FACTORS INFLUENCING FARMERS' FERTILIZER PRACTICES ON IRRIGATION SCHEMES IN THE CENTRAL PARTS OF SOUTH AFRICA

by

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DECLARATION

I, Frederikus Jacobus Johannes Nell, with student number , hereby declare that this academic thesis titled: "*Factors influencing farmers' fertilizer practices on irrigation schemes in the central parts of South Africa*", submitted to the Central University of Technology, Free State, for the awarding of the Master of Agriculture degree is my own independent work.

All sources used and quoted in this thesis have been duly acknowledged by means of complete references; and it further conforms to the code of academic integrity, as well as other applicable policies, procedures, rules and regulations of the Central University of Technology, Free State.

This thesis has not been previously submitted to any institution by me or any other person known to me, in either partial or total fulfilment of requirements towards the achievement of any qualification.

I hereby, as also required, do disclaim this thesis in favour of the Central University of Technology, Free State.

12/4/2019

Frederikus Jacobus Johannes Nell

Date:

DEDICATION

I would like to thank the following persons, whom have contributed greatly in helping me, either physically or mentally, to complete this research project successfully.

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To my wife for her support, motivation and help during all the difficult times, especially when I had to work into the early hours of the morning.

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Abstract

Fertilizer containing macro and micro elements forms the basis of a good yield and should be applied in correct quantities. Fertilizer should be applied at the correct physiological growth stage of the plant. Of further importance is the cost associated with fertilizers, since it makes a meaningful contribution to the total input cost per hectare of crop cultivation. A common problem is that some farmers do not have sufficient knowledge of the fertilisation requirements of plants to make an informed decision. This makes the farmer entirely dependent on the recommendations of fertilizer advisors, who are also the salesmen, regarding the types and quantities of fertilizers (macro and micro elements) to be applied. As a result of the ignorance or skepticism of farmers, this may lead to under- or overapplication of inorganic fertilizers.

The overall objective of this study is to determine the fertilisation practices as applied by farmers in the irrigation areas of the Jacobsdal, Prieska, Vaalharts and Douglas regions in the central parts of South Africa. The study consist of four main objectives, namely:

1. to study the behavior of the farmers regarding their fertilizer management practices;
2. to study the fertilizer salesmen's behaviour and their influence on the farmers' fertilizer practices;
3. To determine the fertilizer companies' marketing strategies and how they influence the farmers' decision making; and
4. To determine the level of variations in soil analyses results and recommendations between different laboratories.

Various sub-objectives were formulated within each objective. A stratified random sample was used to select the respondents for the study in order to ensure the representability of all groups.

To satisfy the first three objectives of the study, three questionnaires were constructed and consequently filled via personal interviews with these farmers, fertilizer agents (salespersons) and fertilizer companies as respective respondents. Both Excel and SPSS were used to analyse the data while various statistical tests were used to identify trends and correlations within the data.

Regarding the farmer's behaviour concerning fertilizer management (the 1st objective), significant differences were found between some of the four irrigation (sample) areas for the

average nitrogen input cost per hectare for early planting ($p = 0.0026$) and late planting ($p < 0.0001$). As far as differences in nitrogen cost based on the farm size are concerned, no significant differences could be found between the nitrogen input cost between smaller and larger farm groups. No significant differences were found in the phosphate and potassium input costs per hectare between the four sample areas. However, a significant difference was found between the small and larger farms at Vaalharts ($p < 0.0001$) vis-à-vis potassium costs per hectare for early planting. Concerning the average cost for micro elements per hectare, statistical differences was found for an early plant ($p = 0.0226$), as opposed to a late plant ($p < 0.0001$) between some of the areas. When considering the total input cost of fertilizer per hectare, the Douglas sample group was significantly higher than Vaalharts and Prieska respectively. It was found that the size of the farming unit makes no significant difference as far as the total input cost of fertilizer per hectare is concerned. The only exception was with the Prieska sample group that showed a significant difference in packaging preference of fertilizer bags, i.e. the larger farmers prefer to use large bags and bulk fertilizer, while the small farmers prefer small (50kg) bags that can be moved by hand.

The respondents were divided into three groups according to their highest academic qualification, as well as according to farming experience. No significant differences were found between these education and experience groups when considering the various fertilizer practices and assessment of the fertilizer salesmen. The only exception was the significantly better ($p = 0.0059$) ability of the group with tertiary agricultural qualifications to understand the soil analysis report and verify the fertilizer recommendation made by the fertilizer agent. None of the other demographics (e.g. age, experience and gender) play any significant role in farmers' fertilizer practices.

It is recommended that farmers must apply different strategies to control or manipulate the price of their inputs without compromising yield, soil fertility and the long-term sustainability of the farming unit. These strategies will differ between farmers due to every farm's unique situation, for example economies of scale and the financial position (liquidity) of the farming business.

Regarding the profile of the fertilizer salesman, it was found that when the financial position of the farming business (i.e. restricted or surplus funding and target yield) is disclosed to the fertilizer agent, significant differences were found in the quantities of nitrogen, phosphate and potassium that were recommended by the sales representative, especially reduced N and P when funds are limited, while significant higher application rates of N, P and K were made when funding is no limitation and nutrient reserves need to be improved. It is recommended that a farmer must select the fertilizer salesperson with extreme prudence. This person provides valuable information that will assist the farmer to make decisions that will have a huge impact on the financial success of the farming business, while it will also influence soil fertility and contribute to the long-term sustainability of the farm.

Regarding the 3rd objective, whereby the marketing strategies of the fertilizer companies were perused, the farmer should always bear in mind that a fertilizer company's mail goal is maximum profit and not the welfare of the farmer as individual. They all sell basically the same product and farmers must keep in mind that the company's agronomic services (for example soil sampling and cost of analysis), may be costly as it is then integrated into or added to the price of the purchased fertilizers. Alternative independent agronomic services are available and the cost thereof can be offset by purchasing much cheaper fertilizers, resulting in a much lower total cost.

The 4th objective of the study was to investigated variations in soil analysis reports or results amongst four different laboratories in South Africa. A large soil sample was taken under supervision of an independent agronomist, then thoroughly mixed and divided into forty (40) sub-samples. These were sent to four different soil laboratories one week apart in three different batches. The laboratories were unaware that the three batches were from the same source. By using an ANOVA, the results of the soil samples were statistically analysed and meaningful differences ($p < 0,05$) were found in the analysed levels of macro-elements (N, P and K) between laboratories as well as between different batches within each laboratory. Less variation was found with regard to microelements where significant differences were only found in the analysed copper (Cu) and boron (B) contents of some labs. The study results indicated that meaningful variations may occur between different laboratories, although it was found that some laboratories have less or almost no variation between the different batches that were analysed. A laboratory with the most consistent results must thus be used in order for the farmer to create a reliable record of the trends in soil fertility status of the farming unit.

Chapter 1 – Introduction and Background

1.1 Introduction

The world population is increasing rapidly with agricultural land being a fixed resource. The availability of this resource for agriculture will decrease in time due to the pressure of human settlement and other developments, such as roads and leisure.

According to Du Plessis (2003), maize is one of the most important crops planted by farmers in South Africa and it has many different uses and applications in the modern world. White maize is mostly used for human consumption. With mounting pressure on the availability of agricultural land, which is fast diminishing, it is crucial that farmers produce crops, for example maize, in the most effective, efficient and economical manner. This must be done in such a way that the long-term fertility of the soil is maintained.

1.2 The reason for the study

A common problem is that some farmers do not have sufficient knowledge of the fertilisation requirements of plants to make an informed decision. This makes the farmer entirely dependent on the recommendations of fertilizer advisors, who are also the salesmen, regarding the types and quantities of fertilizers (macro and micro elements) to be applied. As a result of the ignorance or skepticism of farmers, this may lead to under- or overapplication of inorganic fertilizers.

Fertilizer containing macro and micro elements forms the basis of a good yield and should be applied in correct quantities. Fertilizer should be applied at the correct physiological growth stage of the plant. Of further importance is the cost associated with fertilizers, since it makes a meaningful contribution to the total input cost per hectare of crop cultivation. Notably, farmers sometimes use a multi micro fertilizer that is sufficient to satisfy the needs of a specific element, whilst not fulfilling the needs of another deficient micro-element (Halliday & Trenkel, 1992).

1.3 Objectives

1.3.1 Overall objective

The overall objective of this study is to determine the fertilisation practices as applied by farmers in the irrigation areas of the Jacobsdal, Prieska, Vaalharts and Douglas regions in the central parts of South Africa.

1.3.2 Main objectives

The study consist of four main objectives, namely:

1) to study the behavior of the farmers regarding their fertilizer management practices;
2) to study the fertilizer salesmen's behaviour and their influence on the farmers' fertilizer practices;
3) To determine the fertilizer companies' marketing strategies and how they influence the farmers' decision making; and
4) To determine the level of variations in findings (analyses results and recommendations) between different laboratories.

a) Objective 1: To study the farmer's behaviour regarding fertilizer management

The following specific objectives were formulated for this objective:

- To determine the information that farmers will take into consideration when choosing the types of fertilizer to be used;
- To determine the information that farmers will take into consideration when predicting or establishing the amount of fertilizer to be applied during the growing season;
- The information that farmers take into consideration when deciding on the method to be used for applying the fertilizer;

- To determine the information that farmers will take into consideration in order to determine the most optimal physiological growth stage for the plant so that the fertilizer can be applied for optimal use;
- The information that farmers take into consideration when evaluating the fertilizer salesman's recommendations;
- The methods used by farmers to take a soil sample and the way they interpret the results of the soil analysis;
- To determine the ways in which the farmer implements the recommendations from the soil analysis report to improve yield and the condition of the soil in the long run;
- To determine if certain demographical traits of farmers (for instance age, experience and level of schooling) will dictate their fertilisation practices.

b) Objective 2: The fertilizer salesman’s behaviour

The following specific objectives were formulated for this objective:

- To obtain accurate information on the methods used by fertilizer salesmen to determine the amount of fertilizer required;
- To analyse the recommendation of the fertilizer salesman in terms of the types or sources of fertilizer the farmers should use;
- To determine if there is a meaningful correlation between the recommendations of the fertilizer salespersons and the size of the farming unit as well as the financial position (liquidity) of the farm.

c) Objective 3: To access the marketing strategies of selected major fertilizer companies in South Africa

The following specific objectives were formulated for this objective:

- To obtain accurate information on the methods or strategies used by fertilizer companies to market and sell their fertilizer to farmers.

d) ***Objective 4: To determine the level of variations in findings (analyses results and recommendations) between different laboratories***

The following specific objectives were formulated for this objective:

- To determine if there are meaningful variations in soil test results between four major soil analysing laboratories in South Africa.

1.4 Hypotheses

The following hypotheses are tested by the study:

- H1. The laboratories of South Africa will give more or less the same result from the soil analyses;
- H2. Input cost per hectare on fertilizers will be lower on large farms than on smaller farms;
- H3. Farmers that have a tertiary qualification in agriculture will utilize different methods of fertilizer application than farmers without an agricultural-related qualification;
- H4. Farmers that have more experience in terms of years of farming will not be easily influenced by the trends of the fertilizer company or fertilizer agent;
- H5. Fertilizer agents' recommendations will differ from area to area and farmer to farmer as a result of the farmer's financial position;
- H6. The manner of purchasing the fertilizer will differ from area to area due to the farm's size.

1.5 Structure of the report

The structure of this research report is as follows;

- Introduction and background;
- Methodology;

- Theoretical background;
- Results;
- Summary and recommendations;
- References.

Chapter 2 – Methodology

2.1 Study sample area

As dictated by the objectives of the study, the research focused on selected irrigation schemes in the central parts of South Africa, being the Northern Cape and the Free State. The irrigation schemes selected were Vaalharts, Oranje-Riet, Douglas and Prieska, if which their relative positions are indicated in Figure 2.1.

Figure 2.1: Area map of the four selected study areas

2.2 Sample selection

A stratified random sample was used to select the respondents for the study in order to ensure the representability of all groups. The water councils of each area were requested to identify a number of large and small commercial farmers (in terms of the size of allocated water rights) in their respective service areas. With the help of the water council in each area, the identified commercial farmers were subsequently interviewed by appointment, utilising a structured questionnaire (see Par. 2.4 as well as Annexure 1). Consequently, four large-scale and four smaller commercial farmers were interviewed in each of the irrigation areas of Vaalharts, Oranje-Riet, Douglas and Prieska respectively, resulting in thirty-two (32) respondents representing commercial irrigation farmers.

During the interview with the commercial farmers, each respondent was also requested to reveal the identity of the fertilizer salesman that is used. This resulted in identifying eight salesmen that, in turn were subsequently also interviewed, using another structured questionnaire (see Par. 2.4 as well as Annexure 2).

In line with the objectives of the study, information was also required from major national companies selling fertilizers to farmers. In this regard, nine companies were identified and telephonic discussions took place and responses were documented accordingly (as per a structured list – see Par. 2.4 as well as Annexure 3).

Thus, a total of fourty-nine (49) respondents from different backgrounds were interviewed in order to realise the objectives of the study.

2.3 Soil sampling

In line with Objective 4 of the study, the researcher and a qualified person from the local agricultural company obtained a representative soil sample, from a field in the Oranje-Riet area (- see Annexure 4). In order to ensure that each laboratory received exactly the same sample to analyse, the soil sample obtained was mixed thoroughly and then divided into fourty (40) sub-samples and packaged in similar containers prior to sending it off. Three samples were subsequently sent to the four laboratories in three different batches with intervals of a week between batches. Each laboratory therefore received similar soil samples to analyse.

2.4 Questionnaires

Primary information was not sufficient in order to answer the objectives and support/test the hypotheses of the study, hence it was necessary to develop a series of questionnaires to obtain the necessary information from the respective respondents as mentioned in Par. 2.2.

According to the main objectives of the study, these respondents include (i) the farmer, (ii) the fertilizer salesman, and (iii) the fertilizer company. The structured questionnaires consist of the categories following hereafter.

i) Questionnaire to obtain information from the farmer

The objective of the questionnaire was to determine the farmer's behaviour in respect of several categories (- See Annexure 1). The questionnaire contains the following categories or themes:

- Biographic information of the respondent;
- Type and quantities of fertilizer used by the respondent;
- The methods and time of application of fertilizers;
- The fertilizer salesman's recommendation;
- Method of soil sampling and interpretation of the results;
- Opinions on optimal long-term economic practices;
- Interpretation and implementation of soil analysis reports;
- Assessment of the fertilizer company's marketing strategy.

ii) The fertilizer salesman

The objective of the questionnaire was to obtain information from fertilizer salesmen (see Annexure 2). The questionnaire contains the following categories:

- Biographic information;
- Information on the recommended quantity and types of fertilizer to be used by the farmer.

iii) The fertilizer company

The objective was to obtain information from companies that supply fertilizer to farmers. A structured list (see Annexure 3) was used to obtain information regarding the suppliers':

- Manufacturing techniques, agronomical services and the marketing strategy.

In all cases, several questions were listed under each of these headings to obtain all the relevant information to cover the objectives of the study.

2.5 Processing of the data

The data collected from each respondent were documented and statistically processed in order to gather the required accurate information.

In this study, both descriptive statistics and statistical inference were used. Data were obtained in the form of nominal data, ordinal data, interval data and ratio scales. The mean and the mode were used to summarise the distribution of data. Absolute and relative frequencies as relevant descriptive methods were used to describe the relationship between selected variables. The central tendency of interval and ratio data was determined by calculation (Steyn, *et al*., 1987).

The z-test was applied to determine whether there were significant differences between the practices of farmers with a large turnover and those with a small turnover. The t-test was utilised in cases where unequal variances between groups occur (Steyn, *et al*., 1994), while the analysis of variance (ANOVA) was used for two and more variables. Scheffe's method of pairwise comparison of treatment averages was used to determine whether groups differ statistically from one another or not.

Chapter 3 – Theoretical framework

This chapter provides a theoretical description of some of the concepts and principals of soil fertility that are encapsulated in the objectives and hypotheses of this study.

3.1 The type of fertilizer

Deciding on the correct type of fertilizer is crucial for the farmer in order to produce the ultimate crop, therefore this decision should be made carefully and informatively. All the elements in fertilizer have different characteristics that have positive or negative impacts on soil health and ultimately crop yield. Based on this knowledge, it is vital for the farmer to make the correct decision, as this directly affects the farmer's success rate. The best quality fertilizer for the farmer's identified soil needs may not always be obtainable. This could be due to the farmer's lack of available capital or non-availability of the specific element or fertilizer in the country. Choosing an alternative fertilizer that is as close to the elements required, should be decided on.

A chemical soil analysis is one of the best methods to determine the amount of fertilizer that the soil requires. The soil analysis will indicate to the farmer the exact quantity of different elements that is necessary for the soil to reach maximum potential for a specific type of plant, thereby ensuring better crop production and sustainable farming (FSSA, 2003).

There are many factors that play a role in the soil yield potential. For example; depth of the soil, percentage of clay in the soil, organic material in the soil, the texture of the soil, structure of the soil, the way the soil is cultivated in time as well as the characteristics of the subsoil (Martin, 2010).

The supplier of the fertilizer will always be a factor that has to be taken into consideration when choosing the correct fertilizer. Some suppliers import all their fertilizers while others manufacture it locally. These factors may influence the price and the quality of the fertilizer.

Local manufacturers of fertilizer have a steady stream of production, resulting in the local supplier most likely always having fertilizer stock that can be ordered by the farmer, as needed. However, in most cases some elements of fertilizer will be imported, and it will be the fertilizer company that can manage these imports the best that will make sure to have a steady supply of fertilizer. Importing fertilizer suppliers usually only have stock available when their supplies have reached South African shores. When the farm has good fertilizer storing facilities, fertilizer can be purchased even before the season commences and then safely stored. The reasoning behind this practice is that the price of fertilizers is usually lower during times of low demand, i.e. out of season. However, only farmers that find themselves in a favourable financial position, for example producers with cash or other credit facilities, are able to buy fertilizer out of season as they are not dependant on production loans from the local farming inputs supply company (Lotz, 2005).

The main elements required in crop production, the main forms in which it is available to the farmer, its functions within a plant as well as the factors influencing its availability to a crop, will be discussed in the following paragraphs.

3.1.1 Nitrogen (N)

3.1.1.1 Functions of N in the plant

Nitrogen is an indispensable element in all plants. It is known for its genetic, metabolic and structural components found in plant cells (Arayaa *et al*., 2019). Nitrogen is vital due to the fact that it is a major component of chlorophyll, the compound by which plants utilise sunlight energy to produce sugars from water and carbon dioxide (i.e. photosynthesis). It is also a major component of amino acids: the building blocks of proteins (Duana, *et al*., 2019).

3.1.1.2 The main factors affecting N availability to a crop

Soil management is crucial for crop health. When excessive water is in the soil the uptake of many elements is negatively influenced, including nitrogen. Residual nitrogen in soil from previous crops and organic nitrogen from residues improve the available nitrogen for the plant (Spectrum Analytic, n.d.).

The following nitrogen sources will be discussed briefly:

- Urea;
- Ammonium sulphate;
- Ammonium nitrate;
- Limestone ammonium nitrate;
- Urea ammonium nitrate;
- Anhydrous ammonium.

3.1.1.2 Urea (CH4N2O)

Urea is one of the most popular N sources in the world today. Urea contains a 46% nitrogen analysis, which is deemed a high percentage and it is a popular source of N for farmers. It is relatively safe and easy to use on the farm. To transport this fertilizer is hassle-free and requires limited equipment to handle and apply this source. Urease is an enzyme that is catalysed when the hydrolysis of urea to ammonia occurs. This process commences when urea is applied to the soil. The soil's micro-organisms, which is virtually present everywhere in soils, then produce urease (Witte C, 2011).

Ammonia losses can be significant and a costly mistake for farmers. When urea is applied to the soil surface without incorporating the fertilizer into the soil, a significant percentage of the applied N can be lost, especially if the farmer is not weary of the pH status of the soil (Helm Ag, n.d.). Table 3.1 illustrates the percentage of nitrogen that is volatilised in a certain number of days when urea is applied to the surface of soils with different pH levels (Overdahl, *et al*., n.d.).

Table 3.1: Rate of nitrogen volatilisation when the soil has different pH levels

Number of days	Soil pH					
	5.0	5.5	6.0	6.5	7.0	7.5
	(% of added N volatilised)					
0	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	1%	5%
4	1%	2%	5%	10%	18%	20%
6	4%	5%	7%	11%	23%	30%
8	8%	9%	12%	18%	30%	33%
10	8%	10%	13%	22%	40%	44%

(Source: Overdahl, *et al*., n.d.)

From Table 3.1 it is established that, the higher the pH of soil, the higher the N losses that can be expected over time.

Temperature plays a similar role in the volatilisation of nitrogen, as indicated in Table 3.2 (Overdahl, *et al*., n.d.).

Table 3.2: Influence of temperature on the volatilisation of nitrogen

Number of days	Temperature (°C)			
	7.2 °C	15.5 °C	23.8 °C	32.2 °C
	(% of added N volatilised)			
0	0%	0%	0%	0%
2	0%	0%	1%	2%
4	2%	2%	4%	5%
6	5%	6%	7%	10%
8	5%	7%	12%	19%
10	6%	10%	14%	20%

Source: Overdahl, *et al*., n.d.

Table 3.2 demonstrates that when urea is applied to the surface of the soil and not cultivated into the ground, the higher the temperature and the higher the losses occured (Overdahl, *et al*., n.d.).

In order to obtain maximum absorption of ammonia and nitrogen, the following practices should be adhered to:

- Do not apply the urea to the surface of soil with a high pH level, rather incorporate it into the soil;
- If possible apply the urea on a cool and non-windy day;
- If applied to no-till and high pH level soils, ammonia should be watered in (Overdahl, *et al*., n.d.).

Urea is a safe source of N for virtually any produce and crop. When making use of a urease inhibitor the loss of nitrogen from urea can be reduced.

Advantages of urea

- Available in most market places.
- Has a high solvability, top dressing is easy;
- The cheapest source of nitrogen to transport due to its high content of N;
- Low-salt index (FSSA, 2003).

Disadvantages of urea:

- It has a high volatilisation rate compared to other sources;
- It is quickly leached away;
- Chemical burn to plant can easily occur;
- It is toxic to seedlings due to biuret content. If the product has more than 1% of biuret it will be toxic to plant life (FSSA, 2003).

Fertilizer salt index is a measure of salt concentration induced in a soil solution. The salt index is a numerical value expressed as a ratio in which the selected fertilizer product is compared to the same weight of sodium nitrate, where sodium nitrate is assigned a value of 100 (Witte, 2011.) When the salt index was developed, sodium nitrate was used as the measurement point for comparison because it was widely available in market places and it is one hundred percent soluble in water (Mortvedt, n.d.). Table 3.3 provides the salt index of a few popular fertilizer sources.

Table 3.3: Salt index values of different types of fertilizer (Mortvedt, n.d.)

Material and analysis	Salt Index
Nitrogen/sulfur	
Ammonia, 82% N	47.1
Ammonium nitrate, 34% N	104.0
Ammonium sulfate, 21% N, 24% S	68.3
Ammonium thiosulfate, 12% N, 26% S	90.4
Urea, 46% N	74.4
UAN - 28% N (39% am. nitrate, 31% urea)	63.0
- 32% N (44% am. nitrate, 35% urea)	71.1
Phosphorus	
APP, 10% N, 34% P205	20.0
DAP 18% N, 46% P205	29.2
MAP 11% N, 52% P205	26.7
Potassium	
Monopotassium phosphate, 52% P205, 35% K2O	8.4
Potassium chloride, 62% K20	120.1
Potassium sulfate, 50% K20, 18% S	42.6
Potassium thiosulfate, 25% K20, 17% S	68.0

3.1.1.3 Ammonium sulfate (NH4)2 SO4

In the nylon industry, ammonium sulfate is primarily a by-product of nylon. Ammonium sulfate (AS) is not produced solely as a fertilizer source. In most soils, AS has little to no surface volatilisation losses. Ammonium sulfate has proven to be a good source of sulphur, where the crops or soil are in dire need. However, it proves to be the most acidifying source of N fertilizer, thus it should be avoided in already high acidity soils (Raun & Zhang, 2006).

Advantages of ammonium sulfate:

- It will not leach;
- It has a content of 23% sulfur in SO^4 source that is immediately available to the plant for absorption;
- It is easily soluble in water, which makes top dressing easy;
- When the soil has a high pH, acidifying will take place with ammonium sulfate (Bing, *et al.*, 2017).

Disadvantages of ammonium sulfate:

- Due to the low concentration of nitrogen, it is expensive to transport and to store;
- When stored for a long period of time the product will lose quality and become hardened;
- Volatilisation will take place if spread out on the soil, it must be work into the soil or irrigated into the soil;
- Due to the fact that ammonium sulfate has a sour effect on the soil, it cannot be used on soils with a low pH;
- Ammonium sulfate is not a very popular source of nitrogen;
- It is not easily found in the market or local agricultural supplier store (“cooperative”) (Bing, *et al*. 2017).

3.1.1.4 Ammonium nitrate (NH4NO3)

Ammonium nitrate's composition consists of 50% of the nitrogen in the nitrate form and the other 50% in the ammonium form. Ammonium nitrate is less prone to volatilisation than urea, meaning that when ammonium nitrate is applied to the soil surface, less ammonia is lost. Ammonium nitrate is an unpopular nitrogen source of fertilizer, mainly due to its low nitrogen (21%) content, compared to urea (46%). Ammonium nitrate is a hazardous product as it was used for explosives in the past. If waterlogged soil is the case, ammonium nitrate should not be administered together with urea (Grant, 2017).

Advantages of ammonium nitrate as a commercial fertilizer:

- It exhibits low volatility losses;
- It is immediately available to the plant;
- It does not raise the pH of the soil;
- It remains available to the plant longer;
- It can be left on the surface without losses (Hoffmann & Hoffmann, 2019).

Disadvantages of ammonium nitrate as a commercial fertilizer:

- It has a high salt index, easily burns the seedling;
- It is an expensive source of nitrogen;
- It will leach immediately if over-irrigated;
- It loses quality when stored for a long period of time (Ingraham & Salas, 2019).

3.1.1.5 Diammonium phosphate ($(NH_4)_2HPO_4$)

Diammonium phosphate contains 18% nitrogen, and 46% phosphate, making it also a remarkable source of nitrogen. This enables DAP to be sold as a primary phosphorus source to the farmers. The restricted use of diammonium is very low. If the main purpose is to apply DAP as a phosphate source, it is recommended that it be band placement or placed with the seeds (Jasinski, 1998).

Advantages of diammonium phosphate:

- The phosphate is not soluble in water but available to the plant;
- It has a low salt index (26.6);
- It is an excellent source of phosphate in sandy soils;
- It is used as a source of phosphate but also has an 18% nitrogen content (Kumar & Behal, 2017).

Disadvantages:

- It has a relatively low nitrogen content of 18%;
- In heavy soils, the phosphate gets adsorbed and it is thus unavailable to the plant (Kumar & Behal, 2017).

3.1.1.6 Limestone ammonium nitrate ($H_4CaN_2O_3$)

When treating ammonium nitrate solution with powdered limestone, limestone ammonium nitrate (LAN) is created. Limestone ammonium nitrate (LAN) is a source of fertilizer. It is white to gray in color, depending on the limestone used in the manufacturing process. The fertilizer has a chalky powder texture. When produced with dolomitic limestone the fertilizer consists of 20% nitrogen (N), 6% calcium (Ca) and 4% magnesium (Mg). If the quantity of limestone is smaller than that of used ammonium nitrate, the nitrogen content can increase to 28%. In the case of high acidity soils, LAN should rather be used as opposed to ammonium nitrate (Gowarike, *et al*., 2009).

Advantages of limestone ammonium nitrate:

- It is in a nitrate form, therefore the nitrogen is immediately available for absorption by the plant;
- It has a low salt content, which prevents chemical burn on the plant;
- LAN is a popular product and therefore easy to come by;
- Volatilisation is minimal (Fraga et al., 2017).

Disadvantages of limestone ammonium nitrate:

- Leach losses are high;
- It is an expensive product;
- It has a low solvability index;
- It loses quality when stored for a long period of time (Gowarike, et al., 2009).

3.1.1.7 Urea ammonium nitrate (CH_4N_2O+NH_4NO_3)

The composition of urea ammonium nitrate is: one part water, one part urea, and one part nitrate. This specific composition makes urea ammonium nitrate an extremely popular liquid fertilizer amongst farmers. The urea composition of the fertilizer makes it vulnerable to the same losses as urea, therefore the same recommendations apply as would for urea. Severe leaf burns can be expected if UAN is applied on days where temperatures exceed 21 °C. In these temperatures, additional losses due to N volatilisation can occur. This can cause the plant to lose its efficiency. In the case of wheat, if applied on a winter's day where temperatures are below 21°C and is followed by rain, it can be an incredibly beneficial source of nitrate. The application of urea ammonium nitrate varies for maize but should not exceed 35kg/ha. If this limit is exceeded, it could seriously damage the leaves of the maize plant (EFMA, 2000).

Advantages:

- It is immediately available to the plant;
- It has a lower pH than urea;
- It exhibits less volatilisation loss than urea;
- It can be applied through irrigation water (Corbin & McCord, 2013).

Disadvantages:

- It has a lower nitrogen content than urea;
- It requires specialised equipment to handle it;
- Its volatility losses are high (Corbin & McCord, 2013).

3.1.1.8 Anhydrous ammonia (NH_3)

Anhydrous ammonia (AA) is the highest source of nitrogen as it contains 82% N. This effectively renders it the most cost-efficient source of fertilizer to transport. Anhydrous ammonia is a gas type fertilizer source. When transported and handled it presents as a liquid due to the pressure. When making use of AA, special equipment is needed to handle and apply the fertilizer. In order to apply anhydrous ammonia, it should be injected at least 100mm beneath the surface of the soil. When injected beneath the soil drastic loss through volatilisation is prevented. When anhydrous ammonia is not handled under pressure it presents in gas form, which renders it a difficult product to apply. When knifed into moist or slightly sandy soils the opening in the soil does not immediately close up. Mechanical pressure is recommended in order to prevent NH_3 from escaping into the air without being absorbed by the soil. Furthermore, nitrogen volatilisation significantly increases when AA is applied to the soil with a high pH value (Yara, n.d.).

Advantage of anhydrous ammonia:

- The concentration (82%) of the source makes it the cheapest N source to transport, but special equipment is still needed (Yang & Rosentrater, 2017).

Disadvantages of anhydrous ammonia:

- Specialised equipment is required and extremely expensive;
- Volatilisation is very high;
- It kills micro bacteria in the soil;
- It is an extremely dangerous product to work with;
- The equipment must be maintained very well to prevent losses;
- It is toxic to seedlings (Yang & Rosentrater, 2017).

3.1.2 Phosphorus (P)

Phosphorus is an essential plant nutrient for several structural compounds. Phosphorus serves as a catalyst in the conversion of many biochemical reactions in a plant. One of the key roles of phosphorus is to capture and convert the sun's energy into useful compounds for the plant.

Phosphorus is a vital component in the plant's DNA and RNA. RNA reads the plant's DNA code in order to build proteins and other compounds crucial for the plant's structure, seed yield, and genetic transfer. Phosphorus bonds link DNA and RNA together.

Phosphorus is also a vital component for the plant energy unit better known as adenosine triphosphate (ATP). ATP is created during the process of photosynthesis. This makes phosphorus vital for a plant's general health and vigor (Johnston & Steén, 2000).

Some specific growth factors associated with phosphorus are the following:

- Stimulation of root development;
- Stalk and stem strength are increased;
- Greater seed production;
- Earlier crop maturity;
- Increased nitrogen capacity in legumes;
- Grain quality improves;
- Increased resistance to disease (Mullins, 2009).

3.1.2.1 Functions of phosphorus in the plant

The function of phosphorus in the plant involves the following:

- The process of photosynthesis;
- Plant respiratory systems;
- Production of seeds and fruits;
- Production of energy;
- Storage and transfer of minerals and water;
- Cell division;

- Enlargement of the cells (Mullins, 2009).

3.1.2.2 Factors affecting P availability

The following soil factors strongly affect the availability and presence of P:

- The pH level of soil;
- The compaction of soil;
- Soil aeration;
- Moisture levels of soil;
- Soil temperature;
- The soil texture;
- Organic matter in soil;
- Crop residues;
- Zinc availability.

The following phosphorus sources will be briefly discussed in the following paragraphs:

- Mono-ammonium phosphate;
- Di-ammonium phosphate;
- Triple super phosphate;
- Single superphosphate (Johnston & Steén, 2000)

3.1.2.3 Mono-ammonium phosphate ($NH_4H_2PO_4$)

Mono-ammonium phosphate, commonly known as MAP, is a granular fertilizer. This is a very popular fertilizer. MAP is known for rapidly dissolving into moist soil and is highly water-soluble. Mono-ammonium phosphate is highly recommended in instances where the pH value of soil is neutral or high. The reason for this is that the pH solution that surrounds the granule renders it moderately acidic (Haifa Chemicals, n.d.).

Following hereafter are some advantages and disadvantages of using MAP as a source of fertilizer:

Advantages:

- No leaching into the soil;
- No souring effect on the soil (when pH is correct);
- It is a popular product that is widely available in market places;
- It is a cost-efficient source of phosphorus (Barrett & Arnall, 2011).

Disadvantages:

- Does not contain any sulphur;
- Souring effect on soil when pH is too high;
- The quality of the product easily deteriorates with storage (Barrett & Arnall, 2011).

3.1.2.4 Diammonium phosphate (DAP)

Diammonium phosphate is used in multiple component fertilizers and indirectly applied compound fertilizer. This is due to its high water-soluble nitrogen phosphate. The only rival of diammonium phosphate (DAP) is mono-ammonium phosphate (MAP). This makes diammonium phosphate one of the most popular phosphate fertilizers. Phosphate is mined in the form of rock phosphate. When introducing sulphuric acid to phosphate, it reacts and phosphoric acid is created. Phosphoric acid reacts with ammonia. During this process, poorly water-soluble rock phosphate can be converted to water-soluble phosphate fertilizer. These processes enable the plant to easily absorb the fertilizer. DAP is gray or beige-gray in colour and has a granular substance texture (Vitosh, 1990).

Advantages:

- It is primarily a phosphate source but contains nitrogen;
- It has a low salt index;
- Low solubility, therefore it is good to use on sand soils (Oldham, 2017).

Disadvantages:

- Its nitrogen component is volatile;
- It contains only 18% nitrogen (Oldham, 2017).

Examples of different variations of superphosphates will be discussed in the following paragraphs.

3.1.2.5 Triple superphosphate (TSP)

Approximately up until the 1960s, triple superphosphate was an exceedingly commonly used fertilizer and readily available in the marketplace. This frequent usage is due to its highly concentrated levels of phosphate. TSP can be used as a direct application fertilizer or as a raw material in the production of complex fertilizers. Most of the phosphate, approximately 90%, in TSP is water-soluble. Due to its water solubility, it becomes rapidly available for uptake by plants. Hoverer, in the modern era MAP and DAP, both nitrogen phosphate fertilizers, have become exceedingly popular.

Triple superphosphate is a phosphate nutrient mostly found in legumes, for instance, peas, lentils, and beans. TSP is a very popular and highly concentrated source of phosphate fertilizer (45%). TSP does not require additional nitrogen sources. One of the advantages of TSP is that it is water-soluble. TSP is grayish in color. Monocalcium phosphate is one of the active ingredients in TSP (Yusran, 1993).

3.1.2.6 Single superphosphate (SSP)

Single superphosphate, better known as SSP, contains18% to 22% phosphate. SSP has a sulphur content of 10% to 12%. SSP is thus also a good source of sulphur for crops. However, if compared to other sources of superphosphate such as DSP (43%) and TSP (45%), it has a much lower phosphate content. As mentioned, SSP provides a high concentration of sulphur (Ploteghera & Ribeirob, 2015).

Advantages:

- Contain sulphur content (10-12%);
- Good for soil preparation to grow seedlings;
- Ready for uptake by the plant (Ploteghera & Ribeirob, 2015).

Disadvantages:

- The most expensive source of phosphate;
- Doesn't contain any nitrogen (Ploteghera & Ribeirob, 2015).

3.1.3 Potassium (K)

Potassium is an essential plant nutrient. The general term used to describe a variety of K-containing fertilizers is potash. Plant deficiencies are commonly controlled through the use of inorganic potassium. If the soil is not able to supply the sufficient levels of potassium needed by the crops, it is a necessity to supplement (Johnston, n.d.).

3.1.3.1 Functions of potassium (K) in a plant

Potassium does not form a structural part of any plant component or compound, but is required for various metabolic activities and physiological functions.

Some of these include the following:

- Role in photosynthesis and plant food formation;
- It has a role in sugar and carbohydrate production, transport, and storage.

A common effect of potassium is an N shortage in legumes when a shortage of potassium occurs. The reason being that the potassium deficient plants produce and transport less sugar to the legume nodules, thus causing the N-fixing bacteria in the nodules to reduce the amount of N produced. Significantly, in conjunction with Ca and B, potassium controls plant cell turgor in the proper development of cell walls and through this, the opening and closing of leaf stoma. This, in turn, controls the plant's ability to effectively respond to drought stress (Abaye, n.d.).

3.1.1.2 Solubility of potassium

In Figure 3.1 the different sources of potassium are compared to each other in terms of their solubility in water at different temperatures (Source: Mikkelson, 2013).

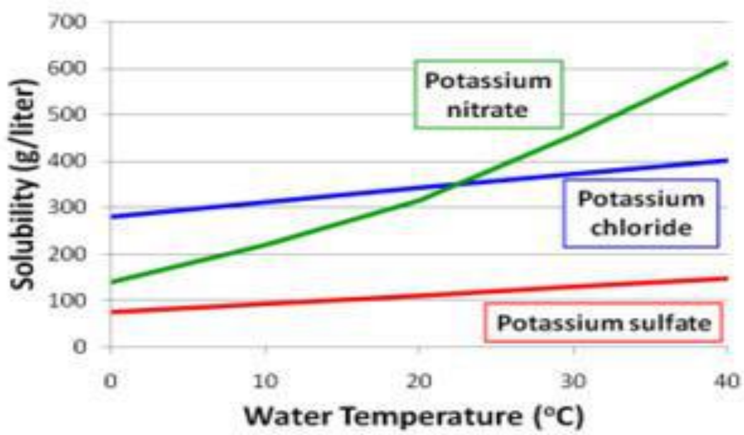


Figure 3.1: Solubility of potassium

Figure 3.1 shows that potassium nitrate is highly soluble (600g/litre H_2O) and potassium sulphate has a low rate of solubility in water. Furthermore, temperature does not have a huge effect on the solubility of the source (Mikkelson, 2013).

The following sources of potassium will be briefly discussed in the following paragraphs:

- Potassium sulfate;
- Potassium chloride;
- Potassium nitrate.

3.1.3.3 Potassium sulfate (K2SO4)

Potassium sulfate (K_2SO_4) is an excellent source of nutrients for plants. It is also a common potash fertilizer due to the K portion in K_2SO_4. In addition, this fertilizer is a valuable source of S, which enhances plant growth. Notably, sulphur is a vital requirement for the process of photosynthesis and enzyme functions of the plant. Potassium sulfate makes for a very suitable source of K. Potassium sulfate is only approximately one-third as water-soluble as KCI. This characteristic of potassium sulfate prohibits it from being readily dissolved in water, which becomes an inhibiting factor when applied through water irrigation systems. In the instances where the farmer needs an additional source of S, K_2SO_4 is applied through the water irrigation system (Zehler, *et al*., 1981).

Advantages of potassium sulfate:

- Sulphur contents;
- Compared to KCL, it has a low salt index;
- Can be used on soil with a high pH index (Adhikari *et al*., 2019).

Disadvantages:

- It exhibits low water solubility;
- It is an expensive source of potassium (Adhikari et al., 2019).

3.1.3.4 Potassium chloride (KCl)

Potassium chloride has a higher source of K than most other fertilizers. The K content of potassium chloride is 50% to 52%. This makes Potassium chloride (KCI) a very popular source of potassium. KCI is also a relatively low-cost fertilizer. KCI is commonly spread across the soil surface, prior to tillage or planting. It may also be applied in a concentrated band in close proximity to the seeds. If KCI is dissolved, it increases the soluble salt concentration. As a direct result of this specific property, KCI is band placed to the side of the seeds. This avoids damage to the germinating plant.

Potassium chloride rapidly dissolves in soil water. Potassium chloride can be dissolved and be applied as a liquid fertilizer through a water irrigation system (Thompson, n.d.).

Advantages:

- It is a low-cost source of potassium;
- It is highly concentrated and transport is cost-efficient;
- It is highly water-soluble (Lanzerstorfer, 2019).

Disadvantages:

- It has an extremely high salt index;
- Chemicals can burn the plant;
- It is not recommended for soil with high pH levels (Lanzerstorfer, 2019).

3.1.3.5 Potassium nitrate (KNO3)

Potassium nitrate is a chloride-free source of nutrients and is water-soluble. The N being immediately available to the plant for absorption in the form of nitrate, renders it a recommended fertilizer. There is no need for transformation or microbial action in the soil. The N to K ratio for potassium nitrate is 1:3, suggesting that potassium nitrate contains high quantities of K.

KNO_3 can be applied either during or prior to the growing season. The time of application depends on the results the farmer wishes to achieve. If applied prior to the season, it is applied as a preparation method for the soil. When applied during the season it serves as a supplement for the growing stages of the plants. In order to stimulate physiological processes or to overcome nutrient deficiencies in the plant, a diluted solution of KNO_3 could be sprayed onto the plant's foliage. Only a small portion of the global K fertilizer market consists of potassium nitrate (Vitosh, 1996).

Potassium nitrate is generally compatible with other fertilizers and is easy to handle and to apply. Unlike most commonly used K fertilizers, potassium nitrate becomes highly soluble under warmer weather conditions, allowing for a more concentrated solution. In order to prevent nitrate from moving beneath the rooting zone, careful water management procedures are necessary.

Advantages:

- It has a low salt index;
- It is immediately ready for absorption and use by the plant;
- It is chloride free;
- It contains nitrogen (Oosthuyse & Napier, 2012).

Disadvantages:

- It is an expensive source of potassium;
- It contains no chloride;
- It is fast leaching (Oosthuyse & Napier, 2012).

3.1.4 Calcium (Ca)

One of the three secondary nutrients is calcium, along with magnesium and sulfur. Primary nutrients and secondary nutrients are essential for healthy plant growth, albeit secondary nutrients in lesser volumes.

Calcium forms calcium pectate in the plant's metabolic system, which keeps the cell walls of plants together. Calcium pectate strengthens the cell wall structures, which provides stability and binds cells together. In the case of calcium deficiency, new tissue (such as root tips, young leaves and shoot tips), often display signs of growth distortion. This is caused by the formation of improper plant cell walls (Buechel, 2016).

One of the primary uses of calcium is to activate certain enzymes and to send signals that coordinate cellular activities. Calcium has a huge effect on the role of regulating the plant stomata. Calcium strengthens the plant's stomata function, which causes the induction of heat-shock proteins (Buechel, 2016).

3.1.4.1 Functions of calcium in the plant

- Proper cell division;
- Promotes greater elongation;
- Enhances nitrate uptake;
- Carbohydrate metabolism;
- Activates certain enzymes;
- Participates in hormonal processes;
- Starch metabolism;
- Develops proper cell walls;
- Protects plants against heat stress;
- Improved fruit quality;
- Protects plants against diseases (Sela, 2017).

3.1.4.2 Factors affecting Ca availability

- Soil pH levels;
- Cation exchange rate (CEC) of the soil;
- Sub-soil or parent material (Sela, 2017).

According to Spectrum Analytic (n.d.), cation exchange capacity (CEC) is a calculated value that is an estimate of the soil's ability to attract, retain, and exchange cation elements. In order for a plant to absorb nutrients, the nutrients must be dissolved. When nutrients are dissolved, they present in a form referred to as "ions". This means that they have electrical charges. Some important elements carry a positive electrical charge in their plant-available form, which are called cations and include potassium (K+), ammonium (NH4+), magnesium (Mg++), calcium (Ca++), zinc (Zn+), manganese (Mn++), iron (Fe++), copper (Cu+) and hydrogen (H+). Other important elements carry a negative charge and these are referred to as anions, which include nitrate (NO_3^-), phosphate ($H_2PO_4^-$ and HPO_4^{--}), sulfate (SO_4^-), borate (BO_3^-), and molybdate (MoO_4^{--}).

Figure 3.2 is a schematic presentation of the cation exchange in the soil CEC (Source: Spectrum Analytic, n d.).+

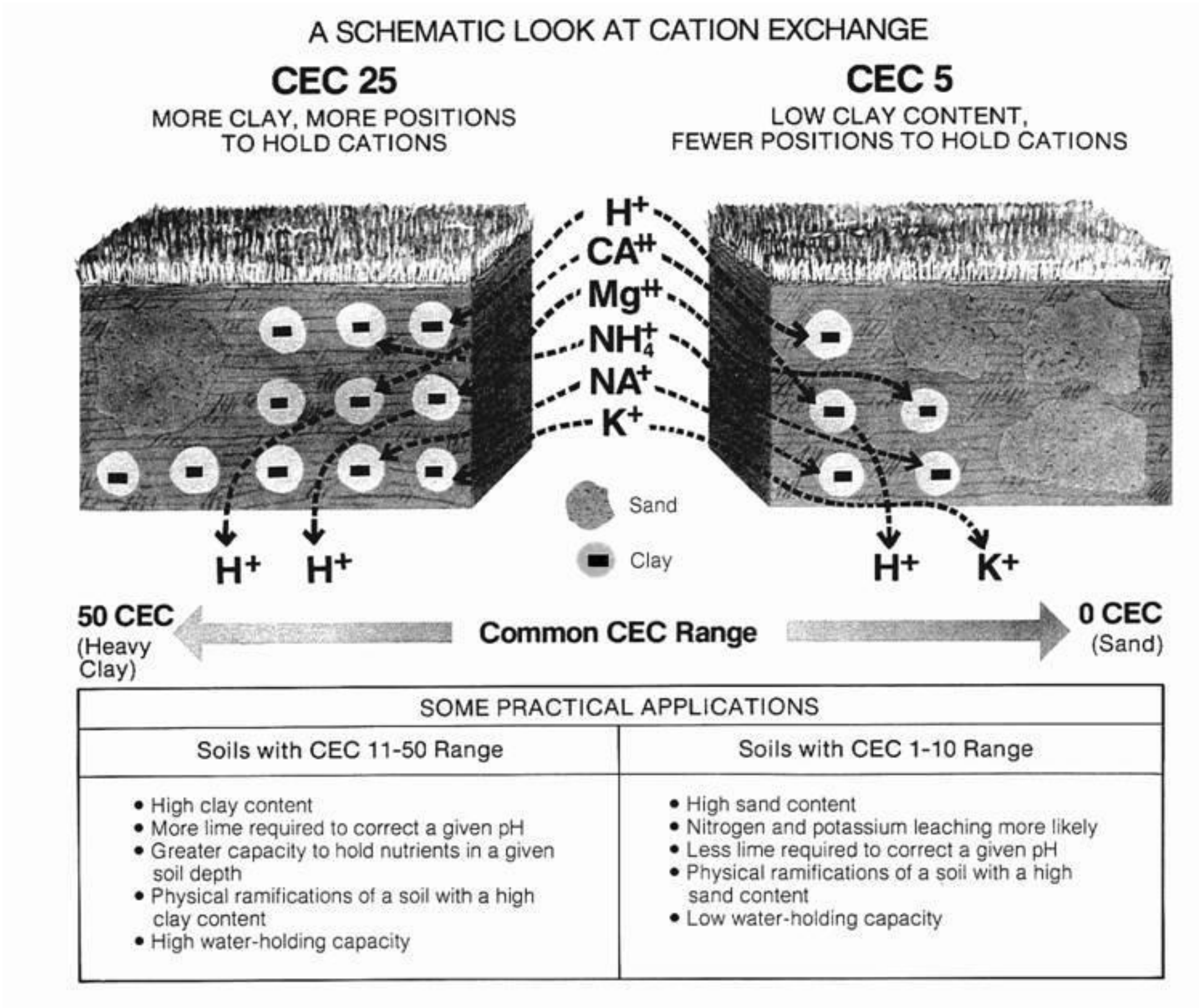


Figure 3.2: Schematic illustration of the CEC in soil

3.1.5 Magnesium (Mg)

Magnesium plays a wide variety of key roles in the functioning of plants. One of these roles is the photosynthesis process ($6CO_2 + 6H_2O \rightarrow C_6H_{12}O_2 + 6O_2$). Magnesium is a building block for chlorophyll. Without chlorophyll, plants are not able to absorb any sunlight. Chlorophyll is also an enzyme that causes leaves to appear greener. Low levels of magnesium in plants can lead to significant limitations in crop production (Senbayram, *et al.*, 2015)

3.1.5.1 Functions of magnesium in the plant

- Photosynthesis: Mg is the central element of the chlorophyll molecule;
- Carriers of phosphorus in the plant;
- Magnesium is both an enzyme activator and a constituent of many enzymes;
- Sugar synthesis;
- Starch translocation;
- Plant oil and fat formation;
- Nutrient uptake control;
- Increases iron utilisation;
- Aids nitrogen fixation in legume nodules (Cole, et al., 2016).

3.1.5.2 Factors affecting the availability of magnesium

- Soil Mg content;
- Soil pH;
- Cation exchange rate of the soil;
- Low soil temperatures (Härdter, et al., 2004).

3.1.6 Sulphur (S)

Sulphur is another element of the three secondary nutrients, along with calcium and magnesium. The plant needs secondary nutrients for normal and healthy growth procedures. Secondary only refers to the quantity that needs to be applied and not necessarily the importance of the nutrients. The deficiency of secondary nutrients can have the same negative impact on a plant as any other mineral deficiency. Sulphur's importance to a crop is sometimes overlooked and largely underestimated. There needs to be a significant balance between sulphur and nitrogen in crops. Without the correct amount of sulphur, a plant cannot efficiently utilise nitrogen and other nutrients, therefore it is necessary in order for the plant to reach its full potential (Vong, *et al*., 2007).

3.1.6.1 Functions of sulphur in the plant

- It is the structural component of protein and peptides;
- It converts inorganic nitrogen into a useable protein;
- It is the acting catalyst in the production of chlorophyll;
- It enhances nodule formation in legumes;
- It is a structural enhancer of various enzymes (Powel & Hons, 1992).

3.1.6.2 Factors affecting the availability of sulphur

- The texture of the soil;
- Soil organic matter;
- The temperature of the soil;
- Poor drainage;
- Irrigation water quality (Powel & Hons, 1992).

3.1.7 Zinc (Zn)

Zinc is essential to plant development and is one of the most essential micronutrients. Plants require zinc in smaller amounts but cannot reach their full potential without it. Zinc is a component of many enzymes and proteins found in plants. Zinc is needed to stimulate the plant's growth hormone production. Without the presence of zinc, the plant will be susceptible to internodes elongation (Montalvo, 2016).

3.1.7.1 Functions of zinc in the plant

- It produces auxins (essential growth hormone);

- It is the acting enzyme in protein synthesis;
- It is involved in the consumption and regulation of sugars;
- It influence the rate of seed and stalk maturing;
- It leads to the formation of chlorophyll and carbohydrates;
- It can withstand lower air temperatures (Sturikova, *et al*., 2018).

3.1.7.2 Factors affecting Zn availability

- Soil pH;
- Phosphate quantity in the soil;
- Organic matter;
- Nitrogen stress;
- Soil saturation;
- Cation exchange rate of the soil (Sturikova, et al., 2018).

3.1.8 Boron (B)

Boron (B) used alongside calcium ensures growth and health for crops as it is a micronutrient. Boron is one of the components that enhances the stability and growth of plant cell walls and functions in the reproductive structures. As boron is a mobile nutrient in the soil it is prone to movements in the soil. It is important to apply boron as evenly as possible across the soil as it is required in small doses (Uluisik, *et al*., 2018).

Boron is a component in cell wall formation and plant stability. It ensures the maintenance of the structural and functional integrity of the biological plant membrane. Boron activates the conversion of sugar into energy in the growing parts of the plant. In legume crops, an adequate amount of B is required for effective nitrogen fixation and nodulation (Uluisik, et al., 2018). In the case of Boron deficiency, empty pollen grains can be spotted. Boron deficiency can be detected in the early stages of growth: poor pollen vitality and a reduced number of flowers are key signs. In soybean plantations, a deficiency of boron can cause stunted root growth (The Mosaic Company, 2016).

3.1.8.1 Functions of boron in the plant

- It maintains a balance between sugar and starch;
- Translocation of carbohydrate and sugar;
- It is involved in the pollination process;
- It is a component for seed production;
- Protein formation;
- It assists in normal cell formation;
- It influences nitrogen metabolism;
- The necessity for proper cell wall formation;
- It is involved in the proper functioning of cell membranes;
- It transports K (K guards cells for proper control of internal water balance);
- Regulation of hormone levels (Hasenmueller & Criss, 2013).

3.1.8.2 Factors affecting availability

- pH levels;
- Low organic matter;
- Cation exchange rate of soil;
- Nitrogen stress (Hasenmueller & Criss, 2013).

3.1.9 Manganese (Mn)

Plants utilise manganese in very small quantities, yet Mn is of the utmost importance for healthy plant growth. Manganese is a key component in the process of photosynthesis. Manganese is similar to iron and its absence is often mistaken for an iron deficiency or toxicity. Manganese contributes to various biological systems; these include photosynthesis, respiration, and nitrogen assimilation. A healthy balance of manganese enables plants to enjoy resistance against root pathogens. Manganese is involved in the growth of pollen tubes and root elongation. In the process of pollen germination, manganese is required (Szymanko, 2013).

3.1.9.1 Functions of manganese in plants

- It activates fat forming enzymes;
- It aids in protein synthesis;
- It is a key component of chlorophyll;
- It is involved in nitrate assimilation;
- It functions in the formation of riboflavin, carotene, and ascorbic acid;
- It is involved in electron transport during photosynthesis;
- It contributes to hill reaction - water split during photosynthesis (Azzouzi, *et al*., 2016).

3.1.9.2 Factors affecting manganese availability

- Soil pH levels;
- Organic matter;
- Soil moisture levels;
- Cation exchange rate of the soil (Azzouzi, et al., 2016).

3.1.10 Copper (Cu)

Copper deficiencies or toxicities rarely occur but it is best to avoid either extreme, as this has a negative effect on crops. Copper is the key component involved in the formation of chlorophyll molecules in plants.

Copper activates the enzyme, which is involved in lignin synthesis. This makes Cu an indispensable source of plant enzymes. Proper plant respiration depends on good levels of copper. Copper assists in plant metabolism of carbohydrates as well as protein metabolism. Copper intensifies the flavour of fruit and vegetables, as well as a healthy colour glow (Xiaorongab, 2006).

3.1.10.1 Functions of copper in plants

- It is the catalyst in the photosynthesis and respiration process;
- It assist enzymes in building and converting amino acids to proteins;
- It has carbohydrate and protein metabolism functions;
- It is vital for the formation of lignin in plant cell walls;
- It contributes to structural strength of cells and plants (Ellingsen, *et al*., 2015)

3.1.10.2 Factors affecting availability

- Root growth;
- Soil pH levels;
- Flooding;
- Cation exchange rate of the soil;
- N stress (Ellingsen, *et al*., 2015)

3.1.11 Iron (Fe)

Iron plays a basic but important role in plants. Without sufficient levels of Iron, a plant cannot produce chlorophyll. The chlorophyll is a necessity for the plant's survival, as this produces oxygen. Iron aids the transportation of important elements through the plant's circular system (Baley, 2017).

Iron facilitates the reduction of nitrate and sulfate in plants. Iron is a required component for energy production in a plant. A sign of iIron deficiency will be indicated by the colour of the new sprouts (El - Jendoubi, et al., 2011).

3.1.11.1 Functions of iron in plants

- Development of chlorophyll;
- It enhances the function of chlorophyll;

- It is a component of certain enzymes and proteins;
- It is involved in plant respiration;
- It is a component of plant metabolism;
- It is involved in the chemical process (El - Jendoubi, et al., 2011).

3.1.11.2 Factors affecting availability

- pH levels of soil;
- Low organic matter;
- Saturated, compacted, or other poorly aerated soils;
- High P-value in the soil;
- Form in which N is applied;
- Cation exchange rate of the soil (Calabi-Floody, *et al*., 2018).

3.2 Predicting and establishing the amount of fertilizer required

A soil analysis is the best approach in order to establish the amount of fertilizer that needs to be utilised in order to achieve maximum production. Soil analysing prevents wastage of funds and over-fertilisation of the soil. It also assists farmers in their efforts to prevent the soil elements from being drained.

In Table 3.4, the required N, P and K application levels needed to obtain one ton of grain for selective crop types are shown. In other words, it shows how much of these elements are removed in a ton of the specific grain. This enables the farmer to apply the exact amount of fertilizer in order to farm sustainably and profitably. When the farmer applies less fertilizer than what the plant removes from the soil, the soil will become infertile and the farmer will not be able to farm sustainably in the long run (FSSA, 2007).

Table 3.4 Plant requirements of N, P and K to produce one ton of grain and plant material respectively

Grain type	N (kg)		P (kg)		K (kg)	
	Grain	Total plant	Grain	Total plant	Grain	Total plant
Production of 1 ton maize	15	27	3	4.5	3.5	20
Production of 1 ton wheat	22	27	3.8	4.8	4.3	13.9
Production of 1 ton sunflower	25.8	67	1.9	7.1	8.5	96.1
Production of 1 ton groundnuts	28	70	3	5.15	5	43
Production of 1 ton soybean	187	210	20	23	57	73

Source: FSSA, 2007

Table 3.4 illustrates the requirements of NPK fertilizer to various different crops. It demonstrates, first of all, in the "Grain" column the amount of fertilizer that is necessary for the crop to produce one ton of grain, and secondly, the "Total" column indicates the amount of total fertilizer that is necessary for the specific plant in order to produce one ton of plant material (including grain, leaves, stems, etc.). The latter is relevant should e.g. the maize plant be cut and used as silage or when stubble has been utilized by cattle after harvesting.

It is critical for the farmer to predict each season's yield potential. This should be a realistic prediction, often per hectare, that is based on the production (yield) history of that crop on the farm. If the prediction is unrealistic it could ruin the potential growth or yield of the crop and/or waste funds.

The weather has a direct influence on the fertilizer programme. Accurate climate predictions for a specific planting season is extremely important and should be based on the farm's history. This prediction is only possible if the farmer has such records of the farm and the area's historical weather data. If the farmer has extensive historical records it could assist in correctly predicting the weather for the upcoming season (FSSA, 2007).

It is a well-known fact that urea slowly sets to NO_3 in cold weather conditions. It is best then if the farmer applies LAN because it is already in NO_3 form, thus ready for absorption by the plants. In hot weather conditions, urea will rapidly turn to NO_3 form (Table 3.5). This enables the plant to absorb the fertilizer immediately. High temperatures will significantly increase ammonia volatilisation from the surface application but the volatilisation of urea and UAN will remain low (Adriaanse, 2012a).

Table 3.5: The estimated rate of conversion of Urea to NO_3

Av. soil temperature at 50 mm depth	50% conversion to nitrate (days)	100% conversion to nitrate (days)
1 °C	190	380
5 °C	38	76
10 °C	19	38
15 °C	13	26
20 °C	10	20

Source: Heard, 2014.

Table 3.5 is an estimated rate of conversion of urea to NO_3 at different temperatures at a soil depth of 50mm, and the estimated number of days that it will take to convert urea to NO_3 (Heard, 2014).

During a season that experiences more rain than expected, NO_3 leaching will be higher. The fertilizer programme should then be adapted to accommodate the variation in weather. A suitable solution for this situation is to apply less fertilizer at a time but more frequently.

The fertilizer salesman and the farmer should work together when deciding on the fertilising formula. The fertilizer salesman needs to make use of a recent soil analysis. An up to date soil analysis will accurately reflect the immediate status and nutrient needs of the soil. It is also crucial for the salesmen to understand the farmer's financial position. This will enable the salesmen to assist the farmers who have limited or restricted liquidity to optimally address the soils' needs over a period of time within the available budget. This approach is more affordable for such farmers, rather than attempting to correct all the needs at once during one season. It is important for the salesmen to have sufficient agronomical knowledge in order to understand the crop's nutritional requirements and physiological limitations. With this knowledge, the salesmen can assist the farmer to select the correct compilation or compendium of cultivars for the specific farmer's area and weather conditions. The salesman and the farmer can then collaborate to decide on the most suitable fertilizer programme (Adriaanse, 2012 b).

According to Lotz (2005), there are a few factors that influence a farmer's decision regarding the most appropriate source of fertilizer to be utilised. The following aspects should be considered by the salesperson and farmer respectively:

For the salesperson:

- Quality;
- Price;
- Availability.

For the farmer:

- Price;
- Climate conditions;
- Storage facilities;
- Quality;
- Transportation costs;
- Method of application.

3.3 When to apply the fertilizer

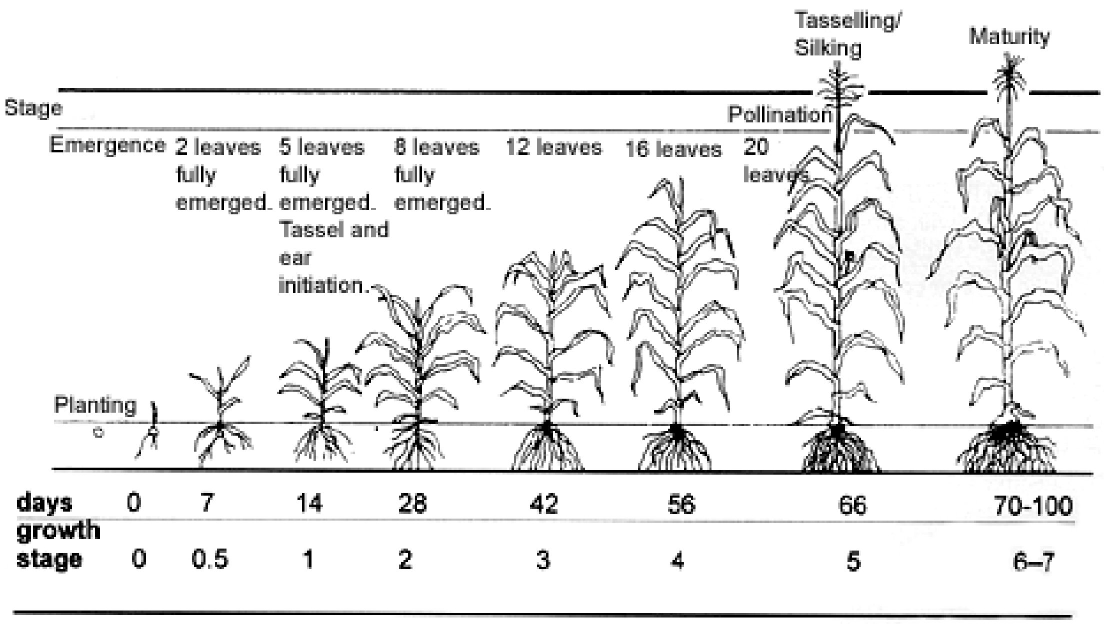
The timing of fertilizer application is crucial to the success of a crop. According to Cooke (1982), the weather is a very important factor and must always be taken into consideration when deciding when the fertilizer must be applied, while the different growth phases of the crop have different fertilizer requirements that must be met to ensure a good yield. The farmer must always endeavour to satisfy the specific plant needs by applying the correct fertilizer timeously in order to ensure that the soil doesn't lose its fertility (Cooke, 1982).

3.3.1 Weather

As previously discussed in Par. 3.1, the temperature has a huge influence on different aspects of fertilizers. This is illustrated in Table 3.2 which demonstrates the daily volatilisation of urea under different temperatures (Overdahl, et al., n.d.). Figure 3.1 demonstrates the influence that water temperature has on the solubility of potassium (Mikkelsen, 2013). Table 3.5 illustrates the different rates necessary for urea to set to NO_3 under different soil temperatures (Heard, 2014). Therefore, it is of the utmost importance that farmers carefully consider the factors that are influenced by different weather conditions when planning the fertilizer programme.

3.3.2 Different growing phases

The growth phase of a plant determines the fertilizer requirement. Figure 3.3 indicates the different growth stages of a maize plant:



Source: Bondesio, *et al.*, nd.

Figure 3.3: The different growth stages of the maize plant

Figure 3.3 illustrates the different growing stages of the maize plant; it indicates the number of leaves and the days it will take to grow from planting to maturity.

Table 3.6 illustrates the weekly requirement of fertilizer (in percentage) with specific regard to the maize plant to achieve the crop's maximum potential.

Table 3.6: Percentages of fertilizer required on a weekly basis by maize plants

	WEEKLY REQUIREMENTS (as percentage of total)			
MATURITY	% N	% P	% K	% Water
20 weeks	Less than 1	Less than 1	-K	Less than 1
19 weeks	Less than 1	1	-K	1
18 weeks	Less than 1	2	-K	2
17 weeks	Less than 1	5	-K	3
16 weeks	2	8	--	5
15 weeks	4	9	--	6
14 weeks	6	11	1	8
13 weeks	10	13	5	11
12 weeks silking	12	15	8	12
11 weeks tasseling	16	11	16	12
10 weeks	15	10	20	11
8 weeks	14	7	21	10
7 weeks	11	4	16	7
6 weeks	7	2	9	5
5 weeks	2	1	3	4
4 weeks	Less than 1	Less than 1	1	2
2 weeks	Less than 1	Less than 1	Less than 1	1
EMERGENCE	Less than 1	Less than 1	Less than 1	Less than 1

Source: Pioneer, 2013.

Table 3.6 provides information about the different types of fertilizers as well as a predicted time period that the plant will need certain quantities of relative nutrients. For maximum achievement, it is crucial for farmers to follow a strict schedule pertaining to the fertilizer programme.

If the farmer fails to follow the fertilizer schedule, it will inevitably result in a negative impact on the crop yield. Once the tasselling process commences, the plant's ability to absorb the fertilizer rapidly decreases. Hence, it is advisable that all of the fertilizer be made available to the plant before that period (Pioneer, 2013).

3.4 Methods used to apply the fertilizer

Fertilizer placement is an essential part of efficient crop management. Correct fertilizer placement is crucial for maximum crop yields under reduced tillage operations, but it is also very important under normal conditions. Correct fertilizer placement can protect both surface and groundwater quality (Mutchler, et.al., 1996). The most common means of applying fertilizers will be discussed in the paragraphs that follow.

3.4.1 Broadcast

Broadcast fertilizer application refers to a uniform distribution of fertilizer on the soil surface. This method has become very popular over the years due to a need to reduce the time involved in handling the fertilizer, whilst it is also less labour-intensive when compared to other methods of fertilizer application (Follett, et al., 1981). Figure 3.4 presents an image of a trailed fertilizer spreader.

Figure 3.4: Broadcast fertilizer application

According to Follett, *et al*. (1981), the advantages and disadvantages of this method of application are the following:

Advantages:

- Easy to apply;
- Relatively uniform fertilizer distribution;
- Inexpensive application equipment is required (Follett, et al., 1981).

Disadvantages;

- Leaves more fertilizer available for weed;
- Enhances losses of N by volatilisation;
- More susceptible to erosion;
- Requires rainfall or irrigation (to move N to plant's root zone);
- Leaves non-mobile nutrients on top of the soil (only available to the plant root system if the soil is tilled again) (Follett, et al., 1981).

3.4.2 Band application

Band application is also known as starter application. This is due to the fact that the fertilizer can be spread (positioned) during planting, giving the plant a great start. Band application is the method where fertilizer is placed underground next to a row of seeds or plants. This is a process that can occur during planting or at a later stage when the plant is already (partially) grown. According to Wells (1982), the band application is a very safe method of supplying nutrients to the seedlings, since the fertilizer is placed just in reach so that the root system can obtain the nutrients, but not close enough for it to result in chemical burn to the roots.

The most common practice is for farmers to place the band fertilizer 50mm deeper than the seed and 50mm to the side of the seed. This enables the plant to absorb the available nutrients more efficiently. In summary, band application therefore provides the seedling with a concentrated zone of nutrients without causing a chemical burn to the plant's root system (Wells, 1982). According to Mahler (2001), the advantages and disadvantages of this method of application are the following:

Advantages of band application:

- Fertilizer is placed within reach of roots;
- The root system can absorb nutrients more effectively;
- Less fertilizer is required per hectare compared to broadcasting;
- Fertilizer is more readily reached by the crop than by weeds;
- During soil erosion, fertilizer is retained;
- Provides a great start for plants;
- Rapid early plant growth is stimulated;
- P availability (Mahler, 2001).

Disadvantages of using band application methods:

- Increased leaching losses of N and S compared to surface placement;
- Equipment is costly;
- Requires equipment modification;
- Slower planting process (Mahler, 2001).

3.4.3 Injection

The injection is a procedure performed by farmers to release a gaseous fertilizer into the ground in order to provide nutrients to the growing crop. This fertilizer should be injected at least 100 mm beneath the surface of the soil. It is a costly method and can only be performed with specialised equipment (Eckert, 1990).

Anhydrous ammonia is a source of fertilizer that, with the assistance of pressurised equipment, can be injected into the soil. This is a popular process as it is an efficient source of nitrogen (Eckert, 1990). The chemical composition of anhydrous ammonia is three parts hydrogen and one part nitrogen. The properties of this fertilizer render it a hazardous chemical for use in agricultural application. The use of anhydrous ammonia should thus be done correctly in order to ensure safety. Anhydrous ammonia is a colourless gas with a sharp penetrating odor. When anhydrous ammonia is compressed into a liquid, it can be used as a fertilizer. In this liquid state, it can be stored in pressurised tanks designed to withstand internal pressure (Souther, et al., 2000).

According to Montgomery (1980), the advantages and disadvantages of this application method are the following:

Advantages of gaseous fertilizer application:

- Easy application;
- Reduces nutrient losses;
- The application of nutrients is precise (Souther, *et al*., 2000).

Disadvantages of gaseous fertilizer application:

- Costly method;
- Requires specialised or modified equipment;
- Slow;
- Maintenance of equipment must be precise to prevent losses;
- Hazardous if workers are not educated to perform the procedure (Montgomery, 1980).

3.4.4 Fertigation

Fertigation is the process of injecting water-soluble products, soil amendments and fertilizer into the irrigation system. These fertilizer products are prepared beforehand. The preparation commonly entails a process whereby water-soluble fertilizer is added to water in stock tanks in order to dissolve the fertilizer, making it easier to pass through the irrigation system (Kant & Kafkafin, 2013).

Fertigation and chemigation are related processes. These two terms are commonly used interchangeably. Chemigation involves the injection of pesticides, herbicides, and fungicides into the irrigation system (Kant & Kafkafin, 2013). Chemigation is a more regulated and controlled process; this is due to the nature of the chemicals that are used. These chemicals can pose a health threat to humans, animals, and the environment.

According to Tianac (2017), the advantages and disadvantages of this method of application are the following:

Advantages of fertigation:

- High source of nutrients;
- Easy application;
- The nutrient source is used efficiently (Tianac., 2017).

Disadvantages of fertigation:

- Time-consuming when preparing the fertilizer;
- The process needs irrigation equipment;
- Risk of uneven application;
- Irrigation system damage can occur if not cleaned properly;
- Preferably not to be applied on windy days;
- Irrigation system must be monitored (avoid double application);
- Plants can suffer chemical burns (Tianac, 2017).

3.4.5 Foliar application

This is a technique that involves the application of liquid fertilizer directly onto the plant. During this process minerals and nutrients are absorbed through the plant stomata and epidermis. Transportation of the minerals and nutrients that have been absorbed is faster through the stomata but more efficiently absorbed through the epidermis. The foliar application enables the plant to absorb minerals and nutrients through the leaves as well (Li, *et al*., 2018).

According to Li *et al*. (2018), the advantages and disadvantages of this method of application are the following:

Advantages of the foliar application:

- Rapidly taken up by the plant;
- Easily absorbed;
- Overcomes the disadvantages of soil application;
- Restores vigour to plants injured during winter.

Disadvantages of foliar:

- Costly method;
- Limited to small amounts;
- Repeated application;
- Not to be applied on windy days;
- Time-consuming method (Li et al., 2018).

3.5 Sustainable farming practices

As defined by SARE (2012), sustainable agriculture is: "an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- Satisfy human food and fibre needs;
- Enhance environmental quality and the natural resource base upon which the agricultural economy depends;
- Make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;
- Sustain the economic viability of farm operations; and
- Enhance the quality of life for farmers and society as a whole."

An objective of the study is to determine what farmers can do to obtain higher yields and to produce more optimally and economically in the long run. The section will focus on a few aspects that can contribute to sustainable fertilizer farming practices namely: soil sampling, scheduling, weed control and variable rate fertilizer technology.

3.5.1 Soil sampling

The main objective of taking a soil sample is to have a basis for recommending a specific fertilizer. Plant nutrients are not distributed evenly through the land because of the different methods implemented by farmers when applying fertilizer. The goal of a fertilizer programme is to neutralise any kind of chemical soil restriction in the most economically viable manner. This will only be possible when the soil sample is taken correctly so that the restriction that occurs in the soil will also occur in the soil sample (LNR-Kleingraan Instituut, 2010).

According to FSSA (2007), a soil sample must be taken in the following manner:

Start by dividing the field into practical homogeneous units not bigger than 50 ha. To decide on the different units, class them by color, depth of the soil, texture, and topography. Make a drawing of the field indicating the direction (north, roads, and distance).

Remove all the material on the soil like rocks and grass before taking the sample but do not remove the topsoil. The sample should be taken from twenty (20) samples that are mixed together to create one bigger representative sample. The topsoil should be taken at a depth of 150mm and the subsoil sample should be taken at a depth of 300mm.

There are two means of taking soil samples:

a) Smart sampling

The process of smart sampling consists of the use of digital yield maps to identify the problem areas on the land and soil samples are taken in the specific areas to determine the problem. Figure 3.5 illustrates a digital yield map from which a soil sample should be taken in each area marked with a different colour. When using smart sampling it is very important to take more than one sample in an area (FSSA, 2007).

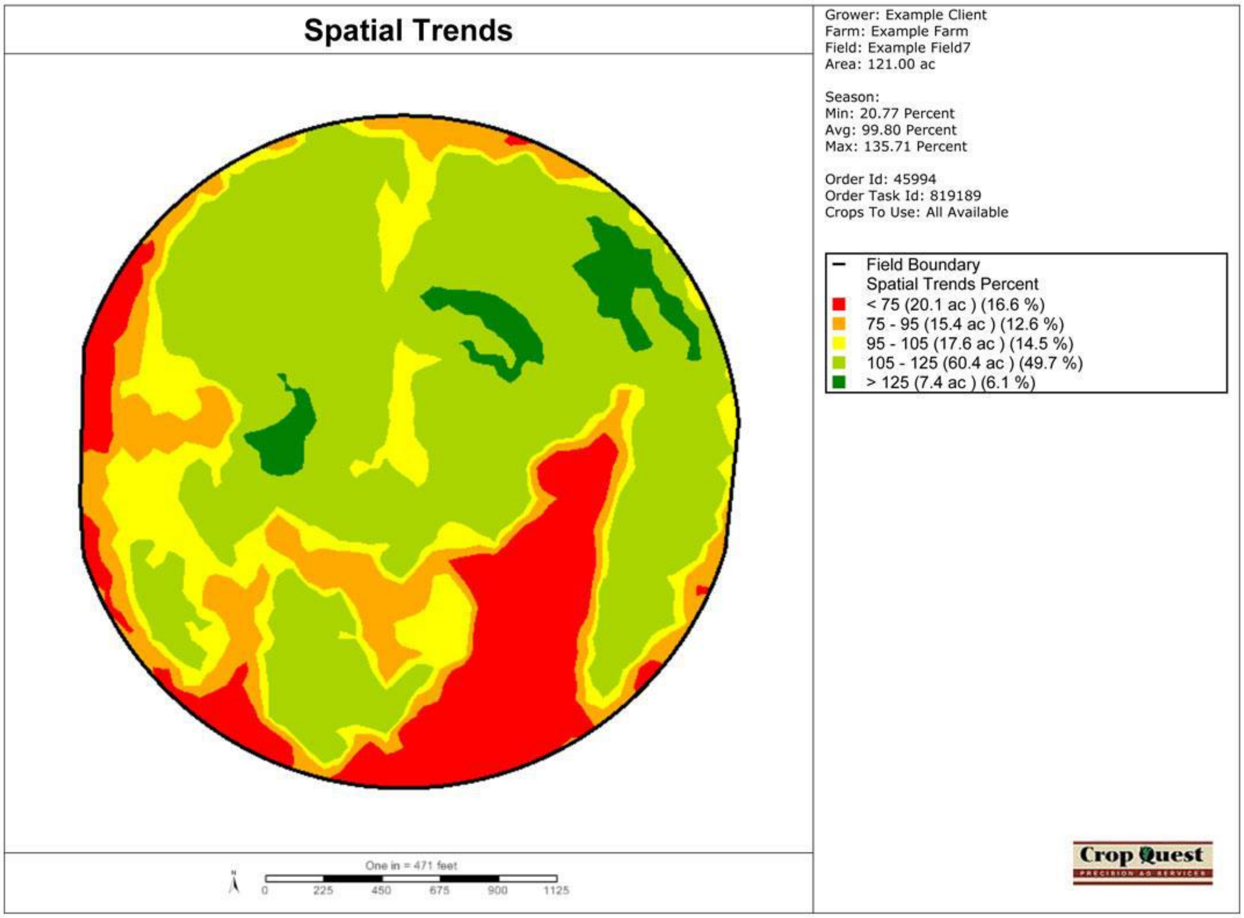


Figure 3.5: Smart soil sampling method illustration (Source: Crop quest., 2019)

b) Grid sampling

Grid sampling is employed when the field is divided into small blocks and a sample is taken in every block. The block must not be more than five hectares in size. Figure 3.6 illustrates what a field upon which grid sampling is applied will look like (FSSA, 2007).

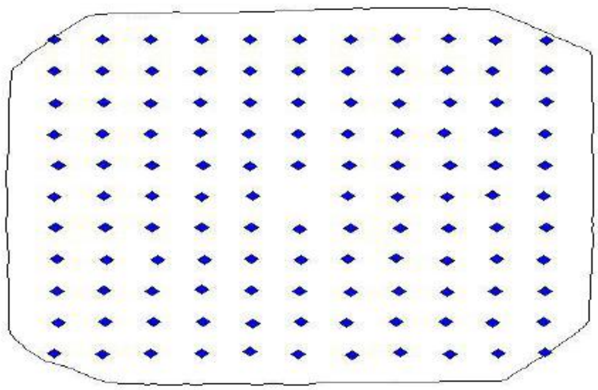


Figure 3.6 Grid soil sampling method illustration.

Following are the most important aspects of taking the soil sample correctly:

- If more than one soil type in the same field, accurate soil samples are to be taken from each soil;
- One soil sample per fifty (50) hectares is sufficient;
- A representative sample should consist of twenty (20) sub-samples;
- Sub-samples must be mixed properly;
- Soil samples should not be placed in a used fertilizer bag;
- A grid sample should not represent more than five (5) hectares (FSSA, 2007).

3.5.2 Scheduling

Irrigation scheduling is the process by which it is determined how much water as well as the frequency thereof should be applied to a crop in order to achieve optimum water usage. The main purpose is to maximize the efficiency of irrigation systems. This can be achieved by applying the exact amount of water needed, but not exceeding it, for the soil to refill in order to prevent leaching of minerals. Good irrigation scheduling can potentially save a lot of energy as well as conserve precious water reserves (Broner, 2003).

Advantages of an irrigation schedule are:

- Minimising of crop water stress;
- Maximising yield production;
- Reduces the cost of water;
- Maximises water usage;
- Maximum use of soil water storage;
- Minimum leaching of nutrients (Broner, 2003)

3.5.3 Weed control

Crops and weeds share the same aboveground or aerial (sunlight, space, atmospheric gases, etc.) and underground or soil (water and nutrients) resources. Water, nutrients, light, and space are the major factors for which plants compete. Weeds are more aggressive, adaptive and persistent than crops and pose a serious threat to crop production as they have the ability to survive under adverse conditions and extract more water and nutrients from the soil, thereby reducing crop yields and farming income. Fertilizer application has a definite influence on weed diversity, growth, dormancy, and crop-weed competition. The elimination of weeds from crops is the most efficient manner to ensure water and nutrients for crop usage and to obtain higher yields that lead to a better net income for the farmer (Kaur, et. al., 2018).

3.5.4 Variable rate fertilizer

Variable-rate technology (VRT) allows fertilizer, chemicals, lime, gypsum, irrigation water, and other farm inputs to be applied at different rates across a field, without manually changing rate settings on equipment or having to make multiple passes over an area. By using VRT a farmer can potentially save a lot of money on input costs, have a better yield and a can have a more positive influence on the environment (International Plant Nutrient Institute, 2011).

The benefits of having a VRA system is that it can:

- Assist in automating the application of inputs;
- Create savings on fertilizers and chemicals;
- Create a potential yield increase due to more efficient fertilisation and spraying based on actual crop needs and variability of fields and;
- Increase environmental protection from excess fertilisation or spraying of chemicals (International Plant Nutrient Institute, 2011).

Chapter 4 – Results

Specific objectives were formulated for this study (see paragraph 1.3.2). The results in this chapter will be discussed according to these objectives.

Objective 1: To study the farmer's behaviour regarding fertilizer management

4.1 Determine the information that farmers will consider when choosing the types of fertilizer to be used.

The first specific objective is to determine the information that farmers will consider when choosing the types of fertilizer to be utilised. In order to achieve this specific objective that was set out by the study, the price lists of ten fertilizer companies will be evaluated to illustrate one of the reasons for the differences that can be expected in input cost between farmers and areas. The reasoning behind this evaluation is to determine whether there are differences in input costs for fertilizers between the four areas with reference to early and late planting. In addition, it will attempt to determine whether there are significant differences in the input cost of fertilizers between smaller and larger farms.

The data obtained from the farmers were analysed and the results for each of the following fertilizers: nitrogen; potassium; phosphate; micro elements and the total input cost per hectare have been documented in the discussion that follows.

Table 4.1 provides information about the difference in the prices (R/t) of straits and blended fertilizers from ten different fertilizer companies during May/June 2016.

Table 4.1: Fertilizer prices from ten fertilizer companies for May/June 2016 in Rand/ton

Fertilizer type	Fertilizer supplier company									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Straits:										
Map	R5,900	R8,225	R6,640	R6,792				R9,531	R7,580	R7,229
KCl	R4,850	R6,802	R4,960	R5,479		R8,000		R6,967	R6,095	R6,001
Urea	R4,100	R5,159	R4,300	R4,250		R7,210		R5,096	R4,905	R4,640
LAN	R3,600	R5,605	R4,370	R4,026		R5,700	R4,060	R5,507		
Blends:										
1:1:1(35)	R4,922			R5,635		R10,029				
2:3:2(35)	R6,280	R8,046	R6,260	R6,470	R7,902			R9,281		
4:3:4(33)	R5,622	R6,493	R5,800	R5,622	R6,246			R8,387		

Although these are not the only companies selling fertilizers in the selected areas of the study, Table 4.1 provides information about the ten (10) most popular fertilizer companies that were selling fertilizer in the selected irrigation areas of the study. Due to the fixed chemical compound of the fertilizers, it is assumed to be of similar substance and quality across all of the selected manufacturers or companies. Vast differences in the price per ton between companies can be seen in the Table e.g. R4,922 and R10,029 for 1:1:1(35) type fertilizer (i.e. 104% variation).

4.1.2 Nitrogen (N)

Nitrogen is one of the most important essential elements for plants and is required in comparatively large amounts. This part of the chapter will focus on the input cost in rand per hectare and not the source or the quantity of the fertilizer. Firstly, it will compare the nitrogen input cost of the four different sample areas for an early planting versus a late planting for the respective areas and secondly, a comparison will be made of the input cost of large farms versus small farms within each area.

4.1.2.1 Comparison of nitrogen cost between the four areas

The nitrogen input cost of the four different areas was determined. Figure 4.1 provides this cost per hectare for the four different irrigation areas for early and late planting respectively.

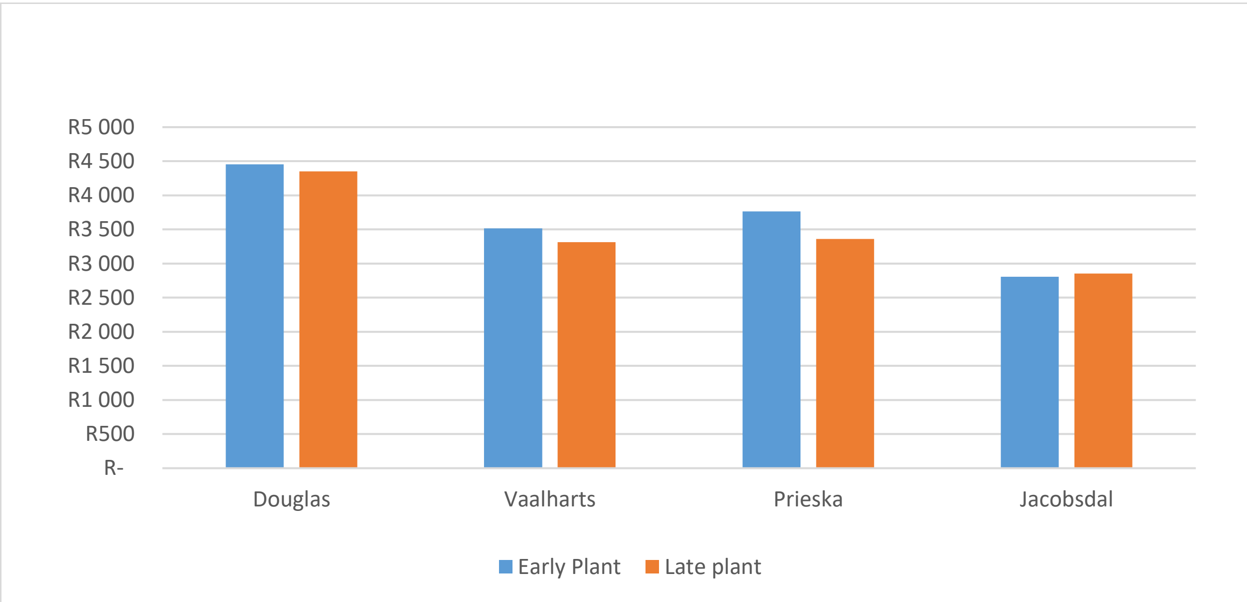


Figure 4.1: Mean nitrogen input cost in rand per hectare in the four areas

It is possible to derive from Figure 4.1 that there are differences between the early and the late planting. These differences were statistically assessed with the ANOVA test and it was found that there is a significant difference between the four areas for the average nitrogen input cost per hectare on an early planting ($p = 0.0026$), whereas on late planting a significant difference was also found ($p < 0.0001$) between irrigation areas.

When the separate areas were compared to each other in terms of the average nitrogen input cost per hectare for an early plant, there was a significant difference between Douglas and Vaalharts ($p = 0.0489$) as well as between Douglas and Jacobsdal ($p = 0.0010$). No significant difference was found at the test level of 95 % between Douglas and Prieska ($p = 0.2060$), between Vaalharts and Prieska (p = 0.4945), Vaalharts and Jacobsdal (p = 0.1404), while a comparison between the N input cost between Prieska and Jacobsdal also proved no significant difference (p = 0.1162).

When the separate areas were compared to each other on a late planting in terms of nitrogen cost per hectare, there was a significant difference between Douglas and Vaalharts (p = 0.0002), Douglas and Prieska (p = 0.0017) and between Douglas and Jacobsdal (p = 0.0003). When the same test level (95 %) was used, no significant difference was found between the Vaalharts and Prieska areas (p = 0.8301), Vaalharts and Jacobsdal (p = 0.1423) or between Prieska and Jacobsdal (p = 0.1430).

4.1.2.2 Large farms versus small farms' input cost per hectare for nitrogen

A comparison was made between the input cost per hectare for nitrogen on large farms versus small farms for early and late plantings in the respective irrigation areas. Figure 4.2 illustrates the different areas with the input cost for each area based on the size group of the farm.

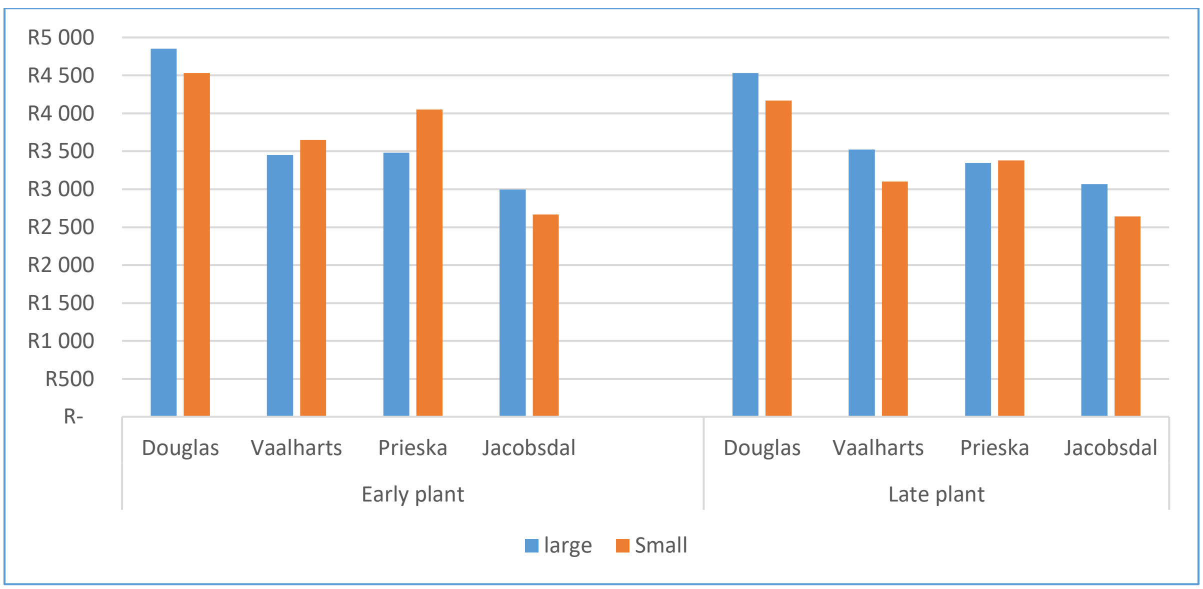


Figure 4.2: Mean nitrogen input cost in rand per hectare for small and large farms for early and late plantings within the selected irrigation areas

From Figure 4.2 it appears that there is quite a big difference between the input costs of nitrogen fertilizer between the four different areas in the study.

The same test level (95%) was used to calculate the significant difference for large and small farms for an early and late planting, of which the P values are indicated in Table 4.2.

Table 4.2: Comparing input cost per hectare for early and late plantings of large farms versus small farm within the selected irrigation areas

Area	Early planting; P Value	Late planting; P Value
Douglas	0.1296	0.3359
Vaalharts	0.7661	0.0783
Prieska	*	0.9379
Jacobsdal	0.5865	0.4699

* Only one respondent in each category of large and small farms plant early and it is not sufficient to calculate a p-value.

From Table 4.2 it is clear that, based on the sizes of farms, there are no significant differences ($p > 0.05$) on a late planting between any regions. In the other areas, no significant difference was found between farm size input costs on nitrogen per hectare in the four selected areas of the study.

4.1.3 Phosphate (P)

Phosphorus is an essential macro-element required for proper plant nutrition. It participates in metabolic processes such as photosynthesis, energy transfer and synthesis, and breakdown of carbohydrates. The focus is placed on the input cost in rand per hectare and not the source or the quantity. Firstly, it compares the phosphorus input cost of the four different areas for an early planting versus a late planting for the respective areas and secondly, a comparison of the input cost of large farms versus small farms within each area.

4.1.3.1 Comparison of phosphate input cost between the four areas

Figure 4.3 provides the trends of the input cost of phosphate for an early planting and a late planting on each of the four different areas of the study.

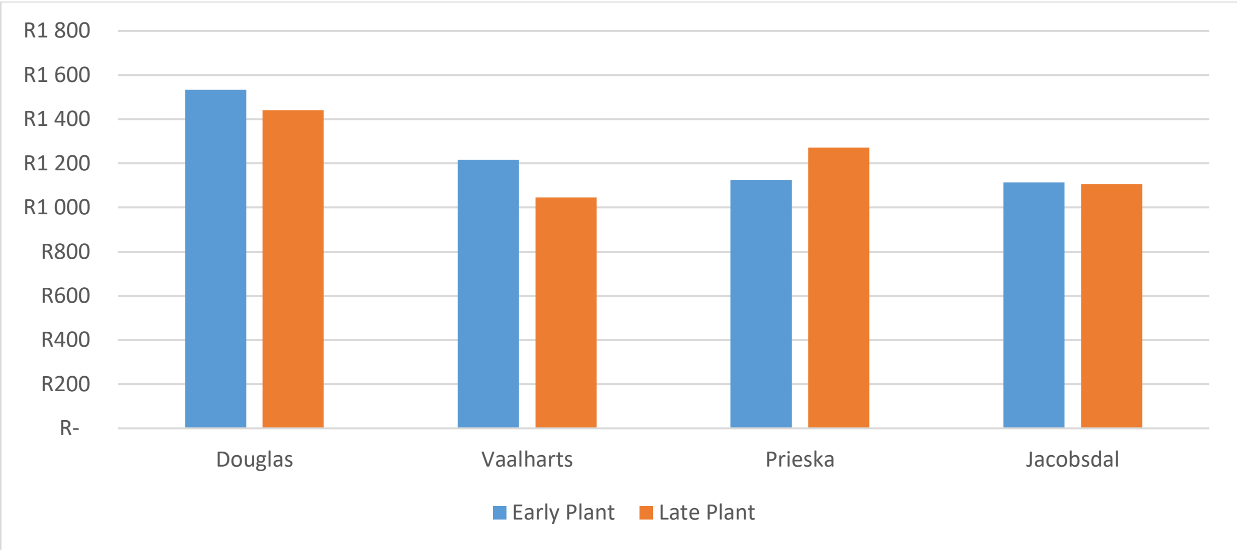


Figure 4.3: Mean phosphate input cost in rand per hectare in the four areas

From Figure 4.3 at a test level of 95%, it was found that there is no significant difference in the phosphate input cost per hectare between the four areas for an early planting ($p = 0.1871$) and late planting ($p = 0.2193$) respectively.

When the separate areas of the study are compared to each other, at the same test level of 95%, no significant difference ($p > 0.05$) for phosphate input costs per hectare was found on an early planting when comparing Douglas and Vaalharts ($p = 0.7768$), Douglas and Prieska ($p = .09785$), Douglas and Jacobsdal ($p = 0.0751$), Vaalharts and Prieska ($p = 0.6605$), Vaalharts and Jacobsdal ($p = 0.1145$) and Prieska and Jacobsdal ($p = 0.0927$).

For a late planting, the same results were obtained from the study. No significant difference ($p > 0.05$) was found when the areas were compared to each other. Douglas and Vaalharts ($p = 0.5636$), Douglas and Prieska ($p = 0.3615$), Douglas and Jacobsdal ($p = 0.2661$), Vaalharts and Prieska ($p = 0.0701$), Vaalharts and Jacobsdal ($p = 0.0679$) and Prieska and Jacobsdal ($p = 0.7007$).

4.1.3.2 Input cost per hectare for phosphate for large versus small farms

By comparing the input cost for phosphate of large versus small farms to each other Figure 4.4 serves to illustrate cost per hectare between the selective areas of the study.

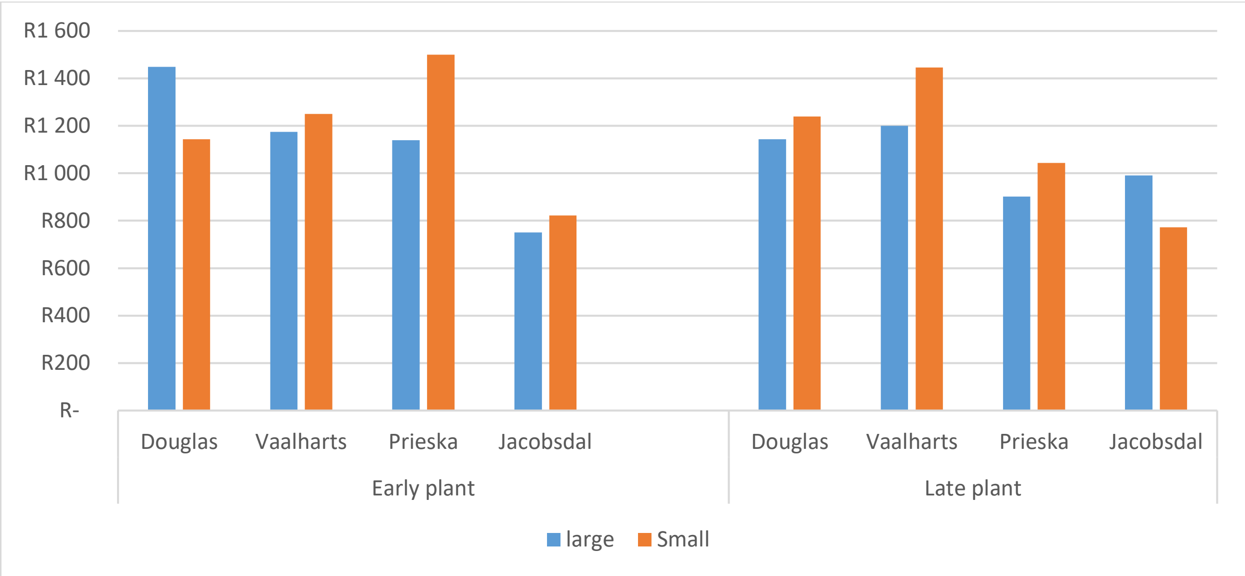


Figure 4.4: Mean potassium input cost in rand per hectare for large versus small farms of the selected areas of the study

From Figure 4.4 it appears that vast differences occur between the areas as well as between the input cost per hectare for phosphate of both large and small farms.

In Table 4.3 the p values that were calculated by means of the ANOVA test during the study are provided to illustrate the difference between early and late planting.

Table 4.3: Comparing input cost for phosphate of large versus small farms for an early and late planting in the selected areas of the study

Area	Early planting	Late planting
Douglas	p = 0.6134	p = 0.8202
Vaalharts	p = 0.9006	p = 0.3296
Prieska	*	p = 0.6365
Jacobsdal	p = 0.8137	p = 0.6041

*Only one respondent in each category of large and small farms plants early and it is not sufficient to calculate a p-value.

Table 4.3 indicates that there are no significant differences at a test level of 95 %, between the sizes of the different farms in the selected areas for an early and late planting on the input cost per hectare for phosphate.

4.1.4 Potassium (K)

Potassium is an essential plant nutrient and is required in large quantities for proper growth and the reproduction of plants. For the purposes of this study, the focus was directed towards the input cost in rand per hectare and not the source or the quantity. Firstly, it compares the potassium input cost of the four different areas for an early planting versus late planting for the respective areas and secondly a comparison is made between the input costs of large farms versus small farms within each area.

4.1.4.1 Comparison of potassium cost between the four areas

The potassium input cost of the four different areas were determined. Figure 4.5 illustrates the cost per hectare for the different irrigation areas of the study for a late and early planting respectively.

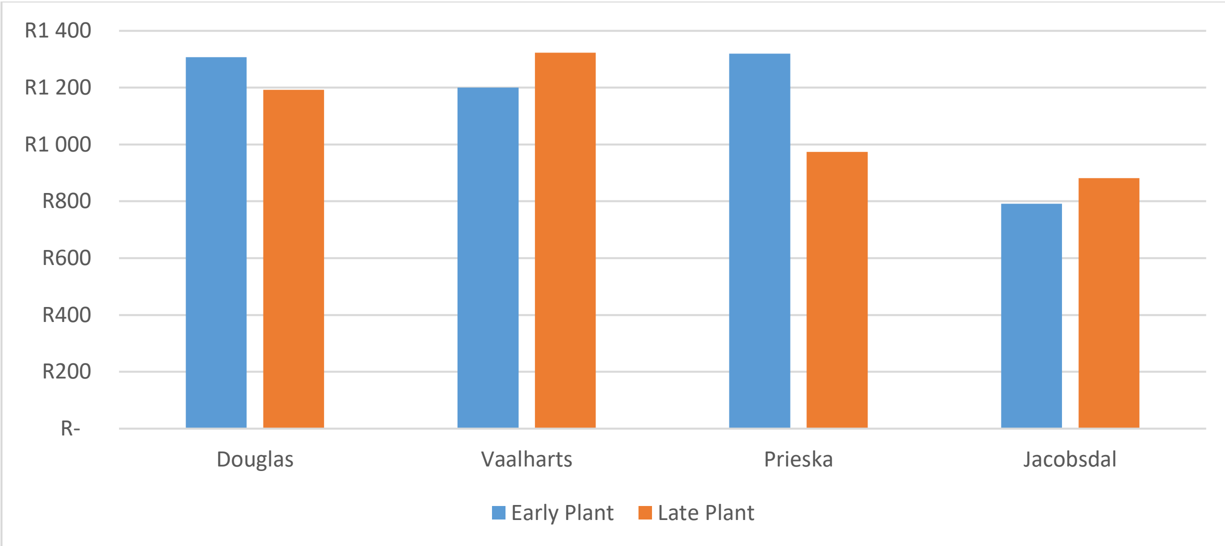


Figure 4.5: Mean Potassium input cost in rand per hectare in the four areas

From Figure 4.5 it can be derived that there are differences between the late and early plantings. These differences were statistically assessed by means of the ANOVA test and it was found that there are no significant differences ($p > 0.05$) between the four areas for the average potassium input cost per hectare on an early planting ($p = 0.2640$) as well as for a late planting ($p = 0.2566$). The p-values were calculated during a comparison between early and late planting of potassium input cost per hectare between the selected areas (Table 4.4).

Table 4.4: A comparison between early and late planting of potassium input cost per hectare between the selected areas

Areas	Early planting	Late planting
Douglas vs. Vaalharts	p = 0.3265	p = 0.1020
Douglas vs. Prieska	p = 0.2833	p = 0.4217
Douglas vs. Jacobsdal	p = 0.0762	p = 0.0891
Vaalharts vs. Prieska	p = 0.7969	p = 0.3508
Vaalharts vs. Jacobsdal	p = 0.6747	p = 0.7834
Prieska vs. Jacobsdal	p = 0.9678	p = 0.4074

As is evident from Table 4.4, there is no significant difference at a test level of 95% between the different areas for potassium input cost per hectare on an early or late planting.

4.1.4.2 Comparing the input cost of large versus small farms in terms of input cost per hectare.

An objective of the study is to compare the input costs of large versus small farms to each other. Figure 4.6 provides the input cost per hectare of potassium.

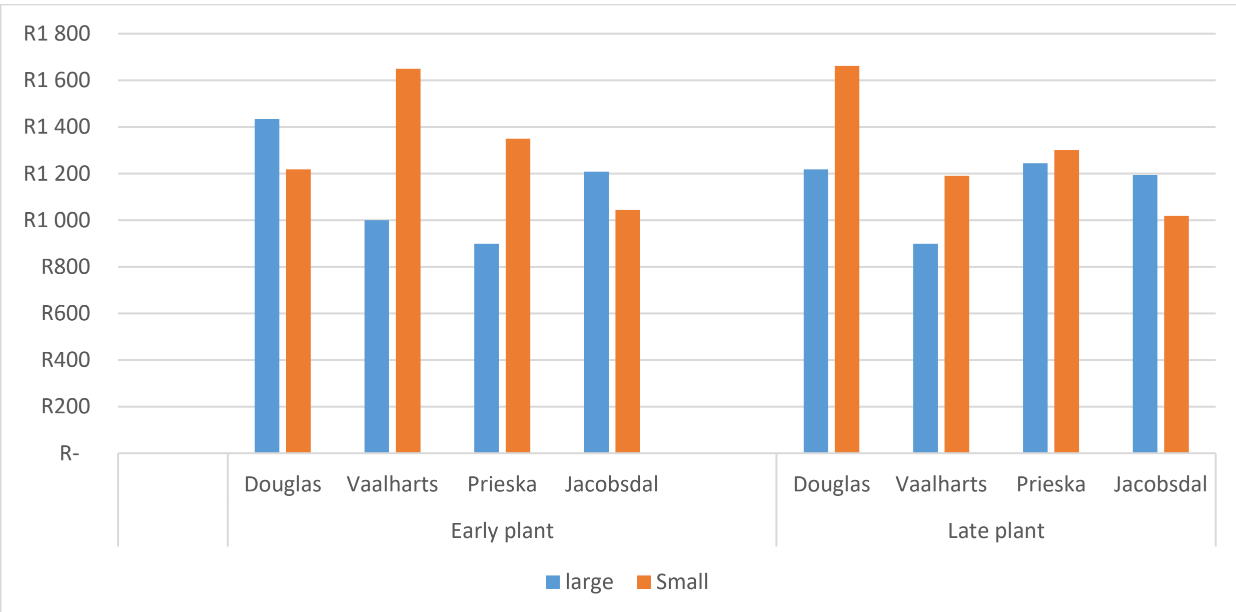


Figure 4.6: Mean potassium input cost in rand per hectare for large versus small farms

Early planting;

A significant difference at a test level of 95% was found between the small and larger farms at Vaalharts ($p < 0.0001$) regarding potassium costs per hectare. However, no significant difference was found between the small and larger farms in the Douglas ($p = 0.6363$) and Jacobsdal ($p = 0.5616$) areas. In Prieska only one respondent has an early planting season and that is not sufficient to calculate a p-value.

Late planting;

For late planting, no significant difference at the same test level of 95% between small and large farmers can be determined ($p < 0.05$), i.e. Douglas ($p = 0.1052$), Vaalharts ($p = 0.4639$), Prieska ($p = 0.8680$) and Jacobsdal ($p = 0.5153$).

4.1.5 Micro elements

Micro elements are plant nutrients that are required in very small amounts by the plant, but are just as important to plant development and profitable crop production as the macronutrients. The focus is on the input cost in rand per hectare and not the source or the quantity. Firstly, it will compare the input cost of the micro elements of the four different areas for an early planting versus late planting on the respective areas and secondly, a comparison of the input costs of large farms versus small farms within each area.

4.1.5.1 Comparison of micro element input cost for the four areas of the study

The micro elements input cost of the four areas was determined. Figure 4.7 illustrates the cost per hectare for the four irrigation areas for early and late planting respectively.

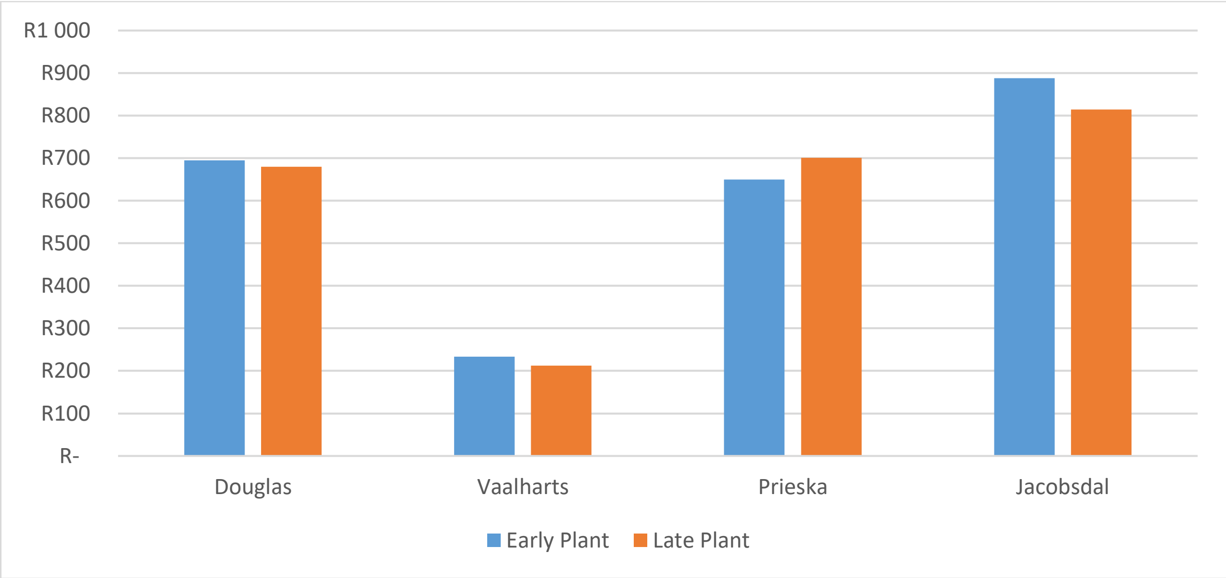


Figure 4.7: Mean micro elements input cost in rand per hectare in the four areas

As is evident from Figure 4.7, there are differences between the early and late plantings. These differences were statistical assessed with the ANOVA test and it was found that there are significant differences between the four irrigation areas of the study for the average micro element input cost per hectare for an early plant ($p = 0.0226$), as opposed to a late plant ($p < 0.0001$). The statistical difference were calculated between early and late planting of micro element input cost per hectare between the selected areas (Table 4.5).

Table 4.5: The comparison between early and late planting of micro element input cost per hectare between the selected areas

Area	Early planting	Late planting
Douglas and Vaalharts	p = 0.0055*	0.0005*
Douglas and Prieska	p = 0.8158	0.8413
Douglas and Jacobsdal	p = 0.2645	0.3099
Vaalharts and Prieska	p = 0.0023*	p < 0.0001*
Vaalharts and Jacobsdal	p = 0.0106*	p < 0.0001*
Prieska and Jacobsdal	p = 0.3654	p = 0.3598

*If $p < 0.05$ there is a significant difference.

Table 4.5 clearly indicates that significant differences at a test level of 95% do occur in the areas when compared to each other, namely between Douglas and Vaalharts for early planting ($p = 0.0055$) and late planting ($p = 0.0005$), between Vaalharts and Prieska for early planting ($p = 0.0023$) and late planting ($p < 0.0001$), and between Vaalharts and Jacobsdal for early planting ($p = 0.0106$) and late planting ($p < 0.0001$) respectively.

4.1.5.2 Large farms versus small farms' input cost per hectare for micro elements

Figure 4.8 provides the input cost of micro elements per hectare for the different irrigation areas of the study, the farm's size group and the timing of planting.

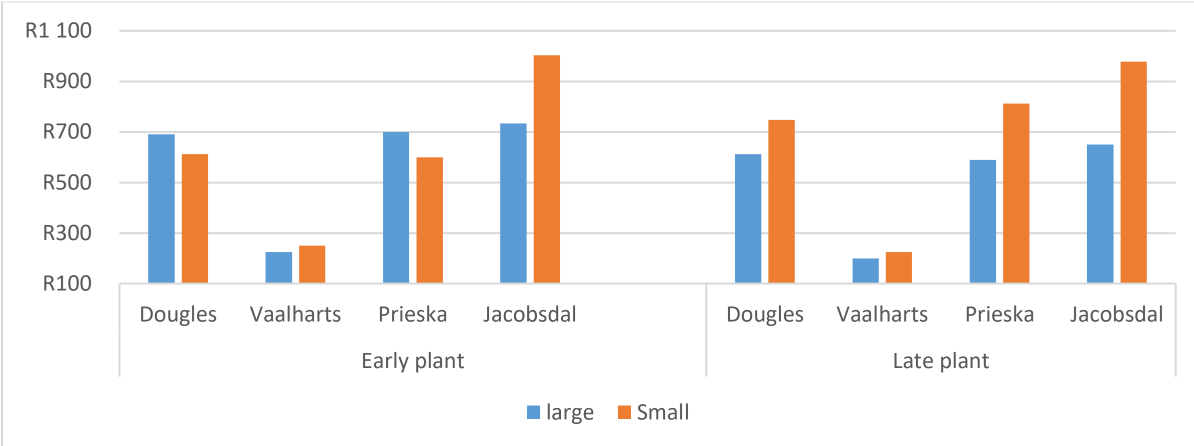


Figure 4.8: Mean micro elements input cost in rand per hectare for large vs. small farms

Figure 4.8 illustrates that differences do occur between the selected areas for the mean micro element input cost per hectare. These differences were statistical assessed and the result are set out in Table 4.6.

Table 4.6 Comparison between large versus small farms' input cost of micro elements for early and late plantings in the selected irrigation areas

Area	Early planting	Late planting
Douglas	p = 0.9666	p = 0.4245
Vaalharts	p = 0.6667	p = 0.3559
Prieska	*	p = 0.0772
Jacobsdal	p = 0.3255	p = 0.1060

*Only one respondent in each category of large and small farms plant early and it is not sufficient to calculate a p-value.

Table 4.6 indicates that there is no significant difference, at a test level of 95%, between the farm size in any of the areas or the different planting seasons.

4.1.6 Total input cost for fertilizer

Total cost for fertilizer refers to all plant nutrient, both micro and macro elements, that the farmer applies to the crop. This section of the chapter focuses on the total input cost in rand per hectare and not the source or the quantity. Firstly, it will compare the total input cost of the four different areas for an early planting versus late planting for the respective areas and secondly, it will provide a comparison of the total input cost of large farms versus small farms within each area.

4.1.6.1: Comparison of the total input cost of fertilizer between the four areas

As discussed in Chapter 1, an objective of the study is to compare the total input cost per hectare of the four different areas. Figure 4.9 illustrates the cost per hectare for the total input cost per hectare of the four different irrigation areas for an early and late planting respectively.

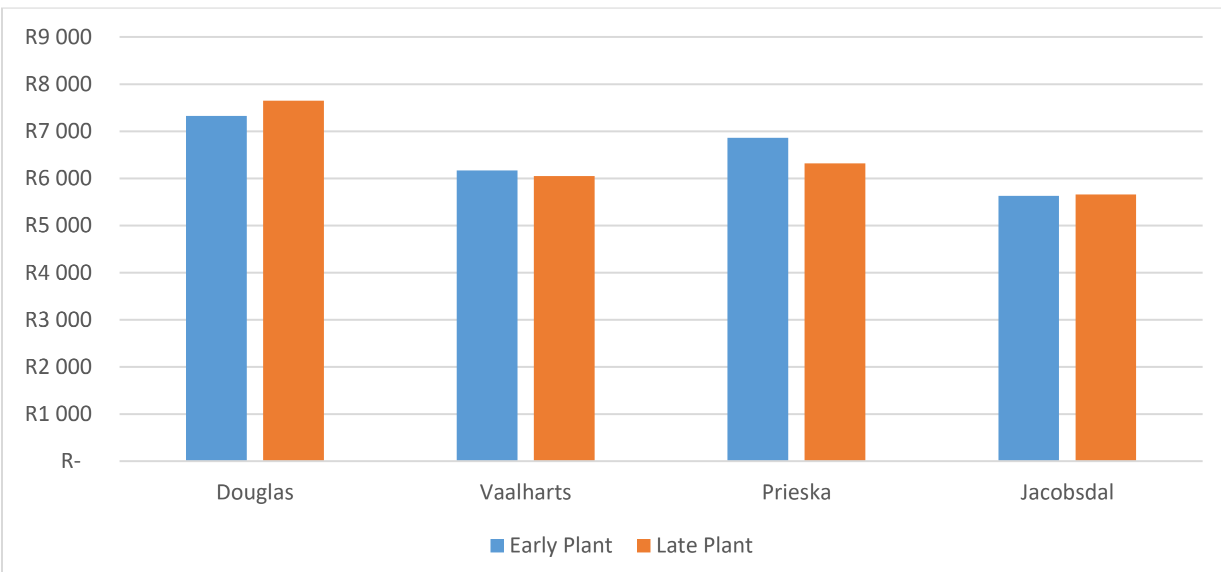


Figure 4.9: Mean of the total input cost in rand per hectare in the four areas

Figure 4.9 clearly indicates that there are differences between the areas. These differences were statistically assessed with the ANOVA test and it was found that no significant difference occurs between the four selected irrigation areas of the study for an early plant ($p = 0.0655$) but for late planting, a significant difference was found between the four areas ($p = 0.0103$).

The same test level of 95% was used to calculate the significant difference between the areas for the different planting seasons, of which the p values are indicated in Table 4.7.

Table 4.7: Comparing the four areas respectively for the total input cost per hectare for an early and late planting

Area's	Early planting	Late planting
Douglas and Vaalharts	p = 0.1100	p = 0.0108*
Douglas and Prieska	p = 0.4127	p = 0.0238
Douglas and Jacobsdal	p = 0.0215*	p = 0.0188*
Vaalharts and Prieska	p = 0.3511	p = 0.3923
Vaalharts and Jacobsdal	p = 0.5780	p = 0.5443
Prieska and Jacobsdal	p = 0.3233	p = 0.3135

*If $p < 0.05$ there is a significant difference.

The only significant difference that occur is for late planting and is between Douglas and Vaalharts ($p = 0.0108$). Between Douglas and Jacobsdal a significant difference occurs for an early planting ($p = 0.0215$) as well as a late planting ($p = 0.0188$). The remainder of the areas and times of planting reflect no significant difference.

4.1.6.2 Large versus small farms for total input cost per hectare

A comparison was made between the input cost per hectare for the total input cost per hectare on large farms versus small farms for early and late plantings in the respective irrigation areas. Figure 4.10 illustrates the different areas with the input cost for each area, based on the size group of the farm and an early planting versus late planting.

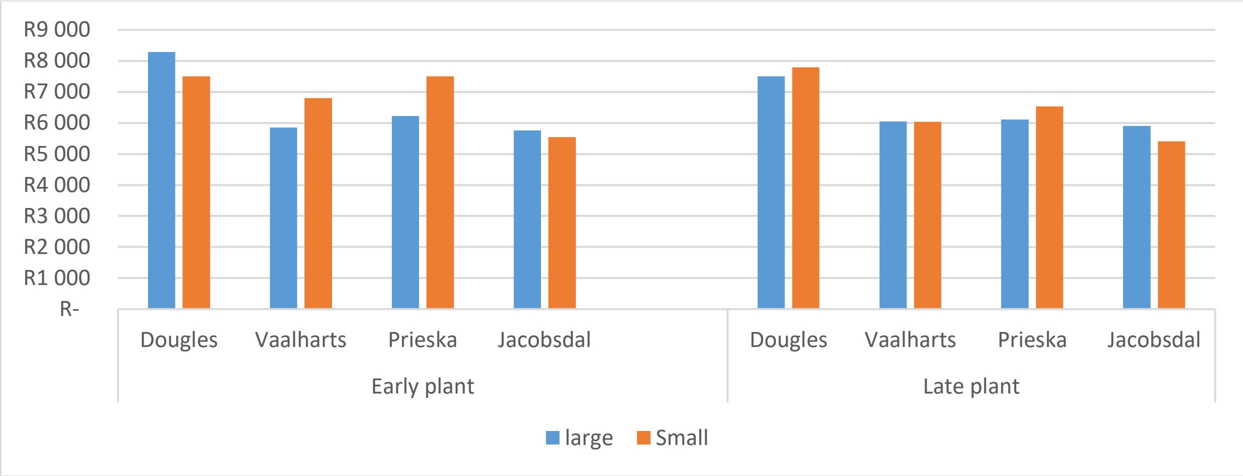


Figure 4.10: Mean total input cost in rand per hectare for large and small farms for an early and a late planting within the selected irrigation areas

From Figure 4.10 it appears that there may be a meaningful difference between the different areas and between an early and late planting in the four different areas of the study.

The same test level of 95% was used to calculate the significant difference between the areas for the different planting seasons, of which the p values are indicated in Table 4.8.

Table 4.8: Comparing large farmers vs. small farms' input cost for an early and late planting

Area	Early planting;	Late planting;
Douglas	p = 0.6294	p = 0.7822
Vaalharts	p = 0.0579	p = 0.9760
Prieska	*	p = 0.4107
Jacobsdal	p = 0.8696	p = 0.7086

*Only one respondent in each category of large and small farms plant early and it is not sufficient to calculate a p-value.

Table 4.8 confirms that there is no significant difference at a test level of 95%, between the areas on farms size. Farm size appears to have no influences on the farmer's production cost.

4.2 Determining the information that farmers will consider when predicting or establishing the amount of fertilizer

The second specific objective of the study is to determine the information that farmers will take into consideration when predicting or establishing the amount of fertilizer to be applied during the season**.** In order to achieve this objective**,** this section of the chapter will examine the plant requirements, the farmer’s target yield, the brand and the price of the fertilizer as well as the soil analysis. All the statistics are presented for three groups according to the highest qualification. The highest academic qualification of the respondents is categorised into three groups, which include “Grade 12” (i.e. respondents that don’t have any tertiary education), “Agri” (i.e. respondents that have tertiary education in agriculture), and “Non agri” (respondents that have tertiary education but in another discipline). Tertiary education includes both diplomas and degrees.

4.2.1 Plant requirements

Plant requirements refer to the quantity of nutrients the plant needs in order to produce an optimal crop yield. Table 3.4 in Chapter 3 illustrates the exact amount of nutrients required to produce one ton of grain. Figure 4.11 provides an indication of what number of respondents (based on the three groups according to highest qualification) take the actual plant requirements into consideration to determine the amount of fertilizer to be applied.

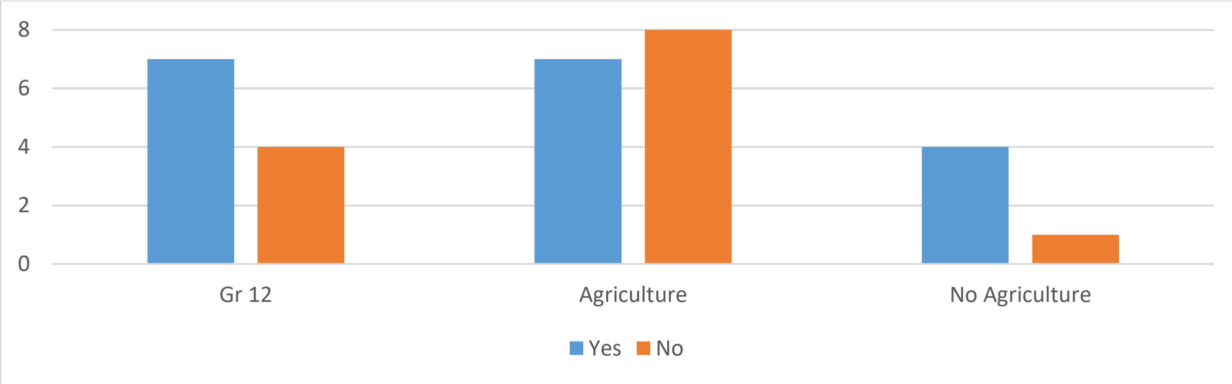


Figure 4.11: Number of farmers that take the plant requirements into consideration to determine the amount of fertilizer that needs to be applied

Figure 4.11 seemingly displays no significant difference between "Grade 12" and "Agriculture", however, a meaningful difference is apparent between the "Agricultural tertiary training" and the "Non Agricultural tertiary training" group. As a result, the Fisher's Exact Test was used to determine if there were significant differences between the three education groups when taking the plant requirements into consideration in order to determine the amount of fertilizer to be applied. However, no significant difference ($p = 0.4422$) was found between the groups.

While conducting the questionnaires, four (4) respondents mentioned that they only follow the fertilizer salesperson's recommendations and plant requirement is not a factor they take into consideration when deciding on the amount of fertilizer to be applied. Three (3) respondents mentioned that more fertilizer than the calculated plant requirement (based on the expected yield) is applied in an attempt to build the fertility status of the soil in order to farm sustainable and achieve higher yields. Three (3) respondents mentioned that they apply more fertilizer to ensure a chemical balance in the soil.

4.1.2 Target yield

Target yield is the amount of grain (expressed in ton/hectare) a farmer expects in the coming season. This is usually based on historical records as well as other scientific data (e.g. relevant cultivar trials).

In Figure 4.12 the three different education groups of the study are compared to each other in terms of target yield.

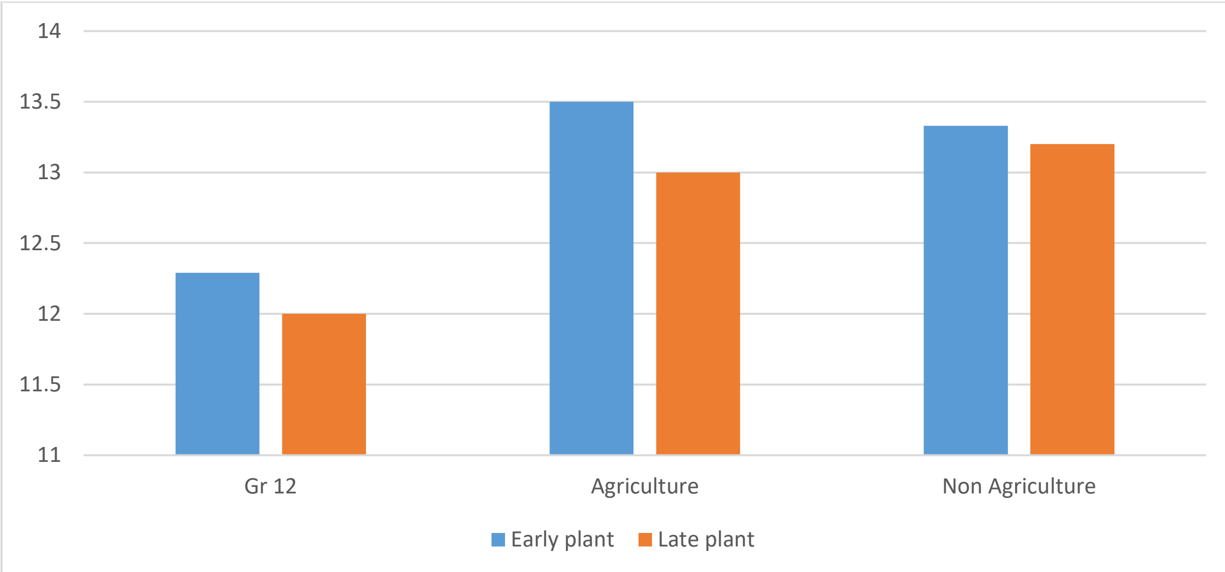


Figure 4.12: Target yield in ton/hectare that the farmers fertilise according to during the different planting seasons

No significant difference ($p < 0.05$) was found between the educational groups as far as the target yield applied during formulation of their fertilizer strategy.

4.1.3: Price of fertilizer

The price of fertilizer is very important to farmers as it contributes to a large portion of the total input cost for the crop. Therefore, most farmers usually attempt to buy the cheapest fertilizer.

In Table 4.9 the three education groups of the study are compared to each other in terms of the regularity with which they consult with the fertilizer salesperson.

Table 4.9: Regularity with which fertilizer salespersons are consulted by respondents (grouped according to highest qualification)

Preferred salespersons	**Education group**		
	Grade 12	**Agriculture**	**Non-Agriculture**
Regular salesperson	72.73%	81.25%	80.0%
Any salesperson	27.27%	18.75%	20.0%

From Table 4.9 it can be seen (as tested by the Fisher's Exact Test) that there is no significant difference ($p = 0.8513$) between the three education groups.

While the questionnaires were conducted, five (5) respondents mentioned that the quality of the fertilizer is more important than the price. Two (2) other respondents said they will only buy at existing companies and will not buy cheaper fertilizer from alternative suppliers. One (1) respondent mentioned that the price is the most important aspect when buying fertilizer due to the fact that fertilizer is a standardised commodity.

4.2.4 Soil test

If the farmer makes use of a soil analysis to determine the amount of fertilizer needed for each season, there are a number of advantages, namely: a saving on input costs; the soil is not drained of its fertility due to under fertilisation; more specific nutrients can be provided to soils with specific deficiencies; and, it also assists with the management and planting for the season. In Figure 4.13 the three education groups of the study are compared to each other in terms of how many of them use the soil analysis to determine the amount of fertilizer that is required for the season.

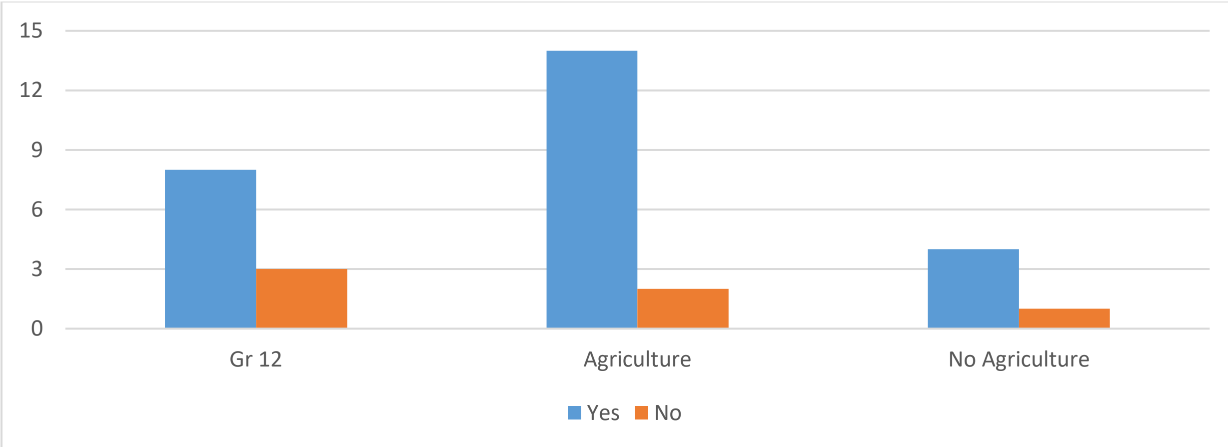


Figure 4.13: Number of farmers that are using the soil analysis to determine the amount of fertilizer required

Figure 4.13 revealed that that there may not be a big difference between the “Grade 12” and “Agricultural tertiary training” groups, however, there is a marked difference between the “Agricultural tertiary training” and the “Non Agricultural tertiary training” groups. This observation was tested by means of the Fisher’s Exact Test and interestingly enough, it was found that there is no significant difference ($p = 0.6091$) between the education groups with regard to taking the soil analysis into consideration when deciding on the amount of fertilizer to be applied.

During the questionnaire interviews, six (6) respondents indicated that they fully rely on and follow the recommendations of the fertilizer salesperson and do not take the soil analysis into consideration during fertilizer planning.

4.3. Information taken into consideration when deciding on the method to be implemented for applying the fertilizer

The study investigates whether there are differences between respondents grouped according to farm size and different irrigation regions, with reference to the packaging of the preferred type of fertilizer and the time that the fertilizer is purchased. This will have a direct influence on the method employed by the respondent to apply the fertilizer.

On larger farms, it can be expected that the fertilizer will be purchased early in the season or during February, before the firm's financial year end in order to reduce the income tax burden of the business. The global price of fertilizer is usually lower during that time of the year due to the lower demand as it is outside of the growing season. Larger farms usually have crop rotation systems that include various types of crops, consequently with fertilizer demands that are spread throughout the year. Smaller farms usually focus on one type of crop per season and require a relatively small amount of fertilizer. Common practice is that they plant the crop and then wait until the field has been harvested before they plant (and fertilise) the follow-up crop. Fertilizer is thus not used in a steady stream on small farms and the cash flow does not always allow the farmer to buy a huge amount of fertilizer a long time prior to the plant season (Lotz, 2005).

4.3.1 Time of fertilizer purchases

Due to the fact that fertilizer is one of the biggest input cost factors of most crops, farmers must carefully manage this part of the input budget. The time and place that the fertilizer is purchased may have a big influence on the price of the fertilizer.

Even though fertilizer can be purchased at any time of the year, it would be important to determine the exact time that the respondents usually make their purchases. This information was collected via a relevant question in the questionnaire (see Annexure 1) of which the results are provided in Table 4.10.

Table 4.10: Time of fertilizer purchases by small and large farms in different irrigation areas respectively

Irrigation area:	Small farms (P Value)	Large farms (P Value)
Douglas	0.1718	0.5930
Vaalharts	0.2802	0.8584
Prieska	0.6539	0.4443
Jacobsdal	0.2200	0.4264

The information in Table 4.10 illustrates that there is no significant difference ($p < 0.05$) in the time that fertilizer is purchased by respondents in any of the irrigation areas grouped according to size.

4.3.2 Packaging of the fertilizer

The type of packaging of the fertilizer can save a lot of time on a farm, but the farm must be big enough (i.e. sufficient turnover and economies of scale) to be able to afford the necessary infrastructure to handle the bulkier types of fertilizer packaging. On smaller farms, the farmers are usually forced to use smaller (50kg) bags that can be handled by hand as a direct result of the low requirement for handling infrastructure. However, a negative spinoff is high labour costs as well as a much slower handling process when compared to machines. Table 4.11 provides the p values for the type of packaging used by different farm sizes.

Table 4.11: Types of fertilizer packaging used by small and large farms in different irrigation areas respectively

Irrigation area:	Small farms (P Value)	Large farms (P Value)
Douglas	0.4839	1.0000
Vaalharts	0.0719	0.1216
Prieska	0.0829	0.0064*
Jacobsdal	0.2200	0.9416

*Indicated a significant difference ($p < 0.05$).

Table 4.11 illustrates that the size of the farm has in most cases no significant influence ($p < 0.05$) on the type of packaging preferred by the respondents. In Prieska only, a significant difference was found ($p = 0.0064$) between the respondents from the smaller and larger farming units, where respondents prefer to use fertilizer in bulk bags.

During the questionnaire interviews, two (2) respondents indicated that they only buy fertilizer in bulk, thirteen (13) respondents indicated that they buy large (500 or 1000kg) fertilizer bags, twenty-five (25) respondents indicated that they buy small (50kg) bags of fertilizer and eight (8) respondents indicated that they prefer liquid fertilizer for top dressing.

4.4 Information taken into consideration to determine the most optimal physiological growth stage of the plant to apply the fertilizer

As discussed in Chapter 3, there are different ways to determine when the plant needs a specific type of nutrient or fertilizer. The farmer can apply the fertilizer in advance to the soil (i.e. pre-plant or during planting) to ensure that it is available when needed, or the farmer can apply the fertilizer when the plant will need it to ensure there is minimum leaching of the fertilizer. However, there is a risk that the fertilizer can be applied too late that may lead to reduced yield. No p-values have been calculated for this section.

4.4.1 Time of fertilizer application

During the questionnaire interviews respondents were requested to indicate their preferred timing of application within their own fertilizer management programme. The different times of applying the fertilizer to the soil are illustrated in Figure 4.14 in accordance with the data collected from the respondents.

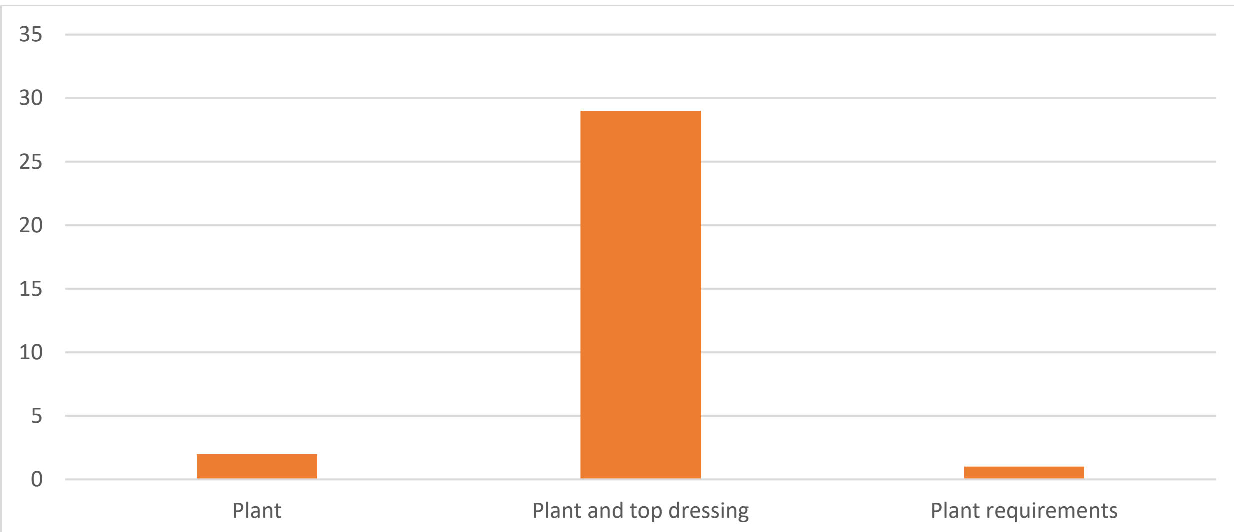


Figure 4.14: Time of fertilizer application by respondents

Figure 4.14 illustrates that only two (2) respondents apply all their fertilizer with the planter at the beginning of the season (refer "Plant" column). Twenty-nine (29) respondents apply their fertilizer both with the planter and top dressing (refer "Plant and top dressing" column). These farmers employ irrigation systems to apply macro and micro elements to the plant during the season. Only one (1) respondent indicated that fertilizer is applied during planting as well as a top dressing according to the requirements of the plant (refer "Plant requirements" column).

4.4.2 The different methods of applying the fertilizer

The respondents were asked to indicate which method they utilise to apply the fertilizer. The different methods of applying fertilizer to the soil were discussed in Chapter 3. No p-value was calculated. Figure 4.15 illustrates the three main methods utilised to apply the fertilizer, as according to the respondents in the study.

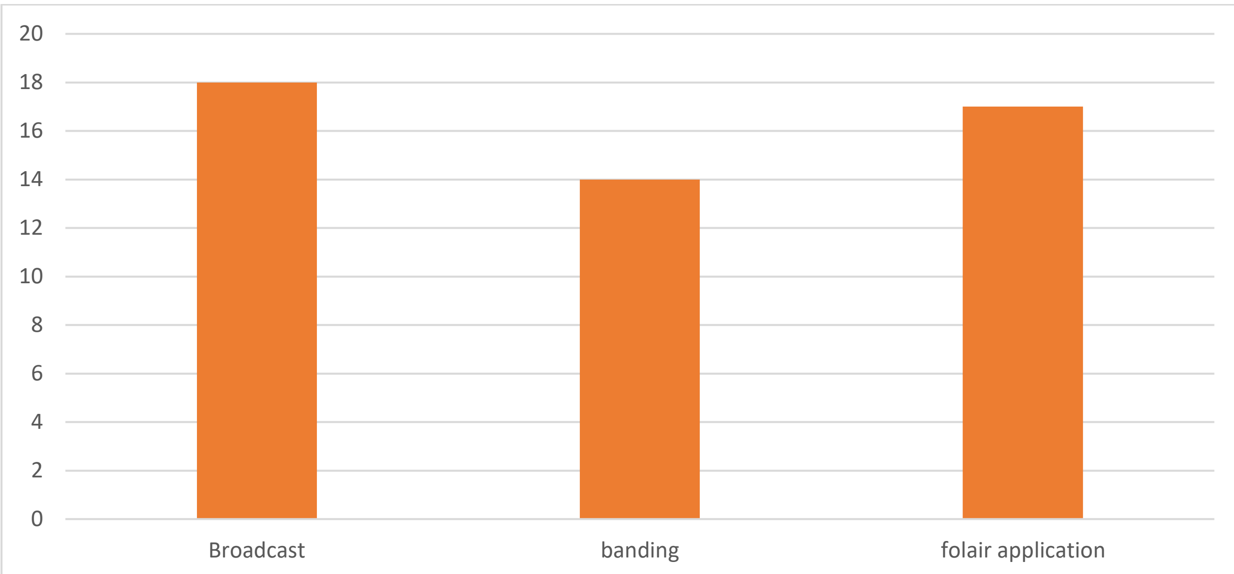


Figure 4.15: Different application methods of fertilizer

As illustrated by Figure 4.15, eighteen (18) respondents indicated that they use the "Broadcast" method to apply fertilizer to the soil. "Banding" is the application method preferred by fourteen (14) respondents, while the remaining seventeen (17) respondents indicated that they employ "Foliar application" of fertilizer. The respondents may employ more than one method of application during the same planting season.

4.5 Information taken into consideration when evaluating the recommendation of the fertilizer salesperson

The farmer has to decide whom to trust to provide him with the necessary information in order to manage the fertilizer aspects of the fields. In light of the fact that farmers will invest a lot of money based on the recommendation of the fertilizer salesperson, the farmer must be able to trust that the information provided by the salesperson is the best option for the specific circumstances. There is a general perception within the farming community that some farmers put emphasis on selective traits of a fertilizer salesperson. For this reason, the study includes a questionnaire aimed at determining the aspects that are important to farmers when choosing a fertilizer salesperson (and to trust that person sufficiently to accept the recommendations made).

4.5.1 Qualification of the fertilizer salesperson

A logistic regression analysis was conducted to determine if the qualifications of the fertilizer salespersons are important to the farmer. The fertilizer salesperson provides the farmer with information on how to manage the crop and how to manage the soil. In Table 4.12 the correlation between respondents' farming experience and the importance placed on the fertilizer salesperson's academic qualifications was tested statistically by means of the "Wald Chi-Square Test" and the "T Test".

Table 4.12: Importance of the academic qualifications of the fertilizer salesperson to the farmer

Correlation between respondents with certain levels of experience and the importance placed on the fertilizer salesperson's academic qualification.		
Parameter	Wald Chi-Square	T-Test
p value	0.1498	0.6987

The results from the model indicated that there is no statistical correlation between the respondent's level of farming experience number and importance placed on the fertilizer salesperson's academic qualification (Wald Chi-Square = 0.0419; p = 0.6987). In the questionnaire (see Annexure 1) the respondents were asked to indicate if the academic qualification of the fertilizer salesperson is important to them. The importance of the fertilizer salesperson's academic qualification was statistically tested against the level of experience of the respondents (measured in years of farming).

4.5.2 Salesperson as part of the community

A logistic regression analysis was conducted to determine whether it is important to the farmers that the fertilizer salesperson is part of the community. Farmers live in unpopulated communities where they mostly know each other. It is important to some farmers that the fertilizer salesperson must be an integrated member of the community. In the questionnaire (see Annexure 1) the respondents were asked to indicate if it was important to them that the salesperson was an integrated member of the community and whether that would influence the decision of the farmer to do business with the fertilizer salesperson or not. In Table 4.13 the correlation between respondents' farming experience and the importance placed on the fertilizer salesperson as an integrated member of the community was tested statistically by means of the "Wald Chi-Square Test" and the "T Test".

Table 4.13: Fertilizer salesperson as part of the community

Correlation between respondents with certain levels of experience and the importance placed on the fertilizer salesperson as part of the community.		
Parameter	Wald Chi-Square	T-Test
p Value	0.4847	0.4863

The model derived did not succeed in indicating that the years of farming experience had any influence on the farmers' assessment of the fertilizer salesperson and whether it was necessary for the salesperson to be part of the community or not (Wald Chi-square = 0.4847; p = 0.4863).

4.5.3 Trust resulting from the physical appearance of the fertilizer salesperson

A logistic regression analysis was conducted to establish if the vehicle and clothing of the fertilizer salesperson have any influence on the farmers with regard to putting their trust in the fertilizer salesperson. In the questionnaire (see Annexure 1) the respondents were asked to indicate if the fertilizer salesperson's appearance is important to them and if it would influence the decision of the farmer to do business with the fertilizer salesperson or not. The correlation between respondents' farming experience and the importance placed on the fertilizer salesperson's appearance was statistically tested by using the Wald Chi-Square and T-Test. The results indicate that the years of farming experience does not influence or change the farmers' trust in the fertilizer salesperson based on his vehicle and appearance (Wald Chi-Square = 0.0351; $p = 0.8513$).

According to the respondents in the study, the appearance of a fertilizer salesperson is an indication of the adequacy of the person as a reliable and trustworthy advisor. The additional comments provided by the respondents indicated that the vehicle used by the fertilizer salesperson indicates how the salesperson takes care of his own property and that indicates how the salesperson will take care of the farmer's fields. The respondents further mentioned that nobody wants to do business with a person that does not dress well, they want to feel comfortable with the fertilizer salesperson.

4.5.4 Selection of the laboratory to be used to analyse soil samples

A logistic regression analysis was conducted to determine if the fertilizer salesperson or the farmer chooses the laboratory. The laboratory of choice must produce a result that both the farmer and the fertilizer salesperson understand completely. Some farmers prefer to make use of the same laboratory annually, since it enables them to build up a nutritional history of the soil. A good record keeping system enables the farmer and the fertilizer salesperson to see in what direction the fertility of the soil is managed and to make corrections, if necessary. In the questionnaire (see Annexure 1) the respondents were asked to indicate who decides on the laboratory. The options were: "the farmer", "the fertilizer salesperson" or "both". The results were statistically tested against the level of experience of the farmer measured in years of farming and in the end, no correlation could be found. In Table 4.14 a correlation between the parties making the decision on which laboratory to use was statically tested: the farmer, the fertilizer salesperson or a joint decision.

Table 4.14: How the laboratory is chosen by the respondents

Correlation between who decides on the laboratory used for soil analysis		
Parameter	Wald Chi-Square	T-Test
P Value	1.8437	0.1745

The model was not significant, indicating that the years of farming experience has no statistical effect on the person that makes the decision with regard to which laboratory is chosen for the soil analysis (Wald Chi-square = 1.8437; p = 0.1745).

An analysis of the results indicated that only three (3) respondents co-decide with their fertilizer salesperson as to which laboratory to make use of. Furthermore, only five (5) respondents specified that only they decide which laboratory to use, whilst the majority (twenty-four (24) respondents) indicated that they do not care which laboratory is used by the salesperson to analyse the soil samples.

4.6 Correlation between selective traits of respondents and the analysing laboratory used

In this paragraph, by using Fisher's Exact Test, the correlation between respondents' traits, grouped into three categories according to their highest qualification, and the laboratory selected, was calculated. Figure 4.16 indicates to what degree the selection of the analysing laboratory differs between the three categories of respondents (grouped according to highest qualification).

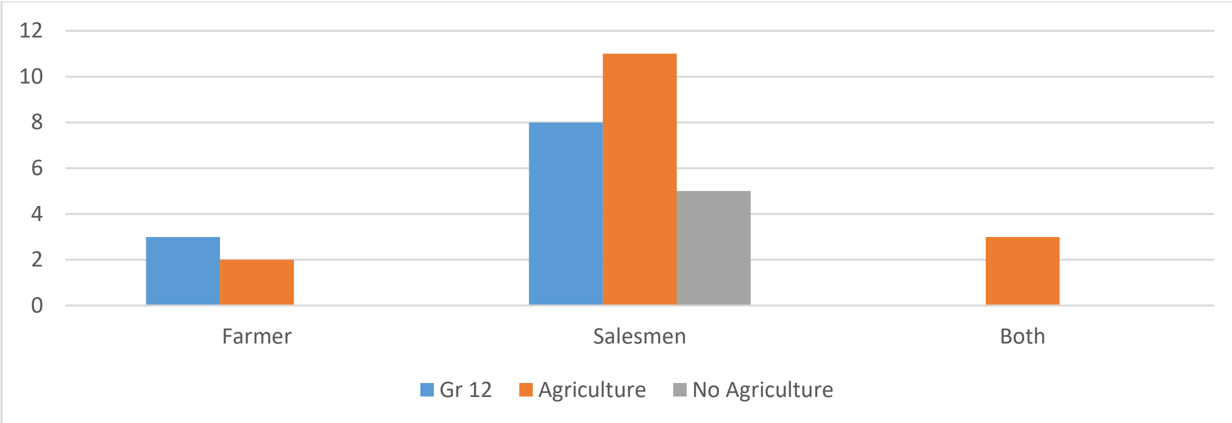


Figure 4.16: Trend in the differences in the person that decides on the selection of the analysing laboratory

From Figure 4.16 it seems like there are apparent differences between the different education groups as far as the selection of the analysing laboratory is concerned, while it is also evident that only in the group of "Agricultural tertiary training" farmers, both the farmer and the salesperson work together in deciding on the laboratory. With the "grade 12" and the "non-agricultural tertiary training" respondent groups, the laboratory is selected or specified by either the farmer or the salesperson.

However, the Fisher's Exact Test was applied and it was determined that there is no significant difference ($p = 0.3992$) between the education groups when nominating the laboratory where the soil samples need to be analysed. Figure 4.16 illustrates a general trend between these groups. The exact percentages are provided within Table 4.15.

Table 4.15: The method by which a laboratory is nominated per education group for a soil analysis

Education	Up to Gr 12	Agricultural tertiary	Non-agricultural tertiary
Farmer	27.27%	12.5%	0%
Salespersons	72.73%	68.75%	100%
Both	0%	18.75%	0%

In Figure 4.17 the three different education groups were tested to see if there are significant differences between the groups in terms of knowledge about the extraction methods that the laboratories use to analyse soil.

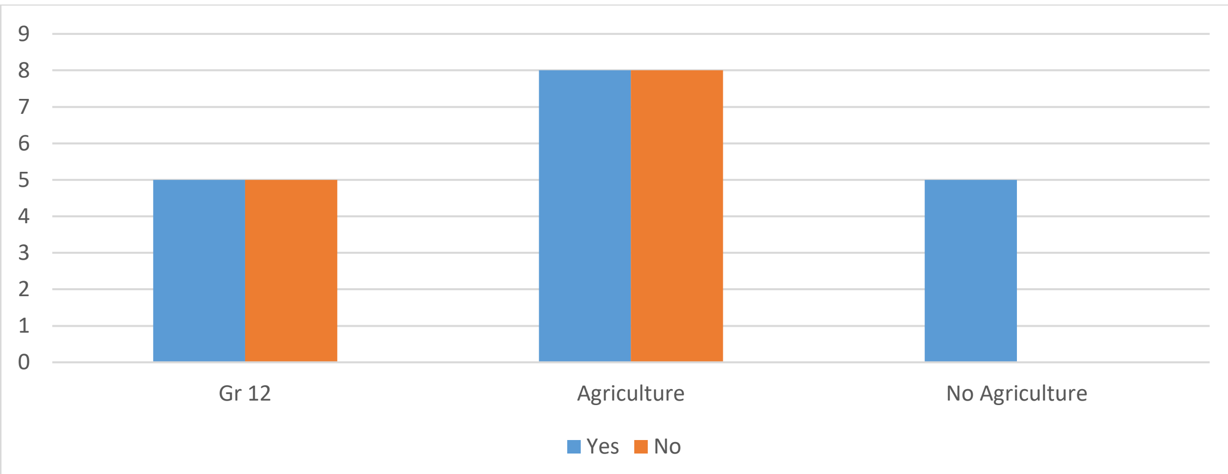


Figure 4.17: Farmers' knowledge regarding the different extraction methods performed by laboratories.

From Figure 4.17 it seems that there is no meaningful difference between the different education groups of farmers. Of the group referred to as "Grade 12", half of the group knows the difference whereas the other half does not. The same applies for the "agricultural tertiary training" group. In the "non-agricultural tertiary training" group, all the respondents know the difference, which may be meaningful. Figure 4.17 illustrates the general trend between these groups. The exact percentages are provided in Table 4.16.

Table 4.16: Awareness of respondents regarding the different extraction methods used by soil analysing laboratories

Education	Gr 12	Agriculture	Non-agriculture
Yes	50%	50%	100%
No	50%	50%	0

When statistically tested, no significant differences ($p = 0.1216$) were found between the three groups of education as far as knowledge are concerned about the different methods that laboratories use to analyse phosphate levels in the soil sample.

4.7 Determining the ways in which the farmer implements the recommendations from the soil analysis report to improve yield and the condition of the soil in the long run.

4.7.1 Fertilizer recommendations

A fertilizer recommendation is the basis of the fertilizer programme, as it contains critical information about the source and quantity of the fertilizer required. It is very important that a farmer must have a good understanding of the fertilizer recommendation in order to implement it in an accurate manner. Figure 4.18 provides a basic trend of farmers of respondents' perception (grouped according to the education category) of their understanding of the soil analysis and fertilizer recommendation.

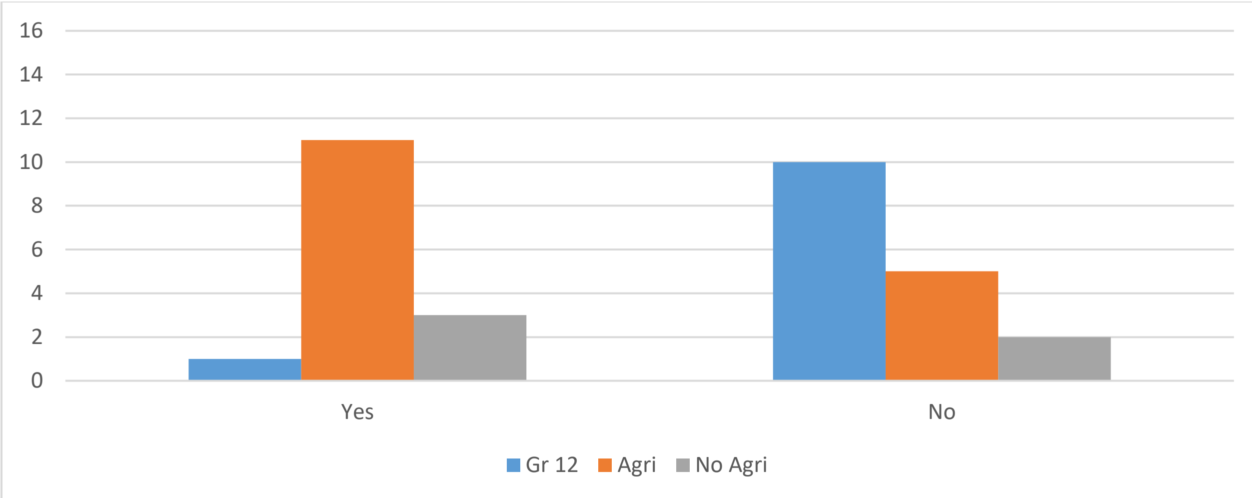


Figure 4.18: Respondents' perception (grouped according to the education category) of their understanding of the fertilizer recommendation

As is apparent from Figure 4.18, the differences between the education groups are quite extensive, therefore a significant difference can be expected. For this reason, Fisher's Exact Test was used to calculate for significance and it was found that there is a significant difference between the different education groups ($p = 0.0059$). From the afore-mentioned, it is evident that respondents with an agricultural tertiary education understand the fertilizer recommendations extremely well and should therefore be much more informed when they are implementing such a recommendation.

4.7.2 The means by which respondents rectify nutrient deficiencies in soils

Rectifying the deficiencies in the soil can increase the fertility of the soil which, in turn, will have a positive effect on the yields derived. This, in turn, will lead to a more sustainable farming business in the long term. No P-value was calculated. Figure 4.19 illustrates a trend in how the respondents of the study rectify the soil by means of three different methods.

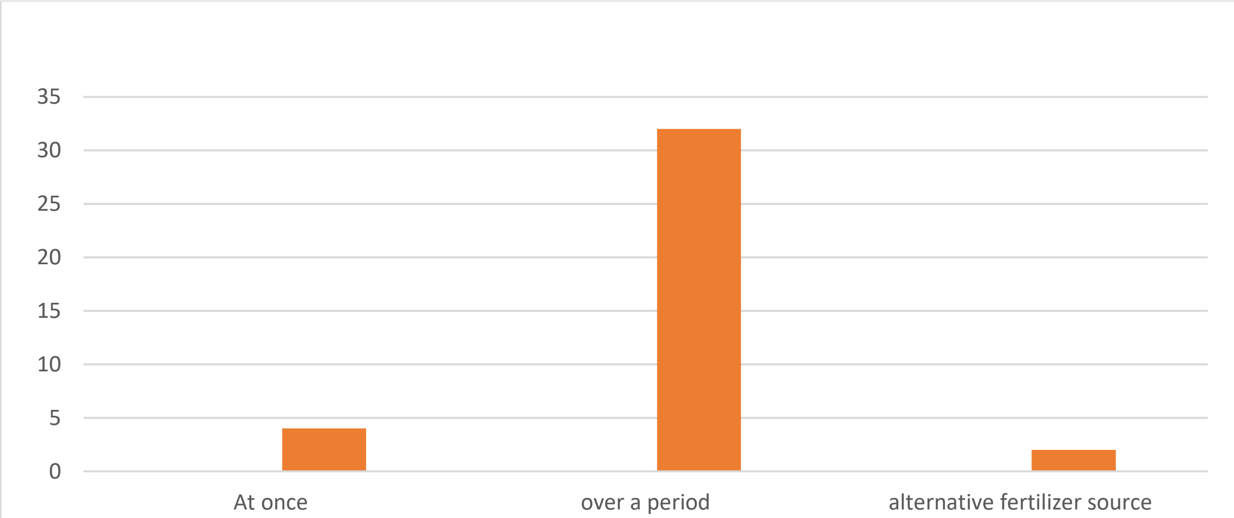


Figure 4.19: How the respondents rectify shortages in the soil

Figure 4.19 indicates how the respondents in the study rectify the soil in order to achieve higher yield and farm sustainably in the long run. The "At once" column indicates that only four (4) respondents rectify the shortages in the soil once-off, the other respondents indicated that it is too expensive to rectify the soil at once. The "Over a period of time" column indicates that twenty-six (26) respondents claimed that they rectify the shortages in the soil over a period of time in order to finance all the necessary products. The "Alternative fertilizer source" column indicates that only two (2) farmers used different sources of fertilizer to rectify the shortages in the soil. The respondents indicated that it is a very slow process, but according to them, the cheapest way to rectify the soil and increase fertility.

4.8 To determine if certain demographical traits of farmers (i.e. age, experience and level of schooling) will dictate their fertilisation practices.

For the purpose of this sub-objective, the study will determine if farmers with post-school agricultural education have different fertilizer practices than farmers with tertiary education in a different non-agricultural discipline. The parameters that will be compared in this hypothesis will focus on the farmer's yield, input cost, the amount of fertilizer applied, methods that are used to determine the amount of fertilizer and how the laboratories that analyse the soil sample are chosen.

The highest academic qualification of the respondents is categorised into three groups. They consist of “Grade 12” (farmers that do not have tertiary education), “No Agri” (farmer that has tertiary education but in another discipline) and “Agri” (farmers that have tertiary education in agriculture). Tertiary may include both diplomas and degrees.

4.8.1 The obtained yield and target yield of farmers

It can be expected that the obtained yield (ton per hectare) of crops will differ between farmers due to different management practices applied and variations in the environment. Figure 4.20 illustrates the different planting seasons and the target yield (i.e. the yield that farmers aim to harvest and accordingly fertilise to) of each education group.

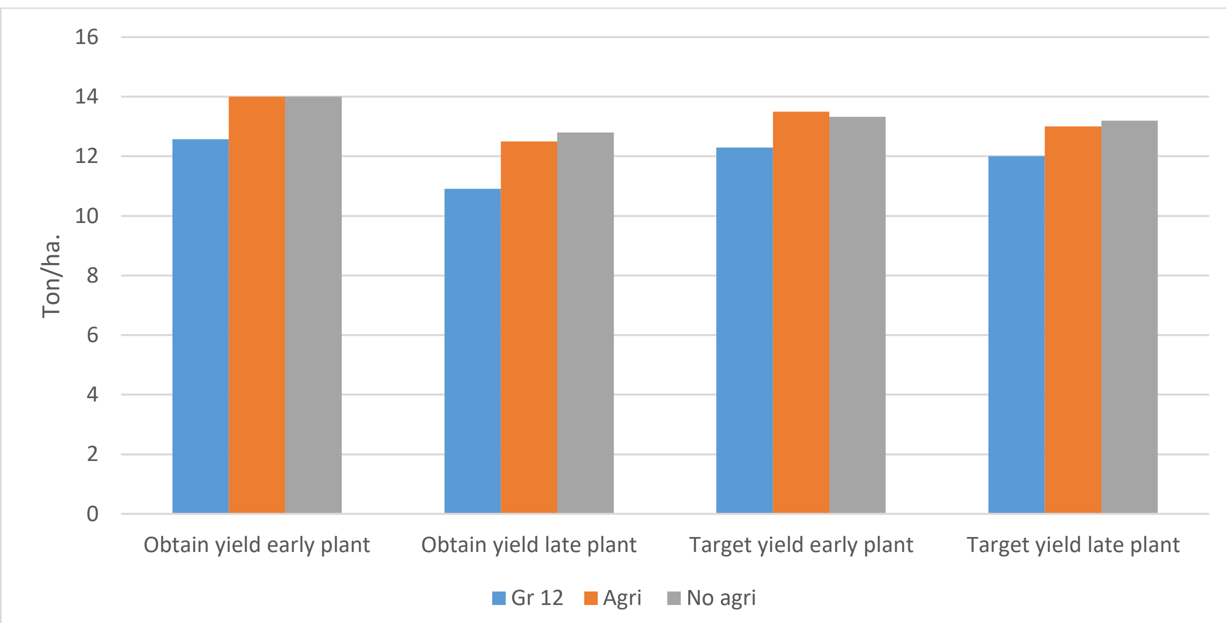


Figure 4.20: The mean values for the different groups of education for target yield and obtained yield.

As can be observed from Figure 4.20, there seems to be variations between the target yield and the yield obtained between the different educational groups and planting times. The ANOVA test was used to determine if the variations are high enough for significant differences to occur between the different education groups, as indicated in Table 4.17.

Table 4.17: The p-values of the comparison between the different education groups

Variable	p - Values of the education groups		
	Gr 12 vs. Agri*	Gr 12 vs. No Agri*	Agri vs. No Agri
Target yield early plant	0.2115	0.2858	0.9000
Target yield late plant	0.2045	0.1916	0.8396
Obtained yield early plant	0.0523	0.2444	1.0000
Obtained yield late plant	0.0652	0.1437	0.7547

*meaningful difference if $p < 0.05$

Early planting:

There were no significant differences for target yield ($p = 0.1449$) between the different education groups. The same finding applies to obtained yield ($p = 0.3896$).

Late plant:

No significant difference was found between education groups with regard to the target yield ($p = 0.1106$) as well as for the actual yield obtained ($p = 0.3271$)

4.8.2 Utilising the soil analysis and plant requirements to determine the amount of fertilizer to be applied

If the farmer makes use of a soil analysis to determine the amount of fertilizer necessary for each season, there may be a few advantages namely: possible savings on input cost; the soil is not drained of its fertility due to insufficient fertilizer quantities; more fertilizer can be administered to soils that are less fertile and less fertilizer to soils that are more fertile; and, it assists with the management and planting for the season. The plant requirements must always be kept in mind to ensure that the amount of fertilizer is sufficient for the target yield. Figure 4.21 illustrates the three different education groups that are being compared to each other in order to determine if education has an influence on whether the farmers use a soil analysis to determine the amount of fertilizer to be applied in order to prevent draining of the fertility of the soil.

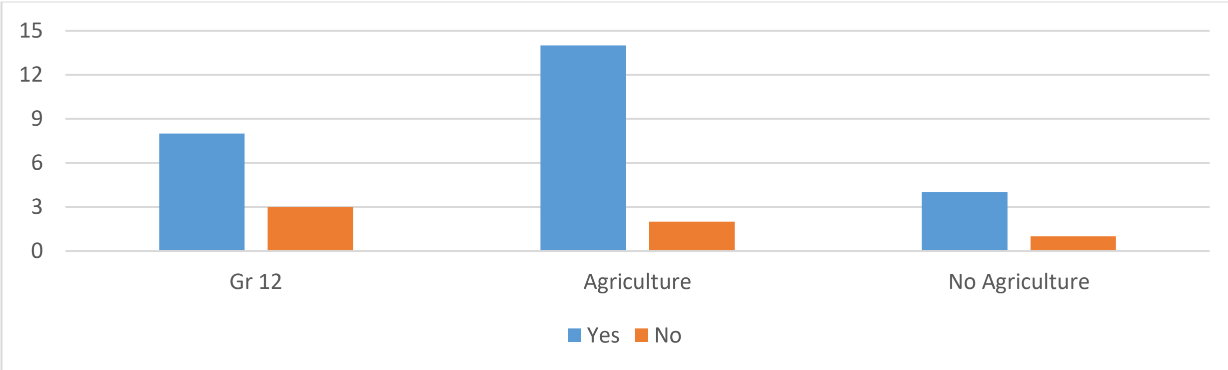


Figure 4.21: Number of respondents that are using a soil analysis to determine the amount of fertilizer to be applied

According to Figure 4.21, it seems that there are vast differences between respondents that have an agricultural related tertiary qualification when compared to the group with a non-agricultural tertiary qualification.

Therefore, the Fisher's Exact Test was implemented to determine if there is a significant difference between the education groups in taking the soil analysis into consideration when deciding the amount of fertilizer to be applied. However, no significance could be found ($p = 0.6091$)

4.8.3 Price of fertilizer and laboratory that is used

The price and the source of fertilizer are extremely important to the farmer. Different sources of fertilizer have different prices that are influenced by the characteristics of that specific source. Laboratories have a different result for the soil analysis. Hence, the farmer and the fertilizer salesperson should carefully decide on a laboratory and always use that specific laboratory. When one laboratory is used, the farmer will be able to see a trend in the soil that will indicate to what extent the soil fertility is managed. This information enables the farmer to make sound management decisions that are based on fact. In Figure 4.22 the three education groups are compared to each other to determine if education has an influence on respondents' preferences when buying fertilizer.

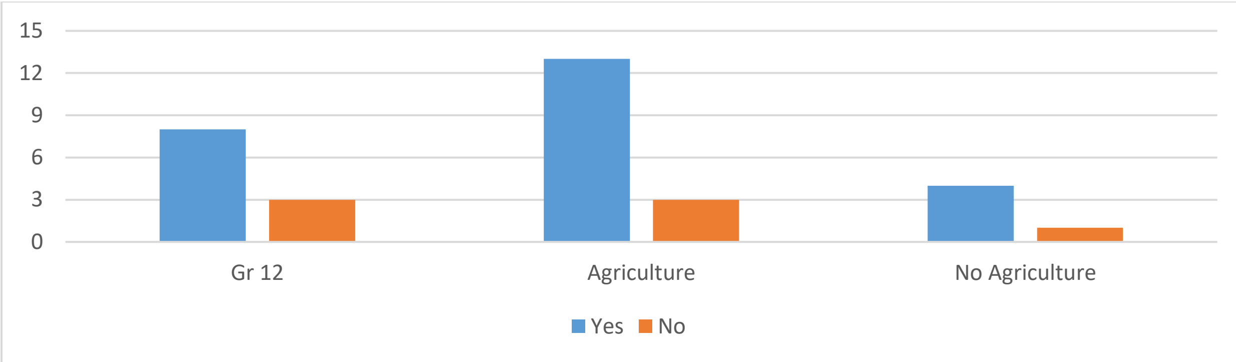


Figure 4.22: A number of farmers that buy the cheapest source of fertilizer from their regular salesperson

It is evident from Figure 4.22 that the majority of the farmers buy the cheapest fertilizer from their regular salesperson, especially the farmers that have “Agricultural tertiary training”. There are a few farmers that always buy the cheapest fertilizer, irrespective of the fertilizer salesperson, but they do not seem to be sufficient in numbers to make a meaningful difference. Education seems to have no influence on where farmers buy. The specific percentages of where the farmers buy are provided in Table 4.18.

Table 4.18: Percentages in terms of where farmers buy the cheapest source of fertilizer

Where farmers buy	Grade 12	Agriculture	Non-Agriculture
Regular salesperson	72.73%	81.25%	80.0%
Any salesperson	27.27%	18.75%	20.0%

From Table 4.18 it can be assumed and proven by Fisher’s Exact Test that there is no significant difference ($p = 0.8513$) between the three education groups. Education has no influence on whether the farmer buys the cheapest source of fertilizer only from his regular salesperson.

4.8.4 Total input cost per hectare for fertilizer

The total input cost for fertilizer comprises a huge part of the total input cost per hectare for the season. Should a farmer put some effort into this section of the budget a lot of money can be saved by just buying the correct fertilizer, from the correct supplier, at the right time. Farmers cannot determine the price of the product but they can control the input cost for the production of the product. Figure 4.23 illustrates a comparison between the three education groups, the total input cost per hectare in terms of fertilizer as well as the different planting seasons.

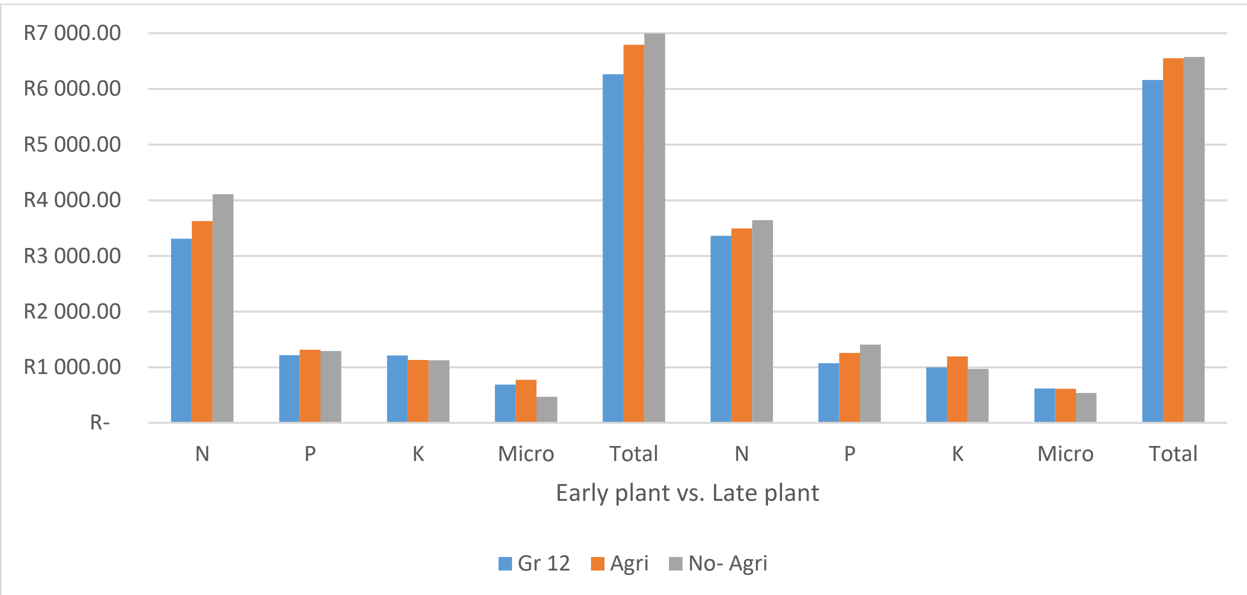


Figure 4.23: Fertilizer input cost per hectare for the different education groups during the different planting seasons

From Figure 4.23 it seems that the differences in input cost between the education groups are not substantial and it could be expected that no significant difference will be revealed.

There are no significant differences between input cost for an early plant ($p = 0.7729$) or a late plant ($p = 0.7377$) for the three groups of education.

4.8.6 Independent agronomical services

Independent agronomists is extremely important to the farmer, since the agronomist is not a salesperson of a product but a specialist source of knowledge. A farmer must always bear in mind that a fertilizer salesperson earns a living from the commission earned on the product that he sells to the farmers. In Figure 4.24 the education groups of the study are compared to each other in order to establish whether they will pay for independent agronomical services or not.

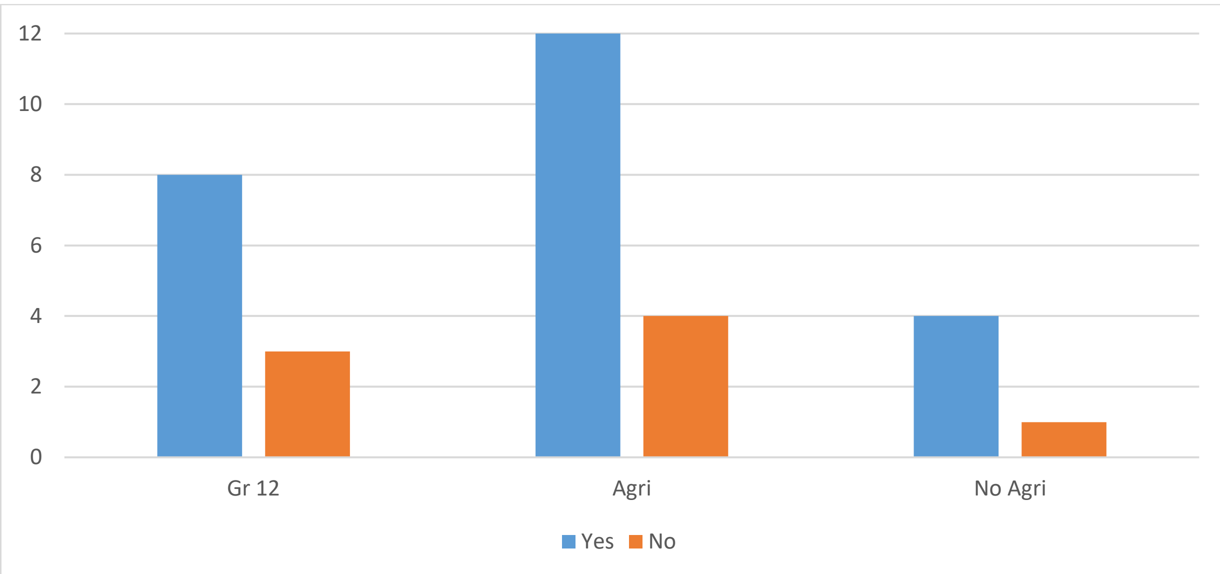


Figure 4.24: Willingness of respondents to pay for independent agronomical services

As is apparent from Figure 4.24, there are major differences between the education groups and therefore typical to expect that there will be a significant difference. However, with Fisher's Exact Test it is proven that no significant difference ($p = 1.0000$) between the three education groups occur. In Table 4.19 the different rates per hour that farmers are willing to pay for independent agronomical advice are compared.

Table 4.19: Comparing the rate (R/hr) that the farmers are willing to pay for an independent agronomical service

Education	Median	Lower Quartile	Upper Quartile	Minimum	Maximum
Gr 12	R 900.00	R 650.00	R 1125.00	R 375.00	R 5000.00
Agriculture	R 1250.00	R 500.00	R 1500.00	R 92.50	R 1600.00
No Agriculture	R 750.00	R 331.25	R 1000.00	R 162.50	R 1000.00

In Table 4.19 the different rates per hour that farmers are willing to pay for independent agronomical advice were provided. The Fisher's Exact Test was used to test significant differences between the following groups;

- Grade 12 versus Agricultural tertiary training ($p = 0.6409$).
- Grade 12 versus Non-agricultural tertiary training ($p = 0.4349$).
- Agricultural tertiary training versus Non-agricultural tertiary training ($p = 0.2191$).

Comparing the values of all three groups, no significant differences ($p = 0.4609$) were observed. It is therefore safe to say that education does not influence the amount that a farmer is willing to pay for sound advice.

4.8.7 Cheapest source of fertilizer

A logistic regression analysis was conducted to predict if a farmer buys the cheapest source of fertilizer by applying years of farming experience as a predictor. In the industry, salespersons and companies devise various marketing strategies to sell their product. In order for farmers to be successful in the long run, they should know the difference between a marketing strategy and the scientific behaviour of fertilizer. All the different available fertilizer sources on the market have different applications (Lotz, 2005), as illustrated in Table 4.20.

Table 4.20: Using farming experience to predict the manner in which a farmer will buy the fertilizer

Farming experience to predict how a farmer will buy fertilizer		
Parameter	Wald Chi-Square	T-Test
P Value	0.0006	0.9810

The model was not significant, indicating that years of farming experience is not a reliable predictor of farmers buying the cheapest source of fertilizer (Wald Chi-square = 0.0006; p = 0.9810).

4.8.8 Cheapest source irrespective of the salesperson

A scientific test was conducted to determine if a farmer buys the cheapest source of fertilizer, regardless of the fertilizer salesperson. Farmers are normally faithful to their fertilizer salesperson because they provide the farmer with knowledge and market trends. When farmers and the fertilizer salesperson have a good relationship and the farmers are satisfied with the yield they receive, farmers will most likely not shop around for more competitive prices and other products. It was thus determined if the cheapest source of fertilizer is the most important, regardless of the fertilizer salesperson. The Wald Chi-Square was used to test this and found not to be significant, indicating that the years of farming experience is not a statistically significant predictor of the farmer buying the cheapest source of fertilizer, regardless of the fertilizer salesperson (Wald Chi-Square = 0.0301; p = 0.8622).

4.8.8 A farmer's ability to make his own fertilizer recommendation

A logistic regression analysis was conducted to determine if the farmer can make his own fertilizer recommendation or if he requires assistance from an extension officer or advisor. Farmers do not need to have the ability to make their own fertilizer recommendations, but they do need to know how it works to prevent the fertilizer salesperson from selling unnecessary products to them.

Table 4.21 provides the p values to determine if a farmer can make a fertilizer recommendation without the assistance from an extension officer.

Table 4.21: Can farmers make fertilizer recommendations or do they need assistance from an agronomist

Can farmers make fertilizer recommendations or do they need assistance?		
Parameter	Wald Chi-Square	T-Test
P Value	0.6776	0.4104

The model was not significant, indicating that the years of farming experience is not reliable in determining if farmers can make their own fertilizer recommendations or if they require assistance from an extension officer (Wald Chi-square = 0.6776; p = 0.4104).

4.8.9 Does an agronomist assist the farmer to decide on a source of fertilizer

A logistic regression analysis was conducted to determine if the agronomist fulfils any role in respect of the source of fertilizer that the farmer is using. Agronomists play an important role in the farming industry due to the specialist knowledge they possess. A farmer cannot have all the information he needs to manage a farm successfully, but he can always obtain some professional assistance. Table 4.22 proves the p values necessary to determine if a farmer consulted an agronomist to help him decide on the best fertilizer source for the specific conditions on the farm.

Table 4.22: Support by an agronomist for the farmer to decide on a source of fertilizer

Does an agronomist help the farmer choose a source of fertilizer		
Parameter	Wald Chi-Square	T-Test
P Value	0.2227	0.6370

The model was not significant, indicating that the years of farming experience has no statistically significant effect in the farmer's decision to make use of an agronomist when choosing the fertilizer source (Wald Chi-square = 0.5598; p = 0.4543).

4.8.10 Willingness to pay for independent agronomical services

A logistic regression analysis was conducted to determine if a farmer will pay for independent agronomical services on the farm. A farmer can obtain important information when an extension officer's advice is considered. Table 4.23 provides the p - values that were calculated to determine if experience can be used to predict if a farmer will pay for agronomical services on the farm.

Table 4.23: Willingness to pay for independent agronomical services

Will a farmer pay for independent agronomical services?		
Parameter	Wald Chi-Square	T-Test
P Value	0.5589	0.4543

The model was not significant, indicating that the years of farming experience has no statistically significant effect on whether a farmer will pay for independent agronomical services on the farm or not (Wald Chi-square = 0.5598; p = 0.4543).

Objective 2: The fertilizer salesman behaviour

4.9 The fertilizer salesman's behaviour

The second main objective of the study is to study fertilizer salesman behaviour. The study will endeavour to determine if there is a meaningful correlation between the recommendations of the fertilizer salespersons and whether the financial position of the farm has an influence on the recommendations that are made by fertilizer salespersons.

4.9.1 Correlation between the recommendations of the fertilizer salesperson and the financial position of the farm

The study aims to determine if the financial position of the farm or farmer influences the recommendations that are made by the fertilizer agent. The data were acquired from fertilizer agents in each area and was statistically analysed with the T-test.

The fertilizer persons were given two different laboratory results of the same soil and requested to make three recommendations regarding nitrogen (N), potassium (P) and phosphate (K) within three different scenarios. The first scenario involves only a standard fertilizer recommendation to the farmer. The second scenario involves a recommendation based on the knowledge that the farm has limited financial capacity and it is therefore imperative to save on input cost. The third scenario involves a recommendation for a farm that has a healthy financial position and as a result, has surplus funds available for fertilizer. The results will be discussed in this order.

It is envisaged that differences will occur from area to area due to environment and management conditions. It can also be expected that here will be differences between the fertilizer agents due to training, experience and the company that they work for. The respondents in the study were requested to make three different fertilizer recommendations according to the three different scenarios put before them. The three scenarios are typical situations that the fertilizer salesperson will encounter.

The two laboratory results that were provided to the fertilizer salesperson are illustrated in Table 4.24.

Table 4.24: Laboratory results for the recommendations requested from the fertilizer salesperson

Lab	Extraction method	pH	P	K	Ca	Mg	Na	Ca	Mg	K	Na
			mg/kg					%			
1	Bray 1	6.4	16	187	2086	712	154	59.9	33.5	2.7	3.9
2	Mehlich 3	7.6	90	264	1197	572	141	49.71	39.59	5.58	5.09

In Table 4.24 the results of the soil analysis of two different laboratories with different extraction methods. The soil that was forwarded to the laboratories consisted of one soil sample divided into two equal parts.

In the first scenario a standard recommendation was made by the fertilizer agent. Neither the farmer interfered, nor was the financial position of the farm taken into account. The recommendations were made for a 12 ton per hectare maize target yield.

Table 4.25: Normal recommendation made by the fertilizer salespersons in kg/ha

Variable	Mean	Std. dev	Minimum	Maximum
Recommendation based on the soil analysis of Laboratory 1:				
N	281.71	41.96	250.00	360.00
P	54.29	6.07	45.00	60.00
K	65.00	18.48	40.00	90.00
Recommendation based on the soil analysis of Laboratory 2:				
N	255.00	23.45	240.00	300.00
P	33.33	6.06	25.00	40.00
K	60.00	14.14	40.00	80.00

As for the second scenario, the fertilizer agent was required to make recommendations, taking into account the poor financial state of the farm and that input costs need to reduced. The recommendation must still be sufficient for a twelve (12) ton per hectare maize yield, without harming the soil fertility.

Table 4.26: Recommendations made by the fertilizer salespersons in kg/ha that need to save funds

Variable	Mean	Std. dev	Minimum	Maximum
Recommendation based on the soil analysis of Laboratory 1:				
N	258.86	30.70	220.00	300.00
P	47.14	4.88	40.00	50.00
K	55.00	11.18	40.00	70.00
Recommendation based on the soil analysis of Laboratory 2:				
N	236.67	26.58	200.00	280.00
P	26.67	8.16	20.00	40.00
K	48.33	9.83	40.00	60.00

The third scenario requires the fertilizer agent to make a recommendation to the farmer based on the knowledge that it is not necessary to save funds due to the fact that the farm's finances are sound. The recommendation must still be made for a twelve (12) ton per hectare maize yield.

Table 4.27: Recommendations made by the fertilizer salespersons in kg/ha where surplus funds are available

Variable	Mean	Std. dev	Minimum	Maximum
Recommendation based on the soil analysis of Laboratory 1:				
N	303.14	53.44	252.00	400.00
P	60.00	8.16	50.00	70.00
K	80.71	16.44	60.00	100.00
Recommendation based on the soil analysis of Laboratory 2:				
N	273.33	27.33	240.00	320.00
P	42.50	8.80	30.00	50.00
K	67.50	11.73	50.00	80.00

The three aforementioned tables substantiates the statistics that were calculated from the data that were obtained from fertilizer salespersons. Table 4.28 illustrates the p-values that were calculated with the T-test.

Table 4.28: Comparison of recommended application rates for N, P and K by fertilizer agents based on the analyses reports of two laboratories for a limited and unlimited budget respectively

Type of recommendation	Nutrient	Recommendation made based on analyses of Laboratory 1 (p-value)	Recommendation made based on analyses of Laboratory 2 (p-value)
Limited budget:			
Normal vs. save money	Nitrogen	0.0186*	0.0379*
Normal vs. save money	Phosphate	0.0030*	0.0103*
Normal vs. save money	Potassium	0.1165	0.1345
Unlimited budget:			
Normal vs. extra money	Nitrogen	0.0113*	0.0379*
Normal vs. extra money	Phosphate	0.0152*	0.0121*
Normal vs. extra money	Potassium	0.0495*	0.150*

*p-value is smaller <0.05, significant difference accrued.

It is evident from Table 4.28 that there is a significant difference between the recommendations made by the fertilizer salesperson (for an expected 12 ton maize yield) when the farm's financial status has an influence on the recommendations requested from the fertilizer salesperson. It can be seen that, between the normal recommendation made without knowledge of the farm's current financial situation and the recommendation where it was requested to save money (due to a limited budget), significant statistical differences were found for both the application recommendations made for nitrogen that were based on the analysis report of laboratory 1 (p = 0.0186) and laboratory 2 (p = 0.0379), as well as for the application rates for phosphate based on the analysis report of laboratory 1 (p = 0.0030) and laboratory 2 (p = 0.0103).

Similarly, between the normal recommendation made without knowledge of the farm's current financial situation and the recommendation where it was mentioned that sufficient funding is available to improve the nutrient reserves of the soil (unlimited budget), significant statistical differences were found for both the application recommendations made for nitrogen that were based on the analysis report of laboratory 1 (p = 0.0113) and laboratory 2 (p = 0.0379), for the application rates for phosphate based on the analysis report of laboratory 1 (p = 0.0152) and laboratory 2 (p = 0.0121). as well as for the application rates for potassium based on the analysis report of laboratory 1 (p = 0.0495) and laboratory 2 (p = 0.0150).

Objective 3: The marketing strategy of fertilizer companies

4.10 The marketing strategy of fertilizer companies

This section of the study investigates the marketing strategies of a selected number of fertilizer companies. The fertilizer companies that were targeted are companies that were referred to by the respondents in the four different areas of the study. No p-values will be given in this part of the chapter.

According to Lotz (2005), companies always have a motive for marketing plans. The farmer and the salesman know that fertilizer is a commodity and that the farmer can buy it anywhere. Hence, companies endeavour to portray their product as the preferred or superior one. In some instances, this will involve a special price strategy, whilst excellent service is also always a factor.

Kynoch is a Swedish fertilizer company that produces a lot of excessive urea. They make use of South Africa's market to sell off their over-produced or surplus product.

According to Lotz (2005), Omnia is the largest fertilizer company in South Africa. Omnia has an excellent infrastructure in South Africa that consists of first-rate laboratories, a well-trained sales team that is represented all over the country and research facilities that can substantiate the quality of their products. Omnia's main purpose is to promote their product locally and in turn, provides farmers with excellent after-sale service.

Sasol's main goal is to use ammonia that is a byproduct of explosives in order to produce their fertilizer products. This enables the company not only to get rid of the byproduct, but also to reduce their contribution to pollution (Lotz, 2005).

Following is a brief description of each of the companies targeted in this study as well as a short overview of their marketing strategies.

4.10.1 Company 1: Gavilon

The company sells approximately 400 000 tons of fertilizer per year. They do not manufacture any of their products. The company imports all of its products from all over the world. Quality and price determine where the product is purchased.

Their marketing strategy is to sell directly to farmers and companies on a wholesale basis. This approach enables the company to keep the overhead costs low, which in turn enables them to keep the price of their product low. They do not offer an agronomical services to the farmers. An additional advantage of their strategy is the fact that they do not load any shipment before payment, thereby ensuring that they never have outstanding payments for their product. A disadvantage is that they have only a small portion of the market as their clients. Should these companies or farmers find alternative suppliers, it may very well lead to the financial demise of Gavilon.

4.10.2 Company 2: Triomf

The company sells approximately 70 000 tons per year. They do not manufacture any fertilizer. All of the fertilizer that they sell is imported or bought from local manufacturers. The company does not offer agronomical services to the farmers. Furthermore, they only sell blends and no straights to the farmers. Their main marketing strategy is to publish their price list on agriculture platforms such as magazines, to buy the product directly from the manufacturer, to mix the fertilizer and then sell directly to the farmer. The disadvantage of this marketing strategy is that they do not sell straights, their only market is consumers that use blends.

4.10.3 Company 3: Sasol

Sasol sells approximately 170 000 tons of fertilizer per year. They manufacture all the fertilizer they sell; nothing is imported. The company does not have any agronomical services that are available to the farmers. The main market strategy is that they only sell on a wholesale basis to companies that handle huge amounts. They do not sell directly to farmers. An advantage of their strategy is that they sell vast amounts of fertilizer in one transaction and insist on payment before the fertilizer is released. This obviously mitigates their own risk.

4.10.4 Company 4: Sidi Parani

Sidi Parani sells approximately 130 000 tons of fertilizer per year. They do not manufacture any fertilizer. They buy from local manufacturers in South Africa and import fertilizer from the rest of the world. They do not sell straights to the farmers because the profit margin is higher on blends. They offer an agronomical service to the farmers but the extension officer is in service of Sidi Parani. The company does not provide production finance on fertilizer to farmers; they provide the farmer with the fertilizer and the farmer must repay the fertilizer with the grain harvested during that planting season. This approach provides them with an advantage, since they conduct a lot of business with the farms directly and in turn, this ensures that the company handles a lot of grain.

4.10.5 Company 5: Constantia

This company sells approximately 100 000 tons of fertilizer per year. They do not manufacture any fertilizer but rather purchase from other fertilizer companies. They provide agronomical services to the farmers and the extension officers are in service of the company. The business is owned by an agriculture company. The main marketing strategy is to provide farmers with production loans by supplying them with the production products, after which the loan is repaid with grain produced by the farmer.

4.10.6 Company 6: OVK

The OVK group sells approximately 20 000 tons per year. They are new to the fertilizer industry. All the products are bought from other companies; they only manufacture blends. No agronomical service is provided to farmers by the company. They form part of a vast agriculture company and the main marketing strategy is to supply all their branches with stock. A huge disadvantage is that all the branches are limited only to their own blends.

4.10.7 Company 7: Driehoek

Driehoek sells approximately 45 000 tons of fertilizer per year. All the fertilizer is bought from other companies on a wholesale basis, after which the fertilizer is blended to the farmer's specifications. They sell blends and straights in order to satisfy the needs of the farmer. They provide agronomical services to the farmers and the extension officers are in the service of the company itself. The marketing strategy of this company differs from the rest in so far that their highest priority is to provide a service to the farmer. They have high-quality blenders to ensure the quality of their product. Furthermore large numbers of field tests are conducted to provide the farmers with the correct information about the products and proof that their products work in the field. The advantage of their strategy lies in the fact that farmers appreciate high levels of quality service and a good product, which turns them into long term clients. The disadvantage of the marketing strategy is that they do not offer production loans, which often forces farmers to turn to other suppliers that do.

4.10.8 Company 8: Vet River

This company sells approximately 80 000 tons of fertilizer per year. No fertilizer is by the company itself; they purchase all the fertilizer from other companies. They provide agronomical services to the farmers and the extension officers are in their employ. Their main marketing strategy is to provide the cheapest possible fertilizer to the farmer by negotiating a better price with the manufacturers to ensure low prices for the farmer. The main advantage of this strategy is that farmers benefit from the company's negotiation power, which is made possible by the vast amounts of fertilizer bought at one given time. The disadvantage of the market strategy is that they cannot provide farmers with production loans, which often force farmers to turn to a company that does offer production capital.

4.10.9 Company 9: Omnia

Omnia sells in excess of a million tons of fertilizer per year. They manufacture and also buy fertilizer from other manufacturers. It is of the utmost importance that the raw materials that are used for the production of fertilizer comply with certain rules, that the price and quality are up to standard, that the products comply with the safety laws of the company and that the raw material is analysed at least four times before it is used in the production line. The company offers agronomical services to the farmer and the extension officers are in the employ of the company. The main strategy of the company is to ensure a sustainable and prosperous agriculture environment and in order to do so, they establish and maintain relationships with the farmers that add value through exceptionally good information. The advantages of this marketing strategy are that they do direct marketing to the farmer to ensure the information reaches the farmer timeously and in the correct format. The disadvantage of this strategy is that they require vast numbers of staff that need to be in the field to give the correct information to the farmer and that leads to higher prices having to be paid for their fertilizer.

Objective 4: The level of variations in soil analyses between different laboratories

4.11 The level of variations in soil analyses between different laboratories

With this objective in mind, the study will endeavour to establish if there are meaningful variations between soil analyses of different laboratories. In order to prove or disprove this specific hypothesis set by the study, a large soil sample was taken, thoroughly mixed and subsequently divided into four samples, which were distributed between four laboratories in three batches a week apart from each other. The data in this chapter are the laboratory results as well as the p – value that were calculated by means of ANOVA.

In Table 4.29 each laboratory's mean value of the ten samples are provided for the ten (10) soil samples that were analysed as well as the p - value that was calculated for the ten samples of each laboratory.

Table 4.29: The mean values and the p value for soil analyses conducted by each laboratory

Variable	Lab 1 Mg/kg	Lab 2 Mg/kg	Lab 3 Mg/kg	Lab 4 Mg/kg	Lab 1 P - value	Lab 2 P - value	Lab 3 P - value	Lab 4 P - value
P - Bray 1	45.70	57.05	69.79	46.60	> 0.05	> 0.05	> 0.05	0.0095
P – Bray 2	76.17	95.08	116.32	77.67	> 0.05	> 0.05	> 0.05	0.0095
P – Mehlich 3	68.30	81.50	99.70	109.53	0.0434	> 0.05	> 0.05	0.0002
K	454.70	445.46	500.60	560.37	0.0057	> 0.05	0.0499	> 0.05
Na	49.80	36.83	-	60.11	0.0059	> 0.05	-	> 0.05
Ca	1168.60	1089.90	-	1402.89	> 0.05	> 0.05	-	> 0.05
Mg	449.60	500.82	-	715.23	0.0027	> 0.05	-	> 0.05
Ca %	51.70	49.70	47.96	48.16	0.0006	> 0.05	<0.0001	> 0.05
Mg %	36.15	36.20	39.79	40.20	0.0003	> 0.05	<0.0001	0.0190
K %	10.23	12.70	10.69	9.83	0.0150	> 0.05	0.0079	> 0.05
Na %	1.92	1.50	1.56	1.81	0.0003	> 0.05	> 0.05	> 0.05

Table 4.29 illustrates the results from the soil samples of the different laboratories. In the instance where a significant difference occurs, the p - value is provided and in the case where no significant difference occurs, the p value is not provided and only indicates that the p - value is greater than 0.05. There are significant differences between all the elements that were analysed and all four of the laboratories have significant differences between the ten soil samples of the same soil that were analysed. Significant differences occurred between the results of different labs, namely Lab 1 showed significant differences between batches for P - Bray 1, P - Bray 2, P - Mehlich 3, K, Na, Mg, Ca %, Mg %, K % and Na %, while the results of Lab 2 showed no significant differences between batches. Lab 3 showed significant differences between batches for K, Ca %, Mg % and K %, while Lab 4 showed significant differences between batches for P - Bray 1, P - Bray 2, P - Mehlich 3 and Mg %.

Table 4.30 to Table 4.33 illustrate the statistics that were calculated with ANOVA for the different batches that were analysed by the laboratories. Three (3) batches of the same soil were sent to each laboratory in order to be analysed. First of all, the tables illustrate the exact data from the laboratory and then the mean p – value of the data as well as the comparison between the three batches.

Table 4.30: Laboratory one results for three different batches of soil analysis

Variable	Batch			p-value			
	1 mg/kg	2 mg/kg	3 mg/kg	Mean	1 vs 2	1 vs 3	2 vs 3
P - Bray 1	44.75	74.58	47.67	> 0.05	> 0.05	> 0.05	> 0.05
P – Bray 2	74.58	64.75	79.44	> 0.05	> 0.05	> 0.05	> 0.05
P – Mehlich 3	64.75	404.00	74.67	0.0057	> 0.05	0.0205	> 0.05
K	404.00	57.50	487.00	0.0059	0.0061	0.0037	> 0.05
Na	57.50	42.00	47.33	> 0.05	0.0094	0.0024	> 0.05
Ca	1121.00	1196.00	1204.67	0.0027	0.0441	0.0422	> 0.05
Mg	460.50	508.67	542.67	0.0006	0.0037	0.0030	> 0.05
Ca %	52.58	51.67	50.57	0.0003	0.0293	0.0017	0.0043
Mg %	35.40	35.97	37.33	0.0150	> 0.05	0.0006	0.0031
K %	9.68	10.80	10.40	0.0003	0.0181	0.0173	> 0.05
Na %	2.35	1.57	1.70	> 0.05	0.0016	0.0001	> 0.05

In Table 4.30 the first laboratory's results from the soil analyses are provided, as well as the p – value that was calculated for the results. In cases where a significant difference occurs, the p – value is provided. In cases where no significant difference occurs, the p value is not provided and only indicates that the p - value is greater than 0.05. Significant differences occurred between the results of the mean of some of the three different batches regarding P - Mehlich 3, K, Na, Ca, Mg. Ca %, Mg %, K % and Na %.

Table 4.31: Laboratory two results for three different batches of soil analysis

Variable	Batch			p-value			
	1 mg/kg	2 mg/kg	3 mg/kg	Mean	1 vs 2	1 vs 3	2 vs 3
P - Bray 1	50.68	56.07	66.53	> 0.05	> 0.05	> 0.05	> 0.05
P – Bray 2	84.46	93.44	110.89	> 0.05	> 0.05	> 0.05	> 0.05
P – Mehlich 3	72.39	80.10	95.05	> 0.05	> 0.05	> 0.05	> 0.05
K	447.43	474.60	413.70	> 0.05	> 0.05	> 0.05	> 0.05
Na	40.75	40.40	28.03	> 0.05	> 0.05	> 0.05	> 0.05
Ca	1148.00	1252.67	849.67	> 0.05	0.0407	> 0.05	> 0.05
Mg	528.58	578.73	385.90	> 0.05	0.0431	> 0.05	> 0.05
Ca %	50.50	50.67	47.67	> 0.05	> 0.05	> 0.05	> 0.05
Mg %	38.00	38.33	31.67	> 0.05	> 0.05	> 0.05	> 0.05
K %	10.00	10.00	19.00	> 0.05	> 0.05	> 0.05	> 0.05
Na %	1.50	1.67	1.33	> 0.05	> 0.05	> 0.05	> 0.05

In Table 4.31 the second laboratory's results for the soil analyses are provided as well as the p – value that was calculated for the results. In cases where a significant difference occurs, the p - value is provided and in cases where no significant difference occurs, the p-value is not provided and only indicates that the p - value is greater than 0.05. This laboratory showed the least significant differences between batches as significant differences could only be found between batch 1 and 2 for Ca and Mg.

Table 4.32: Laboratory three results for three different batches of soil analysis

Variable	Batch			p-value			
	1 mg/kg	2 mg/kg	3 mg/kg	Mean	1 vs 2	1 vs 3	2 vs 3
P - Bray 1	87.50	53.43	62.53	> 0.05	0.0003	> 0.05	> 0.05
P – Bray 2	145.83	89.06	104.22	> 0.05	0.0003	> 0.05	> 0.05
P – Mehlich 3	125.00	76.33	89.33	> 0.05	0.0003	> 0.05	> 0.05
K	485.50	538.33	483.00	0.0499	0.0419	> 0.05	> 0.05
Na	.	.	.	-	-	-	-
Ca	.	.	.	-	-	-	-
Mg	.	.	.	-	-	-	-
Ca %	49.17	43.78	50.53	< 0.0001	< 0.0001	0.0015	< 0.0001
Mg %	38.99	43.15	37.50	< 0.0001	< 0.0001	0.0201	0.0002
K %	10.16	11.58	10.52	0.0079	0.0094	> 0.05	0.0401
Na %	1.69	1.49	1.45	> 0.05	> 0.05	> 0.05	0.8545

In Table 4.32 the third laboratory's results for the soil analyses are provided as well as the p – value that was calculated for the results. In cases where a significant difference occurs, the p - value is provided and in cases where no significant difference occurs, the p-value is not provided and only indicates that the p - value is greater than 0.05. Significant differences occurred between the results of the mean of some of the three different batches regarding P - Bray 1, P - Bray 2, P - Mehlich 3, K, Ca %, Mg %, K % and Na %.

The blank spaces in the table is where the laboratory didn't analyse the specific element.

Table 4.33: Laboratory four results for three different batches of soil analysis

Variable	Batch			p-value			
	1 mg/kg	2 mg/kg	3 mg/kg	Mean	1 vs 2	1 vs 3	2 vs 3
P - Bray 1	44.56	58.23	37.69	0.0095	0.0383	> 0.05	0.0024
P – Bray 2	74.26	97.05	62.82	0.0095	0.0383	> 0.05	0.0024
P – Mehlich 3	118.01	77.28	130.47	0.0002	0.0023	> 0.05	< 0.0001
K	513.66	643.47	539.56	0.0810	0.0320	> 0.05	> 0.05
Na	59.76	52.31	68.37	> 0.05	> 0.05	> 0.05	> 0.05
Ca	1317.11	1531.92	1388.21	> 0.05	0.0627	> 0.05	> 0.05
Mg	649.83	801.05	716.64	> 0.05	0.0097	> 0.05	> 0.05
Ca %	48.80	47.58	47.89	> 0.05	0.0478	> 0.05	> 0.05
Mg %	39.53	40.79	40.51	0.0190	0.245	> 0.05	> 0.05
K %	9.74	10.21	9.56	> 0.05	> 0.05	> 0.05	> 0.05
Na %	1.93	1.41	2.04	> 0.05	0.0239	> 0.05	> 0.05

In Table 4.33 the fourth laboratory's results for the soil analyses are provided as well as the p – value that was calculated for the results. In cases where a significant difference occurs, the p - value is provided and in cases where no significant difference occurs, the p-value is not provided and only indicates that the p - value is greater than 0.05.

Most significant differences occurred between the results of batch 1 when compared to batch 2 regarding the analysed values for P - Bray 1 ($p = 0.0383$), P - Bray 2 ($p = 0.0383$), P - Mehlich 3 ($p = 0.0023$), K ($p = 0.0320$), Ca ($p = 0.0627$), Mg ($p = 0.0097$), Ca % ($p = 0.0478$), Mg % ($p = 0.245$) and Na % ($p = 0.0239$). Statistically significant differences also occurred between the results of batch 2 when compared to batch 3 regarding the analysed values for P - Bray 1 ($p = 0.0024$), P - Bray 2 ($p = 0.0024$) and P - Mehlich 3 ($p < 0.0001$).

The laboratories were also instructed to analyse the micro elements however, not all of the laboratories were able to analyse all of the elements, which is the reason for the blank spaces in the data. Table 4.34 illustrates the data from the respective laboratories and the mean p – value calculated by means of ANOVA.

Table 4.34: The mean values and the p-value for soil analyses of the micro elements performed by each laboratory

Variable	Lab 1 mg/kg	Lab 2 mg/kg	Lab 3 mg/kg	Lab 4 mg/kg	Mean p - value
Fe	78.86	-	80.70	104.68	> 0.05
Mn	164.22	-	190.31	189.19	> 0.05
Cu	2.59	-	3.77	3.51	< 0.0001
Zn	15.92	-	16.28	17.92	> 0.05
S	9.70	6.84	-	9.01	> 0.05
B	0.75	-	1.06	1.67	0.0002
Al	-	-	-	349.53	> 0.05

In Table 4.34 the results from the micro element soil analyses performed by the different laboratories are reflected. There are only two elements that show a significant difference between the laboratories. The remaining five elements do not show a significant difference.

Table 4.35 illustrates a comparison between the different laboratories, of which the results were calculated with ANOVA.

Table 4.35: Comparison between the different laboratories' analysis of micro elements

Variable	P – value					
	1 vs 2	1 vs 3	1 vs 4	2 vs 4	2 vs 3	3 vs 4
Fe	-	> 0.05	> 0.05	-	-	> 0.05
Mn	-	> 0.05	> 0.05	-	-	> 0.05
Cu	-	< 0.0001	0.0003	-	-	> 0.05
Zn	-	> 0.05	> 0.05	-	-	> 0.05
S	> 0.05	-	> 0.05	-	> 0.05	-
B	-	0.0129	0.0006	-	-	0.0102
Al	-	-	-	-	-	-

From Table 3.35 it is clear that there are significant differences for some elements (Cu and B) between the analyses of micro elements performed by the different laboratories. Due to the fact that the laboratories did not analyse all the micro elements, many of the elements could not be compared. Nonetheless, significant differences were found regarding the analysed copper (Cu) contents in the soil between lab 1 and lab 3 ($p = <0.0001$) and between lab 1 and lab 4 ($p = 0.0003$), as well as regarding the analysed boron (B) contents in the soil between lab 1 and lab 3 ($p = 0.0129$), between lab 1 and lab 4 ($p = 0.0006$), and between lab 3 and lab 4 ($p = 0.0102$).

Significantly though, the comparisons set out in the afore-mentioned support the hypothesis stated at the onset: There are significant differences between different laboratories in South Africa. In light of this, it is strongly recommended that farmers should always make use of the same laboratory in order to obtain a reliable record of the soil fertility on the farm, which will confirm whether the management programme adhered to on the farm is sustainable or not.

Chapter 5 – Summary, conclusion and recommendations

This chapter will provide a brief summary of the results of the study as well as some recommendations to farmers. The discussion will be divided into four sections according to the four main objectives that were set by the study. The sections are: 1) the farmer's behaviour regarding fertilizer management; 2) the fertilizer salesman's behaviour; 3) the marketing strategies of the fertilizer companies and 4) the level of variations in soil analysis found between different laboratories in South Africa.

5.1 Farmer's behaviour regarding fertilizer management

The study investigated selective factors that can have an influence on the farmers' behaviour regarding fertilizer management. Each of these will be briefly discussed in the sections that follow.

5.1.1 Summary

c) Input cost of fertilizer per hectare

Fertilizer costs comprise the major portion of the production cost of maize. Significant differences were found between the four areas for the average nitrogen input cost per hectare on an early planting ($p = 0.0026$), whereas on late planting a significant difference was also found ($p < 0.0001$) between irrigation areas. Furthermore, the nitrogen cost of the sample group of farmers in Douglas was significantly higher than Vaalharts ($p = 0.0489$) and Jacobsdal ($p = 0.0010$). When the separate areas were compared to each other on a late planting in terms of nitrogen cost per hectare, there was a significant difference between Douglas and Vaalharts ($p = 0.0002$), Douglas and Prieska ($p = 0.0017$) and between Douglas and Jacobsdal ($p = 0.0003$). As far as differences in nitrogen cost based on the farm size are concerned, no significant differences could be found between the nitrogen input cost between smaller and larger farm groups. No significant differences were found in the phosphate and potassium input costs per hectare between the four sample areas.

However, a significant difference at a test level of 95% was found between the small and larger farms at Vaalharts ($p < 0.0001$) regarding potassium costs per hectare for early planting. The differences in the input cost of microelements were statistical assessed with the ANOVA test and it was found that there are significant differences between the four irrigation areas of the study for the average micro element input cost per hectare for an early plant ($p = 0.0226$), as opposed to a late plant ($p < 0.0001$). More specific, significant differences in the costs of microelements per hectare was found between Douglas and Vaalharts for early planting ($p = 0.0055$) and late planting ($p = 0.0005$), between Vaalharts and Prieska for early planting ($p = 0.0023$) and late planting ($p < 0.0001$), and between Vaalharts and Jacobsdal for early planting ($p = 0.0106$) and late planting ($p < 0.0001$) respectively. However, no significant differences in microelement costs could be found between smaller and larger farms in all four sample regions. When considering the total input cost of fertilizer per hectare, the Douglas sample group was significantly higher than Vaalharts and Prieska respectively, i.e. for late planting between Douglas and Vaalharts ($p = 0.0108$), and Douglas and Jacobsdal for an early planting ($p = 0.0215$) as well as a late planting ($p = 0.0188$). It was found that the size of the farm makes no significant difference as far as the total input cost of fertilizer per hectare is concerned.

d) Influence of education on fertilizer-related decision-making

The respondents were divided into three groups according to their highest academic qualification (i.e. "Grade 12", "Tertiary Agriculture" and "Tertiary Non-Agriculture"). No significant differences were found between the education groups when considering the plant requirements or the target yield to determine the amount of fertilizer to be applied. Furthermore, no significant difference could be found on the consistent use of salespersons in order to obtain the cheapest source of fertilizer. Lastly, no differences were found between the education groups in the manner that they use soil tests to determine the amount of fertilizer to be applied.

e) Method of application of the fertilizer

There were no differences found between the selected areas of the study or the size of the farm for the methods of application of the fertilizer. The study also investigated the time when the fertilizer is purchased as well as the packaging of the fertilizer. Only the Prieska sample group showed a significant difference in packaging between large and small farms ($p = 0.0064$), i.e. the larger farmers prefer to use large bags and bulk fertilizer, while the small farmers prefer small (50kg) bags that can be moved by hand.

f) *Time of application of fertilizer*

All the respondent groups prefer to apply some of the fertilizer at plant, while also applying additional fertilizer as a topdressing later in the season.

g) *Fertilizer salesman recommendation*

The study utilised the experience, measured in years of farming, of the respondents as a tool to measure the fertilizer salesperson against. The study investigated the academic qualifications of the fertilizer salesperson, the fertilizer salesperson as part of the community, trust in the fertilizer salesperson created through their appearance and the selection of the laboratory. No indication (of significant statistical difference) could be found that these parameters influence farmers when evaluating the recommendation made by the fertilizer salesperson.

h) *Selection of soil analysis laboratory*

Based on the academic qualification of the respondents, no significant difference was found between the three education groups when selecting the laboratory for the soil analyses or in their knowledge about the extraction method used by laboratories during the soil analysis.

i) *The soil analysis*

Most respondents (26) indicated that they rectify nutrient shortages in the soil over time due to the financial implication of associated improved yields.

j) Influence of demographical traits on fertilisation practices

The study results indicated that the only significant difference between the respondents, grouped according to highest academic qualification and type, was the significantly better ability of the group with tertiary agricultural qualifications to understand the soil analysis report and verify the fertilizer recommendation made by the fertilizer agent ($p = 0.0059$). None of the other demographics (e.g. age, experience and gender) play any significant role in farmers' fertilizer practices.

k) Consultation tariffs

Significant differences were found between the groups categorised according to academic qualification as far as the hourly tariff is concerned that the different groups were willing to pay for consulting services. On average, the "Gr 12" group is willing to pay R 900.00 an hour, the "Agricultural" educated group R 1250.00 an hour, and the "No Agricultural" educated group is willing to pay R 750.00 an hour.

5.1.2 Conclusion

The factors that influence the respondents' fertilizer practices are mostly external aspects and thus out of the farmer's control.

5.1.3 Recommendations

In the agriculture industry, the farmer has very little control over or bargaining power concerning the price of their produce. In most cases they have to accept the price that the buyer is willing to pay for the product. To farm sustainable in the long run, farmers must find a way to control or manipulate the price of their inputs. The challenge is to have reduced input costs while still obtaining reasonable yields and maintaining soil fertility. This balancing act will also differ between farmers due to every farm's unique situation, for example economies of scale and the financial position (liquidity) of the farming business.

Most farmers use a production loan to finance inputs – a service that is provided by most large agricultural businesses. These firms usually offer a reasonable interest rate on such a loan, but with the condition that all farming inputs must be purchased from this firm and that all produce be sold to this provider of the loan. The price of produce, for example maize, is usually at its lowest during harvesting time, due to the oversupply during that specific period. Farmers using this kind of input finance do not have the luxury to withhold produce, in order to speculate on a higher price at a later stage, as all produce must be delivered to the financier immediately after harvesting.

Farmers that use other financial institutions will usually pay a higher interest rate on the loan but they will be able to source inputs from many suppliers and can thus utilise opportunities to buy at a lower cost. The farmer can also select where and when the harvested produce will be sold. Thus, the farmer pays more for the loan, but purchases the production materials cheaper and sells the product for more. If their financial situation allow the latter, farmers should carefully consider the latter as a measure to increase profitability.

5.2 Profile of the fertilizer salesman

The study investigated how the farmers react to several qualities or characteristics of the sales representatives, for example their academic qualifications and appearance, as well as the laboratory that they recommended for soil analysis. It was also determined that there are different tendencies amongst farmers when grouped according to their academic qualifications. It was also investigated if there is a connection between the financial position of the farmer and the recommendation of the fertilizer sales representative.

5.2.1 Summary

The results indicated that the sales representative's academic qualification, appearance and the laboratory recommended to the farmer, have no significant influence on the way that respondents perceive their ability or trust. It was also determined that if there are different tendencies amongst farmers when grouped either according to type and level of academic qualification, or based on their years of farming experience. In addition, there are differences between the recommendations made by the fertilizer salesperson in different areas, which could be attributed to the different environments of the areas.

If the financial position of the farming business (i.e. restricted or surplus funding and target yield) is disclosed to the fertilizer agent, significant differences were found in the quantities of nitrogen, phosphate and potassium that were recommended by the sales representative. Between the normal recommendation made without knowledge of the farm's current financial situation and the recommendation where it was requested to save money (due to a limited budget), significant statistical differences were found for both the application recommendations made for nitrogen that were based on the analysis report of laboratory 1 ($p = 0.0186$) and laboratory 2 ($p = 0.0379$), as well as for the application rates for phosphate based on the analysis report of laboratory 1 ($p = 0.0030$) and laboratory 2 ($p = 0.0103$).

Similarly, between the normal recommendation made without knowledge of the farm's current financial situation and the recommendation where it was mentioned that sufficient funding is available to improve the nutrient reserves of the soil (unlimited budget), significant statistical differences were found for both the application recommendations made for nitrogen that were based on the analysis report of laboratory 1 ($p = 0.0113$) and laboratory 2 ($p = 0.0379$), for the application rates for phosphate based on the analysis report of laboratory 1 ($p = 0.0152$) and laboratory 2 ($p = 0.0121$), as well as for the application rates for potassium based on the analysis report of laboratory 1 ($p = 0.0495$) and laboratory 2 ($p = 0.0150$).

5.2.2 Conclusion

Since the target yield differs between areas, it was expected that the recommendations by the fertilizer salesmen will differ accordingly. The recommendations made by the salesmen are based on the information they obtain from the client, as well as their training, experience and the company they represent.

5.2.3 Recommendations

It is recommended that a farmer must select the fertilizer salesperson with extreme prudence. The sales representative provides valuable information that will assist the farmer to make decisions that will have a huge impact on the financial success of the farming business, while it will also influence soil fertility and contribute to the long-term sustainability of the farm. However, the farmer must always keep in mind that the fertilizer sales representative, being employed by a specific company, will only be able to sell or promote the products of that company. Recommended products by these salespeople may thus not always be ideal for the specific situation, including nutrient requirements, of the farm. Farmers with sufficient knowledge of different fertilizer products (i.e. types of nutrients and its reaction in the soil after application) will thus be able to better ensure that the correct fertilizer types are obtained from the more appropriate supplier or source in order for it to have the required positive effect on soil fertility and thus expected yield. Farmers must also ensure that they are up to date with the prices and service levels of different suppliers in order to negotiate a good price for the inputs and obtain a quality service and nutrients that are in line with the specific requirements of the farm.

5.3 The marketing strategy of fertilizer companies

In the study, fertilizer companies were requested to provide a brief description of the company and its fertilizer marketing strategy.

5.3.1 Summary

The marketing strategies of the fertilizer companies are more or less the same but are influenced by three major factors. These are: 1) whether they manufacture fertilizer or not, 2) whether they import fertilizer and resell it, and 3) whether they import nutrients, mix it into specific blends and then sell it. As expected, the main objective of all the marketing strategies is to make a profit. With regard to the provision of agronomic services, there are two main groups namely: 1) some companies provide an agronomic service to the farmers as a way to get the product sold, while 2) others offer no agronomic services in order to keep cost as low as possible.

5.3.2 Conclusion

All of the companies have one goal in common and that is maximum profit. Because they are all selling the same products (nutrients), strong competition compels them to implement exceptional marketing strategies to increase sales volumes. The study also highlighted vast differences in the sizes of these competing companies; the biggest company sold over one million tons of fertilizer per annum and the smallest approximately twenty thousand tons per year.

5.3.3 Recommendations

The farmer should always bear in mind that a fertilizer company's mail goal is maximum profit and not the welfare of the farmer as individual. They all sell basically the same product and farmers must keep in mind that the company's agronomic services (for example soil sampling and cost of analysis), may be costly as it is then integrated into or added to the price of the purchased fertilizers. Alternative independent agronomic services are available and the cost thereof can be offset by purchasing much cheaper fertilizers, resulting in a much lower total cost.

5.4 The level of variations in soil analyses between different laboratories

The study investigated variations in soil analysis reports or results amongst four different laboratories in South Africa.

5.4.1 Summary

A large soil sample was taken under supervision of an independent agronomist. This sample was then thoroughly mixed and divided into forty (40) sub-samples. These were sent to four different soil laboratories in three different batches one week apart from each other. The laboratories were unaware that the three batches were from the same source.

By using an ANOVA, the results of the soil samples were statistically analysed and meaningful differences ($p < 0,05$) were found in macro-elements (N, P and K) between laboratories as well as between different batches within each laboratory. Significant differences occurred between the results of different labs, namely Lab 1 showed significant differences between batches for P - Bray 1, P - Bray 2, P - Mehlich 3, K, Na, Mg, Ca %, Mg %, K % and Na %, while the results of Lab 2 showed no significant differences between batches. Lab 3 showed significant differences between batches for K, Ca %, Mg % and K %, while Lab 4 showed significant differences between batches for P - Bray 1, P - Bray 2, P - Mehlich 3 and Mg %.

Less variation was found with regard to microelements, i.e. significant differences regarding the analysed copper (Cu) contents in the soil between lab 1 and lab 3 ($p = <0.0001$) and between lab 1 and lab 4 ($p = 0.0003$), as well as regarding the analysed boron (B) contents in the soil between lab 1 and lab 3 ($p = 0.0129$), between lab 1 and lab 4 ($p = 0.0006$), and between lab 3 and lab 4 ($p = 0.0102$).

5.4.2 Conclusion

Neither the farmer nor the fertilizer sales representative can control or influence the laboratory results. However, the study results indicated that meaningful variations may occur between different laboratories, although it was found that some laboratories have less variation between the different batches that were analysed. A laboratory with the most consistent results must thus be used in order for the farmer to create a reliable record of the trends in soil fertility status.

5.4.3 Recommendations

It is highly recommended that a farmer ensures that soil samples are consistently taken according to the prescribed procedure and, if possible, from the same area in the field in order to create a record of soil fertility over time. It is furthermore recommended that the same laboratory always be used. Only with a reliable soil fertility record will the farmer be able to make important decisions regarding the fertilizer programme that impacts on the soil fertility and the long-term sustainability of resources.

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Annexures

Annexure 1:

Questionnaire to the farmers

Factors influencing farmers' fertiliser practices on irrigation schemes in the central part of South Africa.

Questionnaire to the farmer

In practical fulfilment of the requirement of M. Tech agriculture thesis.

FJJ Nell (213035162)
Supervisor: Prof Carlu van der Westhuizen

The overall objective of this study is to determine the fertilisation practices as applied by farmers in the irrigation areas of the Jacobsdal, Prieska, Vaalharts and Douglas regions the in central part of South Africa.

Non of the information gained will be linked to a person or company/institution during the discussion of the results in the study

Personal and farm details.

Questionnaire number: 1

1,1,1 Age: ______________ 2

1,1,2 Gender: Male 3
Female

1,1,3 Number of years farming:
______________ 4

1,1,4 Your highest academic qualification:
____
______________ 5

1,1,5 Area under irrigation(ha): ______________ 6
7

1,1,6 Area where farming: Douglas 8
Vaalharts 9
Prieska
Oranje-Riet

Specific objective 1: To determine the information that farmers will take into account when choosing the types of fertiliser and predicting/establishing the amount of fertiliser to be applied during the season.

Please specify what sources of the following you are using:

1,1 Nitrogen

Ammonium Sulphate Nitrate 10
Urea 11
Ammonium sulphate 12
Ammonium nitrate 13
Dia-ammonium phosphate 14
Limestone ammonium nitrate 15
Urea ammonium nitrate 16
ANO 17
Anhydrous ammonia (AA) 18
Other: 19
____

1,2 Phosphorus

Mono-ammonium phosphate 20
Dia-ammonium phosphate 21
Supers phosphate 22

	Triple super phosphate	☐ ☐	23
	Rock phosphate	☐ ☐	24
	Other	☐ ☐	25
1,3 Potassium			
	Potassium sulphate	☐ ☐	26
	Potassium chloride	☐ ☐	27
	Potassium nitrate	☐ ☐	28
	Other	☐ ☐	29
1,4 Calcium			
	Gypsum	☐ ☐	30
	Calcite lime	☐ ☐	31
	Dolomitic lime	☐ ☐	32
	Other	☐ ☐	33
1,5 Magnesium			
	Potassium magnesium sulphate	☐ ☐	34
	Kieserite	☐ ☐	35
	Epsom salts	☐ ☐	36
	Dolomitic lime	☐ ☐	37
	Other	☐ ☐	38
1,6 Sulphur			
	Ammonium sulphate	☐ ☐	39
	Magnesium sulphate	☐ ☐	40
	Super phosphate	☐ ☐	41
	Potassium sulphate	☐ ☐	42
	Other	☐ ☐	43
1,7 Zinc			
	Zinc oxide	☐ ☐	44
	Zinc chelate	☐ ☐	45
	Zink sulphate	☐ ☐	46
	Other	☐ ☐	47
1,8 Boron			
	Borax	☐ ☐	48
	Boric Acid	☐ ☐	49
	Sodium pent borate	☐ ☐	50
	Sodium teraborate;	☐ ☐	51
	Fertiliser borate 48	☐ ☐	52
	Fertiliser borate 65	☐ ☐	53
	Solubor	☐ ☐	54
	Other	☐ ☐	55
1,9 Manganese			
	Manganese carbonate	☐ ☐	56

Manganese chelate 57
Manganese chloride 58
Manganese dioxide 59
Manganese oxide 60
Manganese sulphate 61
Other 62
______________________________ 63

1,10 Copper

Copper Chelate 64
Copper sulphate 65
Cupric oxide 66
Cuprous oxide 67
Other 68
______________________________ 69

1,11 Ferrous

Ferrous oxide 70
Chelates 71
Ferrous ammonium sulphate 72
Ferrous Sulphate 73
Other 74
______________________________ 75

1,12 Is the brand of the fertiliser important to you? Yes 76
No 77

Comments: ______________________________ 78

1,13 Do you buy the cheapest source of fertiliser from your regular salesman? Yes No 79

Comments: ______________________________ 80

1,14 Do you buy the cheapest fertiliser available on the moment irrespective of the salesman. Yes No 81

Comments: ______________________________ 82

1,15 Do you take the soil analysis in consideration to establish the amount of fertiliser to be applied? Yes No 83

Comments: ______________________________ 84

1,65 Do you use the plant requirements and only put back what the plant takes out? Yes No 85

Comments: ______________________________ 86

1,17 What is your long term yield on maize for an early plant? t/ha 8 87

10 ☐
12 ☐
14 ☐
16 ☐
18 ☐

1,18 What is your long term yield on maize for an late plant? t/ha

8 ☐ ☐ 88
10 ☐
12 ☐
14 ☐
16 ☐
18 ☐

1,19 For what yield are you fertilising on maize on early plant? t/ha

8 ☐ ☐ 89
10 ☐
12 ☐
14 ☐
16 ☐

1,20 For what yield are you fertilising on maize on early plant? t/ha

8 ☐ ☐ 90
10 ☐
12 ☐
14 ☐
16 ☐

- **Specific objective 2: The information the farmer takes into account when deciding on the method that will be used for applying the fertiliser, and to decide on the most optimal physiological growth state for the plant so that the fertiliser can be applied for optimal use.**

2,1 When do you apply the fertiliser to the soil?

All during the planting process	☐	☐	91
Plant and top-dressing	☐	☐	92
Just top-dressing	☐		
Plant and top-dressing according to the plant requirements	☐		

2,2 Do you have any scientific manner of determining when to give fertiliser to the plant?

Yes ☐ ☐ 93
No ☐

2,3 If you use a scientific manner to determine when to give fertiliser to the plant, please describe it?

94
95

2,4 Which of the following methods are you using to apply fertiliser to the soil.

Broadcast	96
Banding	97
Injection	98
Fertigation	
Foliar application	
Side-dressing	
Top-dressing	

• **Specific objective 4: The information that the farmer uses to accept the fertiliser salesman's recommendation.**

4,1 Are the qualifications and training of you fertilizer salesman important to you? Yes No 99

Comments: 100

4,2 Is it important that your salesmen is respected by of the community? Yes No 101

4,3 Does the vehicle and the clothing of the salesman have an influence on your trust? Yes No 102

4,4 Will you buy fertiliser from a salesman as a result of the car that he drives, or the clothes that he wear? Yes No 103

4,5 How do you decide on a fertiliser salesman?

What the other farmers say about the salesman (word to mouth)	104
Previous experience with the salesman	
The company that he work for	
Qualification and training	
The fact that he is part of the community	

- **Specific objective 5: The method the farmer uses for take a soil analysis, and how the results is interpreted.**

5,1 Where is the laboratory located that the farmer is using?

South Africa ☐ ☐ 105
International ☐

5,2 Does the fertiliser salesman choose the laboratory, or do you choose it?

Farmer ☐ ☐ 106
Fertiliser salesman ☐
Both ☐

5,3 Are you aware of the methods that the laboratory is using for the phosphate analysis?

Yes ☐ ☐ 107
No ☐

5,3,2 If yes; name the method that the laboratory (you are using) is using for a soil analysis?

Bray 1 ☐ ☐ 108
Bray 2 ☐
Ambic 1 ☐
Ambic 2 ☐
Olsen ☐
Citric Acid ☐
Melich 1 ☐
Melich 3 ☐

- **Specific objective 6: What can the farmer do to obtain higher yields and to produce optimally and economically in the long run?**

6,1 In terms of fertiliser, what is your input cost on maize for an early plant?

______________________________ ☐ 109

6,2 In terms of fertiliser, what is your input cost on maize for an late plant?

______________________________ ☐ 110

6,3 When your fertiliser is transported to the farm, do you make the arrangements, or does the fertiliser company do it for you?

Farmer ☐ ☐ 111
Company ☐

6,4 When do you purchase your fertiliser for the season?

When needed ☐ ☐ 112
Before the season ☐ ☐ 113
Low world prices ☐

Tax fertiliser

6,5 Do you make use of production financing?

Yes No 114

6,5,2 If no, do you make use of fertiliser company's credit facility

Yes No 115

6,5,3 If no, do you buy the fertiliser cash

Yes No 116

6,6 Type of packaging when purchased?

Mass 117
Bulk bags 118
Bags (50kg)
liquid
Gas

Specific objective 7: In what way does the farmer implement the recommendations from the soil analysis report to improve his yield and soil in the long run?

7,1 Can you make a fertiliser recommendation on your own, or do you need the help of an extension officer?

I can 119
Need help

7,2 How do you rectify shortages in the soil?

At once	120
Over a period of time	121
Alternative source of fertiliser	
Other	

Comments: ____________________ 122

Specific objective 8: The method used by fertiliser companies to market and sell their fertiliser to the farmer:

8,1 Name the fertiliser company you are buying from.

Sasol 123
kynoch 124
Foskor
Omnia
Gavilon
Triomf
Sidi Parani
Constantia
Other

8,2 What other fertiliser companies are role players in your area?

Sasol	☐	☐	125
kynoch	☐	☐	126
Foskor	☐		
Omnia	☐		
Gavilon	☐		
Triomf	☐		
Sidi Parani	☐		
Constantia	☐		
Other	☐		

8,3 Are you up to date with fertiliser market prices?

Yes	☐	☐	127
No	☐		

8,4 How do you keep up to date with fertiliser market prices?

Your fertiliser agent	☐	☐	128
Internet	☐	☐	129
Market reviews	☐	☐	130
Agriculture magazines	☐	☐	131
Other	☐		

Comments: ____ ☐ ☐ 132

____

8,5 Do you have knowledge of the importing market of fertiliser?

Yes	☐	☐	133
No	☐		

8,5,2 If yes, from what company do you buy from?

Sasol	☐	☐	134
Kynoch	☐	☐	135
Foskor	☐	☐	136
Omnia	☐	☐	137
Gavilon	☐	☐	138
Triomf	☐		
Sidi Parana	☐		
Constantia	☐		
Other	☐		

8,6 Do you get agronomical service/advice from your fertiliser company?

Yes ☐ ☐ 139
No ☐

8,7 Does the agronomist play any role in the source you are using?

Yes ☐ ☐ 140
No ☐

Comments: ______________________________ ☐ ☐ 141

____

8,8 Are you aware that some of the fertiliser companies only mix the fertiliser and buy the product for the same price as farmers can from companies manufacturing the fertiliser?

Yes ☐ ☐ 142
No ☐

Comments: ______________________________ ☐ ☐ 143

____

8,9 Do you experience difference in quality between local manufactured and imported fertiliser?

Yes ☐ ☐ 144
No ☐

Comments: ______________________________ ☐ ☐ 145

____

8,9,2 If yes, which one has the highest quality?

Local
International

Comments: ______________________________ ☐ ☐ 146

____

8,10 Will you pay for a services provided by a independent agronomical advisor on the farm?

Yes ☐ ☐ 147
No ☐

Comments: ______________________________ ☐ ☐ 148

____

Annexure 2:

Questionnaire to the fertilizer agent

Factors influencing farmers' fertiliser practices on irrigation schemes in the central part of South Africa.

Questionnaire to the fertiliser agent

In practical fulfilment of the requirement of M. Tech agriculture thesis.

FJJ Nell (213035162)
Supervisor: Prof Carlu van der Westhuizen

The overall objective of this study is to determine the fertilisation practices as applied by farmers in the irrigation areas of the Jacobsdal, Prieska, Vaalharts and Douglas regions the in central part of South Africa.

Non of the information gained will be linked to a person or company/institution during the discussion of the results in the study

Questionnaire number ☐ 1

1,1 Gender

Male	☐	☐	2
Female	☐		

1,2 Number of years working as an fertiliser agent

____

1,3 For which company are you an agent?

Sasol	☐	☐	3
Kynoch	☐	☐	4
Foskor	☐		
Omnia	☐		
Gavilon	☐		
Triomf	☐		
Sidi Parani	☐		
Constantia	☐		
Other	☐		

1,4 Tons sold per year?

______________________________ ☐ 5

1,5 Area were you are working in?

Douglas	☐	☐	6
Vaalharts	☐	☐	7
Prieska	☐		
Oranje-Riet	☐		

1,6 Please make a recommendation for fertiliser to be used based on the following soil analysis: (Macro and micro elements)

______________________________ ☐ 8

______________________________ ☐ 9

____

____

1,7 Do you use straits or mix recommendations?

Straits	☐	☐	10
Mix	☐	☐	11
Both	☐		

1,8 If you use a mixed fertiliser, is it mixed chemical or mass mix?

Chemical	☐	☐	12
Mass	☐		

1,8,2 Please motivate your answer.

13

1,9 The farmer mentions that he has to save on input costs and on fertiliser. By using the same soil analysis provided above, make a recommendation to the farmer, and motivate why.

14
15

1,10 The farmer mentions that he has surplus money available. By using the same soil analysis provided above, make a recommendation to the farmer, and motivate why.

16
17

1,11 What laboratory do you use to do the soil analysis, and what are the reason(s) for using this laboratory?

18
19

1,12 Please prioritize how do you divide your time between the farmers?

From 1-6

Basis of business done		20
Potential business to be done		21
To monitor the farmer yield and give advice		22
For a social visit		23
To keep the farmer up to date with market trends and prices		
Other		

1,13 Way the micro fertiliser are sold to the farmers

Straits 24

Mixes 25

1,14 On what basis do you recommend micro elements?

Requirements of the plant 26
Shortages of the area 27
Soil analysis

1,15 What different soil analysing methods for phosphate are you aware of? Please name them.

28
29

1,16 Please name the difference between a Brie 1 and Melig 3.

30
31
32

Annexure 3:

Questionnaire to the fertilizer company

Factors influencing farmers' fertiliser practices on irrigation schemes in the central part of South Africa.

Questionnaire to the fertilise company

In practical fulfilment of the requirement of M. Tech agriculture thesis.

FJJ Nell (213035162)

Supervisor: Prof Carlu van der Westhuizen

The overall objective of this study is to determine the fertilisation practices as applied by farmers in the irrigation areas of the Jacobsdal, Prieska, Vaalharts and Douglas regions the in central part of South Africa.

Non of the information gained will be linked to a person or company/institution during the discussion of the results in the study

1,1 Questionnaire number ______________________ ☐ 1

1,2 Total tons of fertiliser sold per year

______________________ ☐ 2 ☐ 3 ☐ 4

1,3 Where does the company buy the following raw material from:

KCL	______________________	☐	4
MAP	______________________	☐	5
Urea	______________________	☐	6
LAN	______________________	☐	7

1,4 Does the company offer an agronomical service?

Yes ☐ No ☐ ☐ 8

1,4,2 If yes, is the officer employed by the company, or not?

Yes ☐ No ☐ ☐ 9

1,5 Does the company manufacture nitrogen fertiliser?

Yes ☐ No ☐ ☐ 10

1,5,2 If yes, Nitrate or Urea?

Nitrate ☐ ☐ 11
Urea ☐ ☐ 12

1,6 Does the company mix the fertiliser or sell only straits?

Mix ☐ ☐ 13
Straits ☐ ☐ 14
both ☐ ☐ 15

1,7 What are your main strategy for marketing of the fertiliser?

____
____
____
____
____

☐ 16 ☐ 17

1,8 What are the advantages and disadvantages for the company of direct marketing to the farmer by other companies?

____
____

☐ 18 ☐ 19

Annexure 4:

Lab fertilizer analyses results

	P- Bray 1	p-Bray 2	P- Mehlich 3	K	Na	Ca	Mg	%Ca	%Mg	%K	%Na	Fe	Mn	Cu	Zn	S	B	Al
	mg/kg		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Lab 1																		
Batch 1	45.00	75.00	66.00	406.00	57.00	1160.00	464.00	53.30	34.90	9.50	2.30	79.40	117.70	2.63	13.18	32.00	1.09	
	43.00	71.67	64.00	392.00	61.00	1115.00	460.00	52.50	35.50	9.40	2.50	76.30	174.20	2.60	13.12	7.20	1.08	
	47.00	78.33	66.00	404.00	57.00	1110.00	464.00	52.20	35.80	9.70	2.30	78.90	176.70	2.56	12.40	7.10	1.06	
	44.00	73.33	63.00	414.00	55.00	1099.00	454.00	52.30	35.40	10.10	2.30	75.60	168.90	2.65	14.43	7.10	1.07	
Batch 2	47.00	78.33	69.00	507.00	34.00	1179.00	500.00	51.60	35.80	11.30	1.30	78.40	170.40	2.57	13.53	6.20	0.59	
	41.00	68.33	61.00	447.00	44.00	1159.00	496.00	51.80	36.30	10.20	1.70	72.70	167.00	2.38	13.20	6.30	0.59	
	47.00	78.33	70.00	516.00	48.00	1250.00	530.00	51.60	35.80	10.90	1.70	79.30	181.90	2.72	14.99	6.60	0.59	
Batch 3	48.00	80.00	77.00	511.00	49.00	1256.00	573.00	50.30	37.60	10.40	1.70	86.60	167.50	2.73	14.35	7.90	0.47	
	45.00	75.00	68.00	451.00	45.00	1147.00	511.00	50.90	37.20	10.20	1.70	77.50	151.60	2.35	12.95	7.90	0.43	
	50.00	83.33	79.00	499.00	48.00	1211.00	544.00	50.50	37.20	10.60	1.70	83.90	166.30	2.67	37.07	8.70	0.48	
Lab 2																		
Batch 1	56.40	94.00	80.57	455.10	46.80	1189.00	539.60	51.00	38.00	10.00	2.00					4.43		
	46.80	78.00	66.86	404.10	42.70	1143.00	517.40	51.00	38.00	9.00	2.00					4.02		
	50.70	84.50	72.43	467.80	38.10	1163.00	545.90	50.00	38.00	10.00	1.00					5.72		
	48.80	81.33	69.71	462.70	35.40	1097.00	511.40	50.00	38.00	11.00	1.00					5.24		
Batch 2	58.20	97.00	83.14	493.60	30.40	1195.00	549.80	50.00	38.00	11.00	1.00					6.28		
	58.60	97.67	83.71	466.00	48.40	1320.00	614.10	51.00	39.00	9.00	2.00					4.52		
	51.40	85.67	73.43	464.20	42.40	1243.00	572.30	51.00	38.00	10.00	2.00					5.91		
Batch 3	85.40	142.33	122.00	523.60	35.30	1242.00	585.10	50.00	38.00	11.00	1.00					9.37		
	55.10	91.83	78.71	415.80	46.00	1127.00	524.90	50.00	38.00	9.00	2.00					9.91		
	59.10	98.50	84.43	301.70	2.80	180.00	47.70	43.00	19.00	37.00	1.00					12.96		
Lab 3																		
Batch 1	19.60	32.67	28.00	510.00				50.64	36.71	10.85	1.80	99.00	236.50	4.20	23.20		0.84	
	88.20	147.00	126.00	460.00				50.65	37.85	10.30	1.20	130.00	232.10	3.90	15.30		1.19	
	79.80	133.00	114.00	479.00				50.29	37.95	10.40	1.36	106.00	241.10	4.10	16.90		1.22	
Batch 2	57.40	95.67	82.00	577.00				43.79	42.95	11.95	1.32	84.00	189.20	4.30	12.80		1.20	
	49.70	82.83	71.00	536.00				43.67	42.99	11.84	1.50	83.00	162.30	3.70	11.80		1.29	
	53.20	88.67	76.00	502.00				43.88	43.50	10.96	1.66	83.00	184.80	4.00	12.50		1.31	
Batch 3	94.50	157.50	135.00	497.00				49.49	38.27	10.48	1.76	51.00	157.70	3.20	18.80		0.96	
	85.40	142.33	122.00	478.00				49.21	39.13	9.89	1.78	53.00	161.00	3.40	12.40		0.97	
	81.20	135.33	116.00	494.00				48.72	39.18	10.50	1.60	56.00	172.10	3.50	12.70		0.78	
	88.90	148.17	127.00	473.00				49.25	39.39	9.76	1.60	62.00	166.30	3.40	26.40		0.80	
Lab 4																		
Batch 1	54.38	90.63	75.78	589.04	52.11	1454.94	764.38	47.63	41.02	9.86	1.48	156.86	257.39	3.99	20.87	8.37	1.11	422.88
	60.00	100.01	77.68	673.98	50.39	1551.09	809.07	47.49	40.61	10.56	1.34	179.10	285.23	4.33	21.85	10.63	1.15	475.92
	60.30	100.50	78.38	667.38	54.42	1589.73	829.69	47.62	40.74	10.23	1.42	179.07	291.84	4.38	23.19	10.97	1.19	482.97
Batch 2	50.87	84.78	114.77	528.62	73.70	1470.71	712.68	49.46	39.29	9.09	2.16	106.47	223.00	3.91	19.21	11.92	2.67	380.29

	51.13	85.21	116.74	595.63	51.16	1403.38	680.66	48.93	38.90	10.62	1.55	104.73	217.09	3.67	18.19	9.52	2.56	378.28
	41.05	68.41	105.94	449.11	54.92	1202.66	589.38	49.16	39.50	9.39	1.95	84.65	168.57	3.15	16.00	8.62	2.22	305.70
	35.19	58.66	134.57	481.28	59.26	1191.70	616.58	47.66	40.43	9.85	2.06	55.03	96.54	2.63	13.48	6.99	1.06	239.08
Batch 3	33.89	56.48	133.70	486.07	55.15	1176.20	603.95	47.76	40.20	10.10	1.95	55.30	99.59	2.59	13.62	6.94	1.16	236.59
	37.32	62.20	131.24	501.73	90.48	1512.63	772.17	48.58	40.65	8.24	2.53	63.74	126.00	3.21	15.96	8.86	1.54	287.16
	41.87	69.78	126.46	630.88	59.49	1475.80	773.79	47.32	40.67	10.35	1.66	61.91	126.69	3.29	16.81	7.26	1.99	286.43