.7	8.18	8.64	5.47	8.74	8.89

From Table 4.3 after a three month time lapse the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime with the addition of 40%w/w gypsum showed most effective in neutralising soil pH. In comparison to pelletised lime, the powdered lime proved more effective in neutralising the pH. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no benefit in pH neutralisation, furthermore it increased the pH over the desired neutral state.

Table 4.4 shows the pH readings obtained post pelletised lime or powdered lime and 60%vol/lime gypsum treatment after a 3month period.

Table 4.4 pH readings after three months under following lime exposure limits plus 60% gypsum added to the soil

	Powdered Lime + 60% Gypsum			**Pelletised Lime + 60% Gypsum**		
Sample Number	5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare
1	6.8	8.3	8.7	5.5	8.8	8.9
2	6.7	8.2	8.6	5.5	8.7	8.9
3	6.7	8.2	8.7	5.5	8.8	8.9
4	6.8	8.3	8.6	5.7	8.7	8.9
5	6.6	8.2	8.7	5.5	8.7	8.9
6	6.7	8.2	8.7	5.5	8.7	8.9
7	6.7	8.2	8.6	5.6	8.8	8.9
8	6.7	8.3	8.7	5.5	8.8	8.9
9	6.7	8.3	8.7	5.5	8.8	8.9
10	6.7	8.3	8.7	5.5	8.8	8.9
Average pH	6.71	8.25	8.67	5.53	8.76	8.9

From Table 4.4 after a three month time lapse the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime with the addition of 60%w/w gypsum showed most effective in neutralising soil pH. In comparison to pelletised lime, the powdered lime proved more effective in neutralising the pH.

Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no benefit in pH neutralisation, furthermore it increased the pH over the desired neutral state.

Table 4.5 shows the pH readings obtained post lime or gypsum treatment after a 6month period.

Table 4.5 pH readings after six months under following exposure limits to the soil

Sample Number	Un-treated Soil	Powdered Lime			Pelletised Lime			Gypsum Only		
		5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare	20 %	40 %	60 %
1	4.6	6.4	8.4	8.6	6.6	8.6	8.8	4.6	4.7	4.6
2	4.6	6.4	8.4	8.6	6.6	8.6	8.9	4.7	4.7	4.7
3	4.6	6.3	8.4	8.6	6.6	8.7	8.8	4.6	4.7	4.7
4	4.6	6.3	8.4	8.6	6.6	8.6	8.9	4.7	4.6	4.7
5	4.6	6.4	8.4	8.6	6.5	8.6	8.9	4.7	4.7	4.6
6	4.6	6.3	8.4	8.6	6.6	8.7	8.8	4.7	4.7	4.7
7	4.6	6.4	8.4	8.6	6.5	8.7	8.8	4.6	4.7	4.6
8	4.6	6.4	8.4	8.6	6.5	8.7	8.9	4.7	4.6	4.6
9	4.6	6.4	8.4	8.6	6.5	8.7	8.9	4.6	4.6	4.7
10	4.6	6.3	8.4	8.6	6.5	8.7	8.8	4.7	4.6	4.7
Average pH	4.6	6.4	8.4	8.6	6.6	8.7	8.9	4.7	4.7	4.7

From Table 4.5 after a six months lapse in time, the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime showed most effective in neutralising soil pH. In comparison to the powdered lime, the pelletised lime proved more effective in neutralising the pH. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no benefit in pH neutralisation, furthermore it increased the pH over the desired neutral state.

Table 4.6 shows the pH readings obtained post pelletised lime or powdered lime and 20%vol/lime gypsum treatment after a 6month period.

Table 4.6 pH readings after six months under following lime exposure limits plus 20% gypsum added to the soil

	Powdered Lime + 20% Gypsum			**Pelletised Lime + 20% Gypsum**		
Sample Number	5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare
1	6.6	8.3	8.5	6.7	8.7	8.9
2	6.5	8.3	8.5	6.7	8.6	8.9
3	6.5	8.4	8.6	6.6	8.7	8.8
4	6.6	8.3	8.5	6.6	8.6	8.9
5	6.6	8.4	8.6	6.7	8.7	8.9
6	6.6	8.4	8.6	6.6	8.7	8.8
7	6.5	8.4	8.6	6.7	8.7	8.9
8	6.7	8.3	8.6	6.7	8.7	8.9
9	6.6	8.3	8.6	6.7	8.7	8.9
10	6.6	8.4	8.5	6.7	8.7	8.9
Average pH	6.58	8.35	8.56	6.67	8.68	8.88

From Table 4.6 after a six months lapse in time the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime with the addition of 20%w/w gypsum showed most effective in neutralising soil pH. In comparison to the powdered lime, the pelletised lime proved more effective in neutralising the pH. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no benefit in pH neutralisation, furthermore it increased the pH over the desired neutral state.

Table 4.7 shows the pH readings obtained post pelletised lime or powdered lime and 40%vol/lime gypsum treatment after a 6month period.

Table 4.7 pH readings after six months under following lime exposure limits plus 40% gypsum added to the soil

	Powdered Lime + 40% Gypsum			**Pelletised Lime + 40% Gypsum**		
Sample Number	5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare
1	6.8	8.2	8.6	6.7	8.8	8.9
2	6.8	8.1	8.6	6.7	8.6	8.8
3	6.6	8.2	8.6	6.7	8.8	8.9
4	6.8	8.2	8.6	6.7	8.7	8.9
5	6.6	8.1	8.7	6.7	8.7	8.9
6	6.6	8.2	8.7	6.7	8.7	8.9
7	6.7	8.2	8.6	6.7	8.8	8.9
8	6.7	8.2	8.7	6.7	8.8	8.9
9	6.7	8.2	8.6	6.7	8.8	8.9
10	6.7	8.2	8.7	6.7	8.7	8.9
Average pH	6.7	8.18	8.64	6.7	8.74	8.89

From Table 4.7 after a six months lapse in time the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime with the addition of 40%w/w gypsum showed most effective in neutralising soil pH. In comparison to the powdered lime, the pelletised lime proved more effective in neutralising the pH. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no benefit in pH neutralisation, furthermore it increased the pH over the desired neutral state.

Table 4.8 shows the pH readings obtained post pelletised lime or powdered lime and 60%vol/lime gypsum treatment after a 6month period.

Table 4.8 pH readings after six months under following lime exposure limits plus 60% gypsum added to the soil

Sample Number	**Powdered Lime + 60% Gypsum**			**Pelletised Lime + 60% Gypsum**		
	5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare
1	6.8	8.3	8.7	6.8	8.8	8.9
2	6.7	8.2	8.6	6.8	8.7	8.9
3	6.7	8.2	8.7	6.8	8.8	8.9
4	6.8	8.3	8.6	6.7	8.7	8.9
5	6.6	8.2	8.7	6.7	8.7	8.9
6	6.7	8.2	8.7	6.7	8.7	8.9
7	6.7	8.2	8.6	6.7	8.8	8.9
8	6.7	8.3	8.7	6.7	8.8	8.9
9	6.7	8.3	8.7	6.7	8.8	8.9
10	6.7	8.3	8.7	6.7	8.8	8.9
Average pH	6.71	8.25	8.67	6.73	8.76	8.9

From Table 4.8 after a six months lapse in time the 5 tons/hectare powdered lime and 3 tons/hectare pelletised lime with the addition of 60%w/w gypsum showed most effective in neutralising soil pH. In comparison to the powdered lime, the pelletised lime proved more effective in neutralising the pH. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no benefit in pH neutralisation, furthermore it increased the pH over the desired neutral state.

4.2 Analysis of Data

The following tests were done to statistically interpret the data collected.

4.1.1 Comparing slopes

Graphs were constructed using the pH values obtained over the three and six month period post lime and gypsum application. The slopes were compared using GraphPad Prism. A p-value (two-tailed) was calculated that tested the null hypothesis by determining whether the slopes were all identical (the lines are parallel). The results were interpreted using the p-value to check statistical significance. According to Welman, Kruger and Mitchell (2005), if the P-value was less than 0.05, the Prism concluded that the lines are significantly different; hence, data is statistically significant. In that case, there is no point in comparing the intercepts. The intersection point of two lines used the P-value for comparing slopes greater than 0.05, Prism concluded that the slopes are not significantly different and calculated a single slope for all the lines to check the statistical significance of data collected further.

4.1.2 Comparing intercepts

If the slopes were significantly different, there was no need to compare intercepts. If the slopes were indistinguishable, there was a possibility the lines could be parallel with distinct intercepts. Furthermore, the lines could be identical with the same slopes and intercepts. Therefore, Prism calculated a second P-value testing the null hypothesis and checked whether the lines are identical. If this P-value was low (<0.05), this concluded that the lines were not identical (they are distinct but parallel). If this second P-value is high (>0.05), there is no compelling evidence that the lines are different and this means that there is no significance in the results obtained.

4.1.3 Regression Analysis

According to Zar (1984), Analysis of Covariance (ANCOVA) is equivalent to using Prism's nonlinear regression analysis with a straight-line model and using an F test to compare a global model where slope is shared among the data sets with a model where each dataset gets its own slope. This tests whether the desired outcome would have been possible with the regression of time. For this study, it tested whether the yield obtained in six months would have been possible at the three month period.

4.2 Analysis of Data

After the three and six month period, a comparison of pH results was graphically illustrated using pH readings of the original, untreated soil and soil treated with each lime variant (powdered or pelletised) only, and with gypsum. The following was deduced:

4.2.1 Analysis of 5 tons/hectare Powdered Lime Variant at three and six month Intervals against Untreated Soil

A graphical illustration using the pH readings obtained for the untreated soil and the soil treated with 5 tons/hectare powdered lime only and with 20%; 40%; 60% vol/ lime gypsum is shown in Figure 4.1.

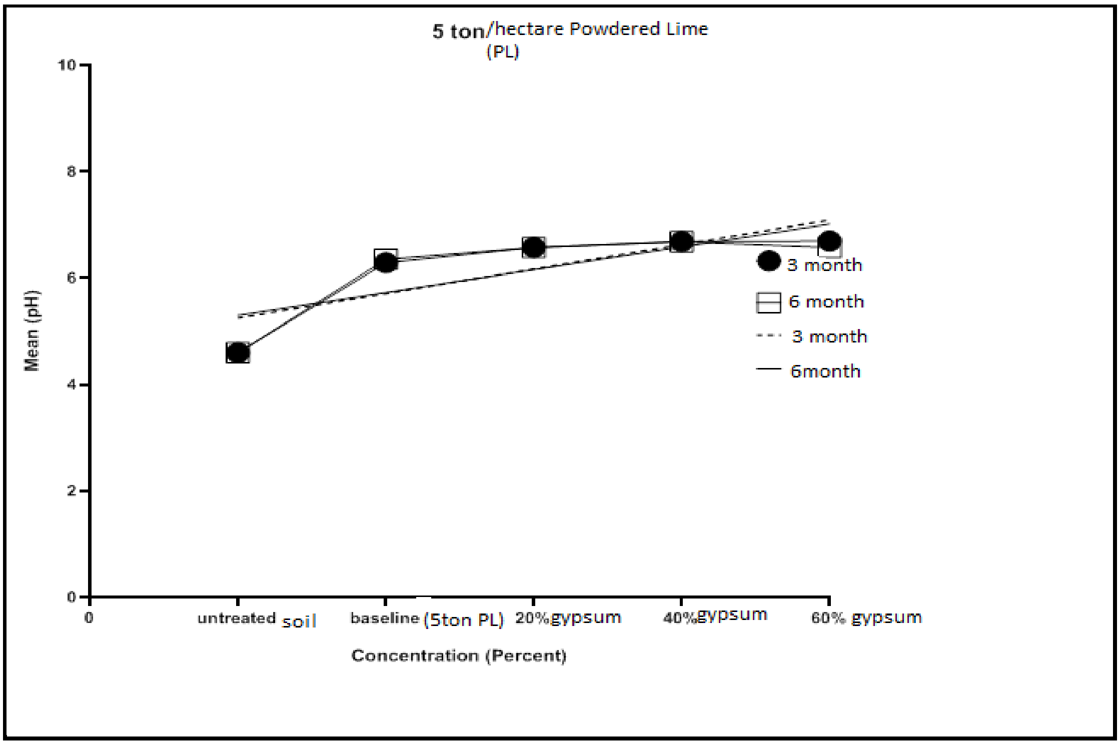

Figure 4.1 The average effect on soil pH with the use of 5 tons/hectare powdered lime and w/w% gypsum at three and six month intervals

Figure 4.1 shows the effect of 5 tons/hectare powdered lime and gypsum at different concentrations on soil pH over a month. From Figure 4.1 the slopes were examined, and the following statistical results were obtained as illustrated in Table 4.9.

Table 4.9 Statistical results for the 5 tons/hectare powdered lime

Test	**Result**
P value	0.5794
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Mann-Whitney U	9.5
P value (data points)	0.915
P(elevations)	0.9766
P(Deviation from zero)	0.953

From Table 4.9 using the P value (data points) there is a 91.5% certainty that the differences between the slopes are not significant. The overall elevations were identical; there is a 98% certainty that the differences between the elevations are not significant. Furthermore, the P value which tested the deviation from zero was 0.953 and proved that the results obtained were not significantly above zero. This means that the results obtained were not significant. Hence, the 5 tons/hectare powdered lime dosage rate on its own and together with 20%, 40% and 60% gypsum showed no statistical significance in its pH neutralisation ability. Therefore, the use of the 5 tons/hectare powdered lime with 20%, 40% and 60% gypsum is not statistically supported in effectively neutralising pH and replicability of such results is not conclusive. Based on the statistical evidence provided farmers should not use this variant at the dosage rate of 5 tons/hectare with 20%, 40% or 60% gypsum as results are not statistically supported in neutralising pH.

4.2.2 Analysis of 10 tons/hectare Powdered Lime Variant at three and six month Intervals against Untreated Soil

A graphical illustration using the pH readings obtained for the untreated soil and the soil treated with 10 tons/hectare powdered lime only and with 20%; 40%; 60% vol/lime gypsum is shown in Figure 4.2:

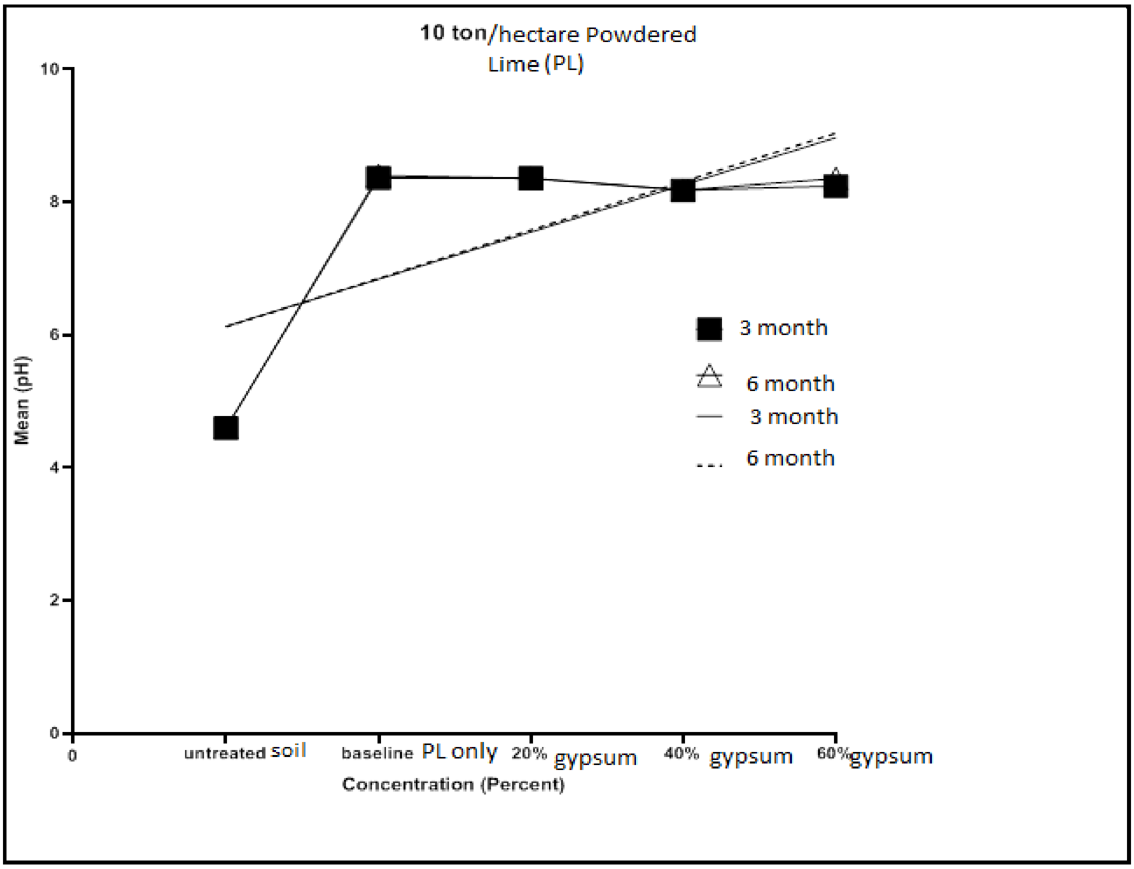

Figure 4.2 The average effect on soil pH with the use of 10 tons/hectare powdered lime and w/w% gypsum at three and six month intervals

Figure 4.2 shows the effect of 10 tons/hectare powdered lime and gypsum at different concentrations on soil pH over a three and six month period.

From Figure 4.2 the slopes were examined, and the following statistical results were obtained as illustrated in Table 4.10:

Table 4.10 Statistical results for the 10 tons/hectare powdered lime

Test	Result
P value	>0.9999
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
P value (data points)	0.9781
Mann-Whitney U	12.50
P(elevations)	0.9706
P(Deviation from zero)	0.2254

From Table 4.10 using the P value (data points), there is a 98% certainty that the differences between the slopes are not significant. The overall elevations were identical; there is a 97% certainty that the differences between the elevations are not significant. Furthermore the P value which tested the deviation from zero was 0.2254 and proved that the results obtained were not significantly above zero. This means that the results obtained were not significant. Hence, the 10 tons/hectare powdered lime dosage rate on its own and together with 20%, 40% and 60% gypsum showed no statistical significance in its pH neutralisation ability. Therefore the use of the 10 tons/hectare powdered lime with 20%, 40% and 60% gypsum is not statistically supported in effectively neutralising pH and replicability of such results is not conclusive. Based on the statistical evidence provided farmers should not use this variant at the dosage rate of 10 tons/hectare with 20%, 40% or 60% gypsum as results are not statistically supported in neutralising pH.

4.2.3 Analysis of 15 tons/hectare Powdered Lime Variant at three and six month Intervals against Untreated Soil

A graphical illustration using the pH readings obtained for the untreated soil and the soil treated with 15 tons/hectare powdered lime only and with 20%; 40%; 60% vol/lime gypsum is shown in Figure 4.3:

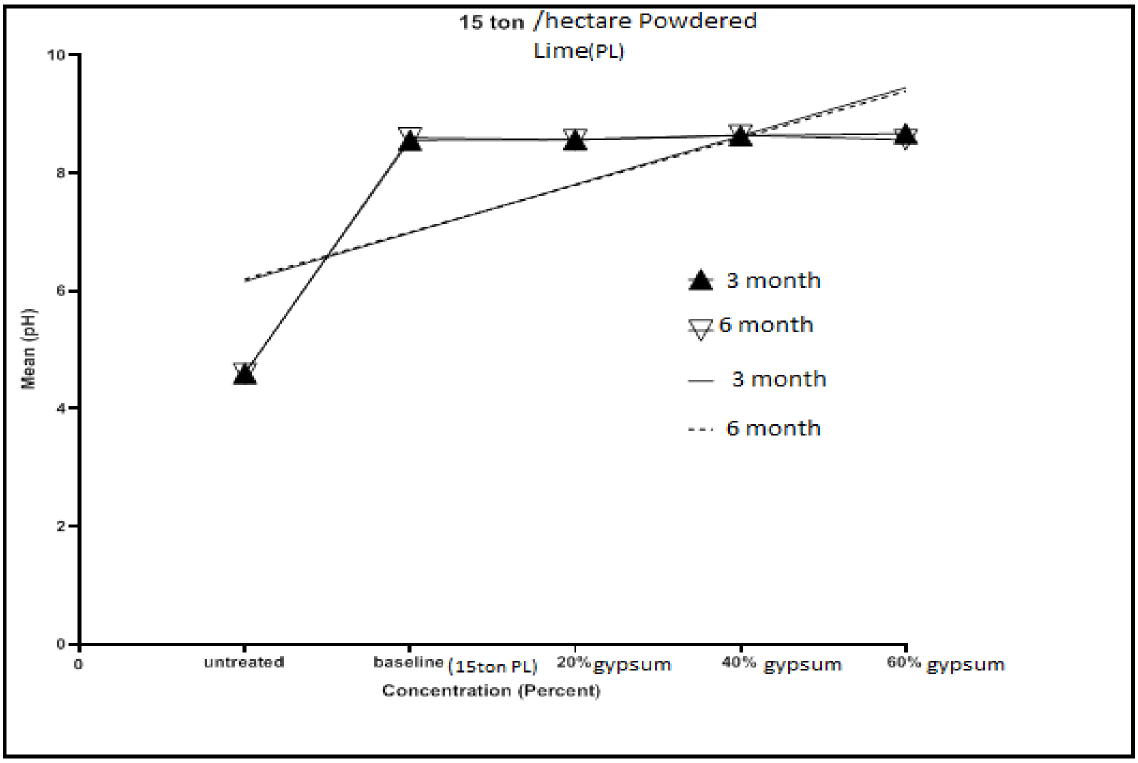

Figure 4.3 The average effect on soil pH with the use of 15 tons/hectare powdered lime and w/w% gypsum at three and six month interval

Figure 4.3 shows the effect of 15 tons/hectare powdered lime and gypsum at different concentrations on soil pH over a three and six month period. From this graphical depiction, the below results were obtained using the slopes. From Figure 4.3 the slopes were examined, and the following statistical results were obtained as illustrated in Table 4.11.

Table 4.11 Statistical results for the 15 tons/hectare powdered lime

Test	Result
P value	0.8730
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Mann-Whitney U	11.50
P value (data points)	0.971
P(elevations)	0.9898
P(Deviation from zero)	0.0355

From Table 4.11 using the P value (data points) there is a 97% certainty that the differences between the slopes are not significant. The overall elevations were identical; there is a 99% certainty that the differences between the elevations are not significant. However, the P value which tested the deviation from zero was 0.0355 and proved that the results obtained were significantly above zero. This means that the results obtained were significant. Hence, the 15 tons/hectare powdered lime dosage rate on its own and together with 20%, 40% and 60% gypsum showed statistical significance in its pH neutralisation ability. Therefore the use of the 15 tons/hectare powdered lime with 20%, 40% and 60% gypsum is statistically supported in effectively neutralising pH and replicability of such results is conclusive. Based on the statistical evidence provided, farmers should use this variant at the dosage rate of 10 tons/hectare with 20%, 40% or 60% gypsum as results are statistically supported in neutralising pH.

4.2.4 Analysis of 3 tons/hectare Pelletised Lime Variant at three and six month Intervals against Untreated Soil

A graphical illustration using the pH readings obtained for the untreated soil and the soil treated with 3 tons/hectare pelletised lime only and with 20%; 40%; 60% vol/lime gypsum is shown in Figure 4.4.

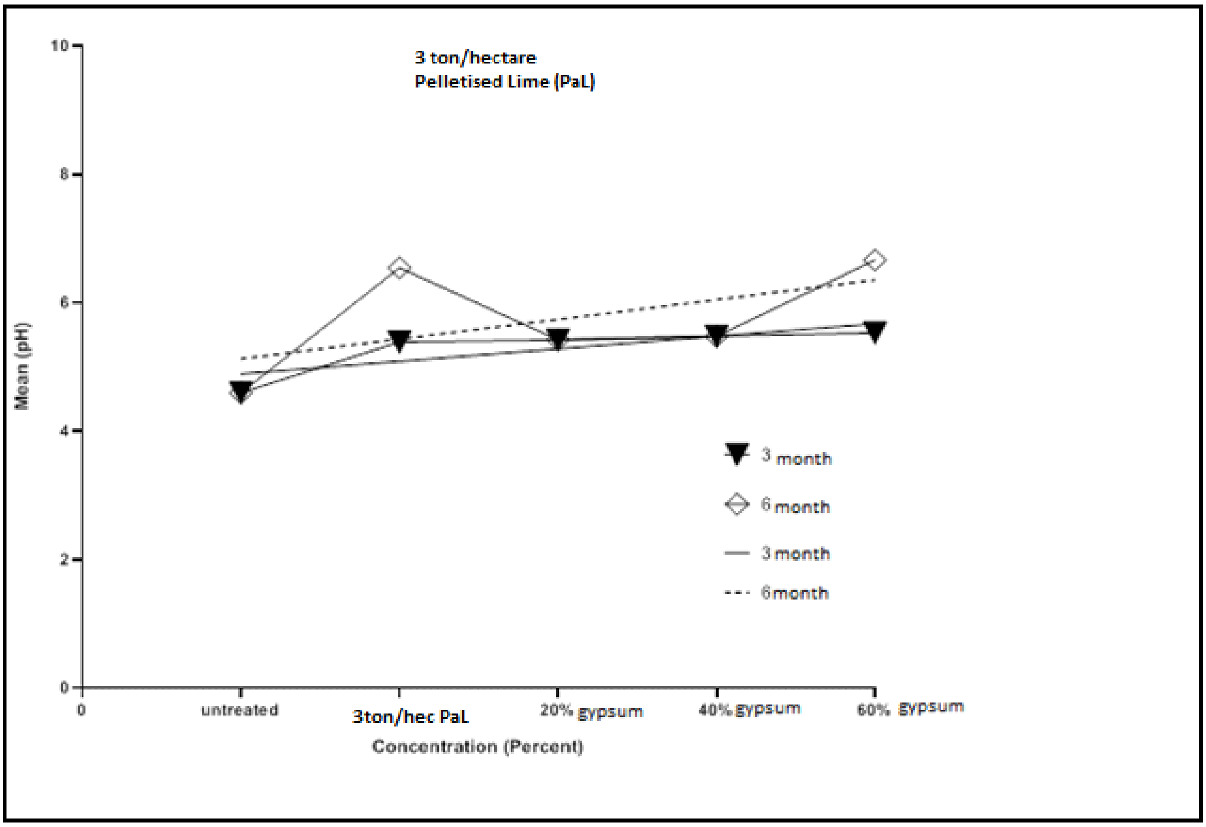

Figure 4.4 The average effect on soil pH with the use of 3 tons/hectare pelletised lime and w/w% gypsum at three and six month intervals

Figure 4.4 shows the effect of 3 tons/hectare pelletised lime and gypsum at different concentrations on soil pH over a three and six month period. From Figure 4.4 the slopes were examined, and the following statistical results were obtained as illustrated in Table 4.12.

Table 4.12 Statistical results for the 3 tons/hectare pelletised lime

Test	Result
P value	0.4603
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Mann-Whitney U	8.50
P value (data points)	0.699
P(elevations)	0.2482
P(Deviation from zero)	0.0077

From Table 4.12 using P value (data points) there is a 70% certainty that the differences between the slopes are not significant. The overall elevations were identical; there is a 25% certainty that the differences between the elevations are not significant. However, the P value which tested the deviation from zero was 0.0077 and proved that the results obtained were significantly above zero. This means that the results obtained were significant. Hence, the 3 tons/hectare pelletised lime dosage rate on its own and together with 20%, 40% and 60% gypsum showed statistical significance in its pH neutralisation ability. Therefore the use of the 3 tons/hectare pelletised lime with 20%, 40% and 60% gypsum is statistically supported in effectively neutralising pH and replicability of such results is conclusive. Based on the statistical evidence provided, farmers should use this variant at the dosage rate of 3 tons/hectare with 20%, 40% or 60% gypsum as results are statistically supported in neutralising pH.

4.2.5 Analysis of 6 tons/hectare Pelletised Lime Variant at three and six month Intervals against Untreated Soil

A graphical illustration using the pH readings obtained for the untreated soil and the soil treated with 6 tons/hectare pelletised lime only and with 20%; 40%; 60% vol/lime gypsum is shown in Figure 4.5:

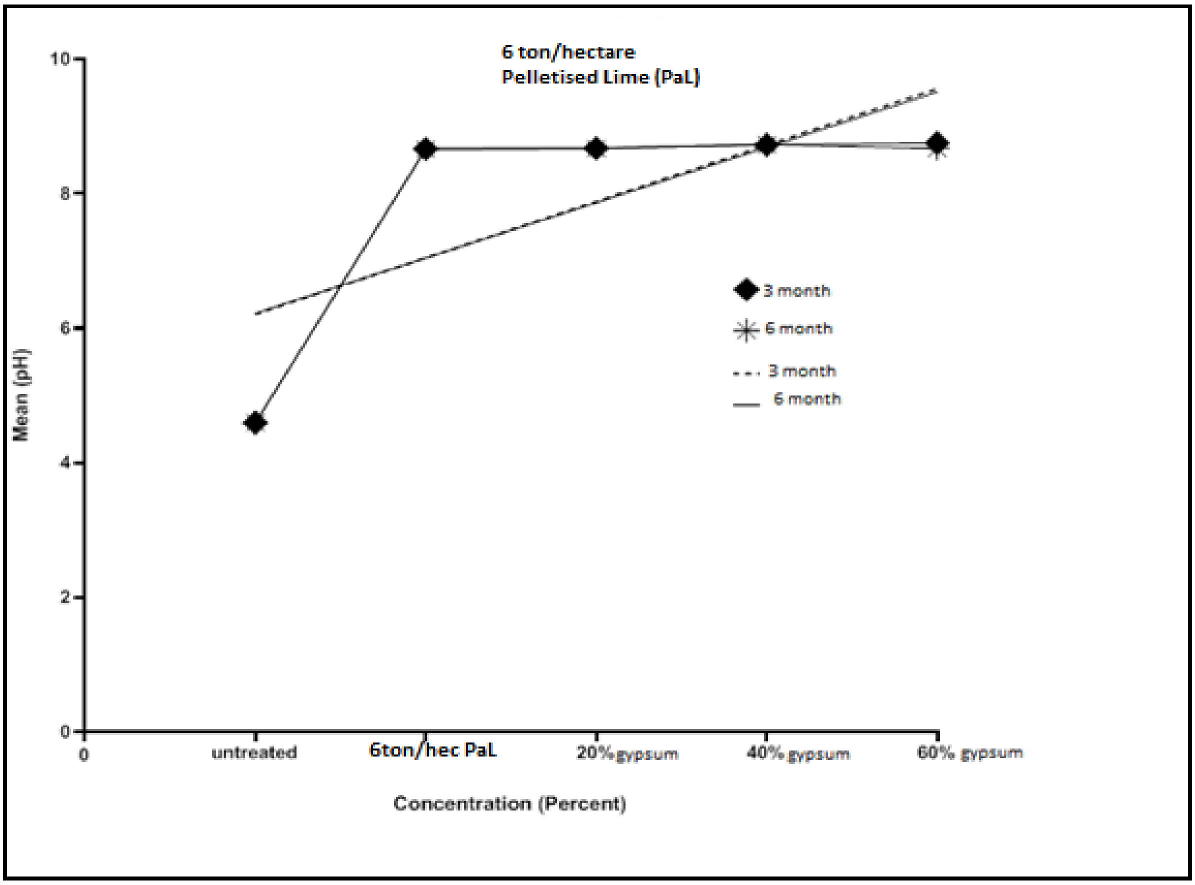

Figure 4.5 The average effect on soil pH with the use of 6 tons/hectare pelletised lime and w/w% gypsum at three and six month intervals

Figure 4.5 shows the effect of 6 tons/hectare pelletised lime and gypsum at different concentrations on soil pH over a three and six month period. From Figure 4.5 the slopes were examined, and the following statistical results were obtained as illustrated in Table 4.13.

Table 4.13 Statistical results for the 6 tons/hectare pelletised lime

Test	Result
P value	0.5794
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Mann-Whitney U	9.50
P value (data points)	0.982
P(elevations)	0.9862
P(Deviation from zero)	0.0263

From Table 4.13 using P value (data points) there is a 98% certainty that the differences between the slopes are not significant. The overall elevations were identical; there is a 99% certainty that the differences between the elevations are not significant. However, the P value which tested the deviation from zero was 0.0263 and proved that the results obtained were significantly above zero. This means that the results obtained were significant. Hence, the 6 tons/hectare pelletised lime dosage rate on its own and together with 20%, 40% and 60% gypsum showed statistical significance in its pH neutralisation ability. Therefore the use of the 6 tons/hectare pelletised lime with 20%, 40% and 60% gypsum is statistically supported in effectively neutralising pH and replicability of such results is conclusive. Based on the statistical evidence provided, farmers should use this variant at the dosage rate of 6 tons/hectare with 20%, 40% or 60% gypsum as results are statistically supported in neutralising pH.

4.2.6 Analysis of 9 tons/hectare Pelletised Lime Variant at three and six month Intervals against Untreated Soil

A graphical illustration using the pH readings obtained for the untreated soil and the soil treated with 9 tons/hectare pelletised lime only and with 20%; 40%; 60% vol/lime gypsum is shown in Figure 4.6:

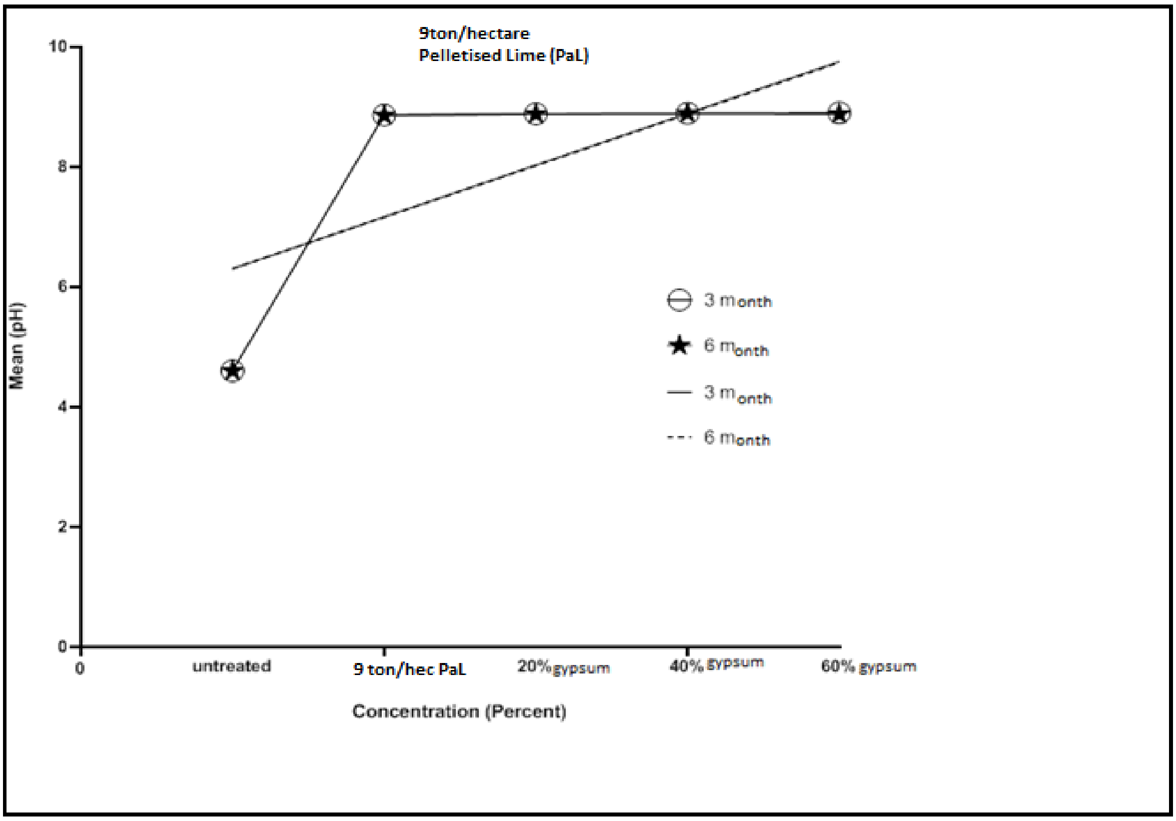

Figure 4.6 The average effect on soil pH with the use of 9 tons/hectare pelletised lime and w/w% gypsum at three and six month intervals

Figure 4.6 shows the effect of 9 tons/hectare pelletised lime and gypsum at different concentrations on soil pH over a three and six month period. From Figure 4.6 the slopes were examined and the following statistical results were obtained as illustrated in Table 4.14.

Table 4.14 Statistical results for the 9 tons/hectare pelletised lime

Test	Result
P value	0.4524
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Mann-Whitney U	8.5
P value (data points)	0.9951
P(elevations)	0.9963
P(Deviation from zero)	0.0173

From Table 4.14 using P value (data points) there is a 99.5% certainty that the differences between the slopes are not significant. The overall elevations were identical; there is a 99.6% certainty that the differences between the elevations are not significant. However, the P value which tested the deviation from zero was 0.0173 and proved that the results obtained were significantly above zero. This means that the results obtained were significant. Hence, the 9 tons/hectare pelletised lime dosage rate on its own and together with 20%, 40% and 60% gypsum showed statistical significance in its pH neutralisation ability. Therefore, the use of the 9 tons/hectare pelletised lime with 20%, 40% and 60% gypsum is statistically supported in effectively neutralising pH and replicability of such results is conclusive. Based on the statistical evidence provided, farmers should use this variant at the dosage rate of 9 tons/hectare with 20%, 40% or 60% gypsum as results are statistically supported in neutralising pH.

4.2.7 Summary of pH stabilisation results after six months:

After six months of post lime treatment, a summary of the pH stabilisation ability of each lime form together with gypsum was recorded and illustrated in Figure 4.7:

PL – Powdered Lime

PaL – Pelletised Lime

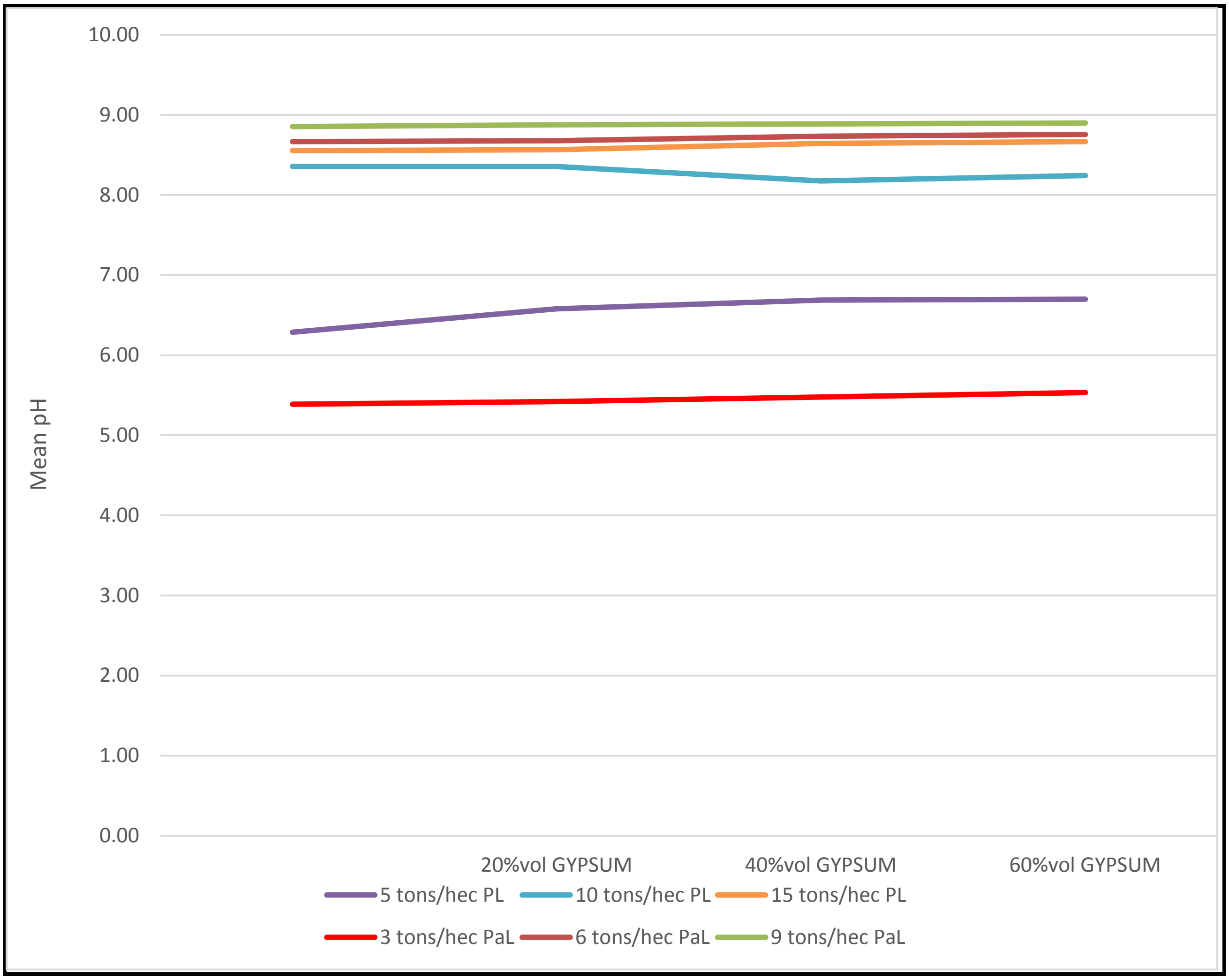

Figure 4.7 Summary of the mean soil pH after the addition of various concentrations of powdered lime and pelletised lime at different w/w% gypsum

From Figure 4.7 it can be seen that after six months, the 3 tons/hectare pelletised lime variant proved more effective in pH stabilisation of the acid soil. Further to this, it can be seen that the addition of gypsum, together with the pelletised lime showed little effect on the pH neutralisation of the soil. However, the powdered lime variant was affected by the addition of gypsum.

4.3 Peanut Yield

The number of peanuts yielded from the untreated soil and soil treated with pelletised or powdered lime and gypsum at different dosage rates were recorded. Table 4.15 shows the amount of peanuts yielded from the untreated soil and soil treated with lime or gypsum.

Table 4.15 Peanut Yield after soil pH stabilisation at following exposure limits

	Powdered Lime			**Pelletised Lime**			**Gypsum Only**		
Sample Number	5 tons / hectare	10tons / hectare	15tons/ hectare	3tons / hectare	6tons / hectare	9tons/ hectare	20% vol/ lime	40% vol/ lime	60% vol/ lime
1	3	0	0	4	0	0	0	1	0
2	3	0	0	4	0	0	0	0	0
3	3	0	0	4	0	0	0	0	0
4	3	0	0	4	0	0	0	0	0
5	3	0	0	4	0	0	0	0	0
6	3	0	0	4	0	0	0	0	1
7	3	0	0	4	0	0	0	1	0
8	3	0	0	4	0	0	0	0	1
9	3	0	0	4	0	0	0	0	0
10	3	0	0	4	0	0	0	0	0
Average Yield	3	0	0	4	0	0	0	0	0

From Table 4.15 soil treated with pelletised lime at 3 tons/hectare yielded 33% more peanuts than the 5 tons/hectare powdered lime variant. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no positive yields.

Table 4.16 shows the amount of peanuts yielded from soil post pelletised lime or powdered lime and 20%vol/lime gypsum treatment.

Table 4.16 Peanut Yield after soil pH stabilisation at following exposure limits plus 20% gypsum

	Powdered Lime + 20%vol/lime Gypsum			**Pelletised Lime + 20%vol/lime Gypsum**		
Sample Number	5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare
1	5	0	0	6	0	0
2	4	0	0	6	0	0
3	4	0	0	6	0	0
4	4	0	0	6	0	0
5	5	0	0	6	0	0
6	5	0	0	6	0	0
7	5	0	0	5	0	0
8	4	0	0	5	0	0
9	5	0	0	6	0	0
10	5	0	0	6	0	0
Average Yield	4.6	0	0	5.8	0	0

From Table 4.16 soil treated with pelletised lime at 3 tons/hectare + 20%w/w gypsum yielded 26% more peanuts than the 5 tons/hectare + 20%w/w gypsum powdered lime variant. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no positive yields.

Table 4.17 shows the amount of peanuts yielded from soil post pelletised lime or powdered lime and 40%vol/lime gypsum treatment.

Table 4.17 Peanut Yield after soil pH stabilisation at following exposure limits plus 40% gypsum

	Powdered Lime + 40% vol/lime Gypsum			**Palletised Lime + 40% vol/lime Gypsum**		
Sample Number	5 tons/ hectare	10 tons/ hectare	15 tons/ hectare	3 tons/ hectare	6 tons/ hectare	9 tons/ hectare
1	3	0	0	4	0	0
2	2	0	0	3	0	0
3	2	0	0	4	0	0
4	3	0	0	3	0	0
5	3	0	0	3	0	0
6	2	0	0	3	0	0
7	2	0	0	4	0	0
8	2	0	0	4	0	0
9	2	0	0	4	0	0
10	3	0	0	4	0	0
Average Yield	2.4	0	0	3.6	0	0

From Table 4.17 soil treated with pelletised lime at 3 tons/hectare + 40%w/w gypsum yielded 50% more peanuts than the 5 tons/hectare+ 40%w/w gypsum powdered lime variant. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no positive yields. Table 4.18 shows the amount of peanuts yielded from soil post pelletised lime or powdered lime and 60%vol/lime gypsum treatment.

Table 4.18 Peanut Yield after soil pH stabilisation at following exposure limits plus 60% gypsum

	Powdered Lime + 60% vol/lime Gypsum			**Pelletised Lime + 60% vol/lime Gypsum**		
Sample Number	5 tons/hectare	10 tons/hectare	15 tons/hectare	3 tons/hectare	6 tons/hectare	9 tons/hectare
1	2	0	0	2	0	0
2	2	0	0	2	0	0
3	2	0	0	2	0	0
4	2	0	0	2	0	0
5	2	0	0	2	0	0
6	2	0	0	2	0	0
7	2	0	0	2	0	0
8	2	0	0	2	0	0
9	2	0	0	2	0	0
10	2	0	0	2	0	0
Average Yield	2	0	0	2	0	0

From Table 4.18 soil treated with pelletised lime at 3 tons/hectare + 60%w/w gypsum yielded the same number of peanuts as the 5 tons/hectare+ 60%w/w gypsum powdered lime variant. Both pelletised and powdered lime forms at two times and three times the optimum dosage rate showed no positive yields.

4.4 Regression Analysis for Peanut Yield

Various regression models were developed to look at the relationship between the yield at a particular tonnage and the effect of time (at three months and six months) at the different concentration levels. Table 4.19 shows the only result that was statistically supported and proved positive for the test.

Table 4.19 Lime Variant(s) which showed significant correlation to Regression Analysis for Peanut Yield

Lime Variant	Beta Coefficient	P Value	Correlation
3month Period Post Powdered Lime addition of 5 tons/hectare	-0.893	0.047	Yes

The Table 4.19, P value of 0.047(<0.05) statistically proved a strong correlation between the independent (powdered lime) and dependent variables (the soil pH, crop yield and crop quality). Since the coefficient is negative, it implies an inverse relationship. This implies that peanuts could be yielded within the time frame of three months using the 5 tons/hectare powdered lime variant. However after the six month time lapse since lime treatment, the 3 tons/hectare pelletised lime with 20%w/w gypsum yielded an average of 5.8peanuts versus 4.6peanuts from the 5 tons/hectare powdered lime variant with 20%w/w gypsum. This means that despite powdered lime being able to neutralise the soil quicker to obtain peanuts in a shorter time frame, the use of pelletised lime had a better effect on crop yield and crop quality over an extended period of time.

The number of peanuts yielded post treatment of powdered lime or pelletised lime together with gypsum was calculated and summarised. This is depicted in Figure 4.8.

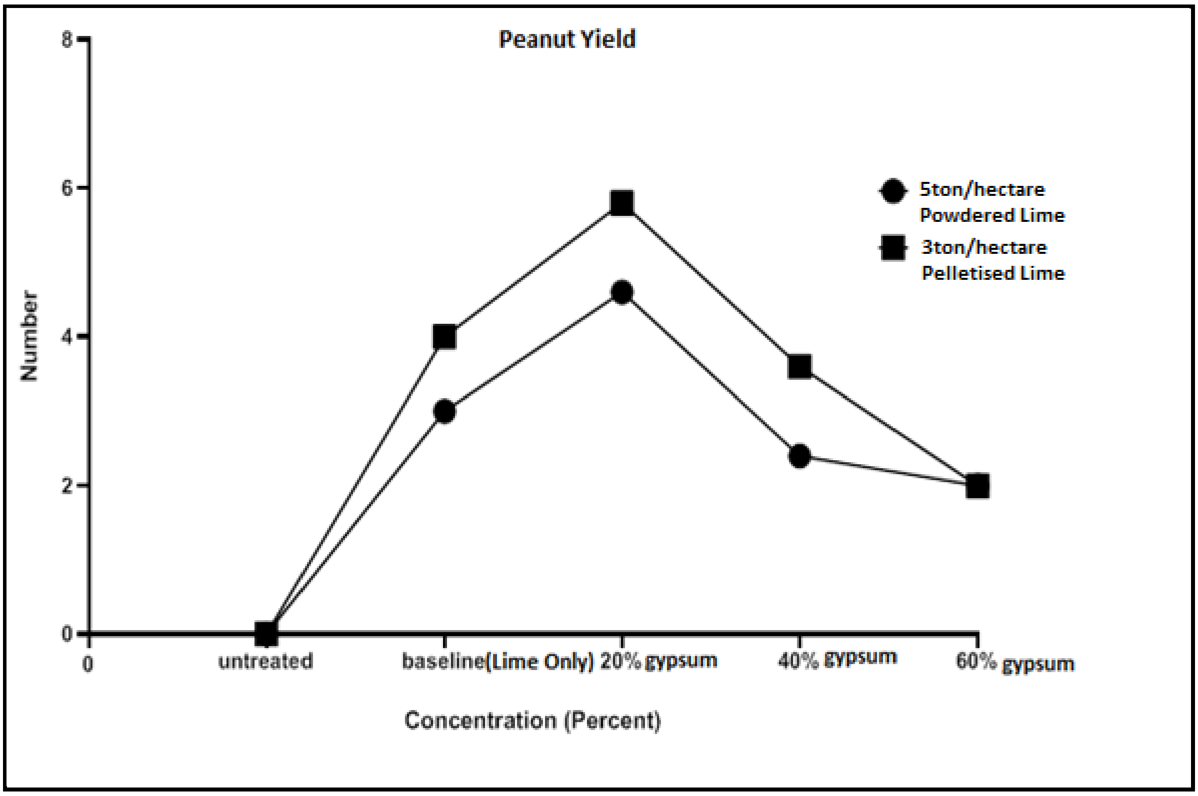

Figure 4.8 Peanut yield at various concentrations of powdered lime, pelletised lime and gypsum

Figure 4.8 compares the yields for 3 tons/hectare pelletised lime and 5 tons/hectare powdered lime at different dosage rates and the addition of gypsum at different dosage rates. It is noticed that the 3 tons/hectare pelletised lime peanut yield was higher than that of the 5 tons/hectare powdered lime for baseline, 20% and 40% gypsum addition.

4.5 Crop Quality (Peanut fullness in the shell)

To determine crop quality, the peanuts yielded from different soil treated with powdered lime or pelletised lime and gypsum were examined for their fullness in the shell cavity. If a peanut filled the shell cavity optimally, then it passed quality standards. The fullness of the peanut in respect of the peanut cavity was ascertained. Peanuts that displayed fullness in the shell cavity were recorded. This was done to determine the crop quality of the peanuts yielded. The results are illustrated in Table 4.20.

PL – Powdered Lime

PaL – Pelletised Lime

G – Gypsum

Table 4.20 Number of peanuts which filled the peanut shell cavity and passed quality standard

Sample Number	5 tons/ hectare (PL)	3 tons/ hectare (PaL)	5 tons/ hectare PL + 20% G	3 tons/ hectare PaL + 20% G	5 tons/ hectare PL + 40% G	3 tons/ hectare PaL+40% G	5 tons/ hectare PL+ 60% G	3 tons/ hectare PaL + 60% G
1	1	2	3	6	1	3	1	2
2	1	2	3	6	1	3	1	2
3	2	2	3	6	1	3	1	2
4	1	2	3	6	1	3	1	2
5	2	2	3	6	1	3	1	2
6	2	2	3	6	1	3	1	2
7	1	2	3	5	1	4	1	2
8	1	2	3	5	1	3	1	2
9	1	2	3	6	1	4	1	2
10	1	2	3	6	1	4	1	2
Average Number of Peanuts	1.3	2	3	5.8	1	3.3	1	2

From Table 4.20 the 3 tons/hectare pelletised lime + 20%gypsum and the same variant with 40%gypsum yielded better quality peanuts than the 5 tons/hectare powdered lime with + 20% gypsum. From the earlier Table 4.16 it was found that the soil treated with 5 tons/hectare powdered lime +20%w/w gypsum yielded an average of 4.6 peanuts however of that only 3 of those exhibited fullness of the peanut in the shell as illustrated in Table 4.20. The soil treated with 3 tons/hectare pelletised lime +20%w/w gypsum yielded an average of 5.8 peanuts (as stated in Table 4.16), and an average of 5.8 of those peanuts all exhibited fullness of the peanut in the shell as illustrated in Table 4.20.

In the form of a bar graph Figure 4.9 shows the comparison between peanuts yielded and crop quality of those peanuts obtained for the 3 tons/hectare pelletised lime + 20%gypsum and 5 tons/hectare powdered lime +20%gypsum.

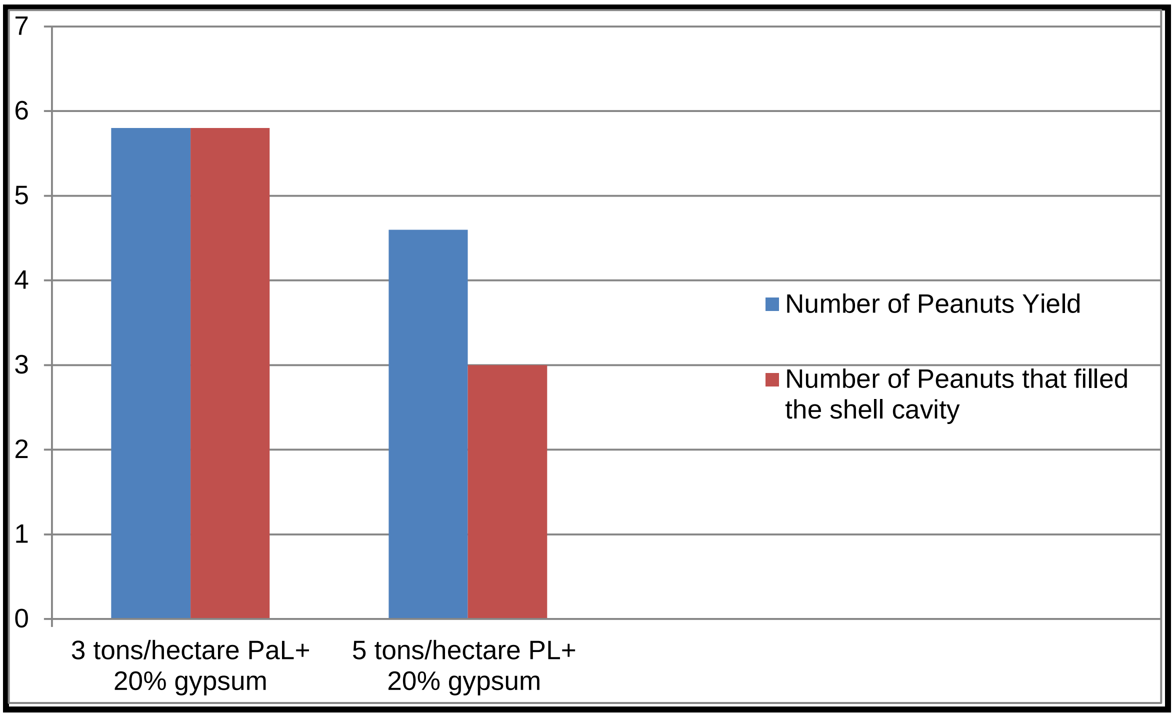

Figure 4.9 Number of peanuts which filled the peanut shell cavity in comparison to the peanut yield

From Figure 4.9 it is graphically shown that the 5.8 average peanuts grown from soil treated with 3 tons/hectare pelletised lime with 20%w/w gypsum, all of these peanuts filled the peanut shell cavity (100% fullness of the peanut in the shell from the yield). However, in comparison to the powdered lime variant at 5 tons/hectare with 20%w/w gypsum only 3 of the 4.6 peanuts yielded exuded fullness within the cavity (65% fullness of the peanut in the shell from the yield).

4.6 Summary of the Chapter

The 5 tons/hectare powdered lime showed a faster pH stabilisation rate after the three month period. However, after the six month time lapse the pelletised lime is more effective in neutralising the soil pH. The powdered lime pH neutralisation ability seemed affected by the addition of gypsum; however, the pelletised lime variant did not exude the same behaviour. From the regression model it can be seen that the 5 tons/hectare powdered lime variant would be able to yield the crop quicker than that of the pelletised lime. Furthermore, 5 tons/hectare powdered lime variant showed the strongest statistic correlation in its effect on soil pH. However, the 3 tons/hectare pelletised lime crop yield is higher than that for 5tons/hectare for powdered lime plus 20% and 40% gypsum. Therefore even though the stabilisation rate of pelletised lime is slower than that of powdered lime, the crop yielded from pelletised lime treatment is higher once stabilisation is reached. In addition, the 3 tons/hectare pelletised lime variant together with 20%w/w gypsum proved 100% fullness of the peanut in the shell from the yield (crop quality). In contrast to the 5 tons/hectare powdered lime variant together with 20%w/w gypsum, which showed only a 65% fullness of the peanut in the shell from the yield (crop quality). This shows that the use of pelletised lime together with gypsum at a lower dosage rate not only neutralises soil pH but also results in higher crop yield and crop quality of peanuts over powdered lime with gypsum at a higher dosage rate. The effectiveness of pelletised lime over powdered lime could be attributed to its larger size, and its ability to release slowly into the soil matrix versus the powdered lime which is easily removed from the surface by environmental factors such as wind and rain.

Chapter Five – Conclusion and Recommendations

The focus of this study was to determine the effect of pelletised lime and powdered lime on crop yield and crop quality. A quantitative research approach and an experimental design were adopted. In the pilot study the pH stabilisation ability; resultant crop yield and crop quality of peanuts using pelletised lime and powdered lime at 3 tons/hectare; 4 tons/hectare and 5 tons/hectare respectively together with gypsum at 10%vol/lime; 20%vol/lime; 30%vol/lime was evaluated. The aim of the latter was to determine the optimum dosage range for pH stabilisation, crop yield and crop quality. Once the optimum dosage range was ascertained the main study examined the effect of two times and three times the optimum dosage rate of 3 tons/hectare pelletised lime + 20%w/w gypsum and 5 tons/hectare powdered lime+ 20%w/w gypsum. The effect of this overtreatment on soil pH stabilisation, crop quality and crop yield was monitored. This chapter will conclude and draw on the discussion of the aforementioned pilot and main study to provide recommendations for farmers to optimise crop yields and crop quality and to propose a direction for future research.

5.1 Conclusions

The objectives of this study were summarised into two parts, and the following conclusions were made.

5.1.1 To treat the acidic soil with pelletised and powdered lime in order to monitor its pH neutralisation rate and stability

This study found that powdered lime though has a faster reaction rate in stabilising soil pH in a shorter period of time; pelletised lime was more effective over an extended period. Furthermore, this study found that where three tons of pelletised lime was used to get the desired pH stabilisation, five tons of powdered lime was needed for the same effect. This is consistent with the findings of Murdock (1997). This means less pelletised lime is needed to obtain a similar pH stabilisation reaction to soil as opposed to powdered lime. Even though the stabilisation rate of pelletised lime is slower than that of powdered lime, the crop yielded from pelletised lime treatment is higher once pH stabilisation is reached. Therefore, pelletised lime proved to be more beneficial to pH stabilisation over powdered lime.

5.1.2 To find the optimum dosage levels of pelletised and powdered lime together with gypsum to achieve maximum crop yield and crop quality of peanuts

From literature Mengel (2016) found that gypsum is required, in addition, to lime to enhance the effects of lime on soil, thus co-assisting in crop yield and quality. This is in line with the findings of this study that gypsum added to soil at a rate of 20%vol/lime together with the powdered or pelletised lime resulted in a higher crop yield and better crop quality as opposed to the addition of lime alone.

The optimum dosage for pelletised lime was 3 tons/hectare + 20%vol/lime gypsum, which resulted in 100% of the crop meeting the quality standard as all peanuts yielded filled the shell cavity. However the optimum dosage for powdered lime was 5 tons/hectare + 20%vol/lime gypsum, which resulted in 65% of the crop meeting the quality standard.

Despite the above findings, it was also evident that over treatment of both pelletised and powdered lime alone and together with gypsum did not result in a better crop yield or quality. The overtreatment of either pelletised lime or powdered lime and gypsum showed a decrease in crop yield and quality once the optimised dose was exceeded. This proves that the over the addition of lime and gypsum leads to a toxic environment in the soil, which inhibits its ability to function optimally. Thus negative crop yield and crop quality.

The results of this research showed that pelletised lime at a lower dosage rate together with 20%vol/lime gypsum results in a better yield and quality of peanuts versus powdered lime with 20%vol/lime gypsum. In conclusion, pelletised lime is more effective on soil pH neutralisation, crop quality and crop yield of peanuts than powdered lime.

5.2 Recommendations and the Way Forward for Future Research

This study was confined to the treatment of soil in the Richards Bay KZN region, and crop yield and quality were determined using one plant species that being the peanut. It is recommended that future research should explore the effect of powdered and pelletised lime together with gypsum on soil pH stabilisation using soil from another region but still testing crop quality and crop yield using the same peanut species. Alternatively, a comparison between pelletised lime and powdered lime together with gypsum can be examined using the Richards Bay KZN soil, but crop yield and crop quality can be ascertained on a different plant species. The reason behind testing the aforementioned scenarios is to determine the effect of pelletised lime and powdered lime on other soils pH stabilisation and other species crop yield and quality. This would assist in combating the issue of acidic soil and food insecurity, both of which were discussed in the literature review.

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