Optimal selection of fertilisers by horticultural consultants

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Abstract

Horticultural consultants recommending fertilisers must consider a large amount of information to determine an optimal fertiliser mix. Difficulty arises when matching the estimated levels of nutrient requirements with those available in fertiliser products, as it is unlikely a single, or combination, of fertilisers will match exactly the required nutrients. It is assumed that consultants are proficient at making fertiliser recommendations, but desire to improve the process of making, and accuracy of, the recommendations. The objectives of this study were to describe the process consultants go through when providing a fertiliser recommendation and then use this information to design a decision support system (DSS) as an aid to the fertiliser selection process.

Data was collected from three consultants to develop a conceptual model of how the fertiliser recommendation service consultants provide operates. With this information a DSS model consisting of client and fertiliser databases, an optimisation component and an user interface was developed. The optimisation component uses a compromise programming approach. The objective function minimises the deviations from the targets of a cost goal and nutrient requirement goals.

The DSS was run using samples provided by the consultants and the results were compared with what they had recommended. Even though the results from the DSS model did not match exactly what the consultant had recommended, most of the DSS solutions were cheaper and weighed less. The information generated provides a good starting point from which to make a fertiliser mix recommendation by combining other factors such as pH and solubility of each fertiliser, and other rules of thumb that consultants use.

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Contents

List of figures

List of tables

Chapter 1

Introduction

1.1. Nutrient use in horticulture

Many New Zealand soils have a low nutrient status in their natural state and are often deficient in one or more essential plant nutrients (McLaren & Cameron, 1986). Thus site selection of horticultural enterprises should be primarily based on soil versatility rather than on fertility as it is easier to enhance a soils nutrient status than to alter its physical characteristics required to improve versatility. After developing land for horticultural use fertiliser application can change the soils nutrient status considerably over time and if performed correctly can increase the soils suitability for growing plants. Fertilisers are, therefore, an important aspect of land management as they are involved in both improving and maintaining soil fertility.

The nutrients that plants require can become unavailable in ways such as the incorporation into plant products, leaching, adsorption by the soil, and volatilisation. Generally nutrients are lost from the soil environment because they have been transported to another area, for example, the harvesting of fruit or pruning removes the nutrients accumulated in these products. Free draining soils are prone to nutrient lose from leaching and of the macronutrients, phosphates leach the slowest and nitrates the fastest (Clark et al., 1986). Fertiliser nutrients are also rendered temporarily unavailable to plants if they are strongly adsorbed by soil particles or incorporated into the organic matter of the soils (Clark et al., 1986). The gaseous loss of nitrogen - volatilisation - can occur whenever there is free ammonia present in the soil surface, for example, following the application of urea or ammonium fertiliser (McLaren & Cameron, 1986). Each of these processes vary between soil types and differ according to climatic conditions. It is, therefore, important to have an understanding about the relationships between the soil and the processes that take place within it. This understanding of the soil system will aid with the estimation of replacement nutrient levels.

1.2. Estimating nutrient requirements

The number of nutrients included in tests when determining the nutrient requirements for a specific crop is generally greater for a horticultural enterprise than for a farm. The frequency of nutrient testing is also usually greater for horticulture than other forms of agriculture. For example, a market garden may test nutrient levels before planting each crop, an orchard may test once or twice a year, while a farm may only test nutrient levels every two to five years. In horticultural enterprises the number of tests conducted on a per unit area is also higher. This more intensive testing increases cost, although this is somewhat offset by the higher value of the crop, on a per unit area basis.

The availability of nutrients for plant uptake can influence both crop quality and quantity. The quality of the crop (e.g., whether there are blemishes on a piece of fruit) is an important factor in determining its value. Therefore, when determining nutrient recommendations the effect the nutrient may have in crop quality needs bearing in mind. Since different crops have different nutrient requirements different optimal levels will exist for each crop and due to changes in the environment the optimal level will also vary from year to year. For optimal growth nutrients availability needs maintaining within a preferred range. If nutrient levels fall outside of this range then crop yield will tend to decrease when nutrient levels are too low then, while if levels are too high then the plant may be damaged and also decrease yield.

There are several methods of assessing the nutrient availability and nutrient requirements of soil; these include, pot and field trials, soil analysis, plant analysis, and fertiliser models.

Pot trials and field trials involve applying a range of fertiliser rates to individual pots or field trials and measuring the change in yield at each rate. Currently there is a lack of detailed information from fertiliser trials regarding the quantity of the fertiliser needed to maintain production for the range of crops, soil types and climates within New Zealand (Clark et al., 1986). Although pot and field trials are time consuming and expensive, they are essential for the development and calibration of soil tests and plant analysis (McLaren & Cameron, 1986).

Soil tests involve the collection of soil samples for analysis to determine their nutrient content. Along with nutrient levels soil test results also provide information such as the soils cation exchange capacity, base saturation and bulk density. These measurements reflect the soil's texture and capacity for nutrient absorption (Yates, 1989). Soil tests need calibrating because the readily available nutrients that soil tests quantify represent only a small fraction of nutrients within the soil environment (McLaren and Cameron, 1986). Currently there lacks a suitable chemical extractant to enable the calculation of the bulk store of nutrients. Clark et al. (1986) state that there is little definitive information available on the optimum soil test values for most horticultural crops grown in New Zealand. Clark et al., therefore, suggest that in the absence of well defined target values for each nutrient, the presence of healthy high yielding plants should be a guide as to whether or not soil conditions are optimal for growth. They also suggest that annual soil tests provide a qualitative guide and should be carried out with the aim of monitoring and correcting trends in nutrient values rather than being in pursuit of attaining particular soil test values.

The effect of plant nutrition on plant yield forms the basis of plant analysis. Reducing a nutrient deficiency increases yield until the critical nutrient level is reached. At the critical nutrient level yield no longer increases, even though the amount of nutrient in the plant still increases (McLaren & Cameron, 1986). The advantage of plant analysis is that results reflect the nutrient availability of the plants full rooting depth, whereas the depths of soil tests are restricted (McLaren & Cameron, 1986).

Models are often used to combine data from a range of sources in an effort to estimate the nutrient requirements for a soil. These models are based on the inputs (e.g., fertiliser) and outputs (e.g., leaching and harvested crop) of nutrients. These models usually assume that the sizes of the nutrient cycling pools remain constant and therefore, fertilisers are only required to replace the nutrients that are permanently lost from the cycle (McLaren & Cameron, 1986). Example of a nutrient models used in New Zealand include the Kiwifruit Nutrition Management Service (KNMS) (Buwalda & Smith, 1988) provided by several Agriculture New Zealand consultants in conjunction with Hort Research and Outlook developed by the Soil Fertility Service of AgResearch (Barton, 1995).

Although the KNMS model is still in use today by some consultants much of its validity has been discredited. A review of the model was commissioned by the New Zealand Kiwifruit Marketing Board in 1991 with the aim of examining the validity of the KNMS model (Bollard, 1991). The model was criticised for high levels of nutrients, namely nitrogen, which it suggested. Smith, Buwalda, Clark and Walton (1990) stated that the fruit production of mature vines is directly related to the size of the canopy, and therefore, the greater the size of the vine due to nitrogen inputs, the greater the fruit yield. However, as Sher and Yates (1992) point out, this ignores the undesirable interactions of vine growth driven by nitrogen upon inter-canopy shading, subsequent unfruitfulness, fruit size and quality.

The results that describe the nutrient requirements from the assessment methods described still only provide an estimate rather than an explicit list of the quantities of each nutrient required. In the past pot and field trials have been used as the basis of calculating optimum economic nutrient inputs (During, 1984). In calculating the optimum economic nutrient inputs nutrient requirements should aim to maximise the return to the grower rather than trying to attain maximum yield. Therefore, the optimal nutrient requirements will change with crop and fertiliser prices. Determining the effect that changing nutrient rates will have on crop returns requires knowledge of the relationships between plant nutrition and crop yield. This is especially important in horticulture where the quality and appropriate quantity of a crop is affected by crop nutrition (McLaren & Cameron 1986). However, data covering the range of crops and soil types in New Zealand does not exist.

1.3. The attributes affecting fertiliser selection

Following the estimation of the required nutrients, the fertilisers that can provide these nutrients need to be determined. In most situations the choice of fertiliser will depend, not on the need for a single nutrient, but on the need for two or more nutrients. When selecting a fertiliser, or group of fertilisers to meet the nutrient requirements, the literature suggests the following attributes must be considered: nutrient availability, effectiveness, rate of application, and cost, these points are now discussed.

The nutrient availability of a fertiliser refers to the proportion of nutrients within the fertilisers that are available to plants and the rate at which they become available (Clark et al., 1986). The proportions of nutrients within each fertiliser - the essential elements for plant life - are outlined by the manufacturer of the fertiliser, these are usually described as a percentage for macronutrients and by weight for micronutrients.

A soil will be able to support continued plant growth only if the nutrients removed from the soil solution by the plant are rapidly replaced (McLaren & Cameron 1986) from the bulk store of nutrients previously adsorbed by the soil. If a nutrient is held very strongly in the soil it may not replenish in the soil solution quickly enough (Archer, 1988) or alternatively the total amount of the nutrient in the soil may be inadequate. If the nutrients within the fertiliser are water soluble then they are immediately available to plants. However, they are also immediately available to react with and become adsorbed by soil particles or be leached out of the rootzone (Clark et al. 1986). For example, under high levels of rainfall or irrigation sulphate and nitrate may suffer substantial leaching losses (McLaren & Cameron 1986), whereas some insoluble nutrients such as nitrogen in organic fertiliser needs releasing through microbial action before it becomes available to plants. The choice of fertiliser may, therefore, depend on the time frame within which the nutrients are required by the plant.

A choice between different fertilisers will often depend on their relative abilities to increase or maintain yields, (i.e. the agronomic effectiveness of the fertiliser). Agronomic effectiveness is usually determined in field experiments by measuring fertiliser response in relation to a standard fertiliser material of known high effectiveness. McLaren and Cameron (1986) state that the agronomic effectiveness of a fertiliser will be determined by its properties (e.g., its solubility and forms of nutrient), and by the soil and climatic conditions in which it is used. A fertiliser that may perform well in one set of conditions may be relatively ineffective in another. Reactive phosphate rock, for example, which may be as good as superphosphate in acid soils, gives very poor responses on well-limed soils.

Comparing the cost of fertiliser is based on the cost per kilogram of nutrient within the fertiliser, rather than on the cost per tonne or kilogram of fertiliser. In addition to the basic cost of the fertiliser the costs of transport and spreading needs considering. The higher the concentration of the nutrient in the fertiliser, the less the weight of the fertiliser required to give the desired application rate, which, therefore, lowers the cost of transport and spreading (McLaren & Cameron, 1986). The application rate, the quantity of fertiliser to apply on an area basis, is derived from the estimate of the nutrient requirement and the percentage of plant available nutrient in the fertiliser.

1.4. Problem Statement

Although fertiliser expenditure is only a small expense within the budget (e.g., approximately 3% for a kiwifruit orchard (Oliver & Burtt, 1995)), fertiliser use can have far reaching effects on yield quantity and quality and, therefore, returns to the grower. The effective use of fertiliser will improve the soil's suitability for growing crops. However, ineffective fertiliser use leads to an inappropriate application of nutrients, which can both damage the environment and reduce returns to the grower. A lack of the required nutrients can lead to a reduction in crop quantity. The use of fertilisers containing nutrients that are not required can cause an excessive build-up of a nutrient, which may damage the plant and is likely to leach from the soil into the waterways. Incorrect timing of the fertiliser application and uneven spreading can be detrimental to the crop and the environment. The budget for the enterprise will reflect the cost associated with incorrect fertiliser usage through reduced crop returns, higher than required fertiliser costs, or payments for fixing damage to the environment.

Fertiliser recommendations typically begin with the testing of soil and, or leaf samples. The samples are analysed and the results provide an estimate of the nutrient status of the sample. The grower's consultant then makes an estimate of the nutrient requirements and the fertilisers to use to replenish the nutrient loss.

The literature suggests that when selecting fertilisers to meet a set of nutrient requirements the attributes that describe the fertiliser need considering. The proportions of each nutrient in the fertilisers and their availability to plants provide a basis for calculating the application rate and comparative costs of each nutrient in the fertilisers. Solubility of the fertilisers gives an indication of how soon after application the plants will be able to utilise the nutrients. If there are any constraints such as handling and spreading requirements of particular fertilisers a grower must ensure that they have the means to overcome the constraints if they wish to use the particular fertilisers.

There is a monetary cost associated with inappropriate fertiliser selection. A fertiliser used within the wrong soil or climatic conditions may be ineffective, for example, in dry conditions sulphate is likely to be more effective than elemental sulphur, while in wet conditions the reverse may be true (McLaren & Cameron, 1986). Where fertilisers are very soluble an excessive application could lead to leaching, damage to the environment and the need to apply further fertiliser to still meet the nutrient requirements. If the nutrient availability is too slow to meet the nutrient requirements then the plant yield or quality may be reduced, leading to a lower return to the grower.

Consultants recommending fertilisers must consider a large amount of information to make an optimal selection. However, difficulty arises when matching the required nutrient levels with those available in fertiliser products, as it unlikely that a single product or a combination of fertilisers will exactly match the ratios of nutrients required. It seems that fertiliser consultants currently make decisions regarding fertiliser using an estimate of the required nutrients in conjunction with their personal knowledge such as previous fertiliser application, crop performance, and fertiliser attributes. This is unlikely to result in the optimal fertiliser selection either in terms of nutrient needs or cost.

1.5. Objectives

The first objective of this study is to describe the process consultants go through when providing a fertiliser recommendation. The second objective involves using the data gathered from the first objective and incorporating this into the design of a decision support system that has the ability to aid the consultant in the fertiliser selection process. The objectives are as follows:

To model the process a consultant uses to make fertiliser recommendations.

To design a decision support system that a consultant could use as an aid in the fertiliser selection process by providing an optimal combination of fertilisers.

The people involved in making many of the recommendations as to which nutrients and fertilisers to apply are consultants acting on behalf of growers. It is assumed that consultants are proficient at making fertiliser recommendations, but that they desire to improve the process for making, and the accuracy of, recommendations. Consultants in the horticultural sector are the focus of this study, and they are likely to be the primary benefactors of this research.

An understanding of the current methods consultants use to make their fertiliser selection recommendations is essential for finding ways to improve the process.

Although the literature studied in this chapter suggests how to select fertiliser this may not reflect how consultants actually perform this task. Qualitative research methods are employed for gathering and analysing the data that describes the fertiliser selection process from the consultants. This technique is used in this study because the data is informal, unstructured and subjective.

The decision support system designed in this study aims to improve the selection of fertilisers by matching nutrient requirements with a combination of fertilisers. Describing the consultant's fertiliser selection process provides a starting point for creating the decision support system. Interviews with the consultants will also allow them to identify areas that they consider need improvement, then these concepts can be implemented within the decision support system.

1.6. Organisation of the chapters

An introduction to fertiliser use in horticulture, estimating nutrient requirements, and the attributes affecting fertiliser have been discussed in this chapter. The role of consultants and how this study aims to improve the current fertiliser selection process was described and the objectives of the study were presented.

In Chapter Two the fertiliser selection process of three consultants is studied. The benefits of studying the process are described. Qualitative research methods are used for studying the consultants. The literature about qualitative data collection and analysis is discussed and the method for this study described. The results are discussed and the fertiliser selection process is presented.

Chapter Three consists of a description of a decision support system that represents the part of the consultant's fertiliser selection process that will be developed as a computer program. The part of the process that the conceptual model focuses on is that of converting nutrient requirements into fertiliser mix combinations. Each of the model components of the are described.

In Chapter Four optimisation techniques (such as linear programming, goal programming and compromise programming) are discussed with regard to optimisation theory and examples of it's application from the mathematical programming and multiple criteria decision making literature. The equations and the optimisation method this study uses are then presented and discussed.

The need for a database in the computer model is explored in Chapter Five. The structure of the database for the model is presented as an entity-relationship model and then its components are discussed.

The purpose of Chapter Six is to describe the implementation and evaluation of the prototype decision support system. The results from an evaluation of the optimisation routine are presented and then discussed.

Conclusions and recommendations are presented in Chapter Seven.

1.7. References

Archer, A. (1988). Crop nutrition and fertiliser use (2nd ed.). Suffolk: Farming

Barton, D. (1995). New fertiliser software a first. Evening Standard, February 21, pp 14.

Bollard, E. G. (1991). A review of some aspects of the nutrition of kiwifruit. NZKMB special report.

Buwalda, J. G. & Smith, G. S. (1988). A mathematical model for predicting annual fertiliser requirements for kiwifruit vines. Scintica Horticulturae, 37(1/2), 71-86.

Clark, C. J., Smith, G. S., Prasad, M., & Cornforth, I. S. (Eds.). (1986). Fertiliser recommendations for horticultural crops. Wellington: New Zealand Ministry of Agriculture and Fisheries.

During, C. (1984). Fertilisers and soils in New Zealand farming. Wellington: Government Printer.

McLaren, R. G. & Cameron, K. C. (1986). Soil science: an introduction to the properties and management of New Zealand soils. Auckland: Oxford.

Oliver, J. R. & Burtt, E. S. (Eds.) (1995). Financial budget manual 1995. Canterbury: Lincoln University.

Yates, P. (1989). Kiwifruit: Computers and controversy. Horticulture News, September, pp 12-14.

Chapter 2

A study of the fertiliser recommendation service consultants provide

2.1. Introduction

The service of interpreting the need for nutrients of a growers' property and preparing a fertiliser mix recommendation by horticultural consultants is studied in this chapter. There may be room for improvement in the service consultants provide, finding out how this could be achieved can be learnt through an understanding of the process they currently use when providing a fertiliser recommendation. The outcome of this chapter will describe the current process several consultants use and highlight how parts of this process could be improved.

The preparation of a fertiliser mix recommendation is a decision making problem. Studying the decision making process requires a description of how a consultant gathers and interprets available information to aid the selection of appropriate fertilisers. The task of describing this complex and interwoven process is best achieved by using a qualitative research approach. In this chapter data collection and analysis using qualitative research methods are described. The data collection and analysis methods used to study consultants are presented and then followed by the results of studying the process of recommending fertilisers.

2.2. Qualitative research

The researcher using qualitative research methods studies people in their natural setting, and attempts to make sense of, and interpret, phenomena in terms of the meanings people bring to them (Denzin & Lincoln, 1994). Qualitative research involves studying a variety of collected empirical materials that describe both the problematic and routine moments in the lives of individuals (Denzin & Lincoln, 1994). The product of the research is a complex, dense, reflective collage-like creation that represents the researchers images, understandings and interpretations of the phenomenon under analysis (Denzin & Lincoln, 1994).

There are basically three major components to qualitative research (Strauss & Corbin, 1990). Data is the first component and may come from a range of sources such as interviews, observation and the use of documentation. The second component of qualitative research is analysis, the interpretative techniques used (i.e., how the researcher conceptualises the data, using techniques such as memos and diagramming of conceptual relationships). Determining the most appropriate means of presenting the results is the third component of qualitative research.

A vast amount of data can be gathered with qualitative research; this means the researcher must clearly define what they intend to study. A framework for the collection of qualitative data is discussed in the next section. Then, in section 0 Qualitative data analysis, the methods described by Dey (1995) and Strauss and Corbin (1990) for analysing qualitative data are described.

2.2.1. Qualitative data collection

Within a process are a collection of integrated parts that can be identified by a boundary, that is, a description of what is part of the process and what is not and is thus a bounded system (Smith, 1978). The parts of this bounded system may not function well or rationally, but still, it is a system with patterned behaviour and consistency (Stake, 1994). The reason for studying the process is, therefore, to find out what goes on within that complex bounded system (Burns, 1994).

Balance and variety are important in the selection of people to study, however, Stake (1994) suggests that the opportunity to learn is of primary importance. This is why Maxwell (1986) suggests non-random selection. Studying a particular person is expected to advance the researchers understanding of the process.

Useful techniques for gathering qualitative data are interviewing, document collection, and observation. Unstructured interviews and the use open-ended questions allow the respondent to take more the role of informant than respondent (Burns, 1994). This interview approach will generate a vast quantity of raw data that will be in no particular order except through connecting the thoughts of the respondent. Documentary information is often useful for corroborating and augmenting evidence from other sources (Yin, 1994). Documents take many forms, some of which are communiqués, mass media and journal articles, reports, and brochures. Observational evidence is useful for gaining further insight into the process being studied.

2.2.2. Qualitative data analysis

This section describes a general qualitative research analysis method advocated by Dey (1995) that is similar to that developed by Glaser and Strauss (1967) and refined in Strauss and Corbin (1990) for analysing grounded theory research. Although the method is similar to that used in grounded theory research, it differs in that the aim of the analysis is to provide only a description of the system being studied rather than to delve deeper and develop a theory about the system. The method involves integrating pieces of the data with other pieces of the data; this then leads to the development of categories that describe groupings of the data. The categories developed are then linked together based on how data in categories relates to data in other categories. These ideas and how this method is carried out through the processes of reading, annotating, grouping of data, and the development and linking of categories constitute the remainder of this section. What follows relates mainly to analysing interview transcript data, however, its essence can be used when analysing other forms of collected data.

Where data collection takes the form of interviews then these need transcribing to make the analysis of the data easier. Strauss and Corbin (1990) suggest that the very first interview should be entirely transcribed an analysed before going on to the next interviews. They state that this early analysis gives guidance to the next interviews. As the researcher gains an understanding of the topic being studied then the researcher can take a more selective approach to what should be transcribed. However, they suggest that if in doubt over what should be transcribed then it is better to transcribe than not, otherwise important points may be missed. Regardless of the amount of the tapped interviews that are transcribed it is important to listen to all of the tapes because a full and varied analysis requires listening as well as transcribing (Strauss & Corbin, 1990).

Reading is an active process with the aim of comprehending what is contained in the data (Dey, 1995). When reading the researcher needs to be constantly asking questions such as what, who, where, why and when about the data as these provide the starting points for further exploration of the data. Dey (1995) also suggests that reading should not necessarily be in a sequential order. The suggested advantage of this non-sequential reading order is that the researcher is in a better position to gain a feel for the language used and acquire a sense of which terms are rare and which are prevalent.

Annotating the data involves writing, what is commonly referred to in the literature as memos; these serve the purpose of recording the researchers ideas about the data as they occur (Dey, 1995; Strauss & Corbin, 1990). The process of annotating takes place in conjunction with reading and takes the form of writing comments. These comments are either on the data (such as a transcript) or on a separate piece of paper that has a note to link the comment with a particular piece of data. Annotating the data opens it up and provides triggers to the researcher during the more rigorous analysis of categorising and linking (Dey, 1995). However, this creative process of generating ideas is not confined to just the initial reading stage of analysis, rather it may be returned to later in the analysis to allow the researcher to come up with new and fresh ideas about the data (Dey, 1995).

Diagrams are another technique for helping the researcher develop their thoughts about the data. The researcher can use diagrams during the interpretation of the data to provide a visual representation of the relationships between concepts (Strauss & Corbin, 1990). A gradual improvement in the diagrams takes place during the analysis of the data and at the end of the analysis the diagrams can form a visual representation of the results.

To gain an understanding of the data requires interpretation of the data. This interpretation involves moving away from the complex detail seen in the raw data to an abstract view of the data where just the important points are noted (Dey, 1995). To develop an abstract view of the data requires grouping similar pieces of the data into categories (Strauss & Corbin, 1990). The ability of the researcher to categorise the data means being able to distinguish *bits*[1] *of data* that can be related for the purpose of

[1] A *bit of data* refers to an excerpt from the data such as a phrase, sentence or paragraph, its size is determined by the researcher and based on what they deem as an appropriate size to ensure it is interpreted in the correct context (Dey, 1995). It is also regarded as having a separate *unit of meaning* for the purpose of the analysis (Dey, 1995).

comparison. During the analysis the researcher is likely to sub-divide and regroups these categories to develop their thoughts and the results further.

The data contains a wealth of ideas and concepts and these should provide the basis for the development of the categories used to group the data. Thus the categories developed must be conceptually and empirically grounded in the data (Dey, 1995), that is, they must be relevant and come from within the data. Therefore, evidence from the data is required to justify the existence of each category and this evidence takes the form of collecting together bits of data. However, when collating these data bits care must be taken by the researcher to ensure that the bits of data are not used out of context (Dey, 1995). Another suggestion by Dey (1995) is that if data is being assigned to more than one category then further improvement in definition of categories may be necessary. A constant switching between deductive and inductive thinking is required to develop categories. There is a constant interplay between proposing and checking and this back and forth movement is what make the results grounded in the data (Strauss & Corbin, 1990).

Following categorisation, the data can now be viewed in a new way, in the context of the researchers categories, rather than in its original context (Dey, 1995). These categories can then be linked, however like categorisation linking must be based on conceptual and empirical evidence (Dey, 1995).

The results of this analysis phase consist of diagrams, descriptions and evidence. Diagrams and descriptions of the categories and their linkages present to the audience a description of what was learnt. Evidence, consisting of excerpts from the data, is used to back up what is stated in the description and presented in the diagrams.

2.3. Method of data collection and analysis

The method of collecting the necessary data and analysis of it to gain an understanding of the fertiliser recommendation service offered by horticultural consultants follows the suggestions presented in sections 2.2.1Qualitative data collection and 2.2.2 Qualitative data analysis. A combination of interviews, observation and collection of documents were used for gathering data, while the method of grounding the description in the data was used for the analysis. The selection of the consultants studied and a brief introduction to how they fit into the consultant and fertiliser industry is presented in the next section. Following this, the data collection and analysis methods utilised are presented.

2.3.1. The consultants studied

The information collected comes from the study of three horticultural consultants involved in making fertiliser recommendations for growers. In this section the definition and boundary of the system along with an introduction to each of the consultants is presented. Three consultants were chosen for study, they were selected because of their availability, eagerness to be involved, diversity, and what was thought could be learnt from them. For the remainder of this study the consultants are referred to as Consultant One, Two, and Three for ease of identification when referring to them in discussions.

The definition of the system being studied in this research is the overall process required to arrive at a fertiliser recommendation by a consultant. The boundary of the system begins with the grower asking the consultant to provide a fertiliser recommendation and ends with the consultant presenting the recommendation to the grower.

Consultant One works for Agriculture New Zealand and the fertiliser recommendations he provides are mainly to growers with orchards in the Franklin district. The consultant is the manager of the branch of this nation-wide organisation. The number of recommendations he does is less than some of the other consultants do in the same practice; this is due to his role as manager. His experience as a consultant, manager, and owner of his own orchard should prove useful in this study.

Consultant Two is employed as the horticultural products sales manager by Ravensdown Fertiliser Co-operative. His job involves providing fertiliser recommendations to growers of a wide range of horticultural crops grown in the Hawkes Bay region. The consultant also looks after the companies' orchard, which Ravensdown use to test their fertilisers and application practices. What he learns from running the orchard he passes on to the growers he prepares recommendations for.

Consultant Three is an independent consultant who specialises in providing fertiliser recommendations for kiwifruit orchards. The consultant works with growers in the Coromandel and Franklin districts. This consultant provides recommendations to two of the three kiwifruit packhouses that lease orchards in the Franklin district. Although asked to provide recommendations for the third one, he has declined based on a perceived conflict of interest because growers often ask which packhouse they should lease their orchard to. The consultant is looking at reducing his fertiliser recommendation service and concentrating on other areas of interest.

2.3.2. Data collection

Four methods of data collection were used; interviews, observation, documents and feedback. Interviews were the main source of data, while observation of, and documents used by, the consultants were used to authenticate and add to the interview data. The function of the interviews was to ask the consultants to explain the fertiliser recommendation service they each offer. During the interviews the consultants were asked to go through the process of preparing a recommendation, the observation of this and questioning during it was recorded with the interview. Copies of fertiliser recommendations that the consultant had previously created were collected following the interview. Other documents collected included fertiliser price lists and fertiliser nutrient analysis information from the fertiliser companies whose fertilisers the consultants based their recommendations on. Feedback from the consultants following analysis of their interview was sought and incorporated back into the analysis.

The interviews took the form of informative conversations where the consultants described their fertiliser recommendation service. When the consultant had finished describing a particular attribute and did not know what else to talk about they were prompted with other topics that they could respond to and continue the conversation. A list of topics to use as prompts was created before the interview to ensure an overview of the fertiliser recommendation service was covered. The prompts were based on information seen in the literature regarding nutrient requirements and fertiliser selection. The interviews were recorded so they could be transcribed to provide a more reliable record of the interview and more detail than just making notes.

2.3.3. Data analysis

Each consultant was analysed separately with analysis of the data beginning with listening to the tapes of the individual interviews. The tapes were then transcribed and read several times and during which time memos were made to help develop an understanding of the fertiliser recommendation service. As the analysis continued diagrams were sketched that represented different parts of the process the consultant being studied went through. The components of the diagram represented possible categories and links between the categories. The diagrams representing the categories and links changed many times, but as the analysis of each of the consultants continued the abstract view of the fertiliser recommendation service the consultants provide emerged.

The initial analysis of the data lead to a multitude of categories. Similar and related categories were grouped together to form an abstract view of the data. After collating evidence of the abstract view the data in each category was then analysed further and lead to the development of categories within the main abstract categories. Thus, the development of the current description of the fertiliser recommendation service is the result of an iterative process of continually going back, rereading, annotating the data, and refining the diagrams and descriptions of the categories.

The analysis process also involved discussions with several people as well as the consultants interviewed. During these discussions, current thoughts were presented and through a constructive discussion new ideas and avenues to pursue often emerged. The feedback was considered and if appropriate incorporated into the current diagram and description of the fertiliser recommendation service.

2.4. Results

In this section, a description of the fertiliser recommendation service that consultants offer is presented. A diagram representing the abstract view of the processes involved is introduced and then each of its components are discussed. Content differences between consultants of these components are discussed. Parts of the service that could be improved and information that will aid in the development of a decision support system to improve the current service are then discussed.

The components of the abstract view of the fertiliser recommendation service are shown in Figure 1. This diagram is based on the service offered by the three consultants. Although each consultant has their own idiosyncrasies, at an abstract level they all follow the same abstract processes. What makes each of the consultants different, within the context of the abstract description is discussed as each part of the abstract view is presented. The evidence to support this description of how consultants perform the fertiliser recommendation service is presented in Appendix Two Evidence of the fertility service offered by consultants.

As seen in the Figure 1 a consultant collects information, which is then incorporated into their knowledge. When required to make a fertiliser recommendation for a grower they then draw on this knowledge. Some of this knowledge is analysed and thus creates new knowledge about the problem at hand. The results of the analysis and the knowledge of a consultant are then used in establishing the nutrient requirements, the selection of fertilisers to meet the nutrient requirements, and the fertiliser recommendation. The output of this group of processes is a recommendation report consisting of what fertilisers the grower should use and how and when to apply them. This is sent to the grower and incorporated into the consultants' knowledge. Each of these components in this process is discussed in more detail in the proceeding sections.

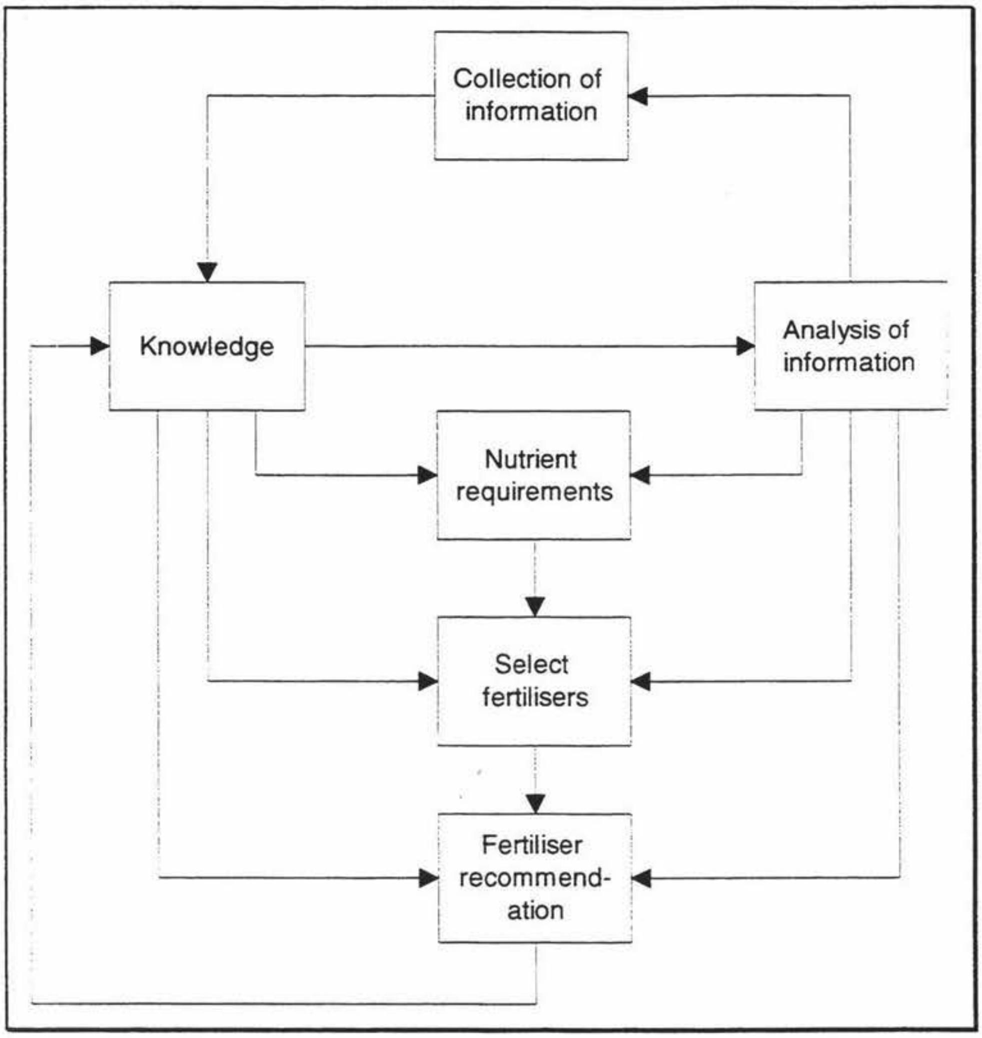


Figure 1 An abstract view of the fertiliser recommendation service offered by consultants.

2.4.1. Collection of information

This category refers to how the consultants collect information and the methods they use. Information collection methods the consultants use include, nutrient tests, visiting the grower's property and talking to the grower. The information that the consultants collect then becomes part of their knowledge.

The consultants use nutrient tests to establish the amount of nutrients present in the soil and leaves. Consultants One and Two use both soil and leaf tests, while Consultant Three no longer sees the need to use leaf tests. Soil testing is usually done annually, although may take place between crops on a market garden property as noted by Consultant One "If they're market gardeners they may test between crops". When taking on a new client (i.e., grower) the consultants ask for previous nutrient test results. Consultant Three also asks the grower to do two soil tests, one of the top fifteen centimetres and one below this depth so he can gain an understanding of the location of the nutrients in the soil. Consultant Two said that "I monitor with leaf test data" because "it gives you added information for next years crop", while Consultant One notes that greenhouse growers using peat pumice mixes and fertigation are "maybe leaf testing as often as once a month, to track how well things are going".

Consultants collect information by talking to growers and visiting their properties. Talking to the growers allows the consultant to obtain information such as yield expectations, any preferences about fertiliser they have and historical information. Visiting a property allows the consultant gain a feel for how the crop is performing and the consultant may, for example, be able to look for nutrient deficiencies, irregularities in the crop and also look at fruit size and hypothesise what the yield may be.

Consultant One mentioned that he keeps in touch with scientists so as to gain information about the nutrient requirements of new crops such as flowers. While to gain similar information Consultant Two carries out experiments within the company orchard. When a grower is growing a new crop, this same consultant uses nutrient tests to monitor "every week or two weeks just, just to get a fix on what is happening".

2.4.2. Knowledge

The knowledge category refers to the repository of information available to a consultant that they can use to aid their decision making. The category encompasses three types of categories that come under the heading of knowledge; these are knowledge sources, subjects, and storage mechanisms.

The sources of information the consultants use include the popular press and scientific literature, nutrient test results, notes from talking to and visiting growers, fertiliser brochures, and previous fertiliser recommendations. The consultants revisit these sources when developing a new fertiliser recommendation.

Three categories that relate to subjects of knowledge were evident in the transcripts, these were, crops, soil, and fertiliser. Theses subject categories contain some of the decision rules that the consultants use. The decision rules are utilised in the decision making processes of determining nutrient requirements, selecting fertilisers, and making the fertiliser recommendation. Consultant Two, for example, said that "we put a little bit in, to maintain where we are, but, normally with Fuji, don't use any nitrogen on heavy soils, this is a wee bit lighter soil". Here the consultant is stating that when growing the apple variety Fuji on a heavy soil he would not put on any nitrogen, but he is making an allowance for the soil having a lower bulk density and less clay. His concern is based on earlier comments where he said "of all the apples, they're [Fuji] the best at picking up nitrogen in the soil" and "if you have too much nitrogen, it [the fruit] doesn't colour up enough". Consultant Three makes a similar statement about the soil in his area; "when you apply K to our soils you create magnesium deficiencies very rapidly". As a result of this knowledge, when he is determining the quantities of potassium and magnesium to apply he uses a decision rule of maintaining a ratio between the quantities of each he recommends.

The consultants' use two storage mechanisms to keep track of their knowledge, paper documents and their memory. The sources of information that were identified are typically in the form of paper based documents; the consultants currently utilise an information system consisting of filing cabinets with folders that relate to each grower or a subject. Consultant One, however, was wanting to move some of the currently paper based information to electronic storage in the form of a database with a decision support system front-end to allow for integration of the information stored. The consultants rely on their memory to store knowledge that is learnt from the information collected or information that is not written down. This includes much of the information growers provide when the consultants visit a growers' property and when talking to them.

2.4.3. Analysis of information

This category refers to how the consultants analyse the knowledge they have to derive new information from. This new information comes from gathering together any relevant historical and current information and looking for trends, such as in nutrient levels, pH, response rates, and yield. These trends give the consultant an idea of where things are heading; by looking at the current position, the consultant can see what nutrients may need adding. Trends and the current position are learnt from the analysis and this is of use when determining the nutrient requirements, selecting fertilisers, and preparing the fertiliser recommendation.

2.4.4. Nutrient requirements

The nutrient requirements category refers to what the consultants do, take into consideration, and use to determine the nutrients that are required for the recommendation they are currently preparing for a grower. The group of categories that are contained within the nutrient requirements category include annual maintenance, corrective levels, nutrient relationships, quantity guidelines, and computer software. Not all of these categories were evident with each of the consultants. The two main categories were annual maintenance and corrective levels, while the use of computer software for helping determine nutrient requirements was only used by Consultant Three.

An annual maintenance requirement of nutrients form part of the overall nutrient requirements. Determining the annual maintenance involves estimating the amount of nutrients that will be permanently removed from the soil system over the next year. Crop yield, and if significant, prunings, are used to establish the annual removal of nutrients from the soil system. The aim of annual maintenance is to replenish the nutrients that are removed on an annual basis at a quantity consistent with the amount that is expected to be removed over the year.

If, after determining the annual maintenance, the consultant thinks that there are deficiencies of particular nutrients in the soil then corrective amounts are required. The need for corrective quantities of nutrients arises when any nutrient level trends are not at preferred levels or when they are undesirably increasing or decreasing. When the current nutrient levels are outside what the consultant would prefer them to be then they select the quantity of the nutrients needed to add to the overall nutrient requirements. What constitutes preferred levels differs among the consultants studied, but as a guide they aim for the soil test results to maintain a steady level and for that level to be in the medium range of the soil test results nutrient level histogram. If the current position, determined during the analysis of information, suggests that any current nutrient levels are too high then the corrective level refers to the amount of nutrient to subtract from the overall nutrient requirements.

Nutrient relationships need considering when determining nutrient requirements, for example, Consultant Two commented that "when you put potassium in, you've got to be vary careful you don't upset the balance with calcium and magnesium". Consultant Three also described maintaining a ratio of between 3:1 and 5:1 of potassium to magnesium when determining nutrient requirements for kiwifruit grown on Frankiin soils.

Quantity guidelines (estimates) are used by the consultants to help determine how much of each nutrient is required on an annual basis and what the most for any one application should be. These guidelines are typically unwritten rules that they have learnt from previous experience and knowledge of the soils and crops of their area. Nutrient requirements are, therefore, determined through first estimating the annual removal of nutrients from the soil using quantity guidelines, this loss is replenished with an annual maintenance quantity of nutrients. If a consultant thinks any of the trends seem detrimental then they are likely to alter the nutrient requirements to reduce the effect of the detrimental trend, again using the quantity guidelines. Although not mentioned by Consultants Two and Three, Consultant One then takes into consideration a wastage factor to account for nutrient losses from the soil system not already considered, such as leaching, which is based on guidelines he has.

For kiwifruit orchards Consultant Three uses computer software to aid in the decision process of how much nutrients are required. The consultant enters information about the orchard into the software, which then searches a database and presents an estimate of what the nutrient requirements are. If the consultant deems the estimates inappropriate then he can change them before using these values for helping select fertilisers.

2.4.5. Select fertilisers

This category refers to what influences fertiliser selection and how the consultants decide what quantity to recommend. Each consultant varies in the way they select fertilisers and set the quantity to use.

Consultant One considers the ability to meet the nutrient requirements, the cost of the fertiliser mix, and grower preferences. The consultant states that "when you are making the mixes up you generally take into account the cost of the products that are going in, but it is more important to get the mix right", that is, aim for the mix to meet the nutrient requirements and grower preferences. Grower preferences include, for example, "a preference for organic fertilisers" and "the client has said they don't want potassium chloride".

As an aid to the selection of fertilisers, Consultant One uses computer software that generates fertiliser mixes based on minimising the cost of the mix. The software was supplied by the New Zealand Soil Fertility Service and developed around 1989. The software requires the cost and nutrient analysis of each fertiliser and the nutrient requirements determined by the consultant. The consultant specifies the number of fertiliser mixes to generate and then gets the software to generate a list of mixes. The fertiliser mix options generated contain the cost of the mix and the names of the fertilisers, and the quantities required of each in the particular mix to meet the nutrient requirements stipulated.

After running the least cost computer software the consultant selects a fertiliser mix from the options generated. From these options the consultant aims to provide the grower with a fertiliser mix recommendation that best meets the needs of the crop on a particular property. In selecting an appropriate mix, the fertiliser preferences growers have, such as organic verses inorganic fertilisers or avoiding fertilisers with particular nutrients are considered. Other factors include, reducing excess quantities of nutrients, and selecting a mix at the lowest cost. The consultant works through each of the options beginning with the cheapest until reaching one to recommend to the grower that meets the growers fertiliser preferences.

Consultant Two bases his fertiliser selection on, the effect of fertiliser on pH and nutrient availability, grower preferences, nutrient uptake, and knowledge of the growers' property and management system. The consultant also uses decision rules to help determine which fertilisers are appropriate and how much of them to recommend. An example of a decision rule he describes is:

> *I've used a magnesium product which is quickly available to the plant. In fact, it's the only one that's really able to be taken up by the plant at that pH. If I was to put dolomite lime in, it's alkaline, very very little of it will go up into the plant. You shift that level up, but it's not available. It is*

over a period of time, soil acids will work on it and you can, you'll get some uptake.

In this statement, the consultant is saying that the choice of a fertiliser to supply magnesium is based on the availability of the nutrient in the fertiliser to the plant. The consultant considers the pH of the soil and has an idea, based on his knowledge and analysis, how quickly the nutrient is required. Rather than trying to keep the cost down the consultants' main aim is to find the best mix to achieve what is best for the plants. The consultant justifies his lack of concern for the cost of the fertiliser mix by stating that it is only a small proportion of operating expenses.

The fertilisers selected by Consultant Three hardly varied between orchards in the same district. What does differ between orchards, and sometimes fertiliser recommendations, is the amount of each fertiliser recommended. The reason for very little change in his recommendations is his philosophy of only making small changes to the quantities of nutrients applied each year. For the two districts he services, Franklin and Coromandel, there are set fertilisers that he uses for each. Only in cases where he is having difficulty in maintaining equilibrium does he change what fertiliser he uses. He notes that cost can be a factor that must be considered on occasion because some growers do ask for cheaper options due to financial pressure. Typically the cost of his fertiliser mixes are expensive compared to options prepared by Consultant One who is in the same district. His reason for this is "we've told the growers, we are the Rolls Royce, we don't deny it, if you want a bloody Japanese copy from the other side you go and fetch it" referring here to Consultant One.

The computer software that Consultant Three used to determine nutrient requirements is also used to aid fertiliser selection. The constant use of the same fertilisers means that the only part of fertiliser selection that needs determining is the quantities of each fertiliser to use. The software is used basically as a calculator, the consultant enters a quantity and the amount of each nutrient this quantity of the fertiliser will supply is calculated and displayed on the screen. The consultant modifies the quantities of each fertiliser until he is satisfied with the quantities of each nutrient being supplied.

2.4.6. Fertiliser recommendation

The fertiliser recommendation category encompasses suggesting when and what fertiliser to apply and the preparation of a recommendation report. As part of the fertiliser recommendation Consultant Two also aims to educate growers about fertiliser usage. The evidence for the application suggestions category mainly consists of decision rules that each of the consultants use to determine the need to split the mix into several applications and the timing of these applications.

2.4.6.1. Application suggestions

Consultant One bases his decision about whether to split the mix into several applications on scientific research, previous experience and trends on the property. Reasons for Consultant One choosing to split a fertiliser mix include, the inability to mix together particular fertilisers, nutrient mobility and the possible wastage if all the nutrients are applied at once. If the quantity of a nutrient being applied is above a threshold guideline then the consultant also elects to split the nutrient into two or more applications. The ability of the soil of a particular property to hold nutrients can also affect the decision of how to split the application. If recent leaf test results suggest low levels of a nutrient within the plant then the consultant may choose to split the application of the nutrient. The need to split the application is because total application of the nutrient may lead to a nutrient loss from the soil system before the plant can take it up. For new crops such as flowers, where previous information is unavailable, the consultant keeps in contact with scientists that may be able to provide information about splitting the fertiliser mix into several applications and asks for their opinions and results of any recent relevant research.

After deciding how to split the fertiliser mix into several applications (if applicable), Consultant One then determines when each should be applied. The knowledge and experience the consultant uses is similar to that required for splitting the initial fertiliser mix. Scientific literature, the mobility of specific nutrients and the ability of the soil system of the property to retain nutrients are taken into consideration by the consultant to determine the timing of each application.

Consultant Two usually has a predetermined set of times to apply fertiliser for a particular crop. It is then a matter of selecting which fertiliser and how much of each to apply at these specified times. Consultant Two said he aims to split the fertiliser mix "according to the best time to apply it in terms of the growth stages" of the crop. An example of how the age of the crop affects his application suggestions is "they're young trees I've put the nitrogen on in spring rather than autumn ... if you put nitrogen on in autumn you'll get it into the sink of the tree and it's used for fruit development, as well as growth. Put it on in the spring and it goes into canopy, goes into canopy growth". Knowledge of the soil's ability to hold nutrients affect the quantities applied at different times, for example, on a light soil he is likely to split the application of nutrients due to the potential for leaching.

Consultant Two aims to educate the growers he provides recommendations for. He explains to the growers why he has suggested a particular strategy for timing the splitting of the quantities of nutrients. Several reasons he sees for growers needing this information are application effectiveness and how crops grow. He explains to the growers, usually when visiting their property or when on the telephone, how to gain as much effectiveness as possible from each fertiliser application, for example, how to avoid leaching. Some growers are unaware of how crops grow and respond to various quantities of nutrients so the consultant explains, for example, that putting large quantities of nitrogen on a crop to make it grow faster is not necessarily a good practice.

The application suggestions by Consultant Three differ very little between years and growers. Remember that this consultant is only dealing with kiwifruit unlike the other consultants that provide recommendations for many crops. Consultant Three has three dates on which he recommends to apply fertiliser; one application on the 20th of August, two applications on the 20th of September and the last on the 30th of October. The two applications in September are because of the inability to mix the two fertilisers together. The first two applications are the same and involve applying all of the phosphorus three quarters of the potassium, two thirds of the calcium, most of the magnesium and none of the nitrogen. In the third application about half of the nitrogen is applied using the fertiliser calcium ammonium nitrate (C.A.N.). In the last application, the remainders of the nutrients are applied including half of the nitrogen and a quarter of the potassium.

2.4.6.2. Recommendation report

Each of the recommendation reports the three consultants give to their clients vary in presentation and content. Examples of the reports they produce are contained in Appendix Three Example fertiliser recommendation reports.

The report that Consultant One prepares depends on what the grower wants. The content of the report depends on whether the grower requires the rationale behind the recommendation and for what service the grower is paying. The following descriptions of the content of the report assume that the grower is seeking the full service. Each report contains an introduction, possibly where the fertilisers can be purchased from to achieve the mix specified, suggested timing and, if necessary, details about splitting of the mix into several applications and what quantity of each fertiliser to apply. Growers that are interested in the rationale behind the recommendation are also given the following information, nutrient test results, trends observed, how problem trends will be dealt with, how previous soil and leaf test results were used, the recommended fertiliser mix, and other mixes generated by the least cost model.

The recommendation report that Consultant Two provides his clients with presents a description of when and how much fertiliser to apply during the year. The growers he prepares the reports for typically have several crops and the reports reflect this by detailing a recommendation for each crop. Besides the recommendations for each crop there is little else written in the report. The consultant states that the growers just want to know how much fertiliser to apply and when, although sometimes he will add brief comments. He supplements the report with a discussion with the grower encompassing what he calls grower education. This is often done on the grower's property when he presents them with the fertiliser recommendation report he has prepared.

Consultant Three's recommendation report consists of a printout generated by the computer software he uses and copies of the soil test results. The printout lists the fertilisers, dates to apply them and in what quantities. Usually the printout applies to the entire orchard, however, if part of the orchard varies markedly then the consultant may prepare separate recommendations for each part.

2.5. Discussion

Several areas highlighted in the results that need further discussion are the information requirements of the consultants and the aim by the consultants to select fertilisers that as close as possible meet the nutrient requirements the consultants specify.

2.5.1. Information requirements

Information requirements fall into two categories, client (grower) information and fertiliser industry information. These two categories are discussed in this section.

The consultants collect and use current client information and then reuse this, now historical information, in following years when looking for trends. The client information the consultants use comes from nutrient test results and recent discussions and visits the consultants have with their clients. The consultants note current fertiliser preferences and observations the growers have for future use when making fertiliser recommendations.

The information that the consultants collect is stored either in manila folders in filing cabinets or in the consultant's head. None of the consultants currently utilise a computer as part of their information system, although Consultant One noted that when they move premises shortly they will consider placing some of the client information in a networked database. In

Figure 2, the sources of client information are shown. The diagram depicts the information the consultants use, except that Consultant Three no longer uses leaf test results. The client information comes from five categories and its use depends on whether it is recently gathered or previously stored.

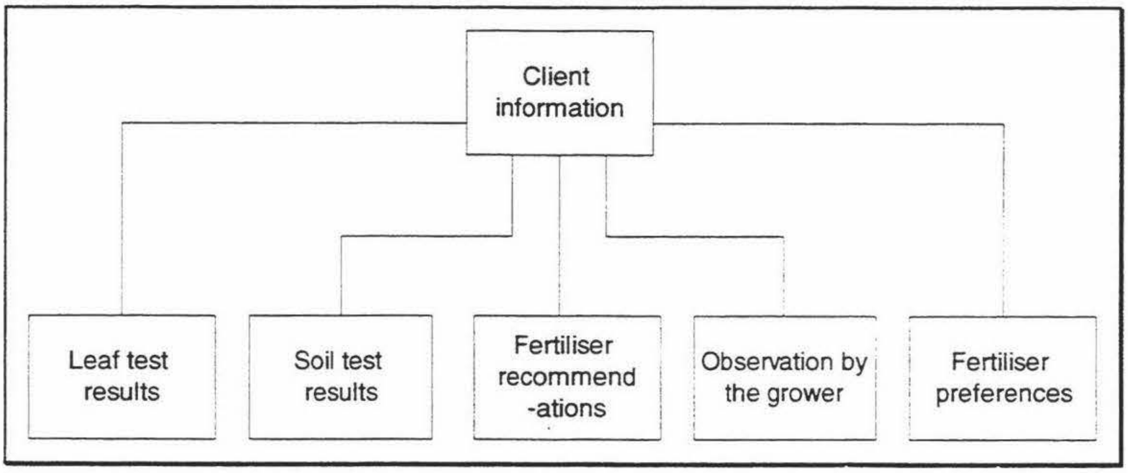


Figure 2 Client information the consultant uses when selecting appropriate fertilisers for a particular client (grower).

The consultants use a variety of information about each fertiliser to aid the preparation of an appropriate fertiliser recommendation. The information that describes each fertiliser that the consultants typically use is presented in Figure 3. Consultant One enters the nutrient analysis, manufacturer, and the cost of the fertilisers from local merchants into the least cost computer software he uses. The computer software Consultant Three uses contains a database of fertiliser information, which includes the cost and nutrient analysis of the fertilisers he uses in his recommendations. The packaging type and size provide the consultant with information that is useful when selecting which fertilisers to use in the least cost program. Certain packaging sizes and types may be more appropriate than others for particular cropping systems. A greenhouse grower, for example, may prefer smaller packaging for micronutrients than say an orchardist, due to total quantity requirements. Other data such as freight and spreading costs give the consultants a guide to work from if the growers ask what costs they should expect for these services.

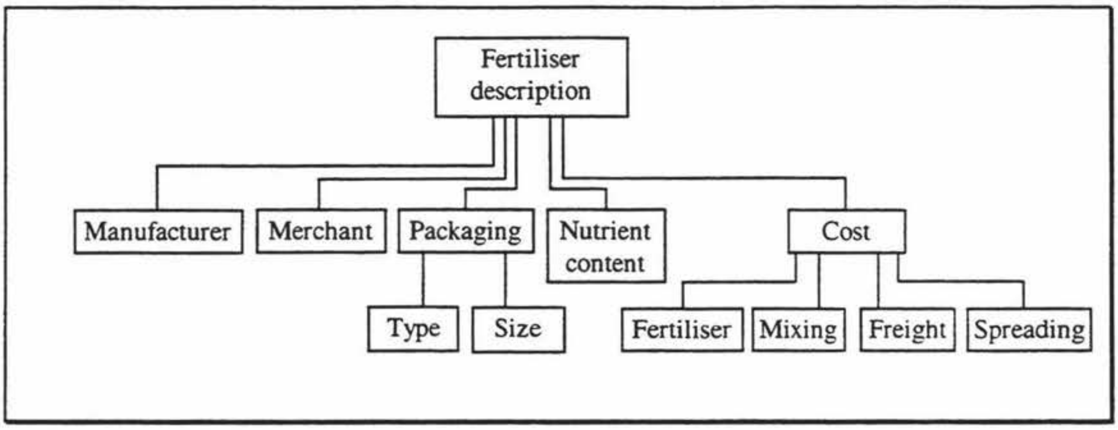


Figure 3 The information categories that describes each fertiliser.

2.5.2. Suggestions of how the current fertiliser selection process could be improved

Consultant One highlighted several areas where computer software could improve the current selection process. The improvements were concerned with avoiding excess nutrient application, and summarising historical information and having it available on a computer. While the other consultants reiterated that an approach to selecting fertilisers and the quantities to apply to meet the nutrient requirements as close as possible was important.

The notion of excess nutrient application was introduced by consultant one; an excess of a nutrient occurs when the amount supplied by the fertilisers recommended is greater than the consultant suggests is required. Deficient nutrient application is the opposite of excess and means that the quantities of the fertiliser recommended do not provide what the consultant suggests is required. Using the approach of recommending quantities of fertilisers that contain as close as possible the nutrient requirements the consultant has specified implies minimising excess and deficient nutrient application.

Consultant One stated that he was trying to avoid excesses of nutrients, but the current least cost computer software he uses produces options that have excesses in some nutrients. The software generates fertiliser mixes that are not deficient in, but may have excesses in, nutrient application. The consultant prefers to select fertiliser programmes "that supply what the grower's property requires and not much more". An example given to show the importance of reducing excesses was that in greenhouses where the rain can not flush nutrients from the soil and high levels of a nutrient can soon build up. Sulphur levels much higher than desirable have been recorded, which means the grower has to resort to using more expensive fertilisers that do not contain sulphur. If the fertilisers recommended initially had less sulphur and were more closely matched to the nutrient requirements then having to use this higher cost fertiliser would not be necessary.

Consultant One also suggests that being able to store and easily retrieve historical information about a grower would reduce the time currently required to sort through this data to elicit trends and problems. The type of information to store as suggested by the consultant included; nutrient test results, notes about nutrient levels and trends and historical yield. The consultant suggests that ideally this historical information would then be available as a one-page summary. The estimated benefit to the consultant was a time saving of ten minutes per recommendation; almost halving the time spent reviewing historical information.

2.6. Summary

In this chapter, the fertiliser recommendation service offered by three consultants was studied. The research problem naturally lent itself to the use of a qualitative research approach due to the type of data required to describe the processes involved. Data was collected from three consultants using interview, observation, documentation, and feedback. The data was analysed by grouping it into categories that when linked provided a conceptual overview of how the fertiliser recommendation service provided by consultants operates.

The initial analysis of the data was influenced by my method of thinking about how the consultants go about providing their fertiliser recommendation service. My information systems and computer programming way of thinking have influenced the interpretation of the data. Although this probably lead to a different interpretation than perhaps what others would develop it has the advantage that the results lend themselves to the requirements of the rest of this study, that is, the development of a decision support system.

The fertiliser recommendation service that consultants provide was presented at an abstract level. Methods that were specific to a consultant were described when discussing each of the components of the abstract description. The fertiliser recommendation service begins with a consultant collecting information, which they then incorporate into their knowledge. When a client requests a fertiliser recommendation they draw on this knowledge, some of which is analysed and thus creates new knowledge about the problem at hand. The results of the analysis and their knowledge are then used to establish an estimate of the nutrient requirements, the selection of fertilisers to meet the nutrient requirements, and the fertiliser recommendation. The output of this group of processes is a recommendation report consisting of what fertilisers the grower should use and how and when to apply them. This is sent to the grower and incorporated into the consultant's knowledge.

An important area worthy of improvement is ensuring that the quantities of fertiliser, and the actual fertilisers chosen meet the nutrient requirements that the consultants specify as closely as possible. Meeting the nutrient requirements as closely as possible implies minimising the excess and deficient quantities of nutrients suggested in the fertiliser recommendation. The current least cost computer software used by Consultant One often generates fertiliser mixes that have excesses of nutrients that are unwanted by the consultant. The cost to the grower of applying excesses of nutrients is higher fertiliser costs in the future. These higher costs are due to having to select fertilisers that do not contain nutrients that have built up to levels in the soil which are considered toxic. The software currently used by Consultant Three requires him to manually enter how much of each fertiliser to recommend, the ability to generate a list of quantities of fertilisers, which he could then use or modify is likely to benefit the consultant.

Another improvement suggested was to have a better means of storing and retrieving the information relating to individual clients. The preferred method suggested implies a database of some kind to store historical data and allow for entering new (current) data.

In the next chapter, an outline of a decision support system that will help improve the current fertiliser selection process the consultants perform is presented. It is important to remember that the use of any software should be as a component to the decision making process and not replace it. An aim of this decision support system is to include the consultants' improvement ideas with others that will improve the current process. In subsequent chapters, parts of the decision support system will be explained in more detail.

2.7. References

Burns, R. B. (1994). Introduction to research methods (2nd ed.). Melbourne: Longman Cheshire.

Denzin, N. K., & Lincoln, Y. S. (1994). Introduction: Entering the field of qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), Handbook of qualitative research (pp. 1-17). Thousand Oaks, California: Sage.

Dey, I. (1995). Qualitative data analysis: A user-friendly guide for social scientists. London: Rouledge.

Glaser, B., & Strauss, A. (1967). The discovery of grounded theory. Chicago: Aldine.

Maxwell, S. (1986). The use of case studies in farming systems research. Agricultural Administration, 21, 147-180.

Smith, L. M. (1978). An evolving logic of participant observation, educational ethnography and other case studies. In L. Shuman (Ed.), Review of research in education (Vol. 6, pp. 316-377). Itasca, Illinois: Peacock.

Stake, R. E. (1994). Case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), Handbook of qualitative research (pp. 236-247). Thousand Oaks, California: Sage.

Strauss, A. L., & Corbin, J. (1990). Basics of qualitative research: Grounded theory procedures and techniques. Newbury Park, California: Sage.

Yin, R. K. (1994). Case study research: Design and methods (2nd ed.). Thousand Oaks, California: Sage.

Chapter 3

A decision support system for fertiliser selection in horticulture

3.1. Introduction

In Chapter Two it was shown that consultants combine a range of current and historical information to estimate the nutrient requirements for a crop. Two of the three consultants studied used computer software to help with this selection process. The consultants said they would appreciate ideas on how to improve the management and retrieval of information to estimate nutrient requirements and select fertilisers. The consultants noted that deficiencies and excesses of nutrients were sometimes present in their fertiliser recommendations and a way to reduce these would improve their recommendations to growers. An important comment made by one of the consultants was that a decision support system, created with the aim of improving what they currently do, should only be part of the decision making process and not replace it.

The consultant's methods and ideas for improvements to these form the basis of the decision support system described in this Chapter. The aim of the decision support system is to aid the determination of nutrient requirements and the selection of fertilisers.

Before introducing the decision support system as a functional model an introduction to decision support systems is presented. The term decision support system is defined along with an outline of the components they generally contain. A method of modelling the function of the decision support system is then presented.

3.2. Decision support systems

A decision support system is an interactive computer-based system (Bennett, 1992) that aids technological and managerial decision making (Sage, 1991). Thus, the purpose of decision support systems is to assist the decision maker and increase the effectiveness and efficiency of decision making (Sage, 1991).

The main components of a decision support system are an interface, data, and models (Sprague, 1980; Sprague & Carlson, 1982; Jolma, 1995). The interface is between the user and the system, data supports the system, and models provide analytical capability. Although the designs of these components vary between applications, they are always present in decision support systems (Watson & Sprague, 1993).

The interface provides the link between the underlying structure and the user of the decision support system. The interface is an important component; from the user's perspective the interface is the system (Watson & Sprague, 1993). Unless it affects the interface the user typically has little interest in the algorithms or database structure the decision support system consists of (Watson & Sprague, 1993). Information about how people and organisations process information and make judgements in a descriptive fashion provides good background information required for the design of affective interfaces (Sage, 1991). The information relevant to the development of an interface for the decision support system in this study was collected in Chapter Two and includes the order in which the consultants make their decisions and how information is grouped together.

There are two sources of data within a decision support system, that entered by the user, and that generated by the models within the decision support system. Data entered by the user comes from a range of information sources such as organisation databases and from documents containing concepts, ideas, and opinions important to the impending decision (Watson & Sprague, 1993). The use of databases is common for storage of the information entered by the user and created by the models. The use of databases then allows the generation of reports about the data and the ability to reuse the data in subsequent use of the decision support system.

The techniques developed for decision analysis in the field of management science and operations research has provided the framework necessary to design useful and relevant models, particularly those concerned with systems analysis techniques (Sage, 1991). Although once used on their own, developers now typically regard systems analysis techniques such as simulation and optimisation models as components of decision support systems that form part of the underlying structure to some more ingenious approach (Jolma, 1995).

Many reported decision support systems are the result of substantial programming work (see, for example, Hochman, Pearson, & Litchfield, 1994; Mainland, 1994; and Bennett, 1992), due usually in an effort to deliver a user-friendly package (Jolma, 1995). Over the past decade huge improvements in both the hardware and software required for the development of decision support systems has taken place. The use of a graphical interface, which is becoming the norm, provides the user with a much easier and friendly to use interface. However, as Jolma (1995) points out, these improvements have also given users new expectations from system designers.

The techniques used for developing and representing the structure of decision support systems are many and varied. The particular technique chosen will depend on the components in the decision support systems. Data-flow diagrams are often used during the development process for systems centred on data, its collection, transformation, and update (von Mayrhauser, 1990). Data-flow diagrams have become an industry standard for presenting a functional description of a system dealing with information (Batini, Ceri, & Navathe, 1992) and seems an appropriate method for an information rich decision support system such as the one required for fertiliser selection. A model depicted by a data-flow diagram is simple and concise as a distinct graphic symbol represents each element of the model (Batini, Ceri, & Navathe, 1992) and provides an easy to understand overview of the decision support system. The symbols used in data-flow diagrams and their meanings are shown in Figure 4.

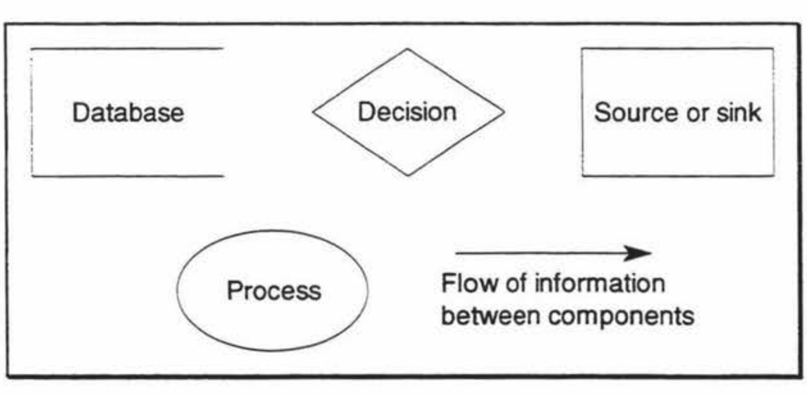


Figure 4 A definition of the symbols used in data-flow diagrams.

Further design and specification of the components of a decision support system, which follows the functional analysis requires modelling techniques used by practitioners of the particular disciplines. For database modelling the entity-relationship approach has emerged as the leading formal structure for conceptual database design (Batini, Ceri, & Navathe, 1992). In optimisation modelling mathematical equations that describe the general model being presented seems an appropriate method (Cochrane & Zeleny, 1973; Yu, 1985; Rehman & Romero, 1993).

3.3. A description of the fertiliser selection decision support system

Although each of the consultants studied use similar information to select fertilisers the processes they use varied. The current fertiliser selection software used by Consultant One minimises the cost of the fertiliser mix subject to attaining the nutrient requirements. The software used by Consultant Three prompts him to select which fertilisers to use and the amount of each to apply. Meanwhile Consultant Two does not use any computer software, but instead uses *rules of thumb* (heuristics) gained through experience. A problem associated with Consultant One's software is that excesses of some nutrients may be included just so that the nutrient requirements are definitely met. With Consultant Three's software, both deficiencies and excesses of the required nutrients may exist, and because of the iterative process needed to find an appropriate mix of fertilisers, a better mix is likely to exist. An optimisation model that improves on these current methods by minimising deficient and excess levels of nutrients along with a database to store the information required for the optimisation process need incorporating into a decision support system.

The aim of the decision support system is to improve the fertiliser selection process. Achievement of this aim is through using some form of optimisation to find a solution that a consultant will deem satisfactory, or at least, useful. Storage of the information required for such an optimisation process requires the use of database technology due to the potentially large quantity of data needed. In Figure 5 a functional description of the decision support system incorporating this optimisation and database requirement is presented.

The rectangle with a dashed line in Figure 5 represents the boundary of the decision support system. The items inside the box are the components of the decision support system, while those on the outside are information either entered or created from the decision support system. The text beside the arrows outlines information flows between components.

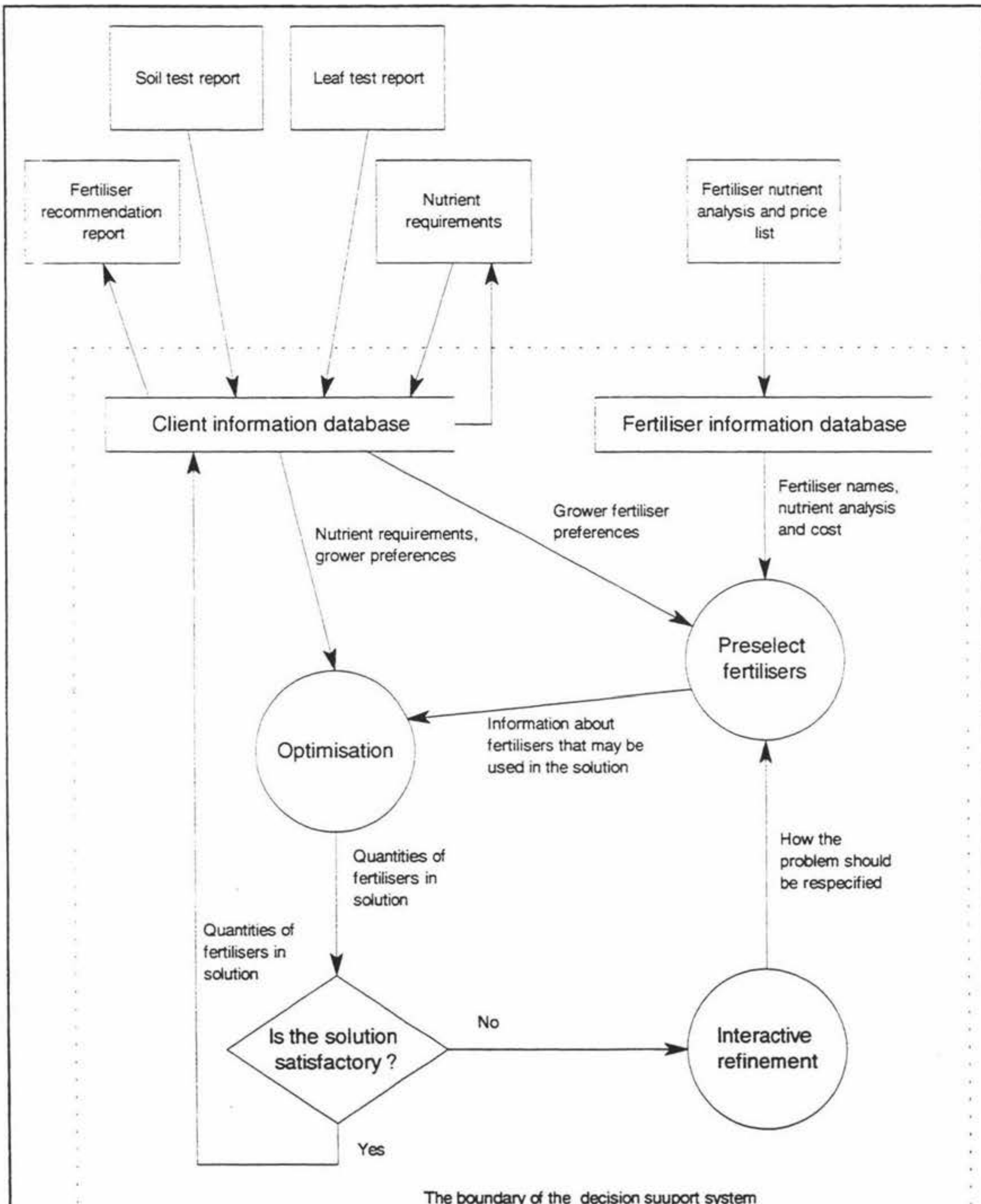


Figure 5 A model of a decision support system to aid the optimal selection of fertilisers by consultants.

3.3.1. Client information database

The consultants use information that is specific to a client (i.e., a grower) when determining nutrient requirements and selecting an appropriate fertiliser mix. The information that consultants use includes fertiliser history and preferences, and soil and leaf nutrient test results. Currently the consultants store this information in paper files. A database that contains client specific information enables reuse of information so a consultant does not have to re-enter the data each time they want to select fertilisers and prepare a fertiliser recommendation. The information in the client database can be used to pre-select fertilisers, set-up the optimisation, and then store the results of the optimisation.

3.3.2. Fertiliser information database

There are many suppliers of fertilisers in New Zealand and each sells a multitude of fertilisers. Information that describes these fertilisers, such as the nutrient analysis of each fertiliser, the cost, the manufacturer and who sells it to the grower needs storing in a fertiliser information database. The optimisation process of the model can use this information from the database when calculating optimum combinations of fertilisers.

3.3.3. Pre-select fertilisers

The optimisation process should only use those fertilisers that may form part of the fertiliser recommendation. A screening process that uses client nutrient requirements, fertiliser preferences and optimisation constraints could reduce the number of fertilisers passed to the optimisation process and thus reduce the time required to generate a solution. For example, the use of nutrient requirements as selection criterion ensures inclusion of only those fertilisers that contain any of the required nutrients.

3.3.4. Optimisation

The optimisation process receives a list of fertilisers along with set-up parameters from the client information database such as constraints, nutrient requirements, and grower preferences. The optimisation process aims to select the combination of fertilisers that minimise cost, and excess and deficient inclusion of nutrients, while achieving any constraints stipulated.

3.3.5. Interactive refinement

The optimisation process produces a mix of quantities of fertilisers, which the consultant, may or may not, deem as satisfactory. An interactive refinement process allows for the reformulation of the optimisation setup parameters to reduce any dissatisfaction with the output generated. Changes to the optimisation setup could include specifying any of the following, the exclusion of certain nutrients, minimum or maximum levels of nutrients, or changes to the nutrient requirements. The process of pre-selecting fertilisers can then use this reformulation to see if it alters the fertilisers that the optimisation process should use. Alterations to the list of fertilisers can be made and the optimisation process rerun with its new setup. This iterative and interactive alteration and rerunning of the optimisation process would continue until the user of the decision support system obtains a satisfactory solution. Storage of the solution in the client information database then allows the consultant to create the recommendation report for the grower.

3.3.6. Is the solution satisfactory?

When the user decides that a solution generated by the optimisation process is satisfactory the client database receives the solution for storage. The satisfactory solution obtained from the optimisation process should provide a list of fertilisers, where to purchase them from, the quantity required of each, and the cost of the fertiliser mix. If the consultant decides that the solution is not satisfactory then the consultant must decide how to reformulate the problem when passed to the interactive refinement process.

3.4. Summary

In this chapter a decision support system that helps select a mix of fertilisers to meet a set of nutrient requirements was described. The two types of information (client specific and fertiliser industry specific) used and created by the decision support system are stored in two databases. An optimisation process uses the information from these databases to generate a mix of fertilisers. Further refinement to the solution may be necessary to ensure a satisfactory outcome. Achievement of a satisfactory solution is through an interactive process of altering the model parameters followed by the generation of a new solution. This interactive process is iterative and continues until a satisfactory solution is reached.

The optimisation component is presented in the next chapter and the databases are presented in Chapter Five. A discussion of optimisation techniques and models reported in the literature are analysed. Using what was learnt from Chapter Two, the decision support system described in this chapter, and the literature, the optimisation routine, and databases developed for this study are presented and described in the next two chapters. In Chapter Six the implementation of the decision support system is discussed along with an evaluation of the optimisation routine.

3.5. References

Batini, C., Ceri, S., & Navathe, B. C. (1992). Conceptual database design: An entity-relationship approach. Redwood City, California: Benjamin/Cummings.

Bennett, R. M. (1992). Case-study of a simple decision support system to aid livestock disease control decisions. Agricultural Systems, 38, 111-129.

Cochrane, J. L., & Zeleny, M. (Eds.). (1973). Multiple criteria decision making. Columbia, South Carolina: University of South Carolina Press.

Hochman, Z. Pearson, C. J., & Litchfield, R. W. (1994). Users' attitudes and roles in the development and evaluation of knowledge based decision support systems for agricultural advisers. Agricultural Systems, 44, 217-235.

Jolma, A. (1995). Design and implementation of environmental decision support systems with object-orientation and spreadsheets. In P. Binning, H. Bridgman, & B. Williams (Eds.), MODSIM 95: International Congress on Modelling and Simulation Proceedings: Vol. 1. Agriculture, catchment hydrology and industry (pp. 376-381). Perth, Australia: Uniprint.

Mainland, D. D. (1994). A decision support system for dairy farmers and advisors. Agricultural Systems, 45, 217-231.

Rehman, T. & Romero, C. (1993). The application of the MCDM paradigm to the management of agricultural systems: Some basic considerations. Agricultural Systems, 41, 239-255.

Sage, A. P. (1991). Decision support systems engineering. New York: Wiley.

Sprague, R. H., Jr. (1980). A framework for the development of decision support systems. Management Information Systems Quarterly, 4(4), 1-26

Sprague, R. H., Jr. & Carlson, E. D. (1982). Building effective decision support systems. Englewood Cliffs, New Jersy: Prentice-Hall.

von Mayrhauser, A. (1990). Software engineering: Methods and management. San Diego: Academic Press.

Watson, H. J. & Sprague, R. H., Jr. (1993). The components of an architecture for DSS. In R. H. Sprague, Jr. & H. J. Watson (Eds.), Decision support systems: Putting theory into practice (3rd ed., pp. 99-110). Englewood Cliffs, New Jersy: Prentice-Hall.

Yu, P. L. (1985). Multiple criteria decision making: Concepts, techniques, and extensions. In A. Miele (Series Ed.). Mathematical concepts and methods in science and engineering: Vol. 30. New York: Plenum Press.

Chapter 4

Optimal selection of fertilisers

4.1. Introduction

An attempt to select an optimum combination of fertilisers that meet consultants' requirements has been made by the Soil Fertility Service, a division of Agriculture New Zealand, and Mínguez, Romero and Domingo (1988). Other authors have studied similar problems involving the selection of an optimum ration formulation for livestock. Notable works in this area of ration formulation models include that by Dent and Casey (1967), Crabtree (1982), Rehman and Romero (1984, 1987) and Lara and Romero (1994). The models developed in these fertiliser and ration formulation studies have used various optimisation techniques including linear programming and several variants of goal programming.

This chapter presents three approaches that could be used to solve the problem of selecting a combination of fertilisers, linear programming, goal programming, and compromise programming. After selecting an appropriate programming approach a formulation of the problem is presented and discussed.

4.2. A linear programming approach

Since the 1950's, blenders of products such as fertiliser and feed have used linear programming to formulate optimum mixes (Rehman & Romero, 1987; Mínguez, Romero & Domingo, 1988). The linear programming paradigm for this purpose uses the mathematical structure shown in Equation 1. This simple example assumes that the decision maker wishes to minimise the cost of a fertiliser mix that meets a set of specified nutrient requirements.

Equation 1 $$\text{Min}\sum_{j=1}^{n} c_j x_j$$

Subject to

Equation 2 $$\sum_{i=1}^{m} a_{ij} x_j \leq, \geq, = b_i$$

Equation 3 $$x_j \geq 0$$

Where

a_{ij} *the quantity of the i^{th} nutrient supplied by the j^{th} fertiliser*

b_i *the requirement of nutrient i, right hand side parameter*

c_j *the cost of the j^{th} fertiliser*

x_j *the quantity of the j^{th} fertiliser in the solution*

Although linear programming has been used widely in the past with notable success (Black & Hlubik, 1980), the use of linear programming for creating least cost fertiliser blends suffers unnecessarily from over-rigid constraints and the ability to only work with a single objective. The exclusive reliance on a single objective, for example, cost, for determining a fertiliser mix is a very rigid assumption. The decision maker is perhaps interested in an optimum solution that achieves a compromise amongst several conflicting objectives such as minimisation of, cost, excesses of nutrients, and the satisfaction of certain relationships (Rehman & Romero, 1984).

A violation of a nutrient requirement equation in the linear programming example leads to an infeasible solution (Lara & Romero, 1994). The nutrient requirements stipulated by the consultant are only estimates of the actual requirements. Some relaxation of nutrient constraints should not seriously affect crop yield; in some cases a drop in yield may be compensated by a decrease in the cost of the fertiliser (Mínguez, Romero & Domingo, 1988). The rigidity of the constraints built into a linear programming model is manifest in the fixed values assigned to the right-hand side parameters and the equal importance attached to each (Rehman & Romero, 1987). Methods of overcoming these rigidities with the use of goal programming and compromise programming are introduced in the forthcoming sections.

4.3. Goal programming

There are many techniques for solving problems with multiple objectives. Amongst the most popular of these techniques is goal programming (Zanakis & Gupta, 1985), which was first introduced by Charnes, Cooper and Ferguson (1955), and Charnes and Cooper (1961). Generally, goal programming is said to be a quantitative decision making tool, which as closely as possible seeks a feasible solution that achieves a certain set of desired, but adjustable, goals (Min & Storbeck, 1991).

Goal programming models are based on the assumption that for each criterion the decision maker chooses a goal value and whether to penalise positive and, or, negative deviations from the specified target (Jones & Tamiz, 1995). The weighted goal programming method minimises a single objective function which consists of the sum of the deviations between each goal's target and the actual value achieved (Jones & Tamiz, 1995). Alternatively, with lexicographic (pre-emptive) goal programming the deviations, according to their importance, are grouped into priority levels with higher levels being considered as much more important than lower levels. The solution aims to satisfy the goals at the highest priority level first and then each of the lower levels in turn (Morris & Lerro, 1984). Although much of the early work on goal programming used the lexicographic method, in the literature most authors now use the weighted goal programming method or derivatives of it.

4.3.1. Goal programming terminology

The terms used in the goal programming paradigm differ from those used in linear programming. As the literature on goal programming has evolved so to have the definitions of the terms used. The early literature on the subject often treats the terms goal and objective as the same (see, for example, Ignizio (1976)). The definitions presented here and used throughout this work are based mainly on those from Romero and Rehman (1989). The terms attributes, objectives, targets and goals are now introduced.

Attributes are an indication of the degree to which alternative policies meet an objective (Keeney & Raiffa, 1993). The value of an attribute can be measured independently of the decision maker's desires and can often be expressed as a mathematical function, $f(x)$, of the decision variables (x).

Objectives represent directions in improvement in an attribute (Romero & Rehman, 1989). Objectives imply the maximisation or minimisation of the functions that represent attributes, for example, maximising value added, minimising risk, and minimising cost. In general, objectives take the form of max. $f(x)$ or min. $f(x)$. Objectives are not limited to just one attribute, and may contain two or more, for example, max. $f1(x) + f2(x)$.

Goals are the result of the combination of an attribute and a target (Romero & Rehman, 1989). Targets or aspiration levels represent an acceptable level of achievement for an attribute. Although goals and constraints are similar their difference lies in the interpretation of the right hand side of the equation. The right hand side of a goal equation refers to the target a decision maker aspires to, which may or may not be achieved. However, the right hand side of a constraint equation refers to a level that must be attained, if it is not, then the problem is infeasible.

4.3.2. The general goal program model

The general form of the weighted goal programming model can be expressed mathematically as Equation 4 through to Equation 8.

Equation 4 $$\text{Min}\sum_{i=1}^{m}\left(\frac{W_i^{+}d_i^{+} + W_i^{-}d_i^{-}}{g_i}\right)$$

Subject to

Equation 5 $$f_i(\underline{x}) - d_i^{+} + d_i^{-} = g_i \quad 1 \le i \le m$$

Equation 6 $$d_i^{+} + d_i^{-} \ge 0$$

Equation 7 $$d_i^{+} \cdot d_i^{-} = 0$$

Equation 8 $$\underline{x} \in \underline{F}$$

Where

d_i^{+} *the positive deviation of the i^{th} goal*

d_i^{-} *the negative deviation of the i^{th} goal*

g_i	*the target of the i^{th} goal*
F	*the feasible region*
W_i^+	*a weight assigned to a positive deviation of the i^{th} goal*
W_i^-	*a weight assigned to a negative deviation of the i^{th} goal*
x	*a vector of decision variables*

In the goal programming model formulation presented, $d_i^+ \cdot d_i^- = 0$ is a necessary condition for optimality (Charnes & Cooper, 1977). Min and Storbeck (1991) note that to avoid the non-linearity that $d_i^+ \cdot d_i^- = 0$ imposes it is not usually included in the formulation. This is because the work of most authors revolves around using linear solvers. However, Equation 10 and Equation 11, which are used to calculate the values of di+ and di- always ensure that one of the variables will equal zero, therefore, making the need for redundant.

4.3.3. Satisficing verses optimising

With linear programming the aim is to attain an optimum solution, while in the goal programming paradigm the aim of the solution is that of satisficing human aspirations by proposing solutions that come as close as possible to the desired target levels (Min & Storbeck, 1991). Consequently, when the solution is deemed unsatisfactory, goal programming allows the decision maker to alter their aspiration levels (goals) in an effort to seek a better solution (Min & Storbeck, 1991).

The concept of satisficing was introduced by Simon (1961) who studied the behaviour of people that satisfice because they do not have the time or resources to obtain an optimal solution. Eilon (1972. p. 9) contributed further to this concept and states:

> *Optimising is the science of the ultimate: the optimizer sets off in a single-minded fashion to determine the best solution to a given problem in given circumstances. On the other hand, satisficing is the art of the feasible: the satisficer acquiesces with the proposition that it is seldom possible to design the ultimate in unambiguous terms, and it is sufficient to do well enough (preferably a little better than on previous occasions), namely to find a feasible solution to his problem.*

Zeleny (1981) suggests that the target values of goal programming are what the decision maker is trying to obtain from the analysis and are really output variables rather than input variables. Zeleny (1981) also adds that determining appropriate target values without knowing the potential values provided by a feasible set of alternatives could be difficult and too arbitrary. These views, however, are based on the assumption as stated by Yu (1985) that more (when maximising), or less (when minimising), of an objective is better (e.g., cost minimisation), however, this may not be the case (e.g., attaining a specified level of nitrogen from a given combination of fertilisers). Although, in the case where more or less of an objective is preferred an infeasible high or low value respectively for target levels of goals can be set to overcome this problem (Min & Storbeck, 1991).

4.3.4. Goal programming and preference modelling

Goal programming, in spite of its advantages over linear programming for tackling the fertiliser combination problem has the weakness of assuming a marginal relaxation in the achievement of a certain goal is equally important, no matter how distant the marginal change is from the target (Mínguez, Romero & Domingo, 1988). Take, for example, the target nutrient requirement of 100 kg's for nutrient x, with an improvement in the application rate of 1 kg from 150 kg to 149 kg or from 97 kg to 98 kg it is unrealistic to assume that these marginal changes will have the same effect on crop yield or that the decision maker would get the same satisfaction from these changes in trying to achieve the target value. In an attempt to overcome this difficulty associated with goal programming authors such as Charnes, Cooper, Harrald, Karwan and Wallace (1976), Rehman and Romero (1987), Mínguez, Romero and Domingo (1988) and Jones and Tamiz (1995) have pursued techniques that alter the weight of the penalisation as the distance from the target changes.

This method of penalising differently as the distance from the target changes is known as preference modelling or adding penalty functions. There are four basic types of preference modelling; increasing penalty, reverse penalty, discontinuity in preference, and non-linear preferences, note that any combination of these can be used together. The concept behind each of these four types are now summarised, for a full description and how to implement them into a goal programming model see Jones and Tamiz (1995). In the case of an increasing penalty the decision maker assigns a heavier weight per unit deviation at some point from the target, this is illustrated in Figure 6. For the reverse penalty the decision maker wants to decrease the penalty per unit at some point distant from the target as shown in Figure 7. In the case where at a certain threshold there is a sudden increase in the decision makers dissatisfaction a discontinuous penalty is used, this, coupled with an increasing penalty, is shown in Figure 8. If the particular solver being used does not allow for non-linear equations then an approximation of a curve can be used. A curve is approximated using a series of straight lines, these can then be modelled as a reverse or increasing penalty as seen in Figure 9.

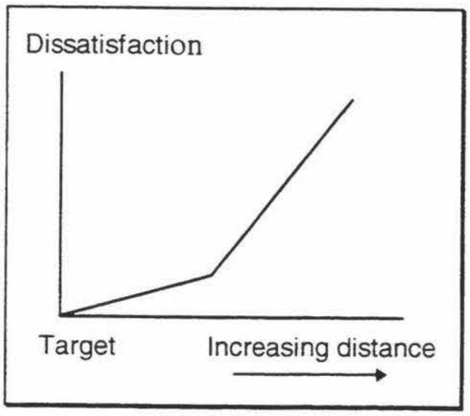


Figure 6 An increasing penalty

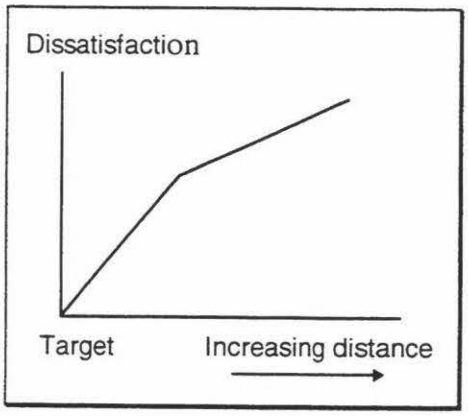


Figure 7 A reverse penalty

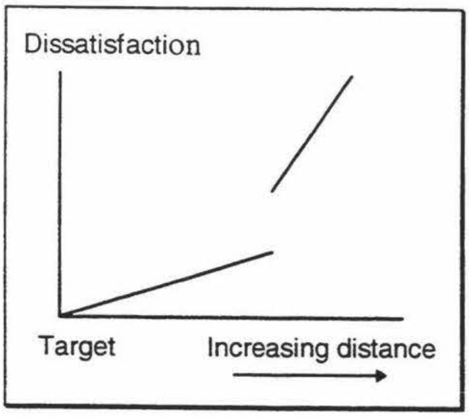


Figure 8 A discontinuous preference with an increasing penalty.

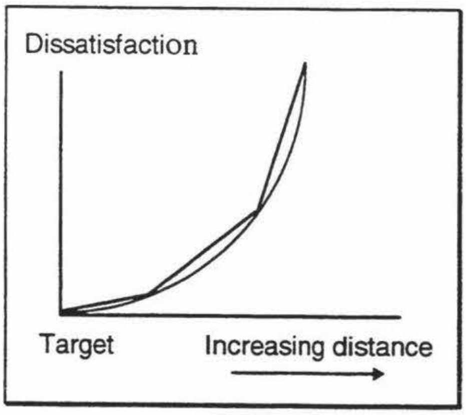


Figure 9 A linear piecewise approximation of a non-linear preference curve.

Rehman and Romero (1987) used an increasing penalty in an animal ration formulation problem. The purpose of their study was to demonstrate the use of penalties rather than describe an application of their use for a real problem. For this, a simple example was used, and the penalties chosen were arbitrary (Rehman & Romero, 1987). Mínguez, Romero and Domingo (1988) took a similar approach in finding the optimum combination of fertilisers for a sugarbeet crop. Rehman and Romero (1987) note that prior to practical implementation of goal programming with penalty functions, research into how livestock performance responds to incremental changes in intake of various nutrients is needed. Mínguez, Romero and Domingo (1988) also noted this problem of setting appropriate penalty scales. Mínguez, Romero and Domingo (1988) state that by including penalty functions it is possible to distinguish the importance of the marginal relaxation in the achievement of certain goals, depending on how far the marginal change is from the targets. However, research regarding crop response to marginal changes in nutrients applied under a range of climatic and soil conditions is required to establish useful penalty functions, but is currently not available.

4.4. Compromise programming

The foundation of compromise programming is based on Zeleny's (1973) axiom of choice, which states that *alternatives which are closer to the ideal are preferred to those that are further away*. Thus, the basic aim in compromise programming is to identify the ideal points for each decision variable and then seek a solution which is as close as possible to these ideal points (Romero & Rehman, 1989). The ideal solution is defined as the one where all of the objective functions reach their preferred values (Zeleny, 1973), which usually implies the minimisation or maximisation of the functions. Although the ideal solution may be achievable in some cases, generally, such a point is infeasible and a compromise solution will be needed (Zeleny, 1973). A compromise solution is a best approximation to the ideal solution with respect to a distance function (Zeleny, 1984).

4.4.1. The distance function concept

Acceptable measures of closeness to the ideal must be determined. To achieve this Zeleny (1973) proposed the use of a family of distance measures known as L_p metrics, which provide a generalisation of Euclidean distance. This multi-dimensional geometrical concept is abstracted to measure human preference distance (Romero & Rehman, 1989). The general formulation of a distance function as based on that presented by Zeleny (1973), Romero (1985a) and Yu (1985) is shown in equation Equation 9.

Equation 9 $$\text{Min } L_p(\underline{x}) = \left[\sum_{i=1}^{m} W_i \left| f_i^* - f_i(\underline{x}) \right|^p \right]^{\frac{1}{p}}, \quad 1 \leq p \leq \infty$$

Subject to

$$\underline{x} \leq \underline{F}$$

Where

F	*the feasible set*
*fi**	*the ideal value of the ith objective*
fi(x)*	*the ith objective function*
Lp(x)	*the compromise solution, a vector of decision variable values for a specific value of p*
m	*the number of objectives*
p	*a parameter that implicitly weights the magnitude of the deviations / distance between the ideal and actual values*
Wi	*weight attached to the ith objective*
x	*a vector of decision variables*

Using several values of the parameter p such as 1, 2 and ∞, approximate what Zeleny (1973) refers to as the compromise set, that is, a group of compromise solutions from which the decision maker can choose a satisficing solution.

If a decision maker attaches equal importance to all objectives, then the particular choice of L_p metric can be interpreted as an implicit assignment of weights to individual deviations (Zeleny, 1973). The underlying assumption of equal importance is not affected by this weighting and the choice of L_p metric simply reflects the way of achieving a compromise (Zeleny, 1973). At any solution there will always be one function that will have the worst value with respect to the ideal solution, this maximal deviation is of major interest (Zeleny, 1973). The aim is to decrease this maximal deviation in relation to all other deviations, to a certain degree, the degree of concern is reflected by the choice of p (Zeleny, 1973).

The use of 1, 2, and ∞ as values for p allows the emphasis of deviations differently in a way that can be easily understood by the decision maker. When $p=1$ the magnitude of all deviations are weighted equally (Zeleny, 1973). Therefore, regardless of the size of the deviation, the difference between the objective function value and its ideal, the weight attached is the same. For $p=2$ the deviations are squared and as Zeleny (1973) states the deviations are weighted proportionately, with the largest deviation having the largest weight. As p increases more and more weight is given to the largest of the specific deviations (Zeleny, 1973). Ultimately the largest deviation gets all the weight when $p=\infty$ (Zeleny, 1973).

4.4.2. Using general target points rather than ideal values

In compromise programming the objective function value is trying to reach the ideal point, however, this may not always be the case.

Using ideal values in compromise programming requires minimising or maximising objective functions. However, the decision maker may want to achieve some target that is not the result of minimising or maximising; instead the decision maker may want to obtain a value as close as possible around the general target point.

When using ideal values with Equation 9 $f_i^* \geq f_i(\underline{x})$ holds, however, when using target values the value of the objective function may be either greater or less than the ideal value. The use of weights between objectives deals only with under achievement when using ideal values.

When using target points both under and over achievement of the target can occur and if the decision maker wants to attach different a weight to under and over achievement then the current formulation of the compromise programming model fails to allow for this.

The addition of deviation variables, as used in goal programming, to the general formulation of the compromise programming model can alleviate this problem. The deviation variables, using the notation and examples by Yu (1985) and Romero (1985a), are presented in Equation 10 to Equation 14. To denote the use of target values rather that ideal values f_i^* (the i^{th} ideal value) is replaced with g_i (the target value of the i^{th} objective).

Let:

Equation 10 $$d_i^+ = \frac{1}{2}\left[\left|g_i - f_i(\underline{x})\right| - (g_i - f_i(\underline{x}))\right]$$

Equation 11 $$d_i^+ = \frac{1}{2}\left[\left|g_i - f_i(\underline{x})\right| + (g_i - f_i(\underline{x}))\right]$$

Which are equivalent to:

$$d_i^+ = \begin{cases} f_i(\underline{x}) - g_i & \text{if } f_i(\underline{x}) > f_i^* \\ 0 & \text{otherwise} \end{cases}$$

$$d_i^- = \begin{cases} g_i - f_i(\underline{x}) & \text{if } f_i^* > f_i(\underline{x}) \\ 0 & \text{otherwise} \end{cases}$$

Then:

Equation 12 $$g_i - f_i(\underline{x}) = d_i^- - d_i^+$$

Equation 13 $$\left|g_i - f_i(\underline{x})\right| = d_i^- + d_i^+$$

Equation 14 $$d_i^-, d_i^+ \geq 0$$

Note that d_i^+ is the value of exceeding gi (i.e., a surplus value) and d_I^- is the value of below g_i (i.e., a slack variable). The definition of d_i^+ and d_I^- previously is only satisfied if and only if d_i^+ and d_I^- are nonnegative and satisfy the following as stated by Yu (1985).

$$g_i - f_i(\underline{x}) = d_i^- - d_i^+$$

$$d_i^- \cdot d_i^+ \geq 0$$

Yilmaz (1984) notes that for any positive value of p used the power $^1/_p$ can be omitted without effecting the compromise solutions generated. Thus, given a target point g_i

the compromise solution with L_p metric distance can be found by solving following (Yu, 1985).

Equation 15 $$\text{Min} \sum_{i=1}^{m} \left(d_i^- + d_i^+\right)^p, \quad 1 \leq p \leq \infty$$

Subject to

$$g_i - f_i(\underline{x}) = d_i^- - d_i^+$$

$$d_i^- \cdot d_i^+ = 0$$

$$d_i^-, d_i^+ \geq 0$$

$$\underline{x} \in \underline{F}$$

The constraint $d_i^- \cdot d_i^+ = 0$ is redundant and can be left out of the above set of equations because the method previously described to calculate d_i^+ and d_i^- ensures that only one can be positive. The constraint ensures that the values of conform to any technical constraints and, therefore, part of the feasible region.

Equation 15 is equivalent to Equation 16, but because either d_i^+ or d_i^- will always be equal to zero then the equation then becomes that shown in Equation 17.

Equation 16 $$\text{Min} \sum_{i=1}^{m} d_i^{+P} + 2d_i^+ d_i^- + d_i^-, \quad 1 \leq p \leq \infty$$

Equation 17 $$\text{Min} \sum_{i=1}^{m} d_i^{+P} + d_i^{-P}, \quad 1 \leq p \leq \infty$$

The assignment of weights to the positive and negative deviations as used in weighted goal programming is easily incorporated into compromise programming as shown in equation Eqn. 18.

Equation 18 $$\text{Min} \sum_{i=1}^{m} W_i^+ d_i^{+P} + W_i^- d_i^{-P}, \quad 1 \leq p \leq \infty$$

Assigning a set of weights, W_i, to the set of objectives can induce a double weighting by W_i and p simultaneously (Zeleny, 1973). When $p=1$ the size of the deviation is not considered rather only the relative weight assigned by W_i For p=2 all deviations are first weighted proportionately (i.e., depending on their distance from their goal) and then weighted by the squares of the weights, W_i, assigned originally. This double weighting is carried out for all values of p greater than 1 and less than infinity. When $p=\infty$ the relative weight is not taken into account, only the magnitude of the deviation is considered in generating the compromise solution.

Zeleny (1973) noted that a common mistake in discussion of L_p metrics is the use of deviations in an absolute sense, this was also commented on by Romero (1985) relating to goal programming. Absolute deviations cannot usually be compared due to varying units of measure and scale. To overcome this they recommend the use of relative (or percentage) deviations such as that shown in Equation 19.

Equation 19 $$\frac{g_i - f_i(\underline{x})}{g_i}$$

When incorporating the concept of relative deviations and weights into the distance function the following general formulation of a compromise program Lp metric is created:

Equation 20 $$\text{Min} \sum_{i=1}^{m} \left(\frac{W_i^+ d_i^{+p} + W_i^- d_i^{-p}}{g_i} \right), \quad 1 \leq \text{p} \leq \infty$$

Subject to:

Equation 21 $$f_i(\underline{x}) + d_i^- - d_i^+ = g_i$$

Equation 22 $$d_i^-, d_i^+ \geq 0$$

Equation 23 $$\underline{x} \in \underline{F}$$

Through the process of using deviation variables and target points, rather than ideal values, the objective functions have been converted into goals, while a new objective function is created that minimises the deviations between the target point and amount achieved. Comparing equations Equation 20 to Equation 23 with equations Equation 4 to Equation 6 it can be seen that these general formulations of the goal programming and compromise programming models are very similar. Using several values for p, that is, using several L_p metrics, transforms a goal programming model into a compromise programming model. Compromise programming with an L_1 metric is really goal programming (Romero & Rehman, 1989) and using the L_2 metric creates a quadratic program (Yu, 1985).

4.5. The model's optimisation technique

The aim of the model, as stated in the second objective in Section 1.5 Objectives, is to improve present fertiliser selection processes. The component described as the optimisation process in Chapter Two is part of the model being created to achieve this. The specific objectives of the optimisation and the mathematical equations and techniques used to achieve them are presented in this section.

The objectives to incorporate into the mathematical model are as follows:

Minimise the excess of unrequired nutrients in the fertiliser mix.

Provide a fertiliser mix that as closely as possible meets the desired nutrient requirements.

Allow for minimum and maximum bounds on nutrient levels contained in the fertiliser mix.

Allow the consultant to specify relationships between a nutrient or fertiliser and any other nutrient or fertiliser.

The first objective refers to three types of excesses, those relating to nutrient quantities over and above the specified requirements, those relating to nutrients in the fertiliser mix that are not required (i.e., set implicitly at zero) and those relating to an imbalance in a specified relationship between nutrients or fertilisers.

The second objective incorporates the first and aims to select a mix that minimises deficiencies (i.e., deviations between the required amount of a nutrient and the amount supplied by the fertiliser mix).

The third objective allows the consultant to set minimum or maximum values on the amount of a specific nutrient that can be contained in a fertiliser mix (i.e., allowing the consultant to enter an upper and, or lower nutrient quantity range).

The fourth objective allows the consultant to specify relationships or ratios between nutrients and fertilisers. The relationships can be between two nutrients, two fertilisers or a nutrient in a fertiliser, and the nutrient and another nutrient in all fertilisers. An example of a common relationship in the kiwifruit industry is where the quantity of potassium may, for example, have to be supplied by at least 50% from potassium sulphate, while the remaining 50% or less can come from potassium chloride. This example can be formulated in several ways such as:

- At least 50% of all potassium must come from potassium sulphate.
- The quantity of potassium from potassium chloride must be less than the amount obtained from potassium sulphate.
- The first example is a ratio between a nutrient and a fertiliser, while the second is a ratio between two fertilisers.

The optimisation component of the decision support system is based on compromise programming. A compromise programming model was chosen over a goal programming model because compromise programming allows the generation of a compromise set, thus giving the decision maker a choice of several options (one for each value of p used) rather than just one as with goal programming. Educating the decision maker so that they are aware of how the options differ will give them a better idea of why the particular solution is the way it is, i.e., what was minimised and what priorities were used in minimising the deviations.

4.5.1. The decision support systems' optimisation component equations

The equations are presented here and followed with a discussion that describes them.

The objective function is to:

Equation 24

$$\text{Min} \sum_{i=1}^{m} \left(W_i^- \left(\frac{d_i^-}{g_i} \right)^p + W_i^+ \left(\frac{d_i^+}{g_i} \right)^p \right) + \left(V^- \left(\frac{e^-}{h} \right)^p + V^+ \left(\frac{e^+}{h} \right)^p \right) \quad \text{for } p = 1, 2, \infty$$

Subject to:

Cost goal

Equation 25 $$\sum_{j=1}^{n} c_j x_j + e^- - e^+ = h$$

Nutrient goals

Equation 26 $$\sum_{j=1}^{n} a_{ij} x_j + d_i^- - d_i^+ = g_i \quad 1 \le i \le m$$

Constraints

Equation 27 $$b_i^{\min} \le r\sum_{j=1}^{n} a_{ij}x_j \le b_i^{\max} \quad 1 \le i \le m$$

Equation 28 $$\sum_{j=1}^{n} a_{kj}x_j \le, =, \text{or} \ge r\sum_{j=1}^{n} a_{ij}x_j \quad 1 \le k \le m, 1 \le i \le m, i \ne k$$

Equation 29 $$x_t \le, =, \text{or} \ge rx_u \quad 1 \le t \le n, 1 \le u \le n, t \ne u$$

Equation 30 $$a_{lv}x_v \le, =, \text{or} \ge r\sum_{j=1}^{n} a_{vj}x_j \quad 1 \le l \le m, 1 \le v \le m$$

Equation 31 $$d_i^+ = \frac{1}{2}\left[\left|g_i - \sum_{j=1}^{n} a_{ij}x_j\right| - \left(g_i - \sum_{j=1}^{n} a_{ij}x_j\right)\right]$$

Equation 32 $$d_i^- = \frac{1}{2}\left[\left|g_i - \sum_{j=1}^{n} a_{ij}x_j\right| + \left(g_i - \sum_{j=1}^{n} a_{ij}x_j\right)\right]$$

Equation 33 $$d_i^- = \frac{1}{2}\left[\left|g_i - \sum_{j=1}^{n} a_{ij}x_j\right| + \left(g_i - \sum_{j=1}^{n} a_{ij}x_j\right)\right]$$

Equation 34 $$e^- = \frac{1}{2}\left[\left|h - \sum_{j=1}^{n} c_jx_j\right| + \left(h - \sum_{j=1}^{n} c_jx_j\right)\right]$$

Equation 35 $$d_i^-, d_i^+ \ge 0$$

Equation 36 $$e^-, e^+ \ge 0$$

Where:

a_{ij} *the quantity of the i^{th} nutrient in the j^{th} fertiliser*

b_i^{max} *the maximum amount of the i^{th} nutrient allowable in the fertiliser mix*

b_i^{min} *the minimum amount of the i^{th} nutrient allowable in the fertiliser mix*

c_j *the cost of the j^{th} fertiliser*

the negative deviation of the i^{th} nutrient goal

the positive deviation of the i^{th} nutrient goal

e^- *the negative deviation of the cost goal*

e^+ *the positive deviation of the cost goal*

g_i *the target of the i^{th} nutrient goal*

h *the target of the cost goal*

m *the number of nutrients*

n *the number of fertilisers*

p *the parameter of an L_p metric used to weight distance*

r *the ratio coefficient of a relationship*

V^- *a weight assigned to the negative deviation of the cost goal*

V^+ *a weight assigned to the positive deviation of the cost goal*

a weight assigned to the negative deviation of the i^{th} nutrient goal

a weight assigned to the positive deviation of the i^{th} nutrient goal

x_j *the quantity of the j^{th} fertiliser*

The sum of the objective function represents the total of all deviations (i.e., the difference between the targets of each goal and the actual amount in the solution). A negative deviation occurs when a target for a goal is under achieved, while a positive deviation refers to the amount of over achievement of a goal's target. Each deviation, whether it be positive or negative, is divided by its respective goal's target that it measures the deviation from. This is so that the deviations represent a percentage (relative) rather than absolute deviation from the targets of goals. The actual value of the objective function depends on the value of p used. The objective function is a means to an end, in that minimising it allows the generation of a compromise solution that best approximates the targets of the decision variables sought after.

The weights, W_i^- and W_i^+, in Equation 24 are used to emphasise the relative importance of particular goals and can be set differently for positive and negative deviations from the goal's target. The values that W_i^- and W_i^+ can be either positive or negative. In this model the use of negative weights are used to reward solutions that reduce the cost of the fertiliser mix below the specified target of the cost goal.

In the model by Mínguez, Romero and Domingo (1988) for determining optimum fertiliser combinations if the cost of the fertiliser mix drops below the target it is not rewarded. This failure to reward when the cost drops below the target may result in the best solution not being reached. In this model a negative weight is attached to V^- so that negative deviations from the target point of the goal are rewarded. Goal one refers to the cost of the fertiliser mix and its target point is based on the least cost solution of a similar linear program version of the model (see section 4.5.2 Solving the optimisation component for information about this linear programme). Due to the relaxation of the constraints (in particular, nutrient requirements) of the linear program version of the model it is possible to actually achieve a cost of the fertiliser mix that is lower than the linear program solution, therefore, the ability to achieve a lower fertiliser mix cost needs rewarding. This rewarding of a cheaper fertiliser mix is achieved through the negative weighting of a negative deviation from the cost goal target and the level achieved.

Three values of the parameter p are used, one, two and infinity. The value of p used when minimising the objective function will influence the solution generated due to the way in which the value of p weights the magnitude of the deviations. When $p=1$ the size of the deviation has no bearing on which deviation should be reduced to improve the value of the objective function, thus all deviations are treated equally. When $p=2$ the deviations are squared and, therefore, as a deviation increases in size it does so at an exponential rate, therefore, the largest deviations are minimised in preference to small deviations as this leads to a better improvement in the value of the objective function. When $p=\infty$ only the largest deviation is of concern and, therefore, the best improvement in the objective function comes from reducing the size of the largest deviation.

The goal depicted in Equation 25 is required to determine the positive and negative deviations between the cost of the fertiliser mix and the target value for the cost of the mix goal (goal one). The target value used for this goal is required and can be generated from the solution to a linear programme discussed later in section 4.5.2 Solving the optimisation component Solving the optimisation component.

The nutrient requirement goals are based on Equation 26. This equation determines the positive and negative deviation variables for each nutrient where the quantity of the nutrient in the fertiliser mix differs from the target requirement of the particular goal.

A constraint to the upper and lower bounds of the quantity of any nutrients is achieved with Equation 27. This equation sums the quantity of each nutrient supplied in the fertiliser mix and ensures it is below the threshold for the maximum or above the threshold specified for the minimum constraint.

A relationship between two nutrients is what Equation 28 specifies. The equation ensures that a nutrient supplied by fertilisers in the fertiliser mix solution is either less than or equal to, equal to, or greater than or equal to the quantity of a different nutrient supplied by fertilisers in the solution multiplied by a ratio. The ratio can take any value that is greater than zero, if it were zero the constraint would be redundant, if it were less than zero the problem would be infeasible.

Equation 29 maintains any specified relationships between two fertilisers. The equation ensures that the quantity of a fertiliser is either less than or equal to, equal to, or greater than or equal to the quantity of another fertiliser multiplied by ratio.

The next type of relationship, one between a particular nutrient in a fertiliser and all other fertilisers containing the same or a different nutrient is possible with Equation 30. The equation ensures that the quantity of a nutrient supplied by a fertiliser is either less than or equal to, equal to, or greater than or equal to the quantity of a nutrient supplied by all fertilisers multiplied by ratio. The nutrient on each side of the equation can be the same nutrient.

4.5.2. Solving the optimisation component

The equations of the optimisation component of the decision support system are non-linear. Being non-linear it is more difficult to find a solution to the problem, especially as the number of goals and constraints increase. To overcome this inability to always find the optimum solution the use of starting values that approximate what the solution may be is recommended by Mínguez, Romero and Domingo (1988).

Appropriate starting values for the fertiliser mix cost goal and starting values for fertiliser quantities need determining. Although both could be set at zero, this would most likely lead to the generation of an erroneous solution. Mínguez, Romero and Domingo (1988) use the least cost of a linear program as the target for a goal programming model used to determine optimum fertiliser combinations. The advantage of using a linear programme is that it is quick to solve and gives a good realistic value for the cost goal.

Using the solution of the problem formulated as a linear program provides an approximate answer, it also generally speeds up the finding of a compromise programming solution because the magnitude of the values in the solution (i.e., the quantities of each fertiliser) do not have to be determined first. This does not mean that these will be the fertilisers in the final solution chosen by the decision maker, but rather the relative size of the quantity of any of the fertilisers that may be chosen.

Both these starting values, cost and fertiliser quantities, can be obtained from a single linear programming. The linear programming problem that is solved to obtain the starting values for the compromise programming problem differs slightly from the problem solved using compromise programming. The linear programming specification of the problem is linear rather than non-linear and treats all nutrient requirements as absolute constraints and thus their values must be achieved rather than goals that may, or may not, be achieved. The following equations outline the general linear programming formulation of the fertiliser combination problem to be solved to gain initial starting values for the compromise programming problem.

Objective function

Equation 37 $$\text{Min} \sum_{j=1}^{n} c_j x_j = g_i \quad 1 \le i \le m$$

Subject to

Equation 38 $$\sum_{j=1}^{n} a_{ij} x_j \geq g_i \quad 1 \leq i \leq m$$

Equation 39 $$b_i^{min} \leq r \sum_{j=1}^{n} a_{ij} x_j \leq b_i^{max} \quad 1 \leq i \leq m$$

Equation 40 $$\sum_{j=1}^{n} a_{kj} x_j \leq, =, \text{or} \geq r \sum_{j=1}^{n} a_{ij} x_j \quad 1 \leq k \leq m, 1 \leq i \leq m, i \neq k$$

Equation 41 $$x_t \leq, =, \text{or} \geq rx_u \quad 1 \leq t \leq n, 1 \leq u \leq n, t \neq u$$

Equation 42 $$a_{l\gamma} x_{\gamma} \leq, =, \text{ or } \geq r \sum_{j=1}^{n} a_{vj} x_j \quad 1 \leq l \leq m,\ 1 \leq v \leq m$$

The objective function of the linear program, Equation 37, minimises the cost of the fertiliser mix. The value of the objective function generated from solving this problem is then used as the target for the compromise programming problem. To ensure that the nutrient requirements are meet by the fertilisers in the solution equation Equation 38 is added as a constraint. The other constraints, Equation 39 to Equation 42, are the same as those in the compromise program formulation of the problem and refer to the maximum and minimum nutrient quantity bounds and nutrient and fertiliser relationships.

4.5.3. Model solution

Four solutions are generated by the model for presentation to the consultant, these solutions are; a least cost linear program based solution and three compromise program solutions based on the L_1, L_2 and L_∞ metrics (i.e., $p = 1, 2$ and ∞). The linear program treats the nutrient requirements as constraints, while the compromise program treats them as goals. Each of these solutions consists of the cost of the mix, the quantities of each fertiliser used, and the quantity of each nutrient supplied by the particular mix.

4.6. Summary

In this chapter various mathematical modelling techniques have been reviewed that could be used to find a suitable combination of fertilisers for use on horticultural crops. Linear programming, although often used in the past has over rigid constraints and it's inability to work with multiple objectives does not suit it for the fertiliser problem. Weighted goal programming is an improvement on linear programming; it suffers, however, from producing only a single solution and that any marginal change in a deviation, no matter how far from the target, is considered the same. The use of penalty functions was described to overcome this problem with marginal change and distance from the target. However, the information necessary to set non-arbitrary penalties is near impossible due to the lack of research into crop response to fertilisers under a wide range of conditions. The next technique introduced was compromise programming, a similar approach to goal programming that allows for weighting the magnitude of the deviations. So rather than trying to develop custom penalty functions, those implied by using various values of p are used instead. With the use of several values of p a set of solutions are generated that each weight the deviations differently.

The optimisation model created for this study uses a compromise programming approach. The objective function minimises the deviation from the targets of a cost goal and nutrient requirement goals. Minimum and maximum nutrient requirements can be set along with ensuring specified relationships between nutrients and, or, fertilisers are held. A least cost fertiliser mix linear program is used to generate good starting values for the quantities of fertilisers and the target value of the mix cost due to the compromise programme problem being non-linear. The compromise solution set presented to the consultant from the compromise program consists of four fertiliser mixes, three based on solutions from using the L_1, L_2 and L_∞ metrics and another from a linear programme solution.

The next chapter presents a description of the databases that store the information used in the optimisation model and the information the model generates.

4.7. References

Black, J. R., & Hlubik, J. (1980). Basics of computerized linear programs for ration formulation. Journal of Dairy Science, 63, 1366-1378.

Brown, L. (Ed.). (1993). The new shorter oxford English dictionary (Vol. 2). Oxford: Clarendon Press.

Charnes, A., Cooper, W., & Ferguson, R. (1955). Optimal estimation of executive compensation by linear programming. Management Science, 19, 357-368.

Charnes, A., Cooper, W. W. (1961). Management models and industrial applications of linear programming (Vol. 1). New York: Wiley.

Charnes, A., Cooper, W. (1977). Goal programming and multiple objective optimizations, Part 1. European Journal of Operational Research, 1, 39-54.

Charnes, A., Cooper, W. W., Harrald, J., Karwan, K., & Wallace, W. (1976). A goal interval programming model for resource allocation in a marine environmental problem. Journal of Environmental Economic Management, 3, 347-362.

Crabtree, J. R. (1982). Interactive formulation system for cattle diets. Agricultural Systems, 8, 291-308.

Dent, J. B., & Casey, H. (1967). Linear programming and animal nutrition. London: Crosby Lockwood.

Eilon, S. (1972). Goals and constraints in decision making. Operational Research Quarterly, 23, 3-15.

Hannan, E. L. (1984). Goal programming: Methodological advances in 1973-1982 and prospects for the future. In H. Thomas (Series Ed.) & M. Zeleny (Vol. Ed.), Decision research: Vol. 1. MCDM Past decade and future trends: A source book of multiple criteria decision making (pp. 117-151). Greenwhich, Connecticut: Jai Press.

Ignizio, J. P. (1976). Goal programming and extensions. Lexington, Massachusetts: Heath (Lexington Books).

Jones, D. F. & Tamiz, M. (1995). Expanding the flexibility of goal programming via preferences modelling techniques. OMEGA, The International Journal of Management Science, 23(1), 41-48.

Keeney, R. L., & Raiffa, H. (1993). Decisions with multiple objectives: preferences and value trade-offs. New York: Cambridge University Press.

Lara, P., & Romero, C. (1994). Relaxation of nutrient requirements on livestock rations through interactive multigoal programming. Agricultural Systems, 45(4), 413-453.

Min, H., & Storbeck, J. (1991). On the origin and persistence of misconceptions in goal programming. Journal of the Operational Research Society, 42(4), 301-312.

Mínguez, M. I., Romero, C., & Domingo, J. (1988). Determining optimum fertiliser combinations through goal programming with penalty functions: An application to sugar beet production in Spain. Journal of the Operational Research Society, 39(1), 61-70.

Morris, R. L., & Lerro, A. J. (1984). A comparison of goal programming and multiobjective linear programming. The Mid-Atlantic Journal of Business, 23(1), 35-44.

Rehman, T., & Romero, C. (1984). Multiple-criteria decision-making techniques and their role in livestock ration formulation. Agricultural Systems, 15(1), 23-49.

Rehman, T., & Romero, C. (1987). Goal programming with penalty functions and livestock ration formulation. Agricultural Systems, 23, 117-132.

Romero, C. (1985). Multi-objective and goal programming approaches as a distance function model. Journal of the Operational Research Society, 36(3), 249-251.

Romero, C. (1985). Naive weighting in non-preemptive goal programming (Letter to the Editor). Journal of the Operational Research Society, 36(7), 647-648.

Romero, C., & Rehman, T. (1989). Developments in agricultural economics: Vol. 5. Multiple criteria analysis for agricultural decisions. Amsterdam: Elsevier.

Simon, H. A. (1961). Administrative behaviour. New York: Macmillan.

Yilmaz, M. R. (1984). A theory of the displaced ideal with decisions under uncertainty. In H. Thomas (Series Ed.) & M. Zeleny (Vol. Ed.), Decision research: Vol. 1. MCDM Past decade and future trends: A source book of multiple criteria decision making (pp. 101-116). Greenwhich, Connecticut: Jai Press.

Yu, P. L. (1985). Multiple criteria decision making: Concepts, techniques, and extensions. In A. Miele (Series Ed.). Mathematical concepts and methods in science and engineering: Vol. 30. New York: Plenum Press.

Zanakis, S. H., & Gupta, S. K. (1985). A categorized bibliographic survey of goal programming. Omega, 13(3), 211-222.

Zeleny, M. (1973). Compromise programming. In J. L. Cochrane, & M. Zeleny (Eds.). Multiple criteria decision making (pp. 262-301). Columbia, South Carolina: University of South Carolina Press.

Zeleny, M. (Vol. Ed.) (1984). MCDM: Past decade and future trends: A source book of multiple criteria decision making (pp. 86) In H. Thomas (Series Ed.). Decision research: Vol. 1. Greenwhich, Connecticut: Jai Press.

Chapter 5

Databases of the decision support system

5.1. Introduction

The decision support system described in Chapter Three requires the development of two databases, one to store fertiliser information and another to store fertiliser recommendation information about each of the consultants' clients. The two databases of the decision support system are described in this chapter using the techniques learnt from the review of the literature in Appendix Four An introduction to databases. This appendix describes the fundamentals and design of databases, and the entity-relationship approach to semantic database modelling. User views of information are used to determine the data requirements of the databases. These are then used to develop conceptual data models using entity-relationship diagrams.

5.2. The fertiliser information database

In this section, the fertiliser information database is presented. The requirements analysis of the database is presented followed by a description of the different user views; these are then combined to form a conceptual data model of the database. The structure of the database that is implied by the entity-relationship diagram is described. The description of the fertiliser information database uses the concepts and notations presented in Appendix Four An introduction to databases.

5.2.1. A statement of requirements

The fertiliser information database is part of the decision support system presented in Chapter Three. The purpose of the database is to store information about fertilisers. The end use of the information is inclusion in a fertiliser recommendation report prepared by a consultant for a grower. Prior to inclusion in these reports, potential fertilisers are selected and used in the optimisation routine described in the previous chapter. Information about fertilisers (e.g., price and nutrient analysis) is included in the solution of the optimisation routine along with the quantities to use, which are then often used in the recommendation report prepared by the consultant.

5.2.2. User views of the fertiliser database

Different segments of the fertiliser industry form the basis of the four user views of the information stored in the database. These four user views, presented in Figure 10, are; a description of the fertilisers, fertilisers price lists, and the costs charged by spreading and cartage contractors. Analysis of the information within each user view leads to the development of an entity-relationship diagram, which is then presented and described.

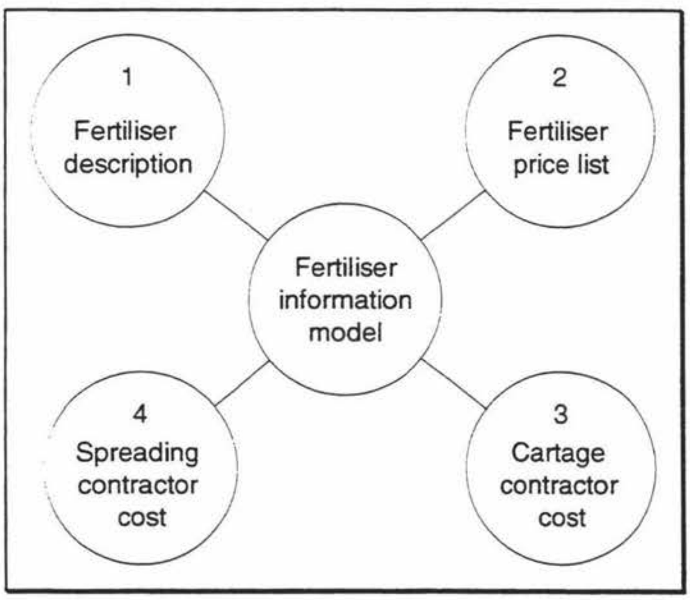


Figure 10 User views of information from the fertiliser industry.

5.2.3. Fertiliser description

The fertiliser description view in Figure 11 shows an example list of fertilisers that a manufacture produces. Each fertiliser manufactured is described by, and referred to by, it's nutrient analysis (i.e., nutrient constituents). The nutrient analysis of the fertiliser is published by the manufacture and is readily available from them or other companies that sell their fertiliser. The manufacturer in this case is the company that produces and then sells fertiliser to merchants, who then sell the fertilisers to growers. Note that a manufacturer may also act as a merchant and sell via its depots to growers. The cost of the fertiliser to the grower is not included in this view, as it will typically vary with who is selling the particular fertiliser to the grower. In Figure 12 an entity-relationship diagram representing the structure of the fertiliser description view is shown.

Manufacturer

ABC Fertiliser Limited
XYZ works
Private Bag
Taupo

Contact:
John Smith
Hort Products Sales Manager

Fertiliser analysis

Fertiliser name	% N	% P	% citric soluble P	% K	% S	S Availability	% Mg	% Ca
Nitrogen fertilisers								
Ammonium sulphate	21.0	0.0	0.0	0.0	24.0	Immediate	0.0	0.0
Urea	46.0	0.0	0.0	0.0	0.0	-	0.0	0.0
Calcium ammonium nitrate	27.0	0.0	0.0	0.0	0.0	-	0.0	8.0
Nitrophoska fertilisers								
Nitrophoska	12.0	10.4	10.4	10.0	1.0	Immediate	0.0	6.0
Floranid permanent	15.0	4.0	4.0	13.0	5.0	Immediate	1.2	0.0
Horticultural products								
Magnesium oxide (Calcined Magnesite)	0.0	0.0	0.0	0.0	0.0	-	52.0	0.0
Magnesium Sulphate (Kieserite)	0.0	0.0	0.0	0.0	20.0	Immediate	15.0	0.0
Magnesium Sulphate (Epsom Salts)	0.0	0.0	0.0	0.0	13.0	Immediate	10.0	0.0

Figure 11 The fertiliser description view depicting the analysis of fertilisers and contact information of the company that manufactures the fertilisers.

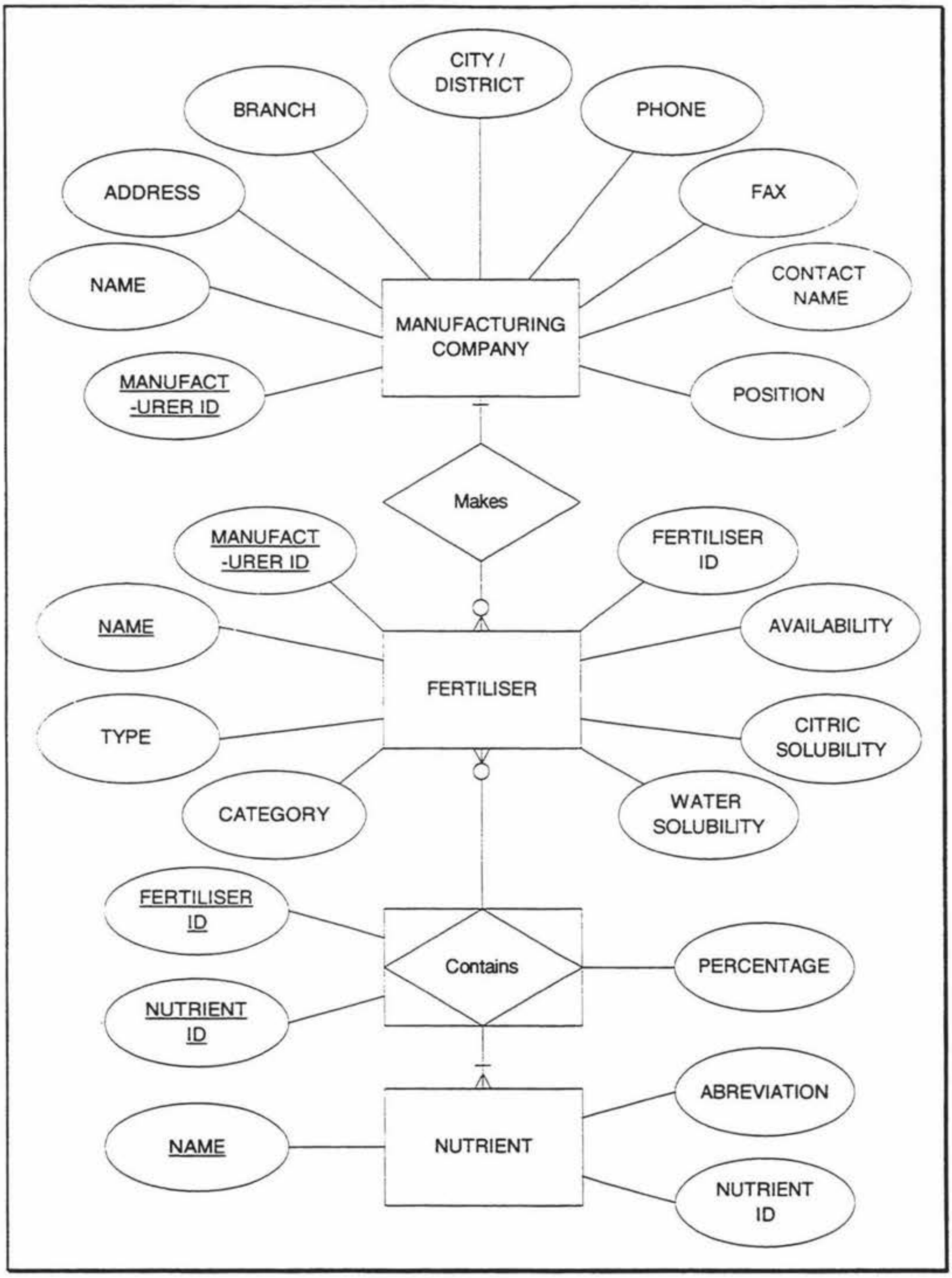


Figure 12 An entity-relationship diagram of the fertiliser description view.

Each instance of MANUFACTURER refers to a fertiliser manufacturing company and its attributes refer to contact information. The fertilisers each manufacturer produces are listed as instances of FERTILISER. Although the primary key of MANUFACTURER could have been based on the attributes NAME, ADDRESS, TOWN and CITY / DISTRICT, a single valued surrogate, called MANUFACTURER ID, was chosen instead because it is possible that several values of the attributes in the composite candidate key may change over the life of an instance of MANUFACTURER.

The cardinality is optional many from MANUFACTURER to FERTILISER, and mandatory one from FERTILISER to MANUFACTURER. FERTILISER is a weak entity and, therefore, an instance of FERTILISER can not be created without a valid instance of MANUFACTURER.

There are two business rules associated with the FERTILISER entity for the attributes AVAILABILITY, CITRIC SOLUBILITY and WATER SOLUBILITY. The attribute AVAILABILITY can only have values when the instance of FERTILISER contains the nutrient sulphur and WATER SOLUBILITY and CITRIC SOLUBILITY can only have values when the fertiliser contains the nutrient phosphorus.

The attribute CATEGORY refers to the values shown in the user view of Nitrogen fertilisers, Nitrophoska fertilisers and Horticultural products. If a value is entered for the CATEGORY attribute then this aids in the grouping and selection of fertilisers by the consultant. The TYPE attribute refers to whether the fertiliser is organic or inorganic.

The entity FERTILISER contains attributes that describe the fertiliser. The primary key of FERTILISER is a composite key of MANUFACTURER ID and NAME because more than one instance of MANUFACTURER can make a fertiliser with the same name. Each fertiliser contains one or more nutrients, this is represented by the relationship Contains between FERTILISER and NUTRIENT. The cardinality from FERTILISER to NUTRIENT is mandatory many; a fertiliser description must contain at least one nutrient and may contain more than one. The cardinality from NUTRIENT to FERTILISER is optional many since a given nutrient may or may not appear in a particular fertiliser description.

The gerund Contains has an attribute PERCENTAGE that represents the amount, as a percentage, of a particular nutrient that a particular fertiliser contains. PERCENTAGE is neither an attribute of FERTILISER or NUTRIENT because the amount of each nutrient in a particular fertiliser varies with each fertiliser. The attributes FERTILISER ID and NUTRIENT ID combine to form the primary key for the gerund.

5.2.3.1. Fertiliser price list

Consultants require price lists from the companies that sell fertiliser to growers so they can determine the cost of a fertiliser mix that they may recommend. This is because cost can impact on what fertilisers the consultant recommends. A price list of fertilisers consists of information about who is selling the fertiliser, (i.e., the merchant) and the price of each fertiliser they sell; the user view depicting this is shown in Figure 13.

Merchant

Wrightsons Limited
Feilding Office
Manchester Street
Feilding

Contact:
Ken Smith
Fertiliser Consultant
06 323-4522

Fertiliser prices

Fertiliser name	Price ($) Per tonne for bulk product	Per 50kg bag
Nitrogen fertilisers		
Ammonium sulphate	313.04	17.73
Urea	471.12	25.64
Calcium ammonium nitrate	400.40	22.10
Nitrophoska fertilisers		
Nitrophoska	543.92	29.28
Floranid permanent	-	-
Horticultural products		
Magnesium oxide (Calcined Magnesite)	-	24.60
Magnesium Sulphate (Epsom Salts)	515.00	27.83

Figure 13 The fertiliser price list user view showing the prices of several fertilisers sold by a merchant.

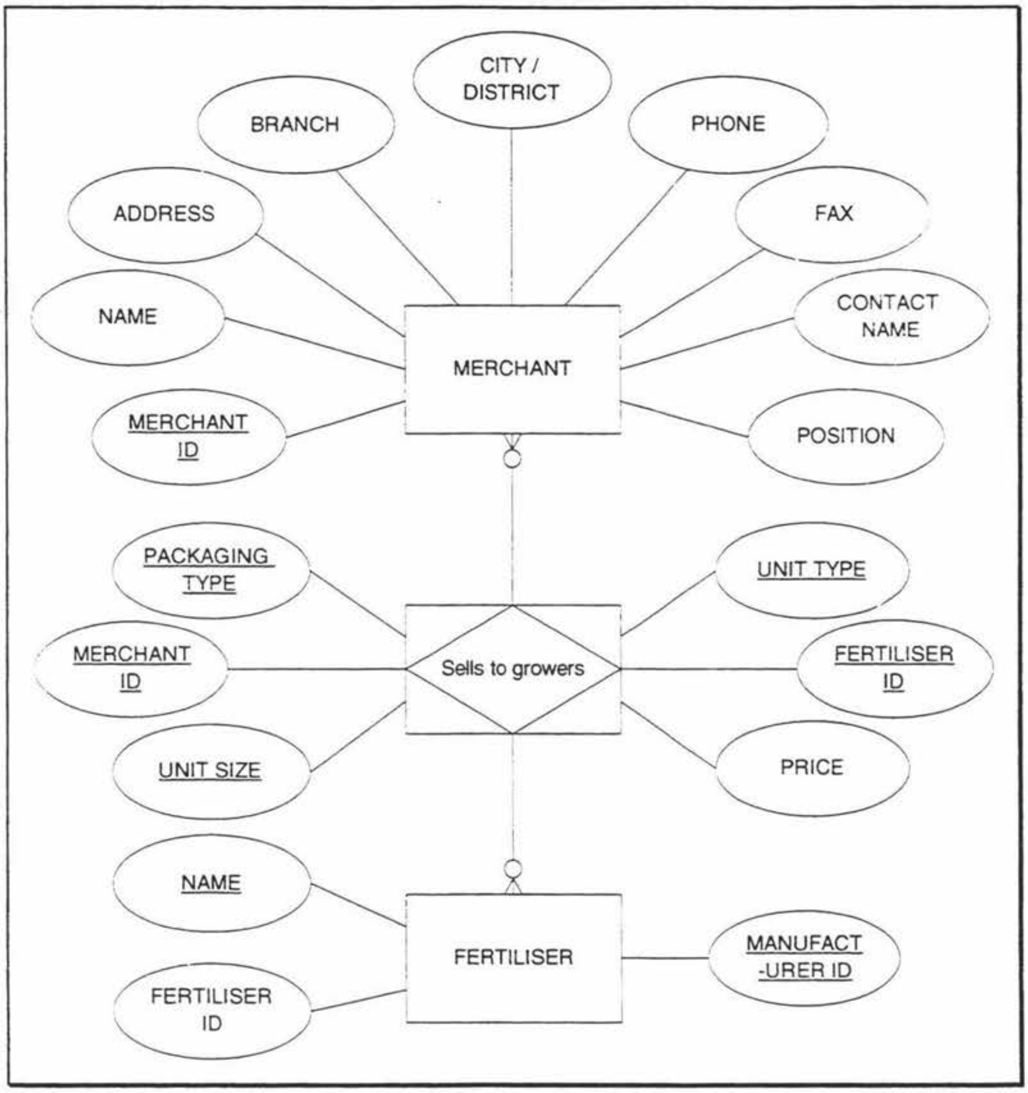


Figure 14 An entity-relationship diagram of the fertiliser price list view.

The entity-relationship diagram that represents the information from the fertiliser price list view is shown in Figure 14. The primary key of MERCHANT is MERCHANT ID, a surrogate key created for the same reasons described for MANUFACTURER ID in 5.2.3 Fertiliser description. The FERTILISER entity shown in Figure 14 represents the same FERTILISER entity as shown in Figure 12. The cardinalities of Sells to growers are optional many in both directions so a given merchant may sell none or any number of fertilisers and a particular fertiliser may be sold by none or any number of merchants.

Due to the size of a grower's enterprise the quantity of a particular fertiliser that a grower may require will vary. To meet this need and allow growers to purchase roughly only as much of a fertiliser they want, merchants stock a range of packaging types and sizes. Each of these packaging types (e.g., bulk or bagged) and sizes are likely to vary in price and unit they are measured in (e.g., tonnes, kilograms or grams). The relationship Sells to growers has the attributes PACKAGING TYPE, UNIT SIZE, UNIT TYPE and PRICE to allow for the different prices of the packaging types and sizes. The primary key of Sells to growers is a composite key of PACKAGING TYPE, UNIT SIZE, UNIT TYPE, MERCHANT ID and FERTILISER ID. The primary key contains MERCHANT ID and FERTILISER ID because without them instances of Sells to growers would not be unique and could not be related to particular instances of MERCHANT or FERTILISER.

5.2.3.2. Cartage costs

When preparing a recommendation report for a grower the consultant may include cartage costs. Although growers may have specific contacts with cartage companies and previously negotiated prices, storing cartage costs provides the consultant with approximate cartage costs. In the absence of actual costs this data enables the consultant to allow for cartage cost and provide the grower with an approximate total cost for the fertiliser recommendation. The user view for cartage costs is shown in Figure 15, which provides an example of the costs of carting different products for a range of distances by a cartage company.

Cartage company

Wrightsons Limited
Feilding Office
Manchester Street
Feilding

Contact:
Jim Smith
Sales Manager
09 238-7522

Cartage costs

Product	Distance (km) and Price ($)			
	10 km	30 km	40 km	50 km
Bagged lime and fertiliser	16.21	24.83	28.44	31.87
Bulk Lime	6.81	11.00	12.89	14.65
Bulk Fertiliser	10.67	19.02	22.86	26.42

Figure 15 The cartage costs user view, which shows how different products carted over a range of distances by a cartage company vary.

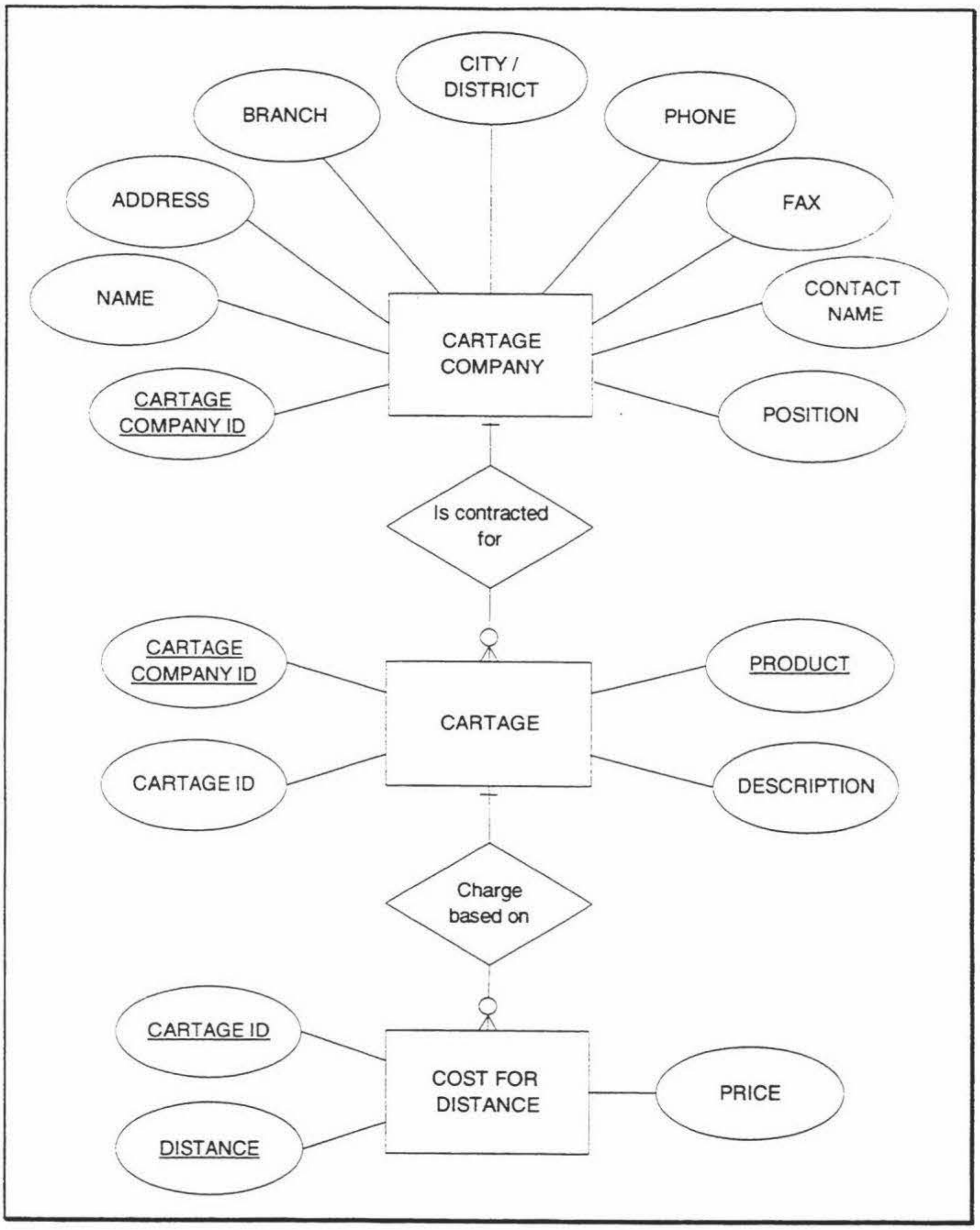


Figure 16 An entity-relationship diagram of the cartage costs user view.

The entity-relationship diagram, shown in Figure 16, represents the structure of cartage costs information from the cartage view. Each cartage company can be contracted to cart any number of products and for each product a price is charged depending of the distance carted. The primary key for CARTAGE COMPANY is CARTAGE COMPANY ID; a surrogate key created for the reasons described for MANUFACTURER ID in section 5.2.3 Fertiliser description. The primary key of CARTAGE is a composite key of PRODUCT (the name of a specific item carted by the company) and CARTAGE COMPANY ID. CARTAGE COMPANY ID is included as part of the primary key because the entity CARTAGE is a weak entity (i.e., instances of CARTAGE have an existence dependency on CARTAGE COMPANY ID).

The entity COST FOR DISTANCE is a weak entity and, therefore, to ensure uniqueness of an instance it requires as part of its primary key the primary key of the entity on which it is dependent, in this case CARTAGE. The attribute CARTAGE ID, which has a unique value for each instance, is added to the CARTAGE and COST FOR DISTANCE entities to reduce the number of attribute values required to maintain referential integrity. When more than one instance of COST FOR DISTANCE is related to an instance of CARTAGE then less attribute values are required, thus when the database is implemented the file size of the database will be less.

5.2.3.3. Spreading costs

In preparing a recommendation report for a grower the consultant may also include fertiliser spreading costs. As with cartage, growers may have specific contacts with spreading companies, however, storing spreading costs in the database provides the consultant with approximate spreading costs and in the absence of actual costs this data enables the consultant to incorporate the cost of spreading and provide the grower with an approximate value of the total cost of the fertiliser recommendation. The user view for spreading costs is shown in Figure 17, which gives an example of the costs of spreading at a range of rates (i.e., kilograms per hectare).

Spreading company

ABC Limited
Franklin Depot
Mill Road
Pukekohe

Contact:
Stacey Jones
Sales Manager
09 238-4528

Spreading costs

Product	Method	Rate (kg/ha) and Price ($/tonne)			
		60	125	250	500
Bulk Fertiliser	Truck	80.86	43.09	33.23	24.22

Figure 17 The user view of spreading costs, showing the cost a spreading charges for applying a product using a particular method.

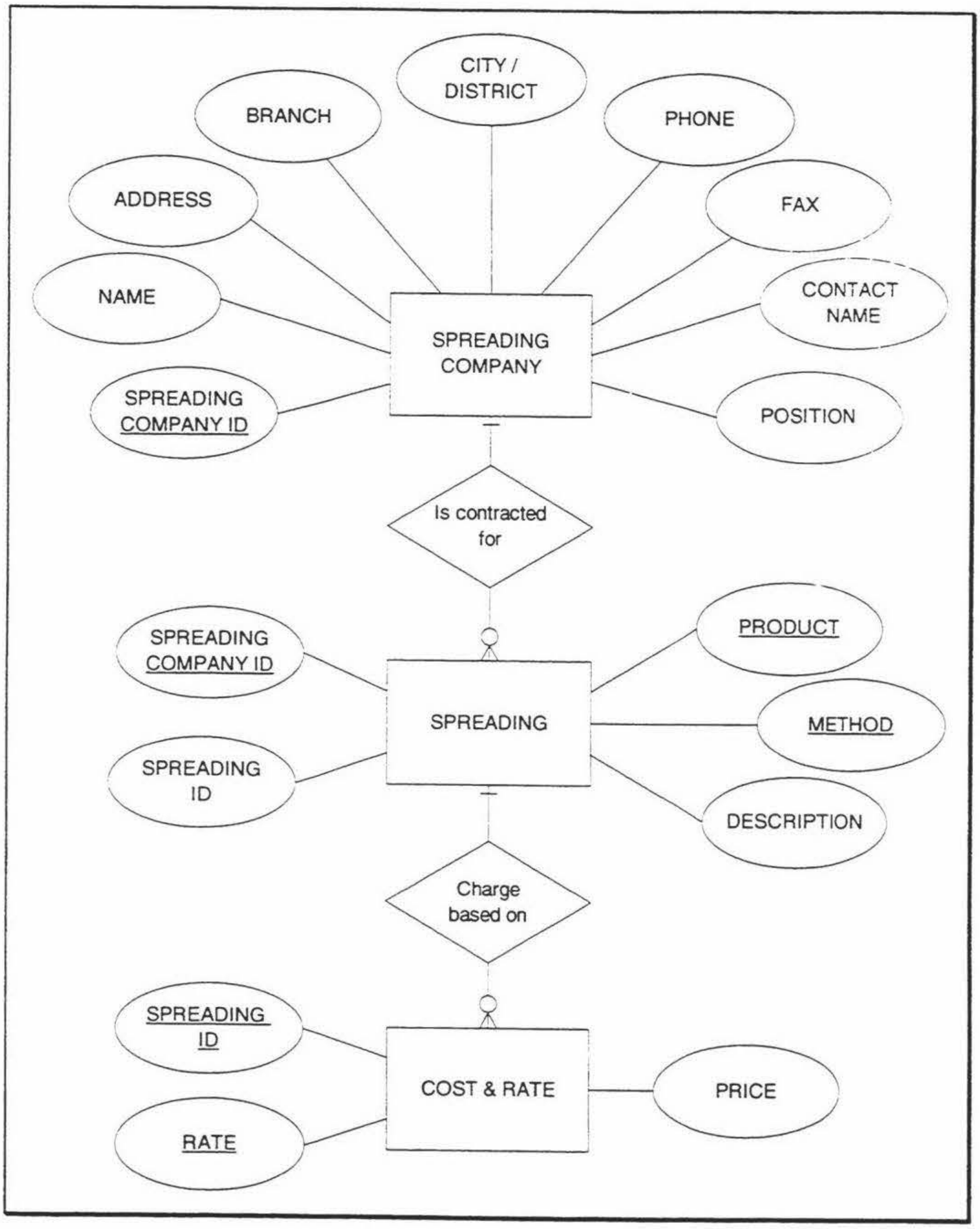


Figure 18 An entity-relationship diagram of the spreading costs user view.

In Figure 18 an entity-relationship diagram of the spreading costs information is presented. The primary keys used for the entities in Figure 18 are similar to those for the entity-relationship diagram of the cartage costs user view. The primary key of SPREADING COMPANY is SPREADING COMPANY ID, a surrogate key created for the reasons outlined for the other supply companies. The addition of SPREADING ID to the SPREADING and COST FOR RATE entities is for the same reason outlined for adding CARTAGE ID to the cartage costs entity-relationship diagram; data storage efficiency.

5.2.4. A conceptual data model of the fertiliser database

Entity-relationship diagrams for each of the user views have been developed. The merging and slight modification of these creates an entity-relationship diagram of the conceptual data model of the fertiliser information database. The resulting entity-relationship diagram appears in Figure 19. For clarity the attributes are not shown in the diagram, but instead are listed in Table 1.

To remove a redundancy of structures that were essentially the same (i.e., the manufacturer, merchant, cartage and spreading company entities) a new entity called SUPPLIER replaces the four entities. It is likely that a supplier may offer several services, so by entering the contact information only once reduces repetition of the same data. If the database design included this repetition then anomalies such as the same company having two addresses could occur when the user updated the data in one place and not the other. The contact information now only needs entering once if a company provides more than one of the manufacturing, merchant, cartage and spreading services.

A new entity created called SERVICE stores the types of service that each supplier provides. The relationship Offers between SUPPLIER and SERVICE is a gerund that maintains a list of the services each supplier offers with the attributes SUPPLIER ID and SERVICE ID. The cardinality of SUPPLIER to SERVICE is optional many, although the most it can have with the current structure is four as only four services are tracked in the database. The cardinality of SERVICE to SUPPLIER is also optional many meaning that a service may be offered by none or potentially many suppliers.

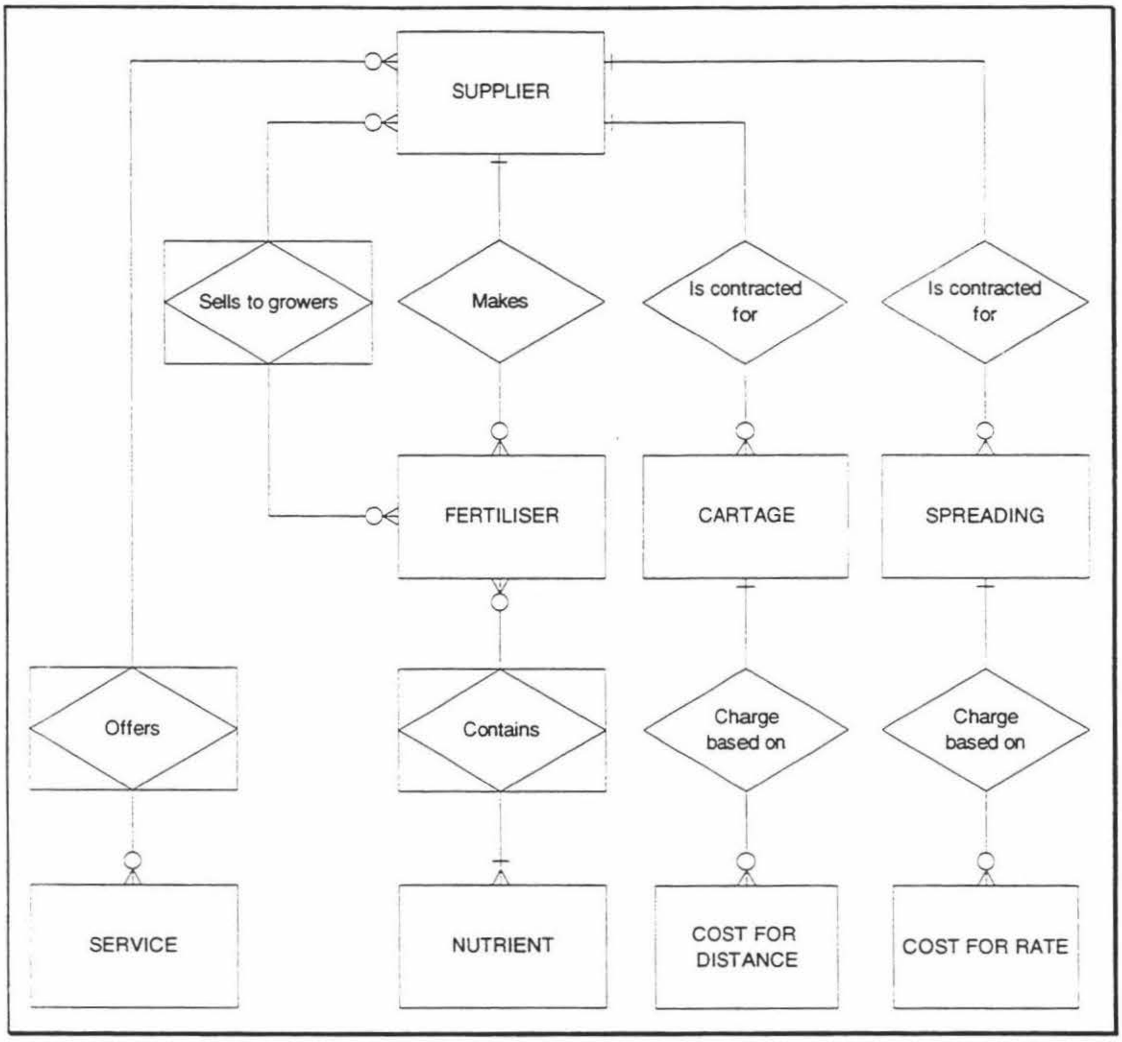


Figure 19 The conceptual data model of the fertiliser information database.

Table 1 Attributes of the entities of the conceptual data model shown in Figure 19.

Entities (or Gerunds)	Attributes (primary keys are underlined)		
Supplier	<u>Supplier ID</u> Name Branch	Address City / District Phone	Fax Contact Name Contact Position
Offers	<u>Supplier ID</u>	<u>Service ID</u>	
Service	<u>Type of service</u>	Service ID	
Fertiliser	<u>Name</u> <u>Supplier ID</u> Fertiliser ID	Type Category Availability	Water solubility Citric solubility
Sells to growers	<u>Supplier ID</u> <u>Fertiliser ID</u>	<u>Packaging type</u> <u>Unit size</u>	<u>Unit type</u> Price
Cartage	<u>Supplier ID</u>	Description	Cartage ID

	Product		
Spreading	Supplier ID Product	Method Description	Spreading ID
Contains	Fertiliser ID	Nutrient ID	Percentage
Nutrient	Nutrient name	Abbreviation	Nutrient ID
Cost for distance	Cartage ID	Distance	Price
Cost for Rate	Spreading ID	Rate	Price

5.3. The client information database

Although the information requirements of the consultants studied in Chapter Two varied, the aim is to utilise the information from the consultant interviews to determine the specifications of a database to store grower related information. The consultants use information for determining nutrient requirements and selecting fertilisers, and needs to store fertiliser recommendations. The main variation was noticed with the fertiliser recommendation reports each consultant prepares for their clients. This variation is studied and considered when creating the conceptual data model. The requirements analysis and user views of the database information are now presented. A conceptual data model using standard entity-relationship model conventions and notation is then presented and described.

5.3.1. A statement of requirements

The purpose of the client information database is to store client specific information that will aid a consultant with the fertiliser selection process. The database needs to store information such as nutrient leaf and soil test results and data created from the optimisation process. This information then enables a consultant to derive new information such as nutrient quantity trends, which a consultant can use to help determine nutrient requirements and aid the selection of appropriate fertilisers.

5.3.2. The user views of the client information database

The user views stored in the database are based on information that the consultant may use when determining a fertiliser recommendation. These user views, presented in Figure 20, are leaf and soil tests, grower observations and fertiliser preferences, fertiliser recommendations, and trends. For each of these views an entity-relationship diagram of the view is presented and described.

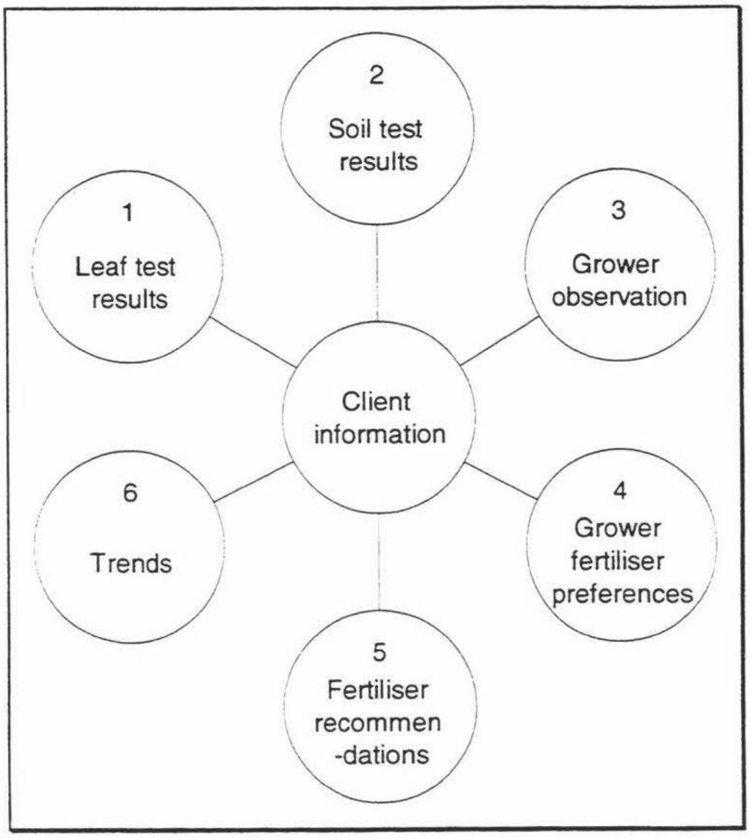


Figure 20 User views of client information involved in a fertiliser recommendation.

5.3.2.1. Leaf test results

Two of the three consultants studied use leaf tests for the purpose of monitoring nutrient uptake by the plant. The consultants use the results to help determine nutrient requirements for the coming year. The laboratory that analyses the growers leaf samples sends the consultant a report of the leaf test results; this report constitutes the user view. An example of the leaf test results report is shown in Figure 21. Each report provides results for one sample. An analysis of the sample provides an estimate of the quantity of nutrients it contains; macronutrients are reported as a percentage of the sample, while micronutrients are reported in micrograms per kilogram, or equivalently, parts per million.

JOE BLOGGS
BLOGGS ORCHARD
RD 1 HASTINGS

CROP TYPE
APPLES
SAMPLE NAME
MAIN BRAEBURN
DATE
14 MARCH 1996

NUTRIENT	ANALYSIS	OPTIMUM	NUTRIENT STATUS LOW	MEDIUM	HIGH
	%				
Nitrogen	2.21	1.9 - 2.4	*********	*******	
Phosphorous	0.18	.14 - .2	*********	*******	
Potassium	1.3	1.1 - 1.5	*********	******	
Sulphur	0.14	.2 - .4	*******		
Calcium	2.74	1 - 2	*********	********	*******
Magnesium	0.26	.25 - .35	*********	*	
Sodium	0.02	.02 - .04	*********		
	Mg/Kg				
Iron	70	100 - 200	*******		
Manganese	128	50 - 160	*********	********	
Copper	7.0	5 - 20	*********	**	
Zinc	65	20 - 50	********	********	****
Boron	42	25 - 70	********	*****	
Cobalt					
Selenium					
Molybdenum					

THE OPTIMUM SAMPLING TIME IS MID-FEBRUARY. LEAVES SAMPLED IN MID-DECEMBER WILL SHOW SLIGHTLY LOWER CONTENTS OF NITROGEN AND CALCIUM AND HIGHER PHOSPHORUS MAGNESIUM AND POTASSIUM.

PT 11/3/4

Figure 21 Example results of a leaf test report.

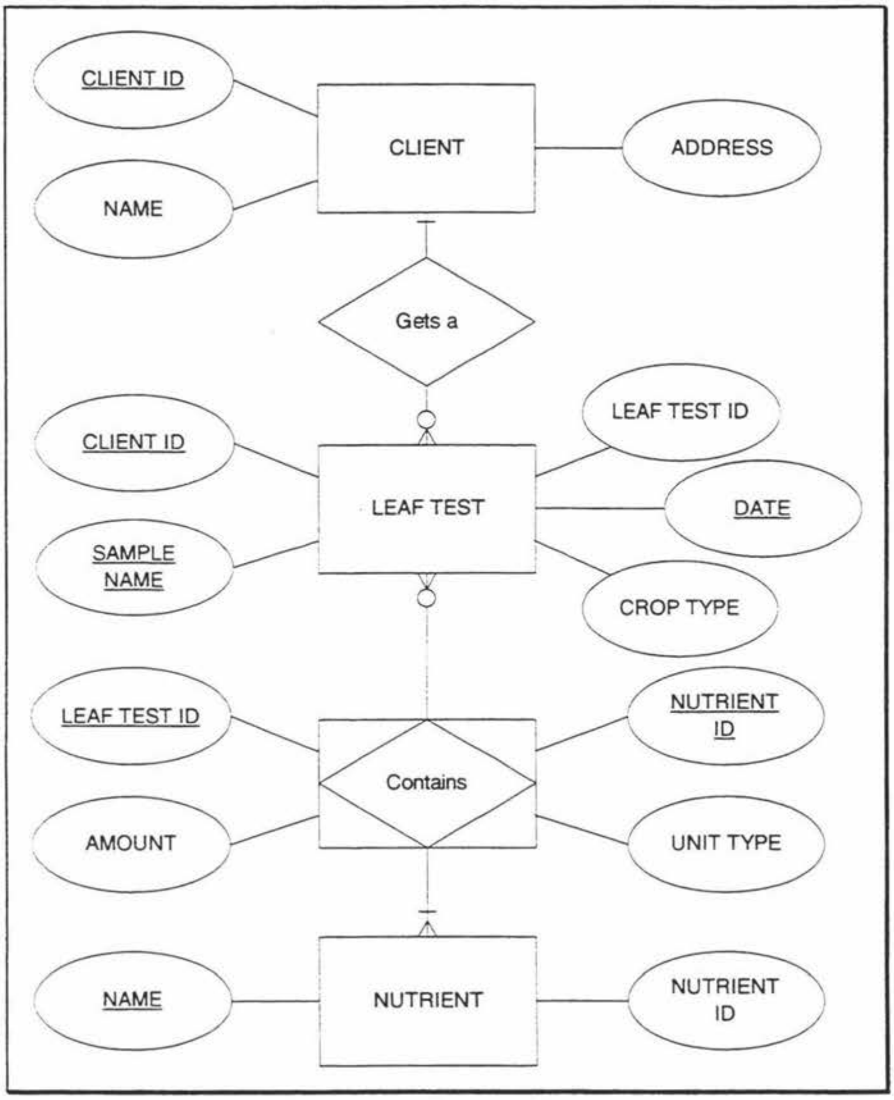


Figure 22 Entity-relationship diagram of the leaf test result view.

An entity-relationship diagram of the leaf test result view is shown in Figure 22. The primary key of CLIENT is CLIENT ID, this was chosen over a composite of NAME and ADDRESS because the address of a client may change and a person's name may not be unique on its own. The primary key of LEAF TEST is a composite key of CLIENT ID, SAMPLE NAME and DATE because more than one client may use the same sample name and get a leaf test on the same date. The attribute LEAF TEST ID was added to the LEAF TEST entity so that it could be used instead of a composite key consisting of CLIENT ID, SAMPLE NAME and DATE. This new key identifies how instances of the gerund Contains are related to instances of LEAF TEST; it is used to ease the implementation process and reduce storage space requirements.

Each client can have many leaf test results, which each contain several nutrients. The cardinality from CLIENT to LEAF TEST is optional many and, therefore, an instance of CLIENT may have from none to many leaf test results. The cardinality from LEAF TEST to CLIENT is mandatory one so for an instance of LEAF TEST to exist it must be associated with one and only one instance of CLIENT because LEAF TEST is a weak entity. From LEAF TEST to NUTRIENT the cardinality is mandatory many, while from NUTRIENT to LEAF TEST the cardinality is optional many. An instance of LEAF TEST must have at least one or more related instances of NUTRIENT and an instance of NUTRIENT can be related to several, but not necessarily any instances of LEAF TEST.

The relationship Contains is a gerund because it is part of a many-to-many relationship and has a composite primary key consisting of LEAF TEST ID and NUTRIENT ID. The attributes AMOUNT and UNIT TYPE represent the quantity of a nutrient and in what unit it is measured in the leaf test result. Clearly the attributes AMOUNT and UNIT TYPE are not part of the entities NUTRIENT or LEAF TEST as the amount of a particular nutrient contained in a leaf test varies with each leaf test and differs for each nutrient. The attribute UNIT TYPE, although typically the same for each nutrient, may change in the future and, therefore, would lead to anomalies in the data if the attribute were part of the NUTRIENT entity rather than Contains.

5.3.2.2. Soil test results

All the consultants studied use soil test results for the purpose of monitoring nutrient levels in the soil system. The consultants also use a comparison of current and historic soil test reports to aid with the estimation of current nutrient requirements. Soil test results provide the consultant with a wide variety of data about each area sampled, including nutrient content, bulk density, cation exchange capacity, base saturation, and many other results, as seen in Figure 23.

JOE BLOGGS
ADDRESS : BLOGGS ORCHARD
: RD 1 HASTINGS
:

DATE: 19 MARCH 1996
MERCHANT:

REF : 1234

REPORT OF SOIL ANALYSIS

Sample Identification	Lab No	pH	Phosphorus ug/ml & MAF	Calcium me/100g: MAF		Magnesium me/100g: MAF		Potassium me/100g: MAF		Sodium me/100g: MAF	
1. COXES	11/3/50	6.4	82	9.2	10	1.89	38	1.01	18	0.04	2
2. MAIN BRAEBURN	11/3/51	6.0	55	9.5	10	1.52	29	1.24	21	0.05	2
3. CREEK R/GALA	11/3/52	6.4	53	7.0	8	1.21	25	0.70	13	0.04	2

Sample Identification	Lab No	Bulk Density g/ml	CEC (pH7) me/100g	Base Saturation Data (%)				
				Calcium	Magnesium	Potassium	Sodium	TOTAL
1. COXES	11/3/50	0.86	16	58.9	12.1	6.4	0.3	77.7
2. MAIN BRAEBURN	11/3/51	0.82	17	56.6	9.0	7.4	0.3	73.3
3. CREEK R/GALA	11/3/52	0.88	12	56.2	9.8	5.6	0.3	71.9

Sample Identification	Lab No	Soluble Salts (%) 1:5 Saturated	Phosphate Retention %	Organic Matter %	Available Nitrogen kg/ha	Sulphate-S µg/g % MAF	Organic Sulphur µg/g % MAF
1. COXES	11/3/50				80		
2. MAIN BRAEBURN	11/3/51				41		
3. CREEK R/GALA	11/3/52				39		

Figure 23 The user view of an example report of soil test results that a consultant would receives from the lab.

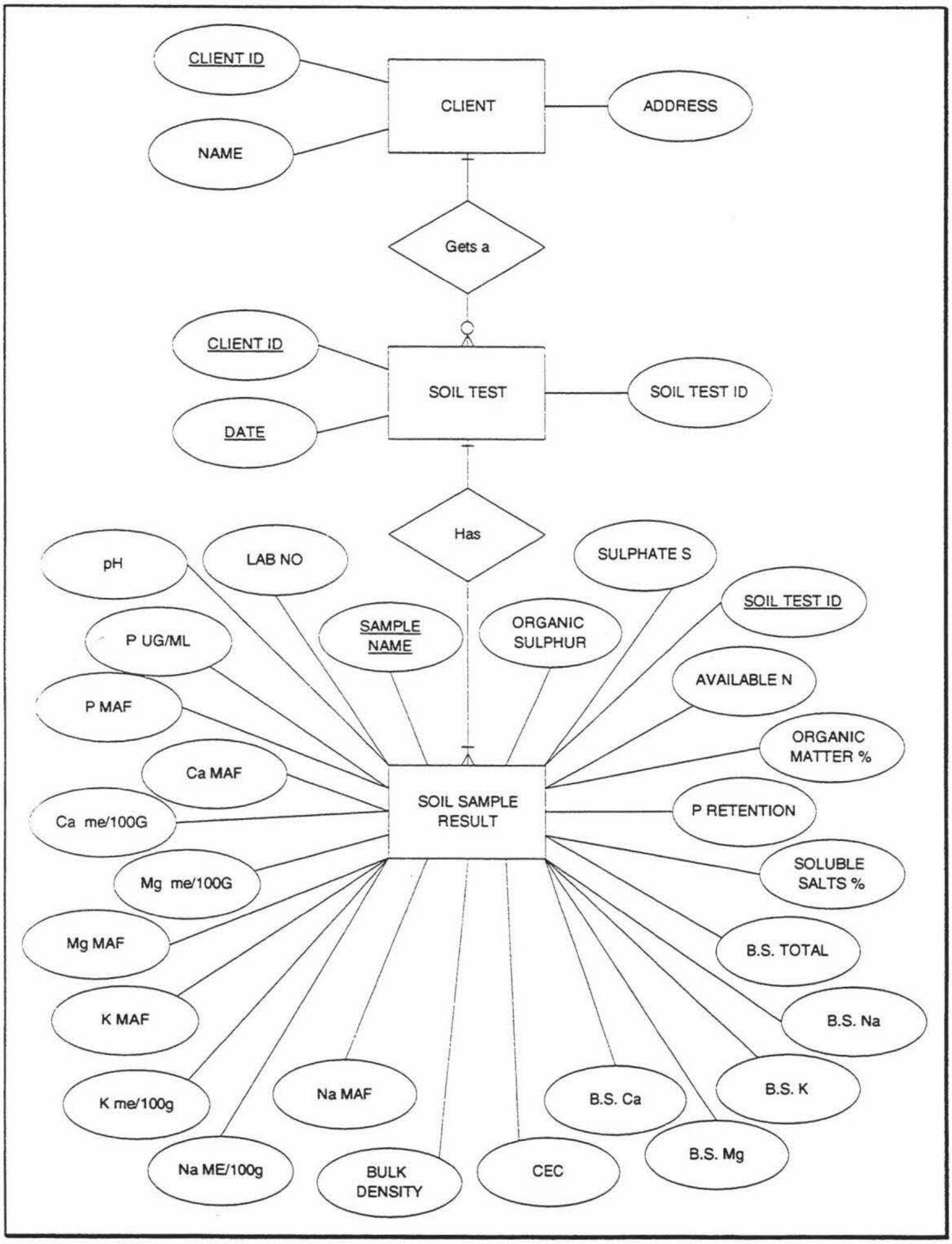


Figure 24 An entity-relationship diagram of the soil test user view.

An entity-relationship diagram that represents the structure of the soil test report is shown in Figure 24. The CLIENT entity is the same as that in the entity-relationship diagram of the leaf test report view. The cardinality from CLIENT to SOIL TEST is optional many and mandatory one from SOIL TEST to CLIENT. Each instance of CLIENT can, therefore, be related to between none and many instances of SOIL

TEST and each instance of SOIL TEST must be related to one and only one CLIENT instance. Each instance of SOIL TEST has at least one, and can have many, instances of SAMPLE related to it, while each instance of SAMPLE must be related to one and only one instance of SOIL TEST.

5.3.2.3. Grower observations and fertiliser preferences

The consultants utilise information elicited from their clients as an aid to selecting the most appropriate fertiliser mix for each of their clients' needs. From the study of the consultants it was noted that there are two types of information collected by consultants, these are grower observations and fertiliser preferences.

During the time growers work on their properties they observe how well the plants respond to the fertiliser mix, while taking into consideration other factors such as the climate and management practices. The consultants talk to their clients to find out why the crop grew better or worse than expected, they then relate this information back to the fertiliser recommendation. This discussion and interpretation of the information provided by the grower helps the consultant highlight where a change in the previous fertiliser mix may be necessary.

The consultant notes fertiliser preferences to aid appropriate fertiliser selection. Growers may have a range of preferences that relate, for example, to whether the fertiliser is organic or not, they may have a preferred merchant, cartage or spreading company, or may want to avoid particular nutrients or fertilisers.

Both grower observations and fertiliser preferences are very similar, differing only in the subject the grower's comment refers to. A combined view of the grower observations and grower fertiliser preferences representing an excerpt from a consultant's notebook, is shown in Figure 25. An entity-relationship diagram that represents both views is presented in Figure 26.

Grower observations and fertiliser preferences

Grower : Joe Bloggs

Date	Subject	Comment
12 Dec 1995	Spreading	Prefers to use XYZ company for spreading his fertiliser on his orchard, they charge $30 / tonne.
15 Dec 1995	Weather	There was a lot of rain just after flowering followed by good canopy growth.
15 Dec 1995	Fertiliser	Wants to avoid using fertilisers that contain chloride.

Figure 25 An example of grower observation and fertiliser preference information.

In the entity-relationship diagram shown in Figure 26 a client may describe any number of observations or fertiliser preferences to the consultant. This is maintained with the cardinality from CLIENT to PREFERENCE OR OBSERVATION as optional many and mandatory one from PREFERENCE OR OBSERVATION to CLIENT. The primary key of PREFERENCE OR OBSERVATION is COMMENT ID, which is a surrogate key and is used because two or more comments a client makes can be made on the same date about the same subject. A composite key of the attributes DATE and SUBJECT would not be unique in this case. The text that could be entered for the attribute COMMENT can be of any length, possibly non-unique and, therefore, impractical for a primary key. CLIENT ID is included in the PREFERENCE OR OBSERVATION entity as a foreign key to maintain referential integrity.

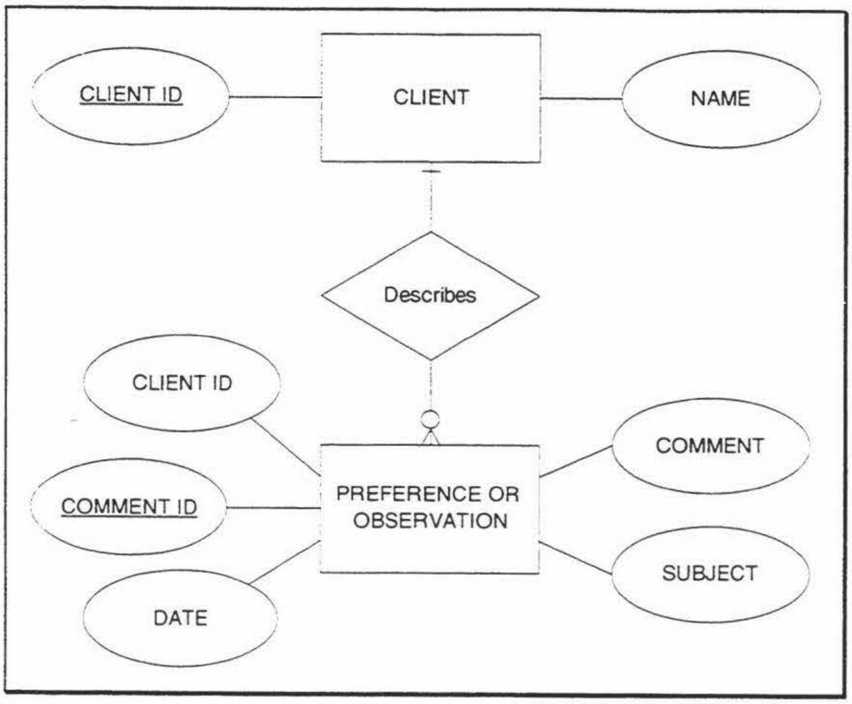


Figure 26 An entity-relationship diagram of the grower observation and fertiliser preference views.

5.3.2.4. Fertiliser recommendations

Each of the consultants studied produced different fertiliser recommendation reports for their clients. The three consultants, however, all used their historic reports to aid with preparing the current fertiliser mix. Three fertiliser recommendation report views, one for each of the three consultants, are now presented along with an entity-relationship diagram that represents the structure of the information contained in each report. Note that each of the views are shortened versions of the originals (see Appendix Three for the full versions), but still show enough to provide an example of the data they contain and the presentation method used.

27 March, 1995

Joe Bloggs
RD 1
Hastings

For your convenience I offer a choice of fertiliser types and rates, giving you more flexibility in managing you nutritional needs for your orchard. Select you choice from each category of the elements or the compound fertiliser and apply at the designated rate of the product to achieve the recommended element rate.

Recommendation

Apples
- 50 kg/ha Nitrogen
- 100 kg/ha Potassium
- 30 kg/ha Phosphate
- 25 kg/ha Magnesium
- Nil req. Lime

Choice of Fertiliser
- Nitrogen
  - 180 kg/ha Calcium Ammonium Nitrate (C.A.N.) 28% N
  - 100 kg/ha Urea 46% N
- Potassium
  - 200 kg/ha Potassium Chloride (50% K)
- Phosphate
  - 300 kg/ha Longlife Superphosphate (10% P)
- Magnesium
  - 50 kg/ha Calcined Magnesite (50% Mg)
- Compound Fertiliser
  - Nitrogen / Phosphate / Potassium / Magnesium
  - 500 kg/ha Nitrophoska blue T.E.
  - (12% N 5% P 14% K 1.2% Mg)

Figure 27 Fertiliser recommendation report prepared by Consultant One.

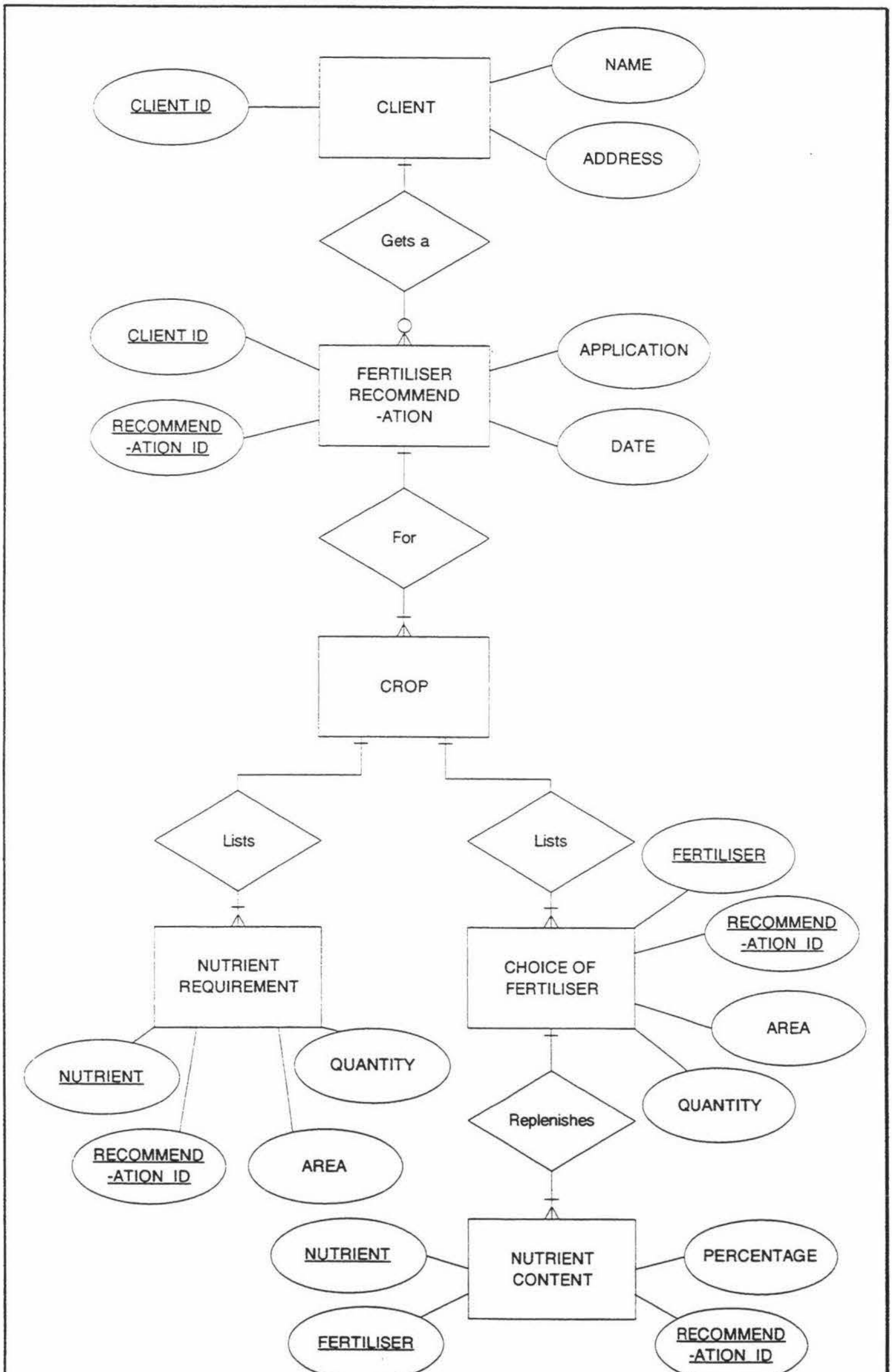

CLIENT ID
CLIENT
NAME
ADDRESS
Gets a
CLIENT ID
FERTILISER RECOMMEND -ATION
APPLICATION
RECOMMEND -ATION ID
DATE
For
CROP
Lists
Lists
FERTILISER
NUTRIENT REQUIREMENT
RECOMMEND -ATION ID
CHOICE OF FERTILISER
AREA
NUTRIENT
QUANTITY
QUANTITY
RECOMMEND -ATION ID
AREA
Replenishes
NUTRIENT
NUTRIENT CONTENT
PERCENTAGE
FERTILISER
RECOMMEND -ATION ID

Figure 28 An entity-relationship diagram of Consultant One's fertiliser recommendation report.

A summarised version of the first consultant's fertiliser recommendation report is shown in Figure 27 and the entity-relationship diagram that represents the structure of the data the view contains is shown in Figure 28. The client receives from the consultant any number of fertiliser recommendation reports. Each fertiliser recommendation can provide recommendations for several, but at least one crop and for each crop the nutrient requirements and a choice of fertilisers are outlined. The fertilisers that are listed aim to replenish the nutrient requirements outlined.

The second of the consultant fertiliser recommendation reports is shown in Figure 29 and an entity-relationship diagram that represents it's structure is then shown in Figure 30. The consultant's clients can have any number of fertiliser recommendations provided, which can each contain a list of when and what fertilisers to apply for each part of the horticultural enterprise sampled.

The consultant prepares a fertiliser recommendation for the sampled area, which coincides with the name on the soil test report. Although the recommendations are crop specific in the other two reports, in this report the recommendations are specific to an area of the horticultural enterprise. Being specific to an area or a block on the property means that a physical location rather than a particular crop is getting a fertiliser recommendation. If the blocks are defined to only contain one crop then this will not pose the problem of different crops requiring different fertiliser recommendations.

Ref: 5/3/4
27 March, 1996

Mr Joe Bloggs
RD 1
Hastings

Dear Joe

FERTILISER RECOMMENDATIONS 1996

1. **COXES BLOCK**

Autumn 1996

Immediately After Harvest	:	250 kg Kieserite, plus
	:	250 kg CAN/hectare
Plus a foliar Boron Spray	:	250 grams Solubor (or Hydrabor)/100 litres

Spring 1996

October	:	A further 250 kg Kieserite/ha
1-2 weeks preflowering	:	100 grams Solubor (or Hydrabor)/100 litres Apply twice a week apart
November/December	:	100 grams Manganese Sulphate, plus 200 grams Urea/100 litres Apply 3 times at fortnightly intervals

Figure 29 The user view of the fertiliser recommendation report created by Consultant Two.

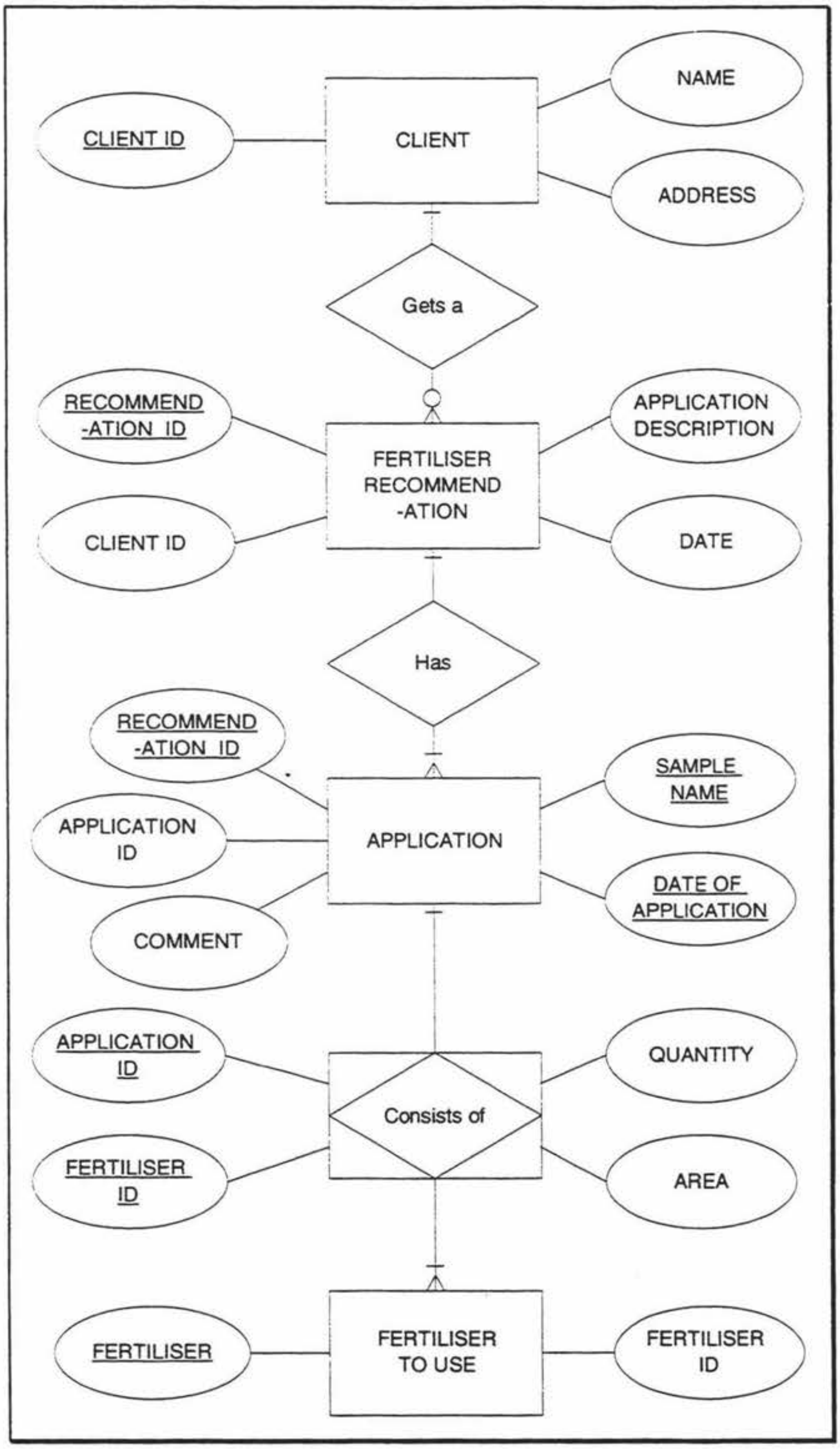


Figure 30 An entity-relationship diagram of the fertiliser recommendation report created by Consultant Two.

The client can get many fertiliser recommendation reports, which each outline a list of applications. Each application is for a particular part of the property, described by the attribute SAMPLE NAME. Each application listed consists of a quantity of one or more fertilisers to apply over a per unit area.

The third consultant's fertiliser recommendation report is shown in Figure 31. The entity-relationship diagram of this consultant's report is then shown in Figure 32. This report, which is primarily aimed at kiwifruit orchard recommendations, is generated from the output of the computer program the consultant uses to aid with the selection process.

JOE BLOGGS	AGE OF VINES (YRS): MATURE
RD 1, HASTINGS	VINE SPACING M: 5X5
SEASON: 1995/96	BAY AREA SqM: 25
CROP: KIWIFRUIT	HERBICIDE STRIP AREA SqM: 15
BLOCK: A123	BAYS/Ha: 400
APPL. METHOD: BROADCAST HERBICIDE STRIP	FRUIT LOAD/BAY: 750

DATE ddmm	FERTILISER/ANALYSIS	RATE grms	N	P	K	S	Ca	Mg	COST /BAY
			(grms of nutrient per bay)						
2008	HYCANE BASE MIX 0-4.6-15-8.8-11-5	1125	0	52	169	99	124	56	0.46
2009	HYCANE BASE MIX 0-4.6-15-8.8-11-5	1125	0	52	169	99	124	56	0.46
2009	CAL. AMM. NITRATE 27-0-0-0-8-0	675	182	0	0	0	54	0	0.32
3010	KF SPECIAL MIX 16-0-11-8-5-2	1050	168	0	116	84	53	21	0.63
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
total grms/bay:			350	104	454	282	355	133	$1.87
estimates need:			330	75	450	100	400	100	
grms excess/deficiency:			20	29	4	182	-45	33	
TOTAL Kg/Ha:			140	42	182	113	142	53	

FERTILISER	Kg/Ha	$/Ha
HYCANE BASE MIX	900.0	369.0
CAL. AMM. NITRATE	270.0	126.9
KF SPECIAL MIX	420.0	251.2
TOTAL COST $/Ha:		747.1

Figure 31 An example fertiliser recommendation report from Consultant Three.

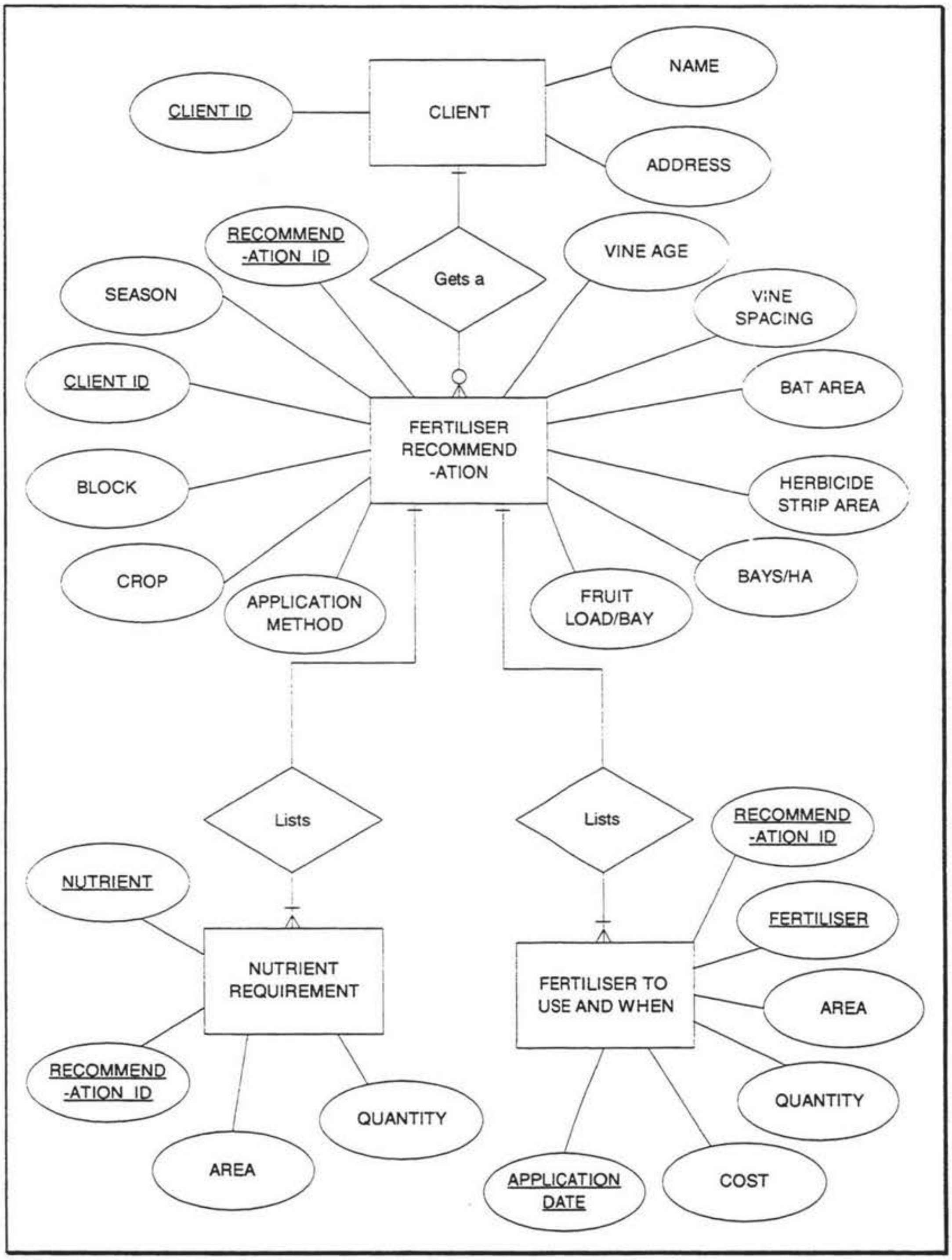


Figure 32 An entity-relationship diagram of Consultant Three's fertiliser recommendation report.

Clients of this consultant can have any number of fertiliser recommendations prepared for them. The fertiliser recommendations each contain a list of nutrient requirements and when and what fertilisers to use. This is seen in the entity-relationship diagram where an instance of CLIENT can have from none to many related instances of

FERTILISER RECOMMENDATION, which can have one or more related instances of both NUTRIENT REQUIREMENT and FERTILISER TO USE AND WHEN.

Each of the three fertiliser recommendation reports (user views) differ in the way they present to the grower the recommendation. The entity-relationships that correspond to these reports also differ because of the information the reports contain and, therefore, need storing. An entity-relationship model created from merging the three entity-relationship diagrams that allows for the information in each of these reports is presented in Figure 33. This new model is based mainly on the second of the three consultants, but with the addition of being able to specify nutrient requirements and noting that the sample names from the soil test results reports represent blocks on the client's property.

The attribute APPLICATION DESCRIPTION of the FERTILISER RECOMMENDATION entity refers to how the fertiliser should be applied and can be used for an explanation consisting of anywhere from a few words to several paragraphs. The CLIENT ID attribute in the FERTILISER RECOMMENDATION entity is a foreign key for maintaining referential integrity.

The gerund Requires has attributes that describe the quantity of a nutrient for a given unit area (e.g. per hectare) that the consultant suggests are required and aims to supply in the fertiliser recommendation. The cardinality from FERTILISER RECOMMENDATION to NUTRIENT is optional many so an instance of FERTILISER RECOMMENDATION may have several related NUTRIENT instances, but optionally may have zero (i.e., when the consultant does not specify any nutrient requirements). The cardinality from NUTRIENT to FERTILISER RECOMMENDATION is also optional many, meaning that a nutrient can be required for many or possibly none of the fertiliser recommendations. The cardinality from Requires to BLOCK is also optional many so a fertiliser recommendation can have nutrient requirements for none or many blocks on the property. If no blocks are specified then no nutrient requirements can be specified because BLOCK ID is part of the primary key for Requires and attributes of a primary key can not be null.

The BLOCK entity contains the attribute NAME, which is the same as the sample identification shown on the soil test report. This sample identification typically refers to a block or the part of the property being soil and, or, leaf tested. Within a fertiliser recommendation report a consultant may provide recommendations for several parts of the property or for several properties, the relationship between the entity BLOCK and APPLICATION ensures this. Each instance of APPLICATION outlines the date to apply the fertiliser and any comments such as to apply the fertiliser a specific number of weeks after an event such as flowering. The cardinality from the entity BLOCK to APPLICATION is optional many and, therefore, an instance of BLOCK can have any number of related instances of APPLICATION. The cardinality from APPLICATION to BLOCK is mandatory one and, therefore, each instance of APPLICATION must be related to one and only one instance of BLOCK.

An instance of APPLICATION can be related by the relationship Consists of to many instances of the entity FERTILISER, while instances of the FERTILISER entity can be related to many instances of the APPLICATION entity. This many-to-many relationship between APPLICATION and FERTILISER requires the relationship Consists of to be a gerund.

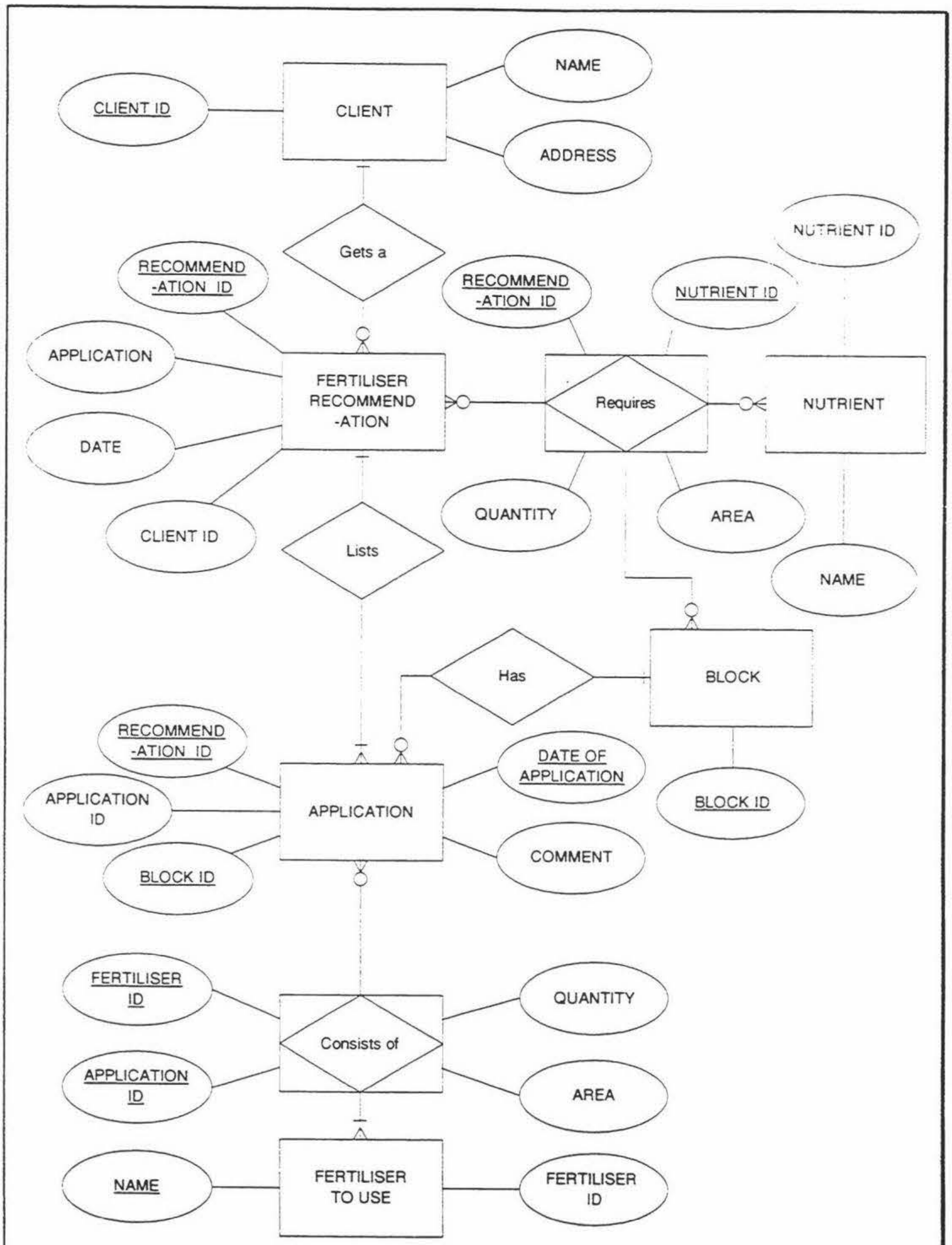


Figure 33 An entity-relationship diagram based on a combination of the information contained in the three fertiliser recommendation report views.

5.3.3. Trend views

All of the three consultants studied stated that they analyse historic information for trends. From the trends they find they decide whether each of the trends are potentially detrimental or beneficial. The consultants try to establish why each trend is continuing so the potential cause of the trends can be taken into consideration when determining nutrient requirements and selecting fertilisers.

The types of trends that the consultants typically look for are changes in nutrient content in the soil and leaves. Changes in nutrient requirements are considered when determining nutrient requirements and previous fertiliser use is considered when selecting fertilisers for the current recommendation. What is required in the entity-relationship diagram of the various trend views is equivalent to the complete conceptual data model for the client information database. Querying and reporting the data stored in the client information database will provide the consultant with the current trend views and possibly many new ones.

5.3.4. A conceptual data model of the client information database

A conceptual data model of the client information database is shown in Figure 34 and is based on the combination of the requirements from the user views previously presented. For clarity the attributes are not shown in the diagram, these are instead listed in Table 2.

The concept of the client as part of the information contained in the database has been extended to link the CLIENT and BLOCK entities. An instance of CLIENT is related to potentially many instances of the PROPERTY entity by the relationship Owns or leases. Each entity of the property entity can be related to many instances of the BLOCK entity by the relationship Consists of. Thus, a client owns or leases any number of properties, which each consist of one or more blocks. The attribute NAME of the BLOCK entity refers to the sample name used on the soil test result report and is the primary key of the BLOCK entity.

The gerund Has yield from records the yield of a crop on a particular block. From BLOCK to CROP the cardinality is optional many so a block can have any number of crops grown on it. The cardinality from CROP to BLOCK is also optional many, meaning that a crop listed in the database can be grown on zero or more blocks.

The FERTILISER RECOMMENDATION entity stores information about each fertiliser recommendation report the consultant creates. The APPLICATION entity and the Requires and Consists of gerunds store the information contained in each fertiliser recommendation report and enable trends to be derived. While the complete document of the report can be stored in the DOCUMENT attribute of the FERTILISER RECOMMENDATION entity, therefore, allowing the consultant to view previous fertiliser recommendation reports.

Each fertiliser recommendation report can list many sets of, and at least one set of application details. The block they refer to groups these sets of application details. Each instance of the APPLICATION entity is related to an instance of FERTILISER RECOMMENDATION and BLOCK and one or more instances of the gerund Consists of. The cardinality from APPLICATION to FERTILISER is mandatory many so each application must consist of one or more fertilisers.

Compared to the entity-relationship diagrams of the fertiliser recommendation views the conceptual data model does not have the relationship Gets a between the CLIENT and FERTILISER RECOMMENDATION entities. Instead this relationship is implicitly implied through the relationships between the PROPERTY, BLOCK and APPLICATION entities. Each of the blocks that have application information in the fertiliser recommendation report may, however, be owed or leased by different clients. This, therefore, means that a particular fertiliser recommendation report could be created that covers recommendations for several clients at once.

If a block that was soil tested contains several crops the fertilisers that the consultant recommends for each crop on the block are likely to differ. To overcome this difficulty each block can be subdivided into smaller blocks and these smaller blocks can be crop specific. This is represented in the entity-relationship diagram by the unary relationship the BLOCK entity has called Are part of. A block can contain zero or many other blocks and each block can be part of none or one block. The parent block can have related soil test results and the blocks that the parent block is divided into inherit the same related soil test results. The attribute PARENT is used to describe the block that a particular block is part of.

Rather than the LEAF TEST and SOIL TEST entities being related directly to the CLIENT entity they are now related through the PROPERTY and BLOCK entities. This method will allow better reporting of any trends by relating together instances of the SOIL TEST and LEAF TEST entities through instances of the BLOCK entity.

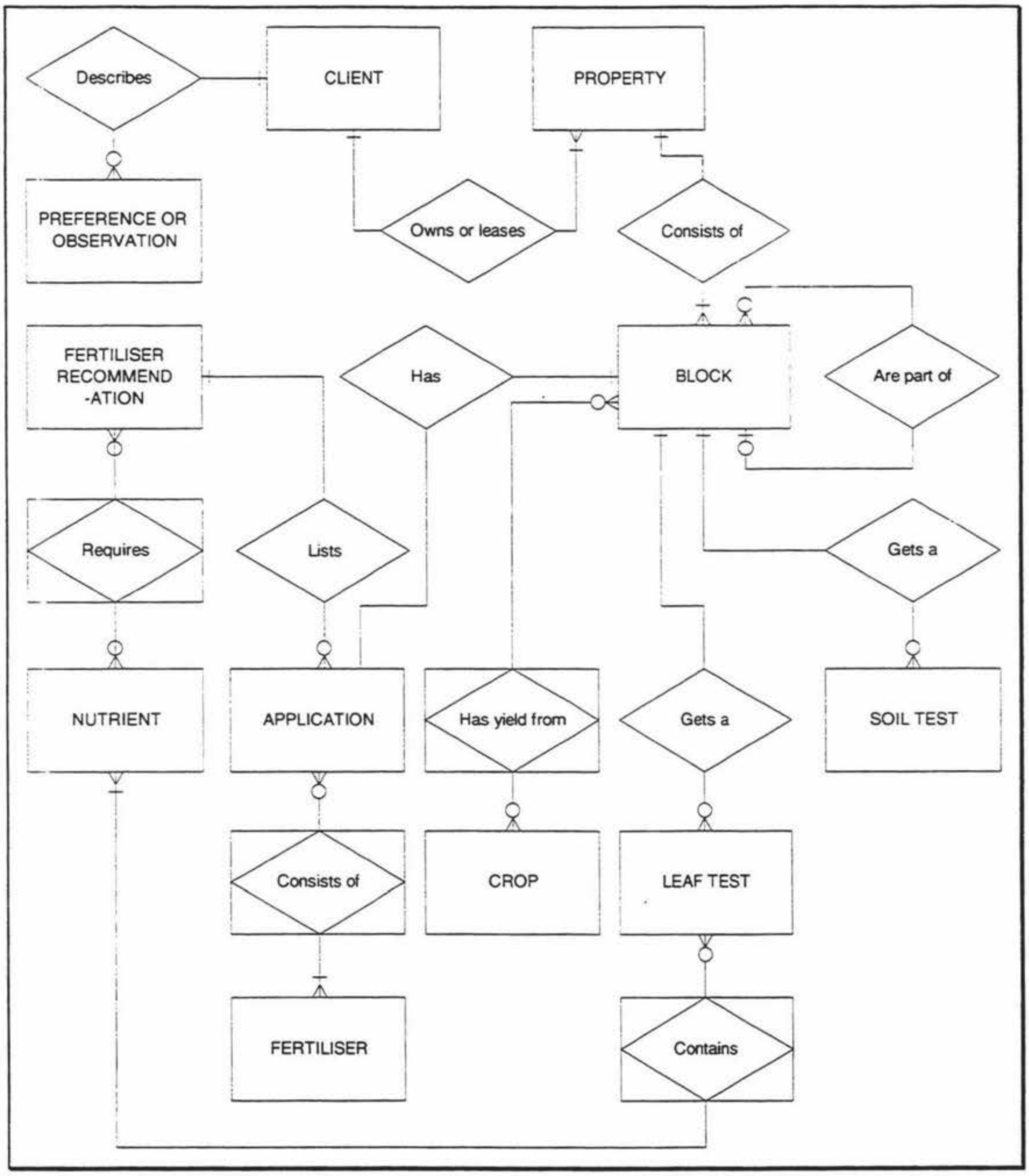


Figure 34 The conceptual data model of the client information database.

This database should be linked to the fertiliser database otherwise it needs to contain entities that represent the NUTRIENT and FERTILISER entities of the fertiliser database. A link between the two databases is preferable as this will mean that the information is only kept in one place and, therefore, reduce storage space requirements and the possibilities of update anomalies.

Table 2 Attributes of the conceptual data model of the client information database.

Entity (or gerund)	Attributes		
Client	Client ID Given name	Family name Address	City/District Phone
Property	Name	Property ID	
Block	Name Property ID	Parent	Block ID
Has yield from	Crop ID Block ID	Date	Quantity
Crop	Name	Crop ID	
Fertiliser recommendation	Recommendation ID Application description	Date	Document
Requires	Nutrient ID Recommendation ID	Block ID Quantity	Area
Nutrient	Name	Nutrient ID	
Application	Recommendation ID Block ID	Date of application Application ID	Comment
Consists of	Fertiliser ID Application ID	Quantity	Area
Fertiliser	Name	Fertiliser ID	
Leaf test	Block ID	Date	Leaf test ID
Contains	Nutrient ID Leaf test ID	Amount	Unit type
Soil test	Block ID Date Lab no pH Phosphorus ug/ml Phosphorus MAF Calcium ug/ml Calcium MAF Magnesium ug/ml	Magnesium MAF Potassium ug/ml Potassium MAF Sodium ug/ml Sodium MAF Bulk density CEC B.S. Calcium B.S. Magnesium	B.S. Potassium B.S. Sodium B.S. Total Soluble salts % P Retention Organic matter % Available N Sulphate S Organic sulphur
Preference or observation	Comment ID Date	Subject Client ID	Comment

5.4. Summary

Within the decision support system being developed for this study their are two databases, a fertiliser information database and a client information database. These databases provide the consultant with a structured method of storing the data they use, which is currently in the form of paper files. A statement of the requirements was followed by descriptions of the user views of each of the databases. The information in the user views were presented as entity-relationship diagrams, which were discussed, analysed, modified where required, and combined to form conceptual data models of the two databases.

In the next chapter, a prototype implementation of the decision support system is evaluated. The resulting fertiliser recommendations are compared with the recommendations in the cases provided by the consultants of this study.

Chapter 6

Implementation and evaluation of the decision support system

6.1. Introduction

The fertiliser selection process used by three consultants was studied in Chapter Two and a decision support system that aims to improve the estimation of nutrient requirements and optimise the selection of fertilisers was developed in Chapter Three. The two main components, the optimisation routine and databases, were described in Chapters Four and Five respectively. The implementation of a prototype of the decision support system is described in this chapter. Following this, the optimisation routine is evaluated using example fertiliser recommendations supplied by the three consultants. The evaluation compares the consultant's fertiliser recommendation with the solutions generated by the optimisation component.

6.2. Implementation

A prototype version of the decision support system described in Chapter Three was developed during this study. The client and fertiliser databases were implemented using Microsoft Access version 2.0, while Microsoft Excel version 5.0 and its Solver Add-In were used for implementing the optimisation component. These two programs both use programming languages (Access Basic in Access and Visual Basic for Applications in Excel) that allow the manipulation and automation of the environment, application and their objects. Data can be easily transferred between both programs using object linking and embedding automation (OLE Automation). The use of these programming languages and OLE Automation combined with the visual design method of Access enabled the rapid development of a prototype application.

The prototype decision support system consists of an interface that links the client and fertiliser databases and optimisation routine together. The interface prompts the user for information such as nutrient requirements and fertiliser selection criteria, using the familiar concept of a Wizard[2]. The information collected from the user is used to generate a list of eligible fertilisers and for setup information in the optimisation routine. This data is transferred to Excel and the optimum solutions are generated. Once the optimisation is complete the solutions generated are retrieved and stored in the client database and displayed on the screen.

6.3. Evaluation of the optimisation routine

This evaluation of the optimisation routine consists of a comparison of the solutions generated by the optimisation routine with the fertiliser recommendations prepared by the consultants. The sources and values of the data required for each of the optimisation equations is presented in the next section, 6.3.1 Information used. Then the output from the optimisation routine is presented alongside the consultant's fertiliser recommendation in Section 6.3.2 Results.

6.3.1. Information used

The equations of the decision support system's optimisation component where presented in Chapter Four as equations Equation 24 to Equation 36. The optimisation technique indicated by these equations is compromise programming, which attempts to minimise the deviation of, in this case, nutrients from desired targets specified by horticultural consultants. The equations require information on nutrient requirements, fertilisers that can be used, the weights used to penalise any deviations with, and p values.

The nutrient requirements used in this evaluation were taken from reports prepared by three consultants for their clients. Where the consultants did not specify any nutrient requirements then these were estimated from the fertilisers the consultant recommended. Note, however, that what a consultant recommends may differ widely from the actual requirements depending on how the recommendation was made. The nutrient requirements from the recommendation reports from each consultant are

[2] A group of dialog boxes that prompt the user for information with the aim of simplifying a task. Wizards are a common feature of many Microsoft products such as those in the Microsoft Office suite of applications.

shown in Table 3 to Table 5. These nutrient requirements are used as the target values in the optimisation equations.

Table 3 The examples of nutrient requirements from Consultant One.

	Nutrients (kg/ha)							
Crop	N	P	K	S	Mg	Ca	Cl	Mn
Kiwifruit	0	180	125	240	275	1015	125	0
Tomatoes	92	54	147	202	50	132	0	0
Peaches	92	0	63	94	50	0	0	0

Table 4 The examples of nutrient requirements from Consultant Two.

	Nutrients (kg/ha)							
Crop	N	P	K	S	Mg	Ca	Cl	Mn
Kiwifruit	173	37	155	115	0	97	0	0.13
Tomatoes	112	106	200	140	0	70	0	2.56
Peaches	99	13	35	10	2.5	35	18	0.13

Table 5 The examples of nutrient requirements from Consultant Three.

	Nutrients (kg/ha)							
Crop	N	P	K	S	Mg	Ca	Cl	Mn
Kiwifruit	124	29	173	38	38	146	0	0
Kiwifruit	132	30	180	40	40	160	0	0
Kiwifruit	160	35	213	48	45	200	0	0

The fertilisers used when solving a particular example were those that were available to the consultant when they prepared the fertiliser recommendation. Details of price and nutrient analysis of the fertilisers are presented in Appendix Five Fertiliser descriptions. The fertiliser nutrient analysis information specifies the quantity of each nutrient contained in a particular fertiliser. The source of this information is the fertiliser company recommended retail price lists.

The optimisation equations allow the user of the decision support system to specify a weight that can be used to emphasise the relative importance of particular goals. In this evaluation the weights for the nutrient goals are set to one. A weight of one is used for positive deviations of the cost goal, however, a weight of negative one is used for negative deviations of the cost goal. This negative weight rewards a fertiliser mix when the cost of the mix is lower than its target value.

Three values of the parameter p are used, one, two and infinity. For each value of p minimising the objective function shown in Equation 24 generates a solution. The choice of p will affect the solution generated due to the way in which p weights the magnitude of the deviations. When p equals one all deviations are treated equally. When p is set to two the deviations are squared, therefore, a greater improvement in the objective function is achieved by placing priority on reducing the larger deviations instead of the small deviations. When p equals infinity, an improvement in the objective function is only achieved by reducing the maximum deviation.

The target value for the cost goal is estimated by solving the compromise program problem as a linear program, as shown with equations Equation 37 to Equation 42 in Chapter Four. It is possible that the fertiliser mix cost will be lower than the target estimated. This problem is overcome by using a negative weight when the cost goal is lower than the target and in this case, negative one is used.

Equations Equation 27 to Equation 30 describe the constraints that ensure minimum and maximum nutrient levels are not breached and ensure that the ratio between specified nutrients and, or fertilisers are maintained. In this evaluation, none of these constraints are utilised.

6.3.2. Results

This results section provides a description of the information generated by the optimisation routine. The description of this information includes differences in fertilisers selected, excesses and deficiencies of nutrients and the cost and weight of the fertiliser mix for the different solutions. A complete set of results is contained in Appendix Six Results. The examples (shown in tables Table 3 to Table 5) provided by the three consultants were put through the optimisation routine and results from each are now described.

6.3.2.1. Consultant One, example one

The fertilisers included in the solutions of each solving method differed from that recommended by the consultant (see Table 6). Although the fertilisers differed, each nutrients' requirement was within 0.5% of the target value (see Table 7). When p was set to one the solution was the same as that generated by the linear program used to determine the cost goal target. When p was set to two the large excess of phosphorous included when p was one was reduced to less than 0.5%. The addition of another fertiliser to the solution from when p was equal to one to when p was equal to two reduced the phosphorous excess, but at the same time introduced minor excesses and deficiencies of less than 0.5% for each of the nutrients required. In reducing the sum of all nutrient deviations from the targets the cost of the fertiliser mix increased from 82% to 86% when the value of p changed from one to two. This 4% increase in cost, however, is somewhat offset by a decrease in the weight of the mix by 31% (see Table 8). When p was set to infinity the solution did not change from that generated when p was set to two.

There was no excess or deficient levels of any nutrient in the fertiliser recommendation (see Table 7) from the consultant because no specific nutrient requirements were specified by the consultant. This meant that the target requirements were estimated by using the amount of each nutrient contained in the fertiliser recommendation.

Table 6 A comparison of the fertilisers recommended by the consultant and those included in the solution for each solving method.

Fertiliser	Fert. Rec.	LP	p=1	p=2	p=infinity
Superphosphate	2000				
Reactive Rock		1182	1182	84	84
15% Potash RPR		1563	1563	1152	1152
Muraite of Potash	250				
Sulphur Super 30		800	800	800	800
Magnox		539	539	234	234
Dolomite	2500			1369	1369
Total fertilisers used	3	4	4	5	5

Table 7 The percentage nutrient excesses from the target.

Solving method	N	P	K	S	Mg	Ca	Cl	Mn
Fert. Rec.	0%	0%	0%	0%	0%	0%	0%	0%
LP	0%	81%	0%	0%	0%	0%	0%	0%
p=1	0%	81%	0%	0%	0%	0%	0%	0%
p=2	0%	*	*	*	*	*	*	0%
p=infinity	0%	*	*	*	*	*	*	0%

* Indicates that the value was less than 0.5%

Table 8 The percentage difference in weight and cost of each fertiliser mix.

	Fert. Rec.		LP	p=1	p=2	p=infinity
Cost	$1080/ha	100%	82%	82%	86%	86%
Weight	4750kg/ha	100%	116%	116%	85%	85%

6.3.2.2. Consultant One, example two

None of the fertilisers recommended by the consultant were included in any of the solutions. The type and quantities of fertilisers in the solutions were, however, all the same for each solving method solution (see Table 9).

The linear program solution met the nutrient requirements exactly. When *p* was set to one the nutrient requirement goals were already met by the linear program starting values, thus no improvement in the cost goal was possible without creating a deficiency in at least one of the nutrients, and this did not occur. The solutions, thus, neither had excess or deficient levels of any nutrients (see Table 10). The cost of the fertiliser mix was almost half of that of the consultant's mix, while the weight was marginally greater (see Table 11). Note that there were no excess or deficient levels in the fertiliser recommendation either, as the consultant did not provide specific nutrient requirements. Instead the nutrient requirements were based on the quantities of nutrients contained in the fertiliser recommendation.

Table 9 A comparison of the fertilisers recommended by the consultant and those included in the solution for each solving method.

Fertiliser	Fert. Rec.	LP	p=1	p=2	p=infinity
Superphosphate	600				
Sulphate of Potash Bagged	350				
Sulphate of Ammonia		438	438	438	438
N-Rich Urea Bulk	200				
Durasul		28	28	28	28
Sulphur Super 30		11	11	11	11
Serpentine Super		71	71	71	71
30% Potash Serpentine Super		980	980	980	980
Magnox		14	14	14	14
Magnesium Sulphate	333				
Total fertilisers used	4	6	6	6	6

Table 10 The percentage nutrient excesses from the target.

Solving method	N	P	K	S	Mg	Ca	Cl	Mn
Fert. Rec.	0	0	0	0	0	0	0	0
LP	0	0	0	0	0	0	0	0
p=1	0	0	0	0	0	0	0	0
p=2	0	0	0	0	0	0	0	0
p=infinity	0	0	0	0	0	0	0	0

Table 11 The percentage difference in weight and cost of each fertiliser mix.

	Fert. Rec.		LP	p=1	p=2	p=infinity
Cost	$671/ha	100%	53%	53%	53%	53%
Weight	1483kg/ha	100%	104%	104%	104%	104%

6.3.2.3. Consultant One, example three

The fertilisers included in the solutions of each solving method differed from those recommended by the consultant (see Table 12). Two of the three fertilisers recommended by the consultant were, however, included in two of the solutions. The cost and weight of all the solutions were less than those recommended by the consultant (see Table 13).

When p was set to one the infinite percentage excess of chlorine that came from the linear programme starting values was removed. Removal of chlorine from the solution was achieved by removing Muraite of Potash, which also supplies potassium. The p equals one solution was, therefore, completely deficient in potassium.

When p was set to two potassium was included back into the solution, but at the expense of deficiencies in nitrogen, sulphur and magnesium (see Table 14). The same nutrient deficiencies were present in the solution when p was set to infinity. The greatest deficiencies were in nitrogen and potassium at 6%. Even though N-Rich Urea was included in the solution (a fertiliser that only contains nitrogen) a deficiency in nitrogen was still seen.

Table 12 A comparison of the fertilisers recommended by the consultant and those included in the solution for each solving method.

Fertiliser	Fert. Rec.	LP	p=1	p=2	p=infinity
Muraite of Potash		126			

Sulphate of Potash Bagged	150			142	142
Sulphate of Ammonia		390	390	276	276
N-Rich Urea Bulk	20	22	22	62	62
Magnox		98	98	95	95
Magnesium Sulphate	333				
Total fertilisers used	3	4	3	4	4

Table 13 The percentage nutrient excesses from the target.

Solving method	N	P	K	S	Mg	Ca	Cl	Mn
Fert. Rec.	0	0	0	0	0	0	0	0
LP	0	0	0	0	0	0	0	0
p=1	0	0	0	0	0	0	0	0
p=2	0	0	0	0	0	0	0	0
p=infinity	0	0	0	0	0	0	0	0

Table 14 The percentage difference in weight and cost of each fertiliser mix.

	Fert. Rec.		LP	p=1	p=2	p=infinity
Cost	$671/ha	100%	53%	53%	53%	53%
Weight	1483kg/ha	100%	104%	104%	104%	104%

6.3.2.4. Consultant Two, example one

The fertilisers included in the solutions of each solving method differed from that recommended by the consultant (see Table 15). The linear programme solution, which was used as the starting values, included chlorine in the solution when none was required, thus providing infinite excess. When p was set to one the fertiliser containing chlorine was removed. The fertiliser containing the chlorine also contained potassium, and consequently potassium was removed from the solution. Although other potassium sources were available, none of these were brought into the solution. When p was set to two, potassium was again included in the solution, although at a 6% deficiency (see Table 16). The fertiliser potassium sulphate was added to the fertiliser mix to include potassium and still exclude chlorine. The addition of potassium sulphate also increased the quantity of sulphur, and to compensate the quantities of other fertilisers that contain sulphur were reduced. The net result of this addition of potassium sulphate and change in quantities of other fertilisers were deficiencies in nitrogen, phosphorous, potassium, sulphur and calcium. These deficiencies, however, were at most 6%. No change in the solution from when p was set to two was evident when setting p to infinity.

The cost of the fertiliser mix was, as expected, much lower than the consultants' mix when p was set to one because of the deficiency of potassium. When potassium was included when p was set to two the cost was slightly less, partly because of the nutrient deficiencies of the solution. The weight of the mix followed the same trend as cost (see Table 17).

Table 15 A comparison of the fertilisers recommended by the consultant and those included in the solution for each solving method.

Fertiliser	Fert. Rec.	LP	p=1	p=2	p=infinity
Maxi Sulphur Super		226	226	98	98
N C Reactive Rock		219	219	251	251
Potassium Chloride		310			
Potassium Sulphate	150			346	346
35% Potash Gold Super	625				
N-Rich Urea	258	375	375	352	352
Calcium Ammonium	200				
Total fertilisers used	4	4	3	4	4

Table 16 The percentage nutrient excesses from the target.

Solving method	N	P	K	S	Mg	Ca	Cl	Mn
Fert. Rec.	0	0	0	0	0	0	0	0
LP	0	9%	0	0	0	0	∞%	0
p=1	0	9%	-100%	0	0	0	0	0
p=2	-6%	2%	-6%	-1%	0	-4%	0	0
p=infinity	-6%	2%	-6%	-1%	0	-4%	0	0

Table 17 The percentage difference in weight and cost of each fertiliser mix.

	Fert. Rec.		LP	p=1	p=2	p=infinity
Cost	$468/ha	100%	78%	55%	88%	88%
Weight	1233kg/ha	100%	92%	67%	85%	85%

6.3.2.5. Consultant Two, example two

The fertilisers included in the solutions of each solving method varied from those recommended by the consultant (see Table 18). The consultant recommended six fertilisers, when p equalled one there were four, and when p was two and infinity there were nine fertilisers in the solution.

When p was set to one the solution had large deficiencies in four of the six required nutrients. Fertilisers containing the required nutrients were added to the solution when p was set to two and the deficiencies were decreased compared to when p equalled one, for example, from 100% to 6% and 28% to 1% (see Table 19). No change in the solution was seen when changing p from two to infinity. The cost and weight of the fertiliser mix solution when p was equal to two was less than those recommended by the consultant (see Table 20). Part of this reduction would be due to the deficiencies in several of the required nutrients.

Table 18 A comparison of the fertilisers recommended by the consultant and those included in the solution for each solving method.

Fertiliser	Fert. Rec.	LP	p=1	p=2	p=infinity
Maxi Sulphur Super		173	197	190	190
N C Reactive Rock		461	147	140	140
50% Potash Super		801			
Potassium Sulphate	75			159	159
Potash Gold 15-10-10	250				
55% Potash Gold Super	625			35	35
N-Rich Urea		242	312	107	107
Cropmaster 15				47	47
Cropmaster 13				191	191
Ammo-Phos MAP	250				
Ammo-Phos / Hycrop 8-12-22				352	352
Manganese Sulphate	8	8	11	8	8
Calcium Ammonium Nitrate	175				
Total fertilisers used	6	5	4	9	9

Table 19 The percentage nutrient excesses from the target.

Solving method	N	P	K	S	Mg	Ca	Cl	Mn
Fert. Rec.	0	0	0	0	0	0	0	0
LP	0	0	0	0	0	258%	∞%	0
p=1	29%	-72%	-100%	-28%	0	0	0	0
p=2	-3%	-4%	-6%	-1%	0	0	0	0
p=infinity	-3%	-4%	-6%	-1%	0	0	0	0

Table 20 The percentage difference in weight and cost of each fertiliser mix.

	Fert. Rec.		LP	p=1	p=2	p=infinity
Cost	$607/ha	100%	71%	36%	80%	80%
Weight	1383kg/ha	100%	122%	48%	89%	89%

6.3.2.6. Consultant Two, example three

There were major differences in the fertilisers included in the consultant's recommendation compared to the solutions from each of the solving methods (see Table 21). There was only one fertiliser that was both recommended by the consultants and included in the solutions (N-Rich Urea). The consultant used it only in a small amount and used CAN as the main nitrogen source, whereas the solutions from the solving methods did not include any CAN. There were three times as many fertilisers in the *p* equals two solution when compared to the consultants mix.

When *p* was set to one there was a 50% deficiency in potassium and a 7% deficiency in calcium (see Table 22). These deficiencies were almost eliminated when *p* was set to two, although at the cost of introducing a 3% deficiency in nitrogen.

In minimising the sum of all nutrient deviations from their targets the cost of the fertiliser mix increased from 58% to 66% of the consultants mix cost when *p* was changed from one to two. A similar increase in weight was also observed (Table 23).

Table 21 A comparison of the fertilisers recommended by the consultant and those included in the solution for each solving method.

Fertiliser	Fert. Rec.	LP	p=1	p=2	p=infinity
Maxi Sulphur Super		18	18		
N C Reactive Rock		100	93	90	90
Potassium Chloride		70	35	35	35
Potassium Sulphate				29	29
20% Potash Gold Super				3	3
35% Potash Gold Super				8	8
55% Potash Gold Super				15	15
Dolomite				10	10
Magnesium Oxide		5	5	3	3
N-Rich Urea	4	216	216	211	211
Nitrophoska Blue TE	250				
Calcium Ammonium	250				
Total fertilisers used	3	5	5	9	9

Table 22 The percentage nutrient excesses from the target.

Solving method	N	P	K	S	Mg	Ca	Cl	Mn
Fert. Rec.	0	0	0	0	0	0	0	0
LP	0	7%	0	0	0	0	100%	0

p=1	0	0	-50%	0	0	-7%	0	0
p=2	-3%	0	-1%	0	0	-1%	0	0
p=infinity	-3%	0	-1%	0	0	-1%	0	0

Table 23 The percentage difference in weight and cost of each fertiliser mix.

	Fert. Rec.		LP	p=1	p=2	p=infinity
Cost	$235/ha	100%	63%	58%	66%	66%
Weight	504kg/ha	100%	81%	73%	80%	80%

6.3.2.7. Consultant Three, example one

The fertilisers recommended by the consultant differed somewhat from the fertilisers included in the solutions of each of the solving methods (see Table 24). Two of the fertilisers used by the consultant are blends of other available fertilisers; neither of these were included in the solutions generated. When changing from *p* equal to one to *p* equal to two two fertilisers were removed, while two others were added. The fertiliser mix remained the same when *p* was changed from two to infinity.

There were large excesses of phosphorous (85%), sulphur (182%) and chlorine (supplied when none required) in the consultants fertiliser mix (see Table 25). A fertiliser mix with only one excess was generated when *p* was set to one. Although the excess was large, it was still less than the excess in the consultant's mix. This was also the only excess, in comparison with the consultant's mix that had excesses in six nutrients and a deficiency in one nutrient. When *p* was set to two the excess from when *p* was equal to one was reduced to 1%, but in doing so several small deficiencies and excesses were introduced to the solution. There was no change in the solution when changing *p* from two to infinity.

The small deficiencies and excesses in the solution when *p* was set to two leads to a much cheaper and lighter fertiliser mix compared to that of the consultant's (see Table 26). The consultant's mix was more costly and heavier because of the many nutrient excesses it contained.

Table 24 A comparison of the fertilisers recommended by the consultant and those included in the solution for each solving method.

Fertiliser	Fert. Rec.	LP	p=1	p=2	p=infinity
Reactive Rock		224	224	106	106

N-Rich Urea Bulk		269	269	240	240
Calcium Ammonium Nitrate	275			43	43
Sulphur Super 30		35	35		
50% Potash Serpentine Super		692	692	526	526
Magnox		34	34		
Dolomite				93	93
Kiwifruit Special Mix	400				
Hycane Base Mix	950				
Total fertilisers used	3	5	5	5	5

Table 25 The percentage nutrient excesses from the target.

Solving method	N	P	K	S	Mg	Ca	Cl	Mn
Fert. Rec.	12%	85%	-18%	18%	33%	19%	∞%	0
LP	0	71%	0	0	0	0	0	0
p=1	0	71%	0	0	0	0	0	0
p=2	-1%	1%	-2%	1%	1%	-4%	0	0
p=infinity	-1%	1%	-2%	1%	1%	-4%	0	0

Table 26 The percentage difference in weight and cost of each fertiliser mix.

	Fert. Rec.		LP	p=1	p=2	p=infinity
Cost	$578/ha	100%	59%	59%	62%	62%
Weight	1625kg/ha	100%	76%	76%	76%	76%

6.3.2.8. Consultant Three, example two

The type and number of fertilisers included in the solutions of each solver method differed from that of the consultant's mix (see Table 27). The consultant's mix contained three fertilisers, only one of which was included in any of the solutions. The solutions had more fertilisers in the mix (five to six) compared to the three in the consultant's mix. The change from *p* equals one to *p* equals two increased the number of fertilisers in the mix and altered those included in it.

The consultant's fertiliser mix contained excesses in five of the required six nutrients and a deficiency in the other (see Table 28). The solution when *p* was set to one had a phosphorous excess of 84% compared to the consultant's 105% excess. The solution had no other excesses or deficiencies. When *p* was set to two this excess was further reduced to 2%, however, this led to the inclusion of other small excesses and deficiencies. There was no noticeable change in the solution from changing *p* from two to infinity.

The cost and weight of the solutions were less than that of the consultant's fertiliser mix as seen in Table 29. Much of the reason for this reduced cost and weight is due to the solutions meeting the nutrient requirement goals better than the consultant's mix.

Table 27 A comparison of the fertilisers recommended by the consultant and those included in the solution for each solving method.

Fertiliser	Fert. Rec.	LP	p=1	p=2	p=infinity
Reactive Rock		258	258	110	110
N-Rich Urea Bulk		287	287	217	217
Calcium Ammonium Nitrate	260			109	109
Sulphur Super 30		37	37		
50% Potash Serpentine Super		720	720	539	539
30% Potash Magnox				266	266
Magnox		36	36		
Dolomite				99	99
Kiwifruit Special Mix	442				
Coromandel Base Mix	936				
Total fertilisers used	3	5	5	6	6

Table 28 The percentage nutrient excesses from the target.

Solving method	N	P	K	S	Mg	Ca	Cl	Mn
Fert. Rec.	7%	105%	-35%	17%	16%	21%	∞%	0
LP	0	84%	0	0	0	0	0	0
p=1	0	84%	0	0	0	0	0	0
p=2	-2%	2%	-3%	1%	1%	-5%	0	0
p=infinity	-2%	2%	-3%	1%	1%	-5%	0	0

Table 29 The percentage difference in weight and cost of each fertiliser mix.

	Fert. Rec.		LP	p=1	p=2	p=infinity
Cost	\$554/ha	100%	66%	66%	70%	70%
Weight	1638kg/ha	100%	82%	82%	82%	82%

6.3.2.9. Consultant Three, example three

The fertilisers recommended by the consultant differed from those included in the solutions of each solving method (see Table 30). The solutions contained from five to seven fertilisers, while the consultants' mix contained three.

The consultant's fertiliser mix had excesses of up to 99% and deficiencies of up to 44% (see Table 31). When using *p* set to one the solution generated had only one excess (phosphorous), which was larger than that of the consultant's mix. When setting *p* to two this was reduced to 3%. In doing so deficiencies of up to 4% and excesses of up to 8% were added to the solution. There was no change in the solution when setting *p* to infinity.

The cost of the solution when *p* was set to two was 12% less than the consultant's mix as shown in Table 32. The weight, however, increased and was 8% higher than the consultant's fertiliser mix.

Table 30 A comparison of the fertilisers recommended by the consultant and those included in the solution for each solving method.

Fertiliser	Fert. Rec.	LP	p=1	p=2	p=infinity
Reactive Rock		337	337	108	108
N-Rich Urea Bulk		348	348	168	168
Calcium Ammonium Nitrate				290	290
Sulphur Super 30	300	45	45	29	29
50% Potash Serpentine Super		850	850	729	729
30% Potash Magnox				142	142
Magnox		38	38		
Dolomite				152	152
Kiwifruit Special Mix	400				
Hycane Base Mix	800				
Total fertilisers used	3	5	5	7	7

Table 31 The percentage nutrient excesses from the target.

Solving method	N	P	K	S	Mg	Ca	Cl	Mn
Fert. Rec.	-9%	34%	-44%	99%	-2%	-21%	∞%	0
LP	0	98%	0	0	0	0	0	0
p=1	0	98%	0	0	0	0	0	0
p=2	-3%	3%	-4%	1%	2%	8%	0	0
p=infinity	-3%	3%	-4%	1%	2%	8%	0	0

Table 32 The percentage difference in weight and cost of each fertiliser mix.

	Fert. Rec.		LP	p=1	p=2	p=infinity
Cost	\$542/ha	100%	81%	81%	88%	88%
Weight	1500kg/ha	100%	108%	108%	108%	108%

6.4. Discussion

This discussion reviews significant trends that were seen in the results, the shortcomings and ideas for improvements of the optimisation routine, and how consultants should use the information the optimisation routine generates.

6.4.1. The significance of *p* values

Throughout the results the solutions that performed best, in terms of minimising nutrient deficiencies and excesses, were those that used a p value of two. The values one, two and infinity were used to generate the solutions, as these were the values suggested in the literature.

When using a p value of one the solutions did not alter much, if any, from the linear programme generated starting values. In the linear programme solution, and in many cases the $p=1$ solution, the target nutrient levels were met, yet there were excesses, some of which were large. The time it took to solve the linear programme version of the problem was much less than when using p set to one in a compromise programme. Based on the time to solve the problem and the insufficient difference that occurred a linear programme version of the problem could be said to give just as good a solution as a compromise programme when p is set to one in the context of this model.

When using a value of infinity for p, the solution generated was, in all cases, the same as that when p was set to two. The solution was better than when p equalled one in terms of being as close as possible to the target values. The time taken to solve the problem when p was set to infinity was larger than when p was set to either one or two. Thus due to no change in the solution generated and the length of time required to arrive at the solution it seems that using a p value of infinity is inappropriate in the context of this model.

The solutions generated when p was set to two had, in most cases, nutrient levels that were very close to the targets set. An exception to this occurred when the target values were met exactly when generating the starting values with the linear programme. In this case each of the compromise programme solutions were the same as the linear programme solution. They were unable to improve the nutrient requirement goals as these were met. The solution could not be generated cheaper without generating a nutrient deficiency. If a nutrient that has a positive target is not present in any of the fertilisers then the solution generated will be completely deficient in this nutrient and thus be another exception to that previously stated.

Fertilisers that contained nutrients that were not required (i.e., had a target value of zero) were often removed from the linear programme starting set when the compromise programme version was solved when p was set to one. It seems that the best improvement in the objective function value could be achieved by removing these fertilisers. This is because the unwanted nutrients caused an infinite excess of the nutrient. Removing the fertiliser from the solution also removed a required nutrient. This typically led to a deficiency in the required nutrient, as another fertiliser in the compromise programme problem did not replace it when p was set to one. However, when p was set to two, although the fertiliser containing the unwanted nutrient was removed from the solution, fertilisers were added that did include the required nutrient. Thus the solution decreased, and in many cases eliminated, the unwanted nutrient excess and typically maintained or improved the required nutrient.

One has to question the need to generate solutions to the compromise programme with p values of one and infinity, as it seems that two is the most appropriate p value. The solutions were closer to the target values, did not take an excessive amount of time to generate, and typically removed unrequired nutrients from the solutions linear programme starting values. Remember that the linear programme is still required to provide the compromise programme with a cost goal target and fertiliser quantity starting values. If the fertiliser quantity starting values are not used then it usually takes much longer to solve the problem, if it can actually find one at all.

6.4.2. Weight

The solutions generated not only presented nutrient levels and cost, but weight as well. The weight of the solutions fertiliser mix was calculated so that it could be compared between solutions and so that the cost of cartage and spreading could be estimated. If more detailed data describing these costs could have been obtained from the consultants then perhaps weight could be added as a goal. A weight goal would probably only be used where a consultant's client was trying to cut costs. Although there is no goal to minimise weight in the current model the majority of solutions had a weight that was less than that any of the consultant's fertiliser mix recommendations. In the rare cases where the consultant's mix weighed less than the model's solutions the consultant's mix had large deficiencies in nutrients. If these deficient nutrients were included then the weight of the consultant's mix would have been greater than the model solution's weights.

6.4.3. Cost

A goal of all business is to keep costs under control, and this is no different in the horticultural sector. The cost goal was added to the model because it was highlighted by the consultants as a goal that their clients have. In all of the cases described in the results the cost of the fertiliser mix generated by the model was less than that of the consultant's fertiliser mix. Using the compromise programme solutions where *p* was set to two the cost was from 12% to 49% less than the consultant's fertiliser mix recommendation. With the mean consultant fertiliser mix cost being $557/ha the savings noted in the model solutions range from $69/ha to $282/ha.

Although these savings may seem significant, they should be considered in comparison to other enterprise costs. In calculating the gross margin for Kiwifruit Oliver and Burtt (1995) state that the cost of fertiliser represents 3.3% of the total indirect costs per effective hectare of a kiwifruit enterprise. In comparison the cost of spraying and chemicals equate to 7.3%. The need to apply an extra spray could thus soon diminish the fertiliser mix saving.

6.4.4. Solution precision

In most cases the quantities of fertilisers in the recommendations the consultants made were given in units rounded to 25kg/ha. The model solutions, however, are reported in the results to the nearest kilogram. Where the fertiliser represents a micronutrient this, or perhaps precision to grams, is possible when mixing the fertilisers. When mixing the macronutrient fertilisers, however, this precision may not be possible. A way to improve the model would be to let the user specify at what increments a fertiliser can be added to, or removed from, the solution mix.

6.4.5. Fertiliser selection

Several significant fertiliser trends were evident in the results, including a difference between the consultants and the models choice of fertilisers, the model solutions usually consisted of a greater number of fertilisers than the consultant's mix, and sometimes inappropriate quantities of fertilisers were evident in the model solutions.

There were two cases in the examples used where the fertilisers selected, or not selected, seemed odd. Both cases involved a nitrogen deficiency. In the first example N-Rich Urea (a fertiliser containing only nitrogen) was included in the solution, but at a low quantity. Yet there was still a nitrogen deficiency and although it could have been overcome by increasing the quantity of N-Rich Urea, it was not. The second example did not have N-Rich Urea in the solution, or any other fertiliser supplying nitrogen, even though several fertilisers containing nitrogen were available for inclusion in the solution fertiliser mix. There exist several possible reasons why this may have happened:

- There may have been a conflict between the cost goal and nitrogen nutrient requirement goal where the added cost outweighed the benefit of better meeting the nutrient target.
- The solver program in Excel may have found what it thought was the global optima, but was actually a local optima.

The fertilisers in the solutions generated by the model differed from those included in the recommendations prepared by the consultants. There were instances where one or two of the fertilisers that the consultant had recommended were included in the solutions generated by the model, however, this was the exception rather than the norm. It seems that the consultants' may prefer to use a particular small set of fertilisers for all their recommendations. This may be because they feel more confident about using certain fertilisers, perhaps because they know the response of particular fertilisers under the conditions and plants in their region. If the subset of available fertilisers that each consultant uses was known prior to running the model the subset could have been used instead of including all available fertilisers. However, the resulting model solutions are likely to become less optimal in terms of their current goals because of the reduced fertiliser set.

There is perhaps a need to be able to turn off the monitoring of any nutrient within the optimisation routine. This means that quantities of the nutrient in the solution are ignored. This may reduce the problem encountered several times in the results where potassium chloride based fertilisers were included in the least cost linear program solution, but removed in the compromise program solution when p was set to one. Although the large excess of chlorine is reduced, this is at the expense of a reduction in the quantity of potassium in the solution. In this potassium chloride example the inclusion of potassium is probably of more significance in many cases than an excess of chlorine. Where this was seen in the results a new source of potassium was not introduced when *p* was set to one, instead, this did not happen until *p* was set to two. Similar scenarios are likely to exist with other nutrient combinations and. therefore, the ability to select which nutrients to monitor and which to ignore may improve the optimisation routine's output.

Notwithstanding the fertilisers that are available for selection, another reason for the differences in what the consultant has chosen and what the model solutions were is the calculation method used to determine these fertiliser mixes. The model uses compromise programme to select an optimal set of fertilisers based on nutrient and cost goals. Consultant One uses a linear programme to match nutrient requirements with fertilisers. Consultant Two uses a calculator or works it out in his head. Consultant Three uses a similar approach, but with a computer programme where he enters the quantities of fertilisers and it adds them and presents nutrient level values. The methods applied by Consultants' Two and Three approximate compromise programming in that they are trying to determine a fertiliser mix that meets as closely as possible the nutrient requirements they have set. Consultant One's method is also similar, but does not allow solutions that have any nutrient deficiencies. The model, therefore, builds on the way the consultants currently select fertilisers, but also provides them with a more optimal fertiliser mix in terms of the goals and constraints used. Note, however, the solution may not be optimal in terms of how the consultant thinks. This is discussed later in Section 6.4.7 Using the information generated.

6.4.6. Nutrient excesses and deficiencies

A consultant's ability to create a fertiliser mix that meets target nutrient requirements could only be compared with the model solution for Consultant Three. This is because only Consultant Three described both nutrient requirements and fertiliser mixes for each example given. The other consultants only said what the fertiliser mix was. Thus the actual nutrient requirements had to be based on what the fertiliser mix supplied. This made the assumption that the consultant's fertiliser mix met exactly the nutrients required. Consultant Threes examples suggest that this assumption is perhaps not true as each of his examples had both excess and deficient levels of nutrients. Consultant

One also noted during the interview that he wanted a way of decreasing the excesses his current linear programme generates.

The excesses and deficiencies of nutrients in the fertiliser recommendation given by Consultant Three are much greater than the solutions generated by the model. Not only are the nutrient levels in the model solutions closer to their target values than the consultant's mix, but they also cost less and typically weigh less.

6.4.7. Using the information generated

The purpose of the optimisation routine is to give a consultant a good starting point from which to base their decision on what to recommend in terms of a fertiliser mix to a grower. None of the four solutions currently generated should be used as is, as a recommendation. Rather, the solutions are there primarily as a guide for the consultant, a starting point from which to base their decision. The aim of the software is not to put consultants out of a job, but rather to reduce the time it takes to produce a fertiliser recommendation and to perhaps improve quality the of the fertiliser recommendation they provide.

Only fertiliser cost and the quantities of nutrients contained in the fertilisers form the basis of selection. This forms only part of the selection process outlined by each of the consultants. The agronomic effectiveness, effect on pH, and solubility of each fertiliser is not considered in the generation of a fertiliser mix by the optimisation routine; nor are any of the rules of thumb that the consultants' described when being studied. To overcome this problem there exists an opportunity to incorporate both a better filtering of which fertilisers the optimisation routine should use and some form of expert system that uses some of the heuristic rules the consultants' currently use themselves. This would require further study of consultants to gain more understanding of these rules. However, due to the vast range and often conflicting methods encountered thus far suggests that a full implementation of these rules could prove difficult.

When interpreting the solutions generated by the optimisation routine the person doing so must have some knowledge of fertilisers if they are to make a good fertiliser recommendation to a grower. The required knowledge about fertilisers includes, the rate at which the nutrients a fertiliser consists of are made available, the effectiveness of the fertilisers at the current pH, the effect on pH that the fertiliser mix will have, and the effectiveness of the fertilisers based on the current levels of other nutrients in the soil system. Failure to understand the interactions of a combination of fertilisers applied to the soil system could lead to reduced returns and, or, damage to the environment. This, however, is true with or without the use of this optimisation routine, but reminds the user of the decision support system that they must still understand the interaction between the soil, plant, and fertiliser.

6.5. Summary

A prototype the decision support system described in Chapter Three was developed using Access 2.0 and Excel 5.0 for the database and optimisation components respectively

Evaluation of the decision support system was limited to the optimisation routine. Examples of nutrient requirements from each of the three consultants studied were used for the evaluation. The solutions to the linear program and compromise programs (were p was set to one, two and infinity) were described and compared with the consultants fertiliser recommendation.

Of the p values used, the solutions that had the least deficiencies and excesses were generated when p was set to two. The cost of the mix generated by the model was between 12% and 49% less than the consultant's fertiliser mix. The weights of the model's solutions were in most cases less than the consultant's mix. Where the consultant specified nutrient requirements, the mix generated by the model had much lower nutrient excesses and deficiencies compared to the consultant's fertiliser mix.

Several shortcomings of the optimisation routine were discussed. These shortcomings were that the optimisation routine only uses nutrient requirements and cost to determine the solutions, treats all nutrients equally and does not let the user decide which nutrient excesses and deficiencies matter when determining the solutions. The precision of the solutions was also questioned as it was noted that the consultant's mixes were given in units of 25kg, whereas the model's solutions were given in 1kg units. The concern is whether this precision can realistically be measured when both blending the mix and spreading it.

The information that the decision support system can provide a consultant should be treated as an additional piece of information to aid the decision making process. The decision support system should not be considered a tool that generates a final decision, instead, it is a starting point from which the consultant can add their personal knowledge, experience, and understanding of the clients they serve to come up with a fertiliser mix recommendation. Using the decision support system it is likely to reduce the time required to prepare a fertiliser recommendation for a grower.

Chapter 7

Conclusions

7.1. Summary of methodology

The fertiliser recommendation service begins with a consultant collecting information, which they then incorporate into their knowledge. When a client requests a fertiliser recommendation the consultants' draw on this knowledge, some of which is analysed and thus creates new knowledge about the problem at hand. The results of the analysis and their knowledge are then used to establish an estimate of the nutrient requirements, and the fertiliser recommendation. The output of this process is a recommendation report consisting of what fertilisers the grower should use and how and when to apply them. This is sent to the grower and incorporated into the consultant's knowledge.

The first objective of this study was to develop a model of the processes that horticultural consultants use to make fertiliser recommendations. Identifying and learning about these processes was achieved using a qualitative research approach that included taped interviews of three consultants involved in making fertiliser recommendations to growers. The decision making process used by the consultants was presented as a flow diagram where each of its components (processes) and links between them were described.

Consultants have found it difficult to design fertiliser mixes that supply the exact amount of nutrients required by the crop (the main nutrients considered in this study are N, P, K, S, Mg, Ca, Cl, and Mn). The fertiliser mixes the consultants recommended supply excess nutrients or are deficient in some nutrients required by the crop. An important outcome from studying the consultant's decision making process was that consultants would like their fertiliser recommendations to meet as closely as possible the nutrient requirements of the crops, at minimum cost.

The second objective of this study was, therefore, to design a decision support system that consultants could use as an aid in the fertiliser selection process by providing an optimal combination of fertilisers that minimises any nutrient deficiencies or excesses.

The decision support system was developed using Microsoft Access 2.0 and Excel 5.0. Using these applications to develop a prototype of the decision support system meant that it could be rapidly built and tested.

The decision support system that was designed to meet this objective consisted of an interface, databases, and an optimisation routine. A data-flow diagram was used to present a functional description of the decision support system. The database and optimisation components of the decision support system were described using entity-relationship diagrams and mathematical equations respectively.

Currently the consultants store their client and fertiliser information in paper files. This decision support system stores much of this information in the client and fertiliser databases. Storing client specific information enables the consultants to reuse this information so that they do not have to re-enter it when they prepare a fertiliser recommendation. The information in the client database can be used to pre-select fertilisers, set up the optimisation routine, and then store the resulting fertiliser mix. Information that describes the multitude of fertilisers available in New Zealand, which includes nutrient analysis, cost, and where growers can purchase these fertilisers, is stored in the fertiliser database.

The optimisation component uses information from the client and fertiliser databases as setup parameters when generating the solution. The optimisation process aims to select a combination of fertilisers that minimise the cost, and excess and deficient levels of nutrients. The consultant can also set minimum and maximum levels of nutrients and specify relationships between nutrients and fertilisers. The relationships can be between a nutrient or fertiliser and any other nutrient or fertiliser.

The optimisation component of the decision support system is based on the compromise programming technique where the goals are represented by equations that describe how each fertiliser could contribute to the requirement of each nutrient. The objective function represents the total of all deviations (i.e., the difference between the targets of each goal and the actual amounts in the solution). The deviations are measured as percentage deviations rather than absolute deviations. This is because absolute deviations cannot be compared when the units of measure or scale vary between goals.

A parameter defined as the p value can be specified to implicitly weigh the magnitude of the total deviation between actual and target values. Three values of the parameter p were used in generating the compromise solution set, there were one, two, and infinity. The p value of two seems the most appropriate since it yielded solutions with nutrient values closer to the target values, did not take an excessive amount of time to generate the solutions, and typically removed unnecessary nutrients from the solution's linear programme starting values (see below).

The formulation of the compromise programming also allows the deviation of each goal from the desired target to be penalised separately. This is known as the W parameter in the formulation. The W parameter was set to one , meaning each goal was assigned an equal penalty of one.

The nutrient requirement targets were calculated by the consultants after accounting for a) the annual maintenance requirements (i.e., the amount that is expected to be removed from the site over the year), b) the desired balance between nutrients, and c) any other site specific requirements based on the knowledge of the soils in the area.

The fertiliser cost target is determined by solving a standard linear programme (LP) of the fertiliser mix problem that minimises the cost of the fertiliser required to meet nutrient requirements. The LP solution, while seeking fertilisers that minimise cost, can also result in supplying excess nutrients, and even supplying nutrients that are not required. The fertilisers recommended by the LP model tend to provide excellent starting values for the compromise programming technique.

The optimisation component was evaluated using data from real fertiliser recommendations that the consultants had made. The solutions that the optimisation component generated were then compared to what the consultant had recommended and the differences discussed. Four solutions were generated, one for each value of p (one, two, and infinity) and the linear programme starting values.

The main observation was that the solutions generated did not match what the consultant had recommended. The fertilisers in the solutions generated by the model differed from those included in the recommendations prepared by the consultants. There were instances where one or two of the fertilisers that the consultant had recommended were included in the solutions generated by the model, however, this was the exception rather than the norm. It seems that the consultants' may prefer to use a particular small set of fertilisers for all their recommendations. This may be because they feel more confident about using certain fertilisers, perhaps because they know the response of particular fertilisers under the conditions and plants in their region.

When the nutrient requirements were explicitly stated by the consultant it was possible to compare how well the consultant and the model met the target nutrient requirements. This was only possible for one of the consultants. In this case the mixes generated by the model had much lower nutrient excesses and deficiencies compared to the consultant's fertiliser mixes.

The information that the decision support system can provide a consultant should be treated as an additional piece of information to aid the decision making process. The decision support system should not be considered a tool that generates a final decision, it is a starting point from which the consultant can add their personal knowledge, experience, and understanding of the clients they serve to formulate a fertiliser mix recommendation.

7.2. Further work required

Only fertiliser cost and the quantities of nutrients contained in the fertilisers form the basis of selection. This forms only part of the selection process outlined by each of the consultants. The agronomic effectiveness, effect on pH, and solubility of each fertiliser is not considered in the generation of a fertiliser mix by the optimisation routine; nor are any of the rules of thumb that the consultants' described when being studied. To overcome this problem there exists an opportunity to incorporate both a better filtering of which fertilisers the optimisation routine should use and some form of expert system that uses some of the heuristic rules the consultants' currently use themselves. This would require further study of consultants to gain more understanding of these rules.

The weight of the solutions fertiliser mix was calculated so that it could be compared between solutions and so that the cost of cartage and spreading could be estimated. If more detailed data describing these costs could have been obtained from the consultants then perhaps weight could be added as a goal. A weight goal would probably only be used where a consultant's client was trying to cut costs.

An alternative use of the decision support system is for fertiliser companies to use it as an aid to determining nutrient content and price of new fertilisers they are developing. The new fertiliser could be included in the model and the company could investigate at what price the fertiliser is included in the solution. They could also modify its' nutrient content to see how that effects its' inclusion in the solution. This could lead to the development of fertilisers tailored to specific crops and regions.

Even after further research is conducted and extra features such as an expert system are added to the current model, getting consultants to use it would still be difficult in the short run. The model has a useful role to play in the recommendation of fertiliser. However, many of the models developed in research projects require considerable effort before they are used commercially. The problem stems from two areas, buy-in, and marketing. Buy-in refers to getting the co-operation of users, consultants in this case, to be involved in the development of the software from the start. The people involved here are those that can be used to champion the product in their firms and get others interested.

Marketing is the greatest hurdle that must be overcome. The software industry is replete with examples of marketing being the dominating factor that has encouraged uptake and product success. The point here is that to get market acceptance requires both a product that delivers the benefits consultants require and one that is aggressively marketed. The New Zealand market for primary industry software is small. Any effort to develop models such as this requires an international market.

The model does have a place in the commercial world of fertiliser recommendations. Of the consultants studied, Consultants One and Two would probably utilise this model. Consultant One would use it to replace his current linear programme, while Consultant Two would perhaps use it for use in the company orchard and for testing new fertilisers the company develops. To bring this to reality the model requires further development to create a version that consultants can use independent of the researcher and thus assess the usefulness of the fertiliser decision support system.

Appendix 1

Transcripts of the interviews with consultants

1.1. Transcript of the interview with consultant one

1. TH Do you want to talk about not only kiwifruit, but all crops?

2. SV Yeah, sort of, probably mainly in the orcharding area, but to try and tie in other areas as well.

3. TH Okay. All right, yeah. In the orcharding side of it the selection process we generally go through is we'll look at historically what information is available in the first instance, say we'll look at historical soil tests, historical leaf tests, and see if there are any problems or trends that are showing in terms of orchards, like round here, for instance, we quite often find there is a potassium or magnesium trend. That shows it has been a difficult area to fix. And that has come through from historical soil and leaf tests and observations of the grower and what a growers, that um, will take account of that when we're putting recommendations together. Because you can sometimes have a perfectly normal soil test in terms of some of the nutrients, but in terms of the leaf test can be a difficulty so we may alter our actual recommendation on the basis of that. That's the first thing we look at. Second thing, definitely talk grower observation, so, in, they quite often say, historically have this problem or have this difficulty. We'll also talk to them about any preferences in terms of the fertilisers that they wish to use. Some of them may have a preference for organic type fertilisers, others may have a preference for avoiding products with chloride in, because there has been a bit of a stigma...

4. SV With the kiwifruit...

5. TH Yes, and some people think that there is a chloride problem. All though there is arguments both ways

6. SV Yeah, some say it is a nitrogen problem, some say it is a chlorine.

7. TH Yeah, its a nitrogen problem as far as I'm concerned.

8. SV Yeah, that's what the literature sort of points to.

9. But we definitely have to take that into account with the grower, and we can discuss that, you know, we consider its a nitrogen problem, but if they are quite insistent that they wish to apply potassium sulphate as opposed to potassium chloride we will take that into account when we do a recommendation. Then we'll look at estimated yield, so we'll do a calculation on the total tonnage of fruit that's going to be taken out, how much nutrients are actually going to be removed from the orchard, and we have some sort of guidelines that we work through...

10. SV Do you take into account other things like prunings and that sort of things ...

11. TH Yeah, a little bit of that as well, yeah, but the yield is the part mainly removed from the orchard, most of the prunings are mulched and put back in. Kiwifruit particularly. Apples they tend to sweep them out but apples are a much lower nutrient requirement crop anyway. So, those factors, then from there we'll run a recommendation which may be on the old least cost fertiliser program, and that will then print out a range of options for us, based on, we'll estimate how much nitrogen, potassium, magnesium, phosphate, sulphur are required and punch in what we can into the model and it produces a least cost option for us, but if the client has said they don't want potassium chloride and the first one that punches out has potassium chloride in it then we keep on going down 'til we find an option that fits. But, more and more now what I'm taking into account to is that some of the models actually, when least cost, it actually has excesses of some nutrients, and we're trying to avoid that if we can, so we're trying to look at fertiliser programs that supply what we want, but not a hell of a lot more.

12. SV Yeah, try and reduce those excesses. I've noticed with some of the ones I've just run through the prototype, through a least cost sort of model, you can come up with say, excesses in sulphur for example, is quite a good one, but when you minimise the excesses it will change the fertilisers to meet that lower sulphur requirement.

13. TH Yeah, it is particularly important when you get into some of the vegetable crops and the greenhouse crops and indoor crops particularly because you don't

have the rain flushing the soil and so on, and you can get built up sulphur that goes through the roof, sulphur readings as high as 300 - 400, you know, which is absolutely ridiculous, and you then have to look at products like potassium nitrate, which are a lot more expensive.

14. SV Farmers and growers won't be to happy about that.

15. TH No.

16. SV So, what sort of model do you use currently, say, a linear program, least cost...

17. TH Least cost one, yes. Its put out by the soil fertility service, probably about 7 or 8 years ago, and what you do is you will punch in, for your nearest depot, you will punch in all the fertilisers and put in all the N P K Mg analysis of it and the sulphur analysis of it, and the price. And so you can put in your complete list of fertilisers in there, and for instance, the ones that mostly our consultants use have got BOP fertilisers supplied through AnchorMart and Wrightsons, so we'll have an AnchorMart and a Wrightsons price list on there, and generally there's not a lot of difference, it's just the specials that they run. So when they run a special you may go in there and alter the model price so you can go in there for that particular product and alter the price and run it and see whether it actually shows up as being a pretty good option, and deferred payments and stuff like that, sometimes you have to take those into account. There's a lot of the companies will allow you to put on a product and pay for it in 3 months or 4 months, and that can be quite important, particularly for market gardeners putting a crop in and waiting for it to come through...

18. SV Wait for it to come through so they have got the cash flow to pay for it.

19. TH So it's pretty basic sort of a model. I personally don't do a lot of soil fertility work, some of the other guys do a lot more than I do. Its a, well all right, pretty easy for me, I don't do a lot, I just punch in this many kilos per hectare.

20. SV So, what do you exactly start with? You've got your nutrient requirements, they're specified as single numbers, or as a range, or...

21. TH Yes, specified them as a single number. Its actually got a whole selection of different land uses that you can go through. Here's one for Kiwifruit, here's

another one for some other perhaps some other pastoral uses, and so on like that, and then you just put in you want 60 kg per hectare of N and 80 of P or whatever and it just mathematically goes through and makes a selection on it.

22. SV So when you get your results back from the leaf tests, do they come back as a single number as well that you can put straight into there, or are they a range?

23. TH No, generally what comes back on your soil and leaf tests, is the results, they are single numbers for the amount of nutrients, that is there, but then, you have got to interpret that and work out on the basis of that, how many kilograms of product you have to put on per hectare to get a lift or you look at correction levels, to get that from where they are currently up to what we consider to be the base levels, and then you have to look at annual maintenance on top of that. So, in most instances here, we're looking at annual maintenance, there's very few people that we're looking at large levels of corrective fertilisers unless they're looking at going into market gardening out of pasture, which your pasture is generally lower than, so you're looking at a lift. If you're looking at that, you then have to consider how long they're going to go into pasture as well, because to lift some of the base levels may take 4 to 5 years of the fertiliser programs to lift it otherwise you're putting it on to excess and its going out in the drains and in the water.

24. SV One of the guys from the agricultural consultants down in Palmerston was giving us a few ideas on how to start up, to start with and from his side they're only dealing with the macro nutrients, is there any difference in how you deal with some of the micronutrients compared to the macro nutrients?

25. TH Yes, there are. We, in horticulture, we do a lot more testing, pasture farmers might soil test every two or three years, maybe sometimes 5 years, as far as that. Horticulturalists generally soil test, if they're fruit crops, permanent crop type situation they'll soil test at least once a year, usually only once a year. If they're market gardeners they may test between crops, if they're greenhouse growers they'll usually test, depending on what they're doing, they may be growing in the soil, most of them are starting to grow in peat pumice mixes, in bags and so on, they may get an analysis done of that before they start, then they rely very heavily on feeding trace elements in through liquid feed systems, that in itself is a very very exacting field, and we've got 2 or 3 of our consultants, 1 consultant in

particular who's really specialised, and another 2 or 3 that hang around that 1 consultant to work out the mixes, because the plants are virtually reliant on what you are putting through your irrigation system. So you are very heavily leaf testing all the time, maybe leaf testing as often as once a month, to track how well things are going. That's very reliant on all the trace elements and so on, because pumice is a very raw product, very low in nutrient status, so you have to be right on top of it. Kiwifruit and other fruit crops, trace elements and market gardening, if there has been a trace element problem has been identified, you may add it to your bulk fertiliser, like if you have identified you have got a boron deficiency you may add a little bit of boron to your phosphate as it goes on. So you just do that at the works, you say right you want 5 kgs a ton and you get it added in.

26. SV With a lot of fertilisers when you buy them they'll already have different bits of trace elements in them already.

27. TH As impurities.

28. SV As impurities, yes. Do you take that into account at all?

29. TH No, we don't. Not unless they were just off the scale in terms of, it's only a minor deficiency, we might say that the traces, the impurities should be enough to cater for it. But generally you would make a firm recommendation for adding a trace to it.

30. SV What exact information about fertilisers do you use, is the price, is, who the suppliers are, and there nutrient make up, .

31. TH For the greenhouse, intensive cropping, type scene, we go to a lot wider range of suppliers, because there's Vegegrow supplies, Fruitfed supplies and so on, who supply small volumes of the trace element mixes, whereas the big guys, you can only buy it in 40 or 50 kg bag, and a 40 kg bag of some trace element may last a green house grower 20 years, because you are talking such small amounts, and you have quite complex mixes of them they make up, and you can't mix certain products because the coagulate or crystallise or whatever. So you have basically A and B mixes for those particular ones, and when you are making the mixes up you generally take into account the cost of the products that are going in, but it is more important to get the mix right.

32. SV When you are splitting applications, you have got some requirement specified, and you have identified that you need to split it up because of the different types of chemicals that are in there, how do you go about that sort of process?

33. TH How do we actually split it?

34. SV Yeah, what, is there any sort of key way you split it , or is it ...

35. TH Yeah, I don't so much do the traces, but in my other, the other ones, I know, that if you're taking out a crop, of Kiwifruit, for instance, you're taking out 6000 trays, when that goes out for every thousand trays there's so much N P K Mg, sulphur, calcium going out, so you work out that's your maintenance, plus your wastage factor, because not everything that you put on is going to be taken up by the plant. That's how I sort of work out there, but in terms of this, you've got that plus my sort of expected yield, my annual maintenance, plus any deficiencies.

36. SV So, just before you come to apply all your fertilisers at the beginning of the growing season, you decide that, I'm going to put some on here in say November, and then decide to put some on in later months.

37. TH Yes, we do for some of them. For most of your elements like your phosphate, your relatively immobile elements like phosphate, calcium, lime, those sorts of products we tend to broadcast, get 100% ground cover, we put them on early in the season, because we know that they're not going to wash down the drain in the first shower of rain. The other elements like potassium and nitrogen, potassium for Kiwifruit we generally apply early, and in bulk, we may apply 100%, or we may split, depending on the history of the property, in terms of its ability to retain potassium in the soil. So if we know it's a property where we've had a history of low potassium leaf tests we'd probably apply it in 2 or 3 applications. So, nitrogen we definitely split. Nitrogen we'll put on almost every case we'll do 2 applications.

38. SV Do you, ...

39. TH How do we work that out?

40. SV Yes, how do you decide how much to split into each, is it roughly half and half, or...

41. TH No, you usually we have worked with scientists, in terms of the history of it, they'll generally say you put on a third here or two thirds here, general scientific information that we have based it on in the first instance. So, most of the crops, someone has done detailed nutritional work on it, somewhere, either reported in the scientific or public magazines, or if its not, and the papers aren't there, say its a new crop, like flowers, the floricultural consultants are constantly in touch with the research people on that, basically the research people are doing nutritional work, you say, this is what we're doing in the field, is it right, should we be doing something different.

42. SV Once you've made a recommendation, in what form do you present your recommendation to the grower?

43. TH It depends on what the grower wants. Some growers, all they want, you just put it down and I'll go off and get on the phone and ring up Wrightsons or AnchorMart, order my fertiliser and its done. They don't want any of the sort of the rational behind it, so they don't want to understand why you have said what you do, they just want to understand this is what I've got to do, whereas other growers like to see the results, so we present the results as they are, the desirable or target levels, the trends that we have picked up, so we can say right, this has moved since last year, it's gone down or up, as a result of that we're going to take that into account in terms of the nutrient side of it. We'll also look at the leaf test so we might go back later on, having Kiwifruit for instance leaf testing at the moment, we may take that into account when we do the rec., soil fertility rec. in August we'll say right, going back to your summer leaf test it showed this, so we're taking that into account. So you might get a bit of a introduction, these are the results, here's some of the things that we've got to consider, and as a result of and your estimated crop, here's what our recommendation is in terms of amounts of N P K , in kg per hectare or kg per square meter depending on what your crop is, and as a result of that, by our calculations this is the least cost fertiliser option, so we then put in a recommendation in on that.

44. SV And do you keep a record of those recommendations over time, so you can refer back to them?

45. TH Yes, definitely.

46. SV So you can go back, look at the past several years what you've done for that grower?

47. TH Yes.

48. SV What sort of form do you store that in at the moment?

49. TH It's all hard copy, client files. We've got in those little hard copy client files, we haven't got an electronic system that we think is reliable enough or, we haven't got a network, so its just PC operated, and PC's were changing all the time, most of out PC's are here for 4 years and they're gone, so unless you've got some sort of means of backing up the program to a disk or a tape or something, and bringing it back in it's quite messy. And our computers here, most of them are notebook computers, out and about all the time, so unless, each consultant hasn't got a desk and a computer, poor little computers that the consultants have. And, clients go across consultants as well, so, I might be working with a client on the fruit side and they'll have a greenhouse as well, which another consultant will be working on so it's important that we do store information at one central place, and keep access to it, and if a consultant leaves, he won't be able to dive into the records and know where they are.

50. SV So what exactly information are you keeping in those records recommendations, just the ...

51. TH Keeping a copy of all the recommendations.

52. SV How many kgs, or the whole presentation of what you've given them.

53. TH Keep the whole presentation that we've given to the grower. We'll sometimes keep our calculation sheets as well. So if we print a least cost run, to the grower, usually to them we'll present the first 4 or 5 options, but for us we'll keep the whole printout.

54. SV Is there any specific way you use this information that you've stored? In future recommendations, do you...

55. TH Yes, we definitely go through again and look at the historical problems, trends there. A good example is phosphate levels, can build up round here, and so we can get phosphate levels as high as 100, 120, and in some of the soils the desirable

target levels might be about 30, and so you may have a policy of trying to knock your phosphate levels back down, because it may be suppressing copper or zinc, or something like that. And so, if you don't recommend phosphate for a couple of years and the levels start to come back down again, down to a level where you say, all right, I'll start putting some more in as a standard maintenance that you put in. If you've got the historical information there you might think twice about that. Might say well I've had historically a phosphate problem, lets not get too carried away with it, lets just leave it out for a little bit longer. Most consultants are pretty keenly aware of what's going on with their clients in terms of fertiliser history.

56. SV Up to date. What sort of numbers of clients are you dealing with? Making recommendations to.

57. TH The biggest ones would handle about 200 clients a year, in terms of recommendations, and some would do as little as half a dozen to ten, but that's just not their core work area.

58. SV So they've got quite a good knowledge of the area then in terms of the soil.

59. TH Yes, yes.

60. SV So, getting back to the decision processes you go through, your basing most of your decisions on the recommendations from the model, the least cost model that you are using, is that right?

61. TH No, that's just a tool we use to crank out the final fertiliser program.

62. SV So, you start here with the requirements, with how many kgs you're going to need,

63. TH Yeah, you work up to that, that's time, time is taken to develop how many kgs are of each of the nutrients is required. Once you've got that it's two minutes to get your fertilisers sorted out, because you just punch them in, and then it prints them out. It's working it out, you know, we've got to allow this for that, that for that, taking into account historical factors, expected yields, the grower factor, those types of things, and it can take you, typically for a soil test, from soil test to recommendation, takes about half an hour, and you can spend about 20 minutes of

that, 25 minutes of that doing historical, analysing your results you've got, doing your calc's to get the N P K, and the last 5 to 10 minutes is spent getting the fertilisers sorted out, so that's the price, the least cost sort of run on it.

64. SV In that model you use, is there any key areas that you would see that need improvement.

65. TH Yes, it's being able to store more info by client so you don't have to wade through the historical folder of information that you've got, so that when, it would be great if you could electronically pull up for that client, their history, and it has some notes there, and it says has a history of high phosphate, or whatever, like that, has difficulty in getting magnesium levels up, you know, historically shows low magnesium. So that without having to wade through it just pops up, and then you can put in historical yield figures, like 1990, this many trays per hectare, so it shows the sort of trends that are coming through there. Does not want to use these sorts of fertilisers, whatever, so if you had a lot of that there on a one page summary as you started off, it'd short cut it probably 10 minutes.

66. SV Over 200 clients for a person is quite a saving.

67. TH Yes. We've got a fairly standard pricing system too, soil fertility, and soil fertility recommendations, is a very competitive market. For us its not a big, for some of our individual consultants it may be, because they have a heavy involvement in it, but for most of those it's probably 1 to 2 % of our total earnings for the year. It's low margin stuff, because there's tons of people running around offering free soil tests, and recommendations.

68. SV Is that a lot of the fertiliser companies themselves?

69. TH Yes. Or stock and station agents or whatever. And they'll offer a free test because they know they'll get it back when the sell the fertiliser.

70. SV How does their offerings compare to what you offer. Is it as good, or is it biased toward what they particularly sell?

71. TH I think it's biased towards the products they know they get a better margin out of. I've had a few of my clients come to me with recommendations from their particular stock and station or supply agent and said they'd soil tested, here's what

they recommended, what do you think, and I've looked at it, and without looking at their historical information and doing all that analysis, I'll just punch the N P K into the model, least cost, and there'll be far cheaper options for putting it on. So that's number 1. Number 2 is they haven't given the thought and consideration to the history on the property that we usually do. To give you an idea, for a soil test we've got a sliding scale, but we start at $120 for the soil test and recommendation. That's where the grower actually takes the sample. It goes down on a sliding scale until you end up with each marginal one after 10 is about $55, so it sort of flattens off. But a lot of the other companies will do it for free, or they'll do it for 30 or 40 dollars, which, people are saying they're a third of the price of yours, or they're free, and we're saying, well, what's the catch, and where is the catch, because if you do it right, you have got to put in the time to do it, as I said, it takes about half an hour to work out what fertiliser to put on, then you've got to write up the report and everything like that, then you've got the lab fee to take off it, as well...

72. SV So there's not a lot left.

73. TH No. And the other people still get billed a lab fee, so most of them are passing on the charge of the lab fee to the client, and putting their time in for nothing, because they sell the product, so it's part of their sale of the product, or for those that do it for free, they're putting in the lab cost for free, as well, so they're biffing it in, but knowing that when they price the fertiliser, they've got to recover their 50 buck lab fee out of it. So, we don't sell fertiliser, so we consider that our results are what we consider is the best nutrient program for that particular person, for their property. So, it's focused entirely on getting it right, and at least cost as well.

74. SV You were saying about bringing up information about the growers. Is that, do you store any information about your growers at the moment, in terms of ...

75. TH Not electronically, no. They're all, it's hard storage. We're shifting office soon, and when we do that we'll be setting up a network. Network will enable us to start looking at more of those particular systems. It'll just be a local area network, but we may be able to look at some of those things.

76. SV Is there any sort of things besides your historic things, your, like the potassium chloride and the potassium sulphate, are there any other types of, like there's a ratio or a relationship to maintain there for some people, or something to exclude, are there any other types of criteria that you'd put on your selection of fertilisers.

77. TH Not really, no. No, not outside of what we've already discussed.

78. SV That's given me a good rounding there. Would you be able to show us, just roughly, what the sort of things you go through, just, the calculations you use...

79. TH Give you an example you mean?

80. SV Yeah.

81. TH Yeah, hang on, I'll grab a client file, and we'll just sort of work through that one, give you an idea.

82. TH This particular one is for a Kiwifruit, and they've got apples and so on as well. But, when I first went and saw him I got hold of as many of his historical soil test results as I could, so I got all those back, 1991, 1992, and then looked at his historical recommendations and what fertilisers he'd put on, so that's all the historical data there. Then, this is historical rec.s from one of my colleges, he'd done that, and he'd since left, so I took over the client. More historical data there. This here is an interesting sample of my fertiliser selection based on least cost. Right, so...

83. SV A listing of the elements there...

84. TH Yeah, it's got the elements, I punched in, this is my requirement here, it processes them and puts the total of each of those N P K S and Magnesium down here, and that's the first option, that's the second, third, fourth.

85. SV So it gives you 4 different types of ...

86. TH Oh yeah, you can specify how many you want.

87. SV How many different ones.

88. TH Yeah, oh, yeah, I usually specify 4 or 5, it usually gives you enough. In this case here, its showed that a mix of, for that particular mix of nutrients, mix of

D.A.P, Muriate, Magnox, gave a total of $495 per hectare, compared to, there's another one, a hort fertiliser, a special one that one of the companies here does, with muriated potash was 549, and so on up, and he is, a historical user of a 12:10:10 product, which is a lot more expensive, so he was able to save, in this case, about 125 bucks per hectare over his whole orchard, through going back to a program like this. So, he'd get a letter, so, this one here I'd gone over his fertiliser history, so I didn't actually have any soil test results, and see what the recommendation was, chemical, N P K, magnesium, [can't understand a couple of seconds] and, what I'd allowed for in terms of the model, what it'd spat out...

89. SV So, in your calculations you take into account the cost of getting it to them, and spreading it, or...

90. TH Yeah, well, you can put in a cost of freight, and a mixing charge, so if it's freight, if you want to include spreading it might be freight plus spreading. Typically, around here, you can get fertiliser carted and put on for about $30 a ton, most of the orchards are so close, the spreaders don't charge them freight, they just pick it up and put it on.

91. SV So, do they do most of it themselves, the growers, or do they mostly people to come and spread it for them?

92. TH Mostly people come and spread it. They'll put on usually the urea themselves, because that's quite exacting, you can't mix it anyway, and you'd put that on in 2 or 3 applications, but the other ones they'll just get a truck in, tractor scoots round, they've got special ones that go round the Kiwifruit vines. After that we just leaf test, leaf test results, you know, low magnesium, and we recommend here you put on extra Epsom salts or Kieserite, basically just to kick the magnesium along. So that's all we looked at there, and the next winter, some more soil tests here, some more runs of the nutrient model, just sort of shows some options there. And the result of this, two thirds, one third, whenever, and magnesium here. We've just made some comments about the magnesium, what could be suppressing it. So we're still working on that. Right, so that's typically what we do, and that's just carry on again this year. It's pretty straight forward.

93. SV Yeah, gives me a pretty good idea. So what I'll do now is I'll draw up sort of an idea of the different things you take into account, and then look at see how I can build some of those things into the prototype of the model I'm developing now.

94. TH If you could send it through, that'd be good, I could say yes, you've got it right or wrong.

95. SV Yes. Over the next few weeks I'll try and draw it all up and get you a copy so that see that, yep, this is how things fit together and so forth. Well, excellent, thank you for your time.

96. TH That's okay, all the best with it, look forward to seeing the product.

97. SV Yes, hopefully not to far away...

[Tape ends]

1.2. Transcript of the interview with consultant two

1. LG Ok well my role, I've got an overall role in the company, I'm horticultural products sales manager. So I work with our field staff right from Gisborne down to Invercargil and deal with the major clients with regards the horticultural and process cropping, so um, that's the overall role. In terms of what I do on a day-to-day basis I'm dealing with growers and helping them work out what to use as fertiliser, um and I guess and I'm more than half possibly even nearer 70% now is my time spent on vegetables, process crop and that includes things like maize, maize, sweetcorn, potatoes, carrots, tomatoes, and all your greens your cauli, broccoli and so then the rest of its grapes and apples and citrus and stone fruit, or everything except basically pasture, I don't do much in the cereals field, but do a little, so yeah its all those other things apart from grass.

2. SV Right, and um, Ravensdown itself, how does that fit into the horticultural industry compared to other competitors and so forth?

3. LG Well we carry um a big range of products, I mean the horticultural industry is no different to the pasture industry in that it needs nutrients, but it needs a ranges of nutrient types, whereas with pasture you are mainly dealing with mainly

phosphate and sulphur and in the horticultural scene in inverted commas, we're dealing with nitrogen, phosphorous, potassium, magnesium, sulphur, calcium, trace elements, so we've got the whole range and their needed in different quantities, different rates, different times, different ways of applying them and obviously for a vegetable crop where you are trying to grow it quickly you've got to use a quick, more quickly available type of product than you would use perhaps in a pastoral scene because you've got a relatively short time to grow the crop and its out so there's not much use using a slow release type phosphate or sulphur when it's not able to use it in the three or four months its got for growing so we are using products that are, basically water soluble so that they can be taken in by the plants used. What we're trying to do is use products which are the right products to allow the uptake of nutrient and getting the growers to manage their application so that they can gain as much effectiveness from them as possible without using, without loosing through leaching any large quantities and that's applicable mainly to nitrogen, it does apply slightly to potassium, nitrogen is the key one. So my job really is in terms of dealing with growers who ask me to provide them with a program they may have field tomatoes or sweetcorn or potatoes. So the guys will say what do I do? this is what I want to do I've got 400 acres of that I want to grow this this and this in. So I start off by saying well I need to have soil test data for each paddock.

4. SV Is this previous soil test data that they've got for this paddock?

5. LG Previous as well as what the current stuff is. So over a period of time I build up a picture of what they are doing, because if I am linked in year-to-year and I can pick up trends as to what is happening so I can see whether the pH is dropping going up, or what happens to the P level over time and get an idea of response rates on those particular soils. Now over the years I've built up a picture of, of those in my mind anyway so um.

6. SV So I suppose with, when you have several properties over a similar soil types if they are growing similar crops it helps to mingle across between growers and so forth.

7. LG Yes, but even on the Heratunga plains there are differences in terms of how much P you need to shift the soil test values depending on the soil types, you go

from the Meanee silts here to the Havelock clay and its quite different and you go down to the high P retention soils and its quite you're different again, oh yeah, ya know it varies and that, but that comes with experience when you're doing ya know year in year out you're dealing with a whole range of soils you do build up ya know a picture and I can get a soil test come over my desk and a maybe not dealt with that paddock before or, or that block of land, but I know from where it is what characteristics are that I would be looking for and what I've got to be mindful of in terms of inputs so that influences the way I think, so that's something you're going to have to work into your model, a knowledge of soil types. So P retention is probably a good starting point if you've got that you know straight away what sort of quantity of input of phosphate is going to be and you're going to know what the sulphur level in the soil is going to be in terms of high P retention soil you've got high retention of sulphur, so you don't need to worry to much about putting sulphur in. Low P retention soils it is the other way around. So I work with soil test data and I monitor with leaf test data. So we get leaf tests as the season goes on and a, although in many cases you can't do much about changing the returns for those crops given that they have already set fruit and their in the fruit expansion stage or near the end of it you can't get an economic return from anything you apply it gives you added information for next years crop. On those same soils you can say right we know we are going to run into a manganese problem here so lets get in and put on manganese on at the right time or molybdenum or we know we're got an uptake problem with potassium so we've got to increase our inputs. These things all help me, um, formulating here how many kg's of, of K for example, I will put on.

8. SV I suppose with veges you're dealing with a lot of short term cropping as opposed to your orcharding your, there will be more leaf tests I assume through out the year to do with each crop.

9. LG Sometimes, I mean where we, we, where we know we've got to learn about things. We're doing some, for example, with, with carrots at the moment we've been monitoring every week or two weeks just, just to get a fix on what is happening, but that's a separate issue. No, with the permanent crops, kiwifruit was mentioned by Russ in his letter, we'll do annual monitoring of leaf testing and soils so we get a idea as to whether we are putting enough in or not.

10. SV To see how the ones you're putting into the soil are coming out in the plants.

11. LG Year, and what we aim for is an equilibrium a balance between what we're putting in and obviously looking at yield, as long as we are maintaining or improving the yields. If the yields are declining well then we've got problems, but um, we aim for that equilibrium and after about three years you can slot in quite nicely to, inputs equalling what's been taken out or lost or fixed in the soil and you can hold it at a fixed level, and as long as the production levels fine, the growers happy, you can sit on that. So that's the ideal, it doesn't happen very easily, you can get to it, I've done it in Gisborne and I've done it here. So that's basically how we arrive at what we put in and how we check to see what we are doing is right.

12. SV So you, you start off with your soil tests, you'll ascertain you have a certain amount in the soil and from that work out that you need so much N, P, K to um, to, for your corrective levels and for your annual maintenance component of that.

13. LG We've got an idea from the type of soil, from crop removals, what sort of nutrient inputs are needed, and then its just a matter of selecting the right type of fert and the time of when it should be put on and making sure that things like our Boron levels are right so that, ya know, in apple crops we get we get the right Calcium uptake and, ya know, you've gotta look at your relationships between nutrients and what happens if you go wrong. So yeah, and then next step is grower education.

14. SV What do you mean by that?

15. LG Well sometimes they don't understand that you've got to have certain things at a certain level and um, ya know, they may say oh no, I want those trees to grow, I want them to grow faster than they are and also hang a crop so their throwing heaps of nitrogen at them and um.

16. SV There not getting much crop.

17. LG Exactly, yeah, yeah wonder why they end up with very small fruit set and the ones that do set are like pumpkins which are no good for anything and you have to explain to them why you are trying to keep things in balance. That's not an easy part because a lot of growers think they know best and even though that, ya know,

even though I'm perceived to be a fertiliser salesman um, they just think oh year that's what I'll double it or on the other hand they may halve it and say that you told me to do that and your selling it so, therefore, your putting in too much. Its, you can't influence peoples thinking so yeah you've got to accept that sort of thing, but the way we work is to tell them to the best of our knowledge what the tree of the plant needs and how best to apply it. Its not an easy science as such, we try and work with good science, but you have to relate it back to the growing conditions. I think um, what I try and do is monitor, by monitoring and keeping in touch with the grower, I ring my main clients and so Ok this is what we did, given the season we've had, the weather conditions we've had, what are your thoughts.

18. SV So you get some feedback from them.

19. LG Oh yes.

20. SV How they perceived the application went.

21. LG Yeap, and um, we've got some pretty switched on growers now and they take note, they're around their paddock each day and they just jot things down. And then we just sit down together, when they've gone through their harvest, and say, okay, what were the problems and lets see if we can relate them to any aspect of the fertiliser program, and indeed that happens. Its starting to happen as we introduce more varieties for each crop. So instead of having a tomato programme, we'll have a tomato variety programme in the future. Instead of having a potato fertiliser, we'll have potato variety, and what you do with Rua's, you may not do with Agrea. So, these sort of programmes are going to get more refined to variety, and that's the sort of area that I'm looking at now. So, say to the guy, okay, that works well for this variety, but my observations are that you've got a hell of a lot of vine here, and bugger all fruit, and he says, yeah, I'm disappointed in my yield in this one, you know, from day one they've grown like crazy, and obviously the nutrient input for those are different for this. So we have to look at refining by variety.

22. SV Do you get much information through the scientific literature on that, or is...

23. LG No. There's not a lot of work that's done on these things, I mean, these guys are importing new varieties Heinz comes in and they bring in varieties from

Australia or from somewhere else around the world like Spain or something, and things that may happen in those countries, happen differently here. So these guys come in, and they plant them, and they say, okay well, we're aware that they are a hybrid, we're aware that we're going to get growth vigour, so we've got to moderate in terms of nitrogen inputs, we think we've got the phosphate level about right for our current varieties, we've got to really go through a season and see how they go. And then we moderate from there. Adjust it. But no, there's not a lot of data that's available to latch into.

24. SV Yeah, you just have to look at the other varieties that are similar I suppose, and run through a few seasons.

25. LG I try and take note of what's going on around the world, try and pick up comments from visiting people, and when I travel, have a look, you make note of what's said, really, from a whole range, from the scientists to the growers, and the field men for the different companies. You know, you just have to take note of comments that they make. They don't necessarily apply here, but you can gauge from what they say that all right, that's a more vigorous variety than that one. So when it comes in to being here you're fairly cautious. Makes modelling bloody difficult, and you know, people have said to me for years, why don't you just have a simple model. Well, it don't work like that.

26. SV Models aren't simple.

27. LG No, they're not.

28. SV Unfortunately.

29. LG Well, I've seen some of the work that the crop and food people have done, no, they're certainly not simple models.

30. SV Is that the um...

31. LG Oh, some of the cereals models, that what's his name, Dereuto (?) is working on. Yeah. His maize model is being produced now.

32. SV The agricultural ones are, I think, a little bit easier than...

33. LG The pastoral ones.

34. SV Yeah the pastoral ones.

35. LG Yeah, but even the optimum models that have come out for P and S are flawed, you know, it's all very fine theoretically, but when you come to the practical scene, our people find difficulty in using those. It's not a simple thing to sit down with a farmer, and ten minutes later you've got a fertiliser programme. You know, what it spits out, often, is not right. So, um, in terms of modelling, people like Watties are working on individual crop models, its too big a topic to have a whole range of crops, in the same sort of model, but they are working at the moment on a tomato one.

36. SV Also Hort Research's kiwifruit one there, that they were working on.

37. LG Yeah, I don't know where that's gone to.

38. SV Yeah, it's pretty much ground to a halt at the moment, they've got a prototype stage of the, um, they had the kiwifruit management, the nutrition services or something it was, and they were running that out at Ruakura, and they were trying to create a stand alone, just a, something that a consultant could have on his desk basically, version of it. And they've just run out of funding, and the key programmer that was working on it has also left as well, which doesn't help.

39. LG Oh, right. They were working on an apple model, too. Or there were thoughts of putting it together.

40. SV Yeah, that's not as advanced as what the kiwifruit one is.

41. LG Right, yeah. The other thing with all this is that different areas have different requirements. So, what people use in, say, for example, Ohakune to grow carrots, we wouldn't use in Hawkes Bay. You know, the inputs are vastly different for the same crop. But that's because you've got things like P retention, so your phosphate requirements are huge, compared to low P retention soils on the plains here. Your K reserves are quite different, your Nitrogen requirements vary tremendously, you know, in Invercargil I'd be growing carrots without any Nitrogen, whereas here I'm putting it in. These things come into it, so if you have a model for growing carrots, you've got to take into account, ...

42. SV All the soil and climatic factors.

43. LG Yes. And, paddocks coming out of grass, obviously have got a good organic matter content, whereas paddocks which have been cropped and cropped in the nineties, these ones over here, got bugger all organic matter, so you have to take that into account when you're looking at your inputs. So it's not simple.

44. SV No, no. So I've got a feel for how you go through your, your selection now. I was just wondering if you could run through an example of a, say you had, if you've got some soil test results and just start off with those and how you would, if you could explain to me how you would go through with the different information so I could just watch to see what you have done.

45. LG I'll get out a, Russ mentioned Kiwifruit so I'll get out an example of one I did the other day. I haven't actually done many Kiwifruit ones this year yet, but I did do one for a guy the other day, Ericson, so I'll just show you what I've done, um. I file according to, in just alphabetical order so this guys name is Ericson and he's not the only Ericson, but um. All right, these are his latest soil test results and leaf sample results for this current season. This grower is, he grows Kiwifruit and apples so I've given him a program because with apples as each variety is harvested we move in with fertiliser in the autumn. The aim is to replenish the nutrients that are taken out in the season and ensure the buds that are being set up now for next season are well nourished.

46. SV So you're basing that on yield and pruning and anything else that is removed?

47. LG We've got an idea of removals, yeah crop removals and we've got an idea of what's happening from one year to the next. So this guy I've got data here, same sort of data, and I go back and I look and I say Ok what's happened in terms of pH, phosphorous, calcium etc.

48. SV So you make a note on how they have gone up or down, how they have changed?

49. LG Yep, I'll have a look over the past two or three years and see where the trends lie, what's getting out of balance in the soil and then I'll have a look at the leaf and I'll say Ok gosh, here's my little arrows, you can see that things aren't too good here, things are slipping and then I'll say to the guy well look Ok um, here's

what I suggested you do last year, did you do it? Gosh we were a bit short of funds or we were a bit late, no we never got round to putting that on and I look for reasons, Ok, and if he says yes I did everything you did, said, I then have to re-evaluate and say oh gosh I didn't put enough in because we're not keeping up, we're not sustaining the levels in the soil or the leaf and then I'll say well are there any possible reasons and he'll say well I'm hanging a hell of a crop this year and I'll have a look at the crop and Ok I'll say gosh ya know, good size, good crop, obviously we're heading for a bumper season, we've got a bigger crop than the average that I've sorta worked on, there's got to be a reason somewhere. So I'll go and, or there's something happened and his orchards water logged and tile drains blocked up and the roots are rotting or something like that, something's happened um so, anyway in this case the nitrogen dropped, everything's dropped basically um so, then I start saying Ok what have I got to put in um, that's my scratchings at the time, but um, righto I've decided in this case that um, I'm going to increase the nitrogen to what I've put in in previous years, because his N levels dropped um, its still Ok

50. SV But its on the low end of.

51. LG Its on the low end of the optimum scale yes, but I'm more interested in sustaining things as they are to maintain a good crop because if I let them slip he's going to come back to me in a couple of years and say why the hell didn't you tell me to do something about this two years, now look at me I've only got half of the crop and sure I've saved fifty bucks on fertiliser, but he's not going to thank ya.

52. SV No.

53. LG Um, so, I'll just In terms of inputs, er, what I do is um, I don't give them a list of so many kg's of N, P, or K, I convert it into product type and split it according to the best time to apply it in terms of the growth stages of the tree, vegetable, what ever. I've got some ball park figures I work around in terms of a maintenance input for an average crop and then I adjust them up or down depending on the soil and leaf levels

54. SV Right.

55. LG I'll be going in to show you some apples later where, ya know, if the nitrogen level comes back in the leaf and its very high say for apples it should be around 2% and it comes back at nearer three, well I'll drop nitrogen out of the program, all right, um, as long as they're cropping trees and they're doing well and they're is plenty of vigour in the trees. So you've got to take into account the guys, I know a lot of the blocks, but if I'm not sure I'll have a look and if I see he's got heaps of vigour or adequate vigour and if I go and add to that nitrogen that, that problem is already high by putting more nitrogen on now I'm going to stimulate excessive vigour I'll cause him a problem with fruit yield so I'll drop it out and I'll say to him look we're going to leave nitrogen out this year and explain why and I'll back it up by having an idea of what's in the soil anyway and that, that comes down to that explanation that I was talking to you about, I've gotta tell him, back off.

56. SV And do you explain that in the, in the report or just verbally?

57. LG No, no, I usually, I used to, but I find that now um, you could spend all day writing letters and people, they look at the, oh yeah that's all the crap to start with, right what have I got to do? they're into the bones of it and so, this particular one I haven't written anything um, some of them I'll do a brief explanation depends on how well I know them, how long I've been working with them for, but in this case I talked to the people, on site, run through the things with his son and this is the program that they work off. So I'll explain what going on to them. Right getting back to this particular one I've put in um, a little more nitrogen than I would usually use, I suppose you really want to get into a bit of a fix on how much compared with um, mind you I'll give you a copy of this I guess is easiest and you can work it out, but um, all right we've got a 113kg's of N there and another we've got another, and a little bit after harvest there too, 155kg's going in, um with his bud break which is his September Nitrogen and his November Nitrogen which is flowering time, which is higher than I would normally use in Hawkes Bay, I would normally be working in Hawkes Bay around 120 to 140kg's of N as a maintenance type Nitrogen, I've also put in here um, a kilogram per 100 litres as a foliar spray once they've picked right, to get a little bit into the leaf before it starts senescing and goes back into the cane, most of them would be using 2000 litres, all right, so that 20kg's of Urea, which is not a lot of nitrogen, but its a little bit extra and there also using in this case, because their manganese levels are very

low I'm getting him to put on some manganese sulphate sprays and adding Urea with that purely and simply to help the manganese get into the leaf, right. There a little bit more nitrogen going on there, but again, bugger all Ok.

58. SV So why in this particular case did you um, you say you'd normally work between 120-140 so why 155?

59. LG Because the nitrogen levels so low.

60. SV Because its so much lower than.

61. LG Yep.

62. SV So that so you're take into a corrective amount into there as well as your, your maintenance.

63. LG I bumped it up um, as far as I dare given that we've got a reasonable level, he's got good production, but its dropping because I've looked at my trends.

64. SV The nitrogen levels dropping not the cropping?

65. LG Yeah, the nitrogen levels yeah, the cropping levels good, although I did note a slightly smaller size than normal, but the numbers of fruits are good. If we looked a maintenance for kiwifruit in the Bay of Plenty, or through Ag Research Ag MAF, Ruakura, the suggested maintenance rate for nitrogen is around 180 to 200 kg's of N, very high, but um and this is one of the mistakes of the kiwifruit model, is that they forget about soil type and they base all of their recommendations on what they've done on free draining pumice soils and that where they come a gutsa in the Hawkes Bay Gisborn area. So it, it may well be that 200 kg's is fine on a, on those sorta free draining soils in Tauranga.

66. SV And you're going to loose a lot with leaching and it not going to hold a lot anyway.

67. LG But you get down to, well even get down to Opotiki and you get into the heavier soils and those sort of N inputs can lead to problems and you get fruit drop and soft fruit and that sort of thing and you certainly do here, so that's why I've gone as high as I dare, I have to rely on my own experience for this. Um, so I said to him we're going to have to put a little more in, now I'm sure as hell not going

to put so much in that I'm going to cause him a problem, but all I've done is stepped it up over what we've done last year, knowing that um, in this case we're got very little organic matter in the soil that's mineralising and providing nitrogen, so the nitrogen's got to come from some where, it either comes in as water which he is using to spray or irrigate with or I put it in as fertiliser and his water is very very good water, he's got bugger all nitrogen in it, so it's got to come in as fertiliser. So we know that levels of around ah I'll get it out and see what we put in last year, but I did, did do this before, um, I think I had a 132 or something in last year that um, we've grown the crop all right, we've got the crop, grown the plant, got the vine cover, so all I've done is step it up slightly to make sure that we keep that level from dropping further, we're not in dire straits or anything. Um, and so on I just work through the nutrients um, I've used in this case 35% potash gold super, which is simply superphosphate and potassium sulphate blended to provide, I've put some phosphate in because again his phosphate level has dropped and potash, which has again dropped, but Ok its at the bottom end, but, what have I put in here, a normal maintenance level of potassium would be around 150 kg's of K again it bit lighter than the Bay of Plenty, but for this area, for average crops of around 6000 trays a hectare that maintains the size maintains level in the soil so our losses versus removals are pretty well in, in sink, um. I'll just, a 150 of pot sulphate, 7.5 times 15, there's 15% in that, and 1.5 time 42, a 175, so I've gone up above our maintenance input because we were dropping, I've put in a small quantity of another 25 kg's. I've used pot sulphate because we accelerate the chloride content with potassium chloride, he needs sulphur that's dropping as well. We are particularly careful with chlorine on our heavy soils, um, there you can see there's the bulk density or basically the weight per soil, its not a true bulk density, but, Prof White chewed me up on that many years ago, um. We run into problems with chlorine, chloride in the soil, it should be chloride, um, very easily here they don't leach out as quickly because our drainage is not that good.

68. SV And what, and what damage is that going to, does that cause?

69. LG Er, you get toxic levels taken up into the leaf and then they turn a yellowy green colour and swell up like that and then you get breakdown, and when you get breakdown in the leaves you get sunburn of the fruit. The end result is sunburnt fruit, its out of grade, so its a loss factor . We've had lots of problems, and that's

another problem with that kiwifruit model, it pumps in too much K, and MAF's approach had been, I don't know if it still is, but in those days Garth Smith always used to work for the cheapest form of, of um, potassium so he went for chloride, which didn't pose to many problems in the Bay of Plenty, but it sure as hell did over here in Gisborne.

70. SV Yeah, so you have to, you're having to move toward your potassium sulphate which is a lot more expensive.

71. LG It's a wee bit more expensive, but on a per hectare basis it doesn't make much difference at all.

72. SV That's one area that my model can help, in that you can, you can say that well you don't want more than a certain amount of chlorine to go into your, into your selection.

73. LG Yep, yeah Ok, I mean 25, 30 kg's of KCl is no problem, but. What I'll do is um, I'll give you a copy of the um, if I can find one, of the suggested retail price list with the um, all the products listed and their contents, I'll run off a copy, which you could, ya know find useful um.

74. SV Yeah, I think I based my last lot was on of the, um, I was talking to a grower and he gave me a leaflet from you, from you guys, which listed them, all of the different,

75. LG Products

76. SV fertilisers and the contents and so forth.

77. LG Well that's um, that's a summary basically, which we use just for working out prices for farmers and growers just a, so those are um, exclusive of GST, and there bulk prices, but for comparative purposes you can see there that pot sulphate, 531 a tonne verses a, pot chloride 348 so its a bit dearer.

78. SV What's the relative amounts of potassium in each?

79. LG Each is 42, so that puts that a bit more, a bit less expensive, but when you're looking at it basically um, even if you said it was 200, $300 a tonne even if it was double, it still not a big difference per hectare when you look at the rates of K

you're putting in, in terms of the problems that you cause, its, I get dictated to now, growers say there's no way I want chloride. So when you break it back down the cost per hectare is bugger all.

80. SV Unless you have to move to potassium nitrate or something outrageous.

81. LG Arrr, potassium nitrate, not even on that I don't think, but um.

82. SV That's usually a bit more, more expensive.

83. LG Pot nitrate, er, yeah that's about 11 or 1200 I think

84. SV Yeah I was talking to, talking to someone about they were have high, high sulphates in their greenhouses so they had to move, for their potassium source, they had to move to nitrogen, potassium nitrate.

85. LG Er, I can't say I've come across any problems from that, um, we've had people using um, things like maxi sulphur super putting high inputs of sulphur to bring the pH down, they've got horrific soil test levels for sulphur, but they produce some crops. Pot nitrate 965 a tonne, that's trade, Ok, anyway I'll run you a copy of that off after. In this case I've put in some magnesium and calcium. Calcium, its Ok, but magnesium is way out, its too low.

86. SV So that's on your soil test its, its way down.

87. LG Yeah, and on the leaf test its actually dropped. I've used dolomite because the calcium wasn't flash either, so I've put a bit of calcium in, put a bit of magnesium in, 1500 kg's a hectares' not going to influence the pH unduly.

88. SV What sort of quantities of magnesium and calcium are in the, in the lime?

89. LG You're looking at 11% magnesium, and 23% calcium. I don't think that's listed, no, it is on another one I'll give you. Yeah so 23% calcium as against straight lime which is 38 and of course no magnesium in it. So we're putting in 165 kg's of actual magnesium, I work on 10 kg's of magnesium per hectare to get a lift of one of one MAF unit. So theoretically that's going to lift that um.

90. SV Each of these units on here on your soil test.

91. LG So um, theoretically its going to end up at 35. It varies a wee bit, but its approximate it may be 12, its around about there, so what I'm doing is bumping it up so we overcome this drop and bring this level up again.

92. SV Right, this is quite a bit lower isn't it.

93. LG Yeah, and I did note in his vines signs of magnesium deficiency so we could pick it up in the leaves, if its getting to a point where its starting show and if you ever see anything its starting to obviously its causing damage. It may be part of the reason that his fruit looked to be a wee bit smaller at that stage than normal. So, we'll bring that up again, and that's how I worked out how much dolomite to put in. And I didn't want to change to pH too much because it was already 6.5, okay. Um, dolomite lime I find doesn't shift the pH as much as straight lime, and on a soil like he's got there, I wouldn't expect much more than about 0.2 shift in pH from that application of lime. We might get, if we went to ...

94. SV Your sulphur is going to counteract some of that as well, though, isn't it?

95. LG Oh, sulphates sulphur. We haven't got any elemental in here. But, your right, it will take a wee bit out. Generally calcium goes out with sulphate, so, um, there's not going to be much of a change, so I wasn't concerned with putting that much in. Um, we are putting manganese in anyway, otherwise I would have had to have looked at that, because, as you shift your pH, and you're in a range where you're likely to get manganese deficiency, um, I would put it in as a precaution. Very cheap, no extra work, just toss it in with his fungicides. So those are the sort of things that I'm looking at. Boron's all right, copper's all right, zinc's okay, and boron's certainly well up, so I wasn't concerned about any of the others.

96. SV Yeah, it was just your manganese was a bit low.

97. LG Yep, that was the one I was a little bit worried about. So I've put in, I'm giving them a post harvest spray, so they can take some back into the wood, and I'm coming back in next spring, after the fruit's set, I don't like putting things on around flowering, just in case you upset the fertilisation process. Bring them in after that. Flowering's in November, so come in after flowering, and just spray them.

98. SV Before the fruit start to get to any decent size, ...

99. LG Well, their main fruit swell is in December, so we want to have everything right.

100. SV Yeah, otherwise, you could mark the fruit as well, with the foliar ones.

101. LG Ah, yeah. You've got to be a bit careful, but putting them on at that rate, which is a very light rate for manganese, you won't get any fruit damage or spray marking. The old way of putting it in, you see it referred to in various texts, is 600 grams of manganese sulphate, with 800 kgs of hydrated lime.

102. SV Jeepers, that's quite a bit.

103. LG Yes, but what it does is leave a black sticky mess on the fruit, that can last there all season. So, its not good to be putting it on in that form, and the other thing is that it leaves a hell of a mess in your spray tank, terrible job to get out. Now I guess I'm lucky, in that, and I run our company orchard, so I do the practical side of this, as well as this side of it, so I know what the other side has to face. So, there's no way I'd tell growers to do something I wouldn't be doing myself. So you learn those sort of things. You know, I came into this job whenever it was, eleven or twelve years ago, you just read all this stuff and think well, this must be what you do. But I quickly learnt that there's a better way to do it. So, what I do is just do that three times and I end up getting good results. So, you know, if I give you a copy of that is that helpful? Is it go some way to answering ...

104. SV Yeah, its just that with, where we started with when developing my model was, initially going to be in conjunction with Hort. Research and Ag New Zealand, but there's a conflict in interest between those two that they're paying money and so forth for different pieces and stuff, and I got caught up in the middle of all that. And subsequently they haven't been able to help, or Hort. Research hasn't been able to help. I talked to, um, an Ag. New Zealand consultant, and so that's where this started off, and their method is they give you, when they're writing the reports for their growers they have a certain amount of, they spell out the nutrient requirement ...

[side 1 ends, side 2 begins]

105. SV So their reports detail the amount of N, P, K, they say to the grower that this is the amount of NPK you need, and these are the fertilisers that, to meet that. So with these ones here, I'll have to look at, um, your fertilisers and take one step back to get the nutrients.

106. LG Yes. You'll have to see what I've put in, um, ...

107. SV Because their way of doing it is to have a, to work out the least, they have a least cost model, basically a linear program to come up with the cheapest option.

108. LG Yeah, okay, I disagree with that approach. Um, what I do is I look at what's needed, and then I look at the best form of putting that on to get the results that the grower wants. I ignore the cost at that stage. Um, instead of the 35% potash gold super, in their case, they would be using 30% potash super, right, which is chloride based, and is slightly cheaper.

109. SV Yeah, they start off with, um, it generates them a load of different possibles, mixes, and then they go through and look at the different preferences that the grower has in terms of fertilisers, whether they're after, um, organic versus inorganic, ones that don't have chlorine in, and so forth like that, and choosing an appropriate one from the list that it generates.

110. LG Yeah, well I figure that if growers come to me and want me to tell them what to do, so that they are sustaining their fertility, and getting the best production, I tell them what I would use if I was in their position. And if a product costs $80 a ton more, that's neither here nor there, generally you're not using a ton, you're using a portion of a ton, so it might end up costing for a, one product versus another product, a like product but made up of a different composition, it might be 25 or 30 dollars per hectare, more.

111. SV And, of the fertiliser costs, what sort of percentage of their operating costs ...

112. LG Total operating costs? Generally around three to four percent, ...

113. SV So it's quite small ...

114. LG It's absolutely bugger all, and most of them say to me, look, don't bother discussing that, it's neither here nor there, I've only got to put on only one extra

fungicide spray if it rains, and I wouldn't event think about the cost of doing that, it's got to be done, and it blows out ...

115. SV And it could be several hundred dollars

116. LG Yeah, and it blows out that 20, 30, 40 dollars, whatever, without even thinking about it. So what they want is the best for their plants, and that's why I disagree with the least cost approach. It's what's best for the plant is what the growers wanting. He wants that plant to perform to its maximum. So, I endeavour to put the right amount of nutrient in, and I tend to ignore the actual cost per unit of N or K or P, bearing in mind that the difference between the highest and lowest priced products is very little.

117. SV Yeah, fair enough.

118. LG So, um, that all comes into my discussion with the grower. I may work out a program that says well this is going to cost you 500 dollars a hectare, for your kiwifruit fertiliser for the year, and, he says oh look, you know, I'm in dire straits, I can't afford any more that 400 dollars, so I say okay, where I've suggested CAN, we'll take it out and use urea. And we'll cut out that cost or we'll, whatever. So, um, on occasion, where a guy is in economic difficulties, I'll moderate the program accordingly.

119. SV So, why would you choose CAN initially anyway, compared to urea?

120. LG Urea? Um, well, it depends on the crop, in this case I've used a combination, I'll use urea if the pH is pretty well up, and the acidic action of urea, the ultimate acidic action of urea is not going to affect the pH, it's fine, if it's going in at a time of the year when there's adequate moisture, and his volatilisation losses are not high, they're basically negligible, that's fine. Um, I'll use CAN if he's got a moderately acid soil, we don't want to lower the pH, we want to maintain it at its around the 5.8 to six, and we don't want to go dropping it down, and create the need for lime which may not be needed otherwise, if he's got a dripper irrigation system which is not wide spread, so he can't water the urea in, if it's a fairly light sandy soil, um, conditions, and, um, I'll use CAN in that case, even though it's September, and we're expecting perhaps reasonable rainfall. Um,

if it's November, and generally by then it's quite dry, we're putting it on to bare ground, and it gets hot, as it can do in Hawkes Bay, you can expect volatilisation.

121. SV Yeah, and off goes all your Nitrogen, ...

122. LG Well, maybe not all, but a portion of it, so, um, so, we're looking at, you know, I keep in mind, um, anything I can find about volatilisation rates, and the work that Sherlock did, Canterbury, bring in data from Germany and have a look at it, other stuff that's been done in the North Island. So. I'll make the decision about what type of nitrogen based on those factors. In this case I've used urea, in his main block of apples I've used ammonium sulphate. And that's because he's got a very high pH, using an acidic nitrogen form, try and help bring that down, it's a wee bit high. So product selection is based on a study of the factors presented and knowledge of the property, knowledge of his management system. Um, might just use this, I might just give you a copy of the whole thing, it's got apples on here, and you can see what I've done with apples, um, main block [can't understand a few words], that block there, okay. This is a fairly big property, um, kiwifruit he's got, oh, about 20 I s'pose, maybe a bit more, apples he's got, probably 30 acres. Anyway, his main block I've used braeburn as the variety, you know we sample according to variety, rather than a mix. All I've put into his apples is a bit of nitrogen, a post harvest application. He's got a level of 2.4, he's sitting spot on. And again I've gone back to previous years and looked at what we've put in and that, and all I'm working on there is maintenance. And in this case for him I've put in about 50 kg's of N.

123. SV So, on this um, line here, whereabouts are you trying to maintain it, sort of, in the upper parts of the medium?

124. LG Yes, or, the mid to upper part of the medium is where I'm looking at. Some of these get influenced by what they do, rather than what the plant takes up. By that I mean that, with calcium, you see it's quite high, for a variety like braeburn, the board, the Apple and Pear Board and Enza, insist that they apply, x sprays of calcium, because of bitterpip problems, storage problems in varieties like braeburn, cox's orange, in particular. So, they have to buy, by being dictated to by the board. They have to submit their spray diaries, they have to put on what ever it is, 13, 19 sprays of calcium chloride, or whatever. And as a result you do

get leaf contamination of, that, which does influence it. They should be up here. Some of them come back and they're quite low. Which sets alarm bells going in my mind. Gosh, if you've got levels like that, and you've applied all these calcium sprays, you got a problem with uptake into the fruit. And I look at that and I look at the boron level, and generally you'll find that there's a reason. Go back to the soils and you'll find that, you know, got a calcium level of 5, saturation is 34 or something, he's way out of kilter, so you got to bring in some calcium, into the system. Um, in this case, he's got a high pH, he's got a good calcium, errr, 14, he's got good saturation. In fact, it's fairly high. Talking to him, how did you get on with your fruit tests, you know, for the board, they're always testing, yep, fine. He can pack all count sizes. And the board dictate to the growers, if they, they have to pick so many fruit just prior to harvest, and they have them tested. And they, depending on their calcium fruit level, they say, right, you can pack um, up to a certain count size. And the bigger the fruit, the more likely there is to be a calcium problem, so if that level is down a wee bit, they'll say right, you can pack through to 113's, but we won't take the 100 count, or 80 count fruit, for export, you're going to have to send that to the juicing plant, so he's losing money, and he gets on the phone, and he says, Lloyd, we've got a problem, um, you know, why didn't you make sure I had my calcium right last year, cos, you know, the bloody things are too low and they won't accept them. You know, and I'm getting 8.5 cents a kilo instead of whatever they get for export.

125. SV Yeah, quite a bit, well, compared to juicing.

126. LG Yes. Two bucks a carton for juice, or whatever the equivalent. 14 or 15 for export. Yeah, they get a bit uptight. So in this case, I see no need to put in, he's maintain his phosphorous level, he's maintained his potassium level, things are sitting right, they're not dropping, so I've not put anything in. Even though they're middle of the range, they're fine. Sulphur's a bit low, I've used ammonium sulphate, putting some sulphur in in the autumn, um, I've used, in this case, some boron, prior to flowering, and I've done that on the basis that we've done this each year, and the levels aren't increasing, we're maintaining them, and I know that because he's on a high pH soil, boron uptake is not going to be flash, so what we're doing is overcoming that by putting it on as a foliar, and keeping his levels

up, and that's also influencing the uptake of calcium. So we're keeping everything going up. all right, very strong relationship between those two.

127. SV Calcium and, and boron.

128. LG And I know that because I've done work, not only the texts tell you that, but I've done work with blocks where we have problems. And we've been spraying boron on at flowering. At different times, and we've set fruit or allowed it to frizzle up and drop off. And then done calcium tests on the resultant fruits, and we've found we've changed the levels. So I've actually been through that, with the board, with actual field work. So, it's, um, I've established it is an actual fact, a very very strong relation, and I use that in my thinking. I've put in manganese, it's a bit on the low side, um, and again because of a high pH soil, you get lock up of manganese. So, pretty simple programme for him on that one, the fuji block, I've treated slightly differently, um, because he's got a very low magnesium, in the soil, the leaf's not bad, potassium's quite low, um, what I've done there is I've put in some potassium, but when you put potassium in, you've got to be careful that potassium's taken up very easily by the plant. Now I know he's got a low K, so I've had to put some in, because as these trees have aged, the crop load gets heavier, but if you don't keep the potassium up, the fruit size gets smaller. But when you put potassium in, you've got to be very careful you don't upset the balance with calcium and magnesium. And in this case, he's on a high pH soil, it's very difficult for the plant to take up magnesium. He's got a very low level of magnesium, in the soil, so I've supplemented by saying, if we put potassium in we must put some magnesium in at the same time. And I've used a magnesium product which is quickly available to the plant. In fact, it's the only one that's really able to be taken up by the plant at that pH. If I was to put dolomite lime in, it's alkaline, very very little of it will go up into the plant. You shift that level up, but it's not available. It is over a period of time, soil acids will work on it and you can, you'll get some uptake but you're gonna push that up as well. So in each case, I've used some Keisrite, and I've applied a potassium. And I've split the potassium, between there, and there, October, given that we want to get some up into the wood, so that we're setting up these buds for next year, get some into the, into the sink within the tree, but if we put it all on now, and we get a hell of a wet winter, some of that will leach. And that's on a pretty light soil, this

particular block. It's much lighter than where that kiwifruit is, so I'm conscious of the fact that we don't wanta loose nutrients, so I've split applying it, and I've just kept pace with magnesium, no, we don't have to put much in, Keisrite is only 15% magnesium, but we're putting it in in a form which will allow the roots to take up and maintain that level there, without causing a problem. So, it's, um, I don't know how you're going to work this with your model, but you have to keep balances in mind. Um, in this case I've just carried on with the, keeping his boron's up. And I put in some manganese, to maintain that, this is a block which we've been with, because it hasn't been a good block. And we've been getting it right. So, it's, um. It started off, they didn't grow particularly well, and they were shy at bearing, and we were getting a lot of blind budding. So, manganese, ah, magnesium is a, one of the symptoms of low magnesium is blind budding. And, we've been gradually building those magnesium levels up, to the point now we've got good leaf magnesium, and we've got very good fruit set. Plenty of buds burst, you know, keep the numbers up. So it's a balance of looking at what's happening in the field, looking at monitoring your levels from year to year, and maintaining a balance. And then you've got to choose the right fert, all right? Fuji is a, this comes back to that variety thing. You have to watch the amount of nitrogen you put on fuji. Of all the apples, they're the best at picking up nitrogen in the soil.

129. SV Yeah, well, yeah, the shoots will be off.

130. LG Well, yeah, what happens is the fruit doesn't colour. If you have too high a nitrogen, it doesn't colour up enough. So they, the grower's waiting and waiting and waiting for his colour requirement to come up, before he can pick them. And the longer you leave them, the more risk you run of getting water core. So, again, you have to look at that side of it, I've actually put some in, because he's at the low end, and the trees, because they're now carrying a larger crop, they're, these trees are now about 5 or 6 years old, we've got to make sure we actually regenerate some good growth for the next years wood, fruiting wood. So we put a little bit in, to maintain where we are, but, I, normally with fuji, don't use any nitrogen on heavy soils. This is a wee bit lighter soil. So, how you're going to put this in your model I, gonna make provision for it, but. I mean, that's quite a complicated fertiliser programme for apples. But, and it's probably different to from what you'd get from Ag. New Zealand. But this is what growers want. This

is, that's why they come to me. You give them a program which is, and work through their crop with them, um, some of the other consultants are doing this now, you know, you know, they come in and we sit down and I tell them how I'm operating. And they go out and do the same sort of thing as a consultant, and that's fine. I can't deal with them all, so, you know, there's 7 or 8 hundred pipfruit growers, in this area alone. Um, the other reason, I've just realised, that this is a good example of, is that um, of course you can't see it here, these are young trees, I don't know what the age of them, but they are in fact the young block. And it's a young block we've had a problem, it's this house block. It's pacific rose, or their gala splendour, 2085, the new name ...

131. SV Oh, right. Is that what they've called it.

132. LG Pacific rose is it's flash new export name.

133. SV Oh right. It's rather nice, that one.

134. LG Um, so, yeah, he said to me look, we've got a problem, and, ah, see if you can work out why these trees aren't growing. It's a little bit tricky, but what I've come to, I did a sample off the better area, and a sample off the poorer area. And the conclusion I came to was that with nutrition, regards nutrition, there is something that does look as though it is happening, in his poor area, he's got a very high calcium, ah, potassium level, and quite a low magnesium level. Compared to the better area, where the potassium level is a lot lower, and the magnesium level is higher, the balance between the two is a long way out. So, what I've suggested to him is that, he should be putting magnesium onto these poor trees, because, when I looked at them, the leaf size is very small, and they were yellowish. They didn't actually have distinct magnesium deficiency signs, but they were showing symptoms of it. Compared to the rest of the block, which are nice big leaves, healthy green. So, um, when I looked at the soil, and there wasn't much there, to be quite honest, ah, between the two. Much the same pH, 6.2, 6, both got heaps of phosphorous. This was a garden area that he used to grow veges in previously, um, nothing much between them in the calcium or the magnesium levels, but, both of them very high potassium's. 33 is a very high soil potassium. And that's come about because of its vegetable cropping history. All right? Now, what seems to be happening is that in this one particular area, the

trees aren't getting enough magnesium. I'm not dead certain on the reason. I did suggest to him that there may be something in terms of soil structure, which is perhaps causing the water to sit around the roots of these particular trees, whereas the rest of the soil will be free draining. And you know, you're asking questions like, you know, did you have a shelter belt here, and did you have a rubbish pile and, did you use it as a dump, is the soil compacted for some reason, all those sort of things. This guy's gonna look back, oh, you know, well, might of, yeah, could of had a, yeah, and away they go. So you try and search for reasons, and in the end I did suggest that he should try and look in this area, although the soil test didn't show any difference in bulk density, um, to any great degree, .8, .85, um, that he should look at putting some rippers through, and just opening it up, and making sure that there's no barrier. Because if it's sitting in wet soil that could amount to part of the reason for why the potassium is rushing up and the magnesium not. And the other thing was to put on magnesium. So, in this instance, I've gone in with some, this time of the year, some quickly available, um, magnesium, and in the winter time, some dolomite lime, much longer term magnesium source, to provide enough magnesium to counter the rapid uptake of potassium that is occurring. Yeah, the leaf level's very high. So, um, overall I've given him a program for his whole block and then supplemented that with a bit of extra magnesium. I can use dolomite because the pH allows it, 6. It's not low. Um, a bit of manganese, a bit of nitrogen, bit of boron. Because they're young trees I've put the nitrogen in in the spring, rather than the autumn. They'll have a small crop on them, but we're trying to grow the tree, if you put nitrogen on in the autumn, you'll get it into the sink of the tree and it's used for fruit development, as well as growth. Put nitrogen on in the spring, and it goes into canopy, goes into canopy growth. So, that's why I've concentrated on putting nitrogen on in the spring. Young trees. When you're reading this, remember that these are ...

135. SV The young ones.

136. LG Yeah. September and November, I've used, young trees, very small canopy area, um, sunshine's getting in, bare weed strips, I've used CAN. All right. He's at the bottom end of, ah, sort of, pipfruit, really, the ideal is up round 6.5, pH. But he's got good calcium levels, I haven't worried about bumping that up with lime. So, I've used CAN for the apples. For those young ones. So, is that helpful if

I give you a copy of that? You can tie that back to the reasoning. I mean, I guess we could go on and on. We've got, 1800 clients here, but if you go through, it's the same sort of concept.

137. SV Yeah, if I could have, um, if I could get copies of, sort of, half a dozen, that I could use, um, that'd give me an idea.

138. LG Right, do you want to go across a range of crops? Or, ..

139. SV Yeah, that'd probably be good, actually. Cause that way there's going to be different nutrient requirements, some might be more, and less. That'd be, that'd be useful.

140. LG Um, right. I'll give you some vegetable ones as well. Let's get 'em out. Um, [pause]. Uhm, well there's an example of what I was talking about earlier, I've just made some notes and I've been talking to these guys, um, too much nitrogen in the early season, need to space out the side dressings. These are the sort of things that, you know, I forget about if I don't jot them down when I'm talking to them during the season, but I'll come back to this, there's another grower on here to, but, ..., it's on onions, but [can't understand a few words] too late, too late for planting. Um, [pause]. I'll give you a copy of a lot of that and you can go through, [pause]. Some of this is, um, in this particular instance, the maize planting of this particular grower, he told me that he wanted to put a lot of phosphate on. Now, you can have a look at the soil levels, I'll get them and photocopy them. Um, I wouldn't normally put as much in, but he wanted to go that way, so I had to fall in line with his, request. But the nitrogen inputs were what I, suggested to him. I think the rest, he's got a whole lot of tomatoes, these are field tomatoes, for Watties, for processing, making into paste. Um, quite a bit of maize, asparagus, [pause]. Um, some beetroot, all right. That's good. Si I'll give you a copy of that. Now, to get you the results, though, that ah, go with it, [pause].

141. SV What sort of length of time does it take you to, um, from, say when the grower rings you up, or when you get your results back, how long will it, what sort of time frame does it take to calculate your requirements.

142. LG Well, most of these guys are cutting their time down, because by the time they get 'round to doing their soils, even though every year I prompt them to go in early and do them, they come back and say, right, we want to get going, well, you know, well, sometimes tomorrow. I generally, I'm under a fair bit of pressure to get them out. Not this time of the year, because growers are busy picking their apples, and as long as they get their nitrogen on, over the next month or so, it's okay. But in the cropping season, and I get these guys coming in, and they've got quite a few samples, I'll say to them, okay, well, I can't get them all done today, but, which paddocks are you getting into tomorrow and the next day, because, um, you know, I've got, on there you'll see, this divided up into pre plant dressings, ridging, side dressing 1, 2, and 3, that one there is the key one, they've got to get it on. So, ah, they'll just tell me and I'll whip through. In this case, the guy's come in, this was on the 22nd of September, that was pretty close to when he started planting, all right, so that would have been, ah, well, that was his second bet, so he's probably already in, with his program already underway. But, um, I would have had to got that out to him, real quick. Unfortunately, yeah, here's a fax one. People who have faxes think you're going to reply instantly. A real problem. Just because they have a fax they think they can send you something quick, you're going to get back to them quick. [Pause]. Well, that's some of them. I think they're all in there. No, they're not. Yeah, this is obviously one where I had to get something out to him, and it, and I'm just looking through all the soils, but, I guess if you've even got a few there, ah, you've got enough variation there. Go and run those two off. If you go and run those off first, and, ah, and those, them together, and I'll dig out a couple more.

[Tape stops for a short time]

143. SV Ah, it was about mixing, um, when people have, when you've recommended a certain groups of fertilisers, and they blend them together to apply them, what is the smallest size that, ...

144. LG Well, we do look at segregation, so obviously we don't like blending a very fine material with a coarse chip, because you can get segregation occurring. So that's the major problem, is trying to get materials of a similar size so that you get an even spread if they're broadcasting. And the other one is compatibility. So,

um, you know, mixing urea and potassium chloride, for example, on asparagus, is not the way to go. So, um, in that case, if we can we'd use an alternative, if the grower wanted to use a helicopter, and he wanted everything mixed together, in a bag, and sitting on site, well in that case I'd use some CAN and some pot chloride. All right, so we've got to look at that. And you'll come across tables with compatabilities in them, and there'll be no no's, and okays. Some of them are okay for short storage, but not for long term storage. Some of our product lines we have blends, which, if we pack them on days with high humidity, we will run into problems with any long term storage. We'll get interface setting. All that means is that they, they turn into a 50 kg brick.

145. SV Yeah, solid.

146. LG Yeah, but if you drop them on the concrete, they break up. So, they're not permanently set, it's just that interface setting. So, there are product lines which we can run into problems with. So, we try to keep those product line inventories low. To overcome that problem. So that, ah, we're doing them regularly, but we keep the product fresh, in that sense. It's the same age as the stuff in the heap, but we haven't had it together in a bag. So, I'll give you a guide list of [pause]. This one here, you may have seen this one.

147. SV Yeah, that's the one, probably seen an older version.

148. LG Possibly yes. There are products like 16 10 10, for example, it's a different formulation to 15 10 10. It's likely to set, but it's an excellent product for, um, vegetable growing, it's better than 15 10 10 so, that's the reason that it's there, because it's one of those products. If I grab this machine, it's um, free.

[Tape stops briefly]

149. LG Yeah, no, no, it's not a simple formula. Some of it's a formula, but here are other factors which I try and ...

150. SV Yeah, it's good to get a different perspective from someone who has a totally different position to the other people that I've been talking to, so I can get, can pick up on the other different ways of doing things, and, um, yeah, to try and take those into account, to try and work something out.

151. LG Yeah, of course, what I've given you there are the latest results, you, know, I can go back and photocopy the last two or three years so that you can see the trends, well, that's what I'm looking at, but, you know, you end up with ah, when I'm doing them you end up with stuff everywhere. And then you've got to look at response rates, and things like, you know, how much boron do you add into mixes, so that's when you start pulling out textbooks, and, how much you should be putting in, and ...

152. SV Yeah, one of the components of the model, which is sort of, more proposed at this stage, rather than actually starting to firm up, is um, a database that takes a lot of these things into account, about the, so you can bring up the previous trends, so you can look at previous results and so forth. So that you can say, yeah, display how things have changed over the years for that particular client. So, in an effort to reduce that time frame of having to sift through everything.

153. LG Yep, yeah, well, I mean, I get a lot of people, requests from all around. People ring up, and I don't have to go back to my journals, and, the data that I use as a resource. Say, okay, um, you know, yesterday or this morning I had one for a guy who's growing asparagus in Wanganui, very low soil boron levels, and how much boron should I put in. Um, I've been told to put in 9 kgs per hectare, but, you know, so, but I look up the range which is safe to use in any one year, with a very low levels, and what I'll do, is perhaps go in twice, with perhaps not the top rate, but a reasonable rate, but do it two years in a row. So, it's hard to say, you know, when you look at a recommendation, why did he do that, without having the full picture. So. Have a look, see how you go with your model, um, and you know, feel free to ring me up, ah, if you want, just give me a call.

154. SV Yeah, see how we go, ...

155. LG Yes, I'll be interested in following along, and perhaps at some stage sitting down with you, having a look at your model. Um, that might help me. What you're aiming to do is a lot of what I do manually, so, um, ..

156. SV Yeah, that's the sort of idea, to make it easier, sort of decision support systems, to make things easier. So, if a grower like for example rings up, and says

um, we want you to do a recommendation for us, what sort of length of time does it take you to actually create the report for him.

157. LG Oh, um, well, those three there, well, there's, well, Alistairs isn't typed yet, but, is doing them, but I did, um, oh, in about half an hour, last night.

158. SV So you just, does that include sifting through the historical stuff, ...

159. LG Yeah. This one, I had previous data, that's why I had that file's there, I had some soil tests from last season, these two were new. All right. Well, there they are, but all I had to work off was that. So that's when I bring in my knowledge of the area, the soils, the type of soil, the response rates, and, um, we make up the program. That one was actually for stone fruit, but, you know, I look at these, and say okay , we got some mediocre levels here, it certainly needs nitrogen, needs to maintain his potassium, so, um, I've forgotten what I put in, but I've only used that and I've only used that. In his case, plus my knowledge. So, ah, in this case I've gone back to the soils, which I had last winter, plus what he put on, what I suggested, because he said he did everything, so I've got a bit of previous data there, and this, he's done a pretty detailed look at his royal gala apples. He's broken it into three areas this time, so, you know, I've been able to look at it and say yes, there's a bit of a problem, and we'll overcome it. Um, yeah, well I think I started those at half past four and I think I was through them by just after five. For three of them. I can get quite quick at it, if I'm, you know, once you key in on a crop, if I was to switch onto onions, the old brain's got to start again, and you've got to go back into the crop. Because at the moment I'm doing a lot of um, you know, I'm doing um, several orchards each day, from here, and I was in Ohakune on Tuesday, and it was vegetables so, ah, you flick out of what you are doing.

[Tape ends]

1.3. Transcript of the interview with consultant three

1. DS You have to in developing your model, and I spoke to Russ, you have to decide to what level of sophistication you take it and as you increase that sophistication you run risks. Ravensdown have a little model, did you see it?

2. SV No I didn't

3. DS If they go into a pasture situation, they've got one, and they say oh yeah you need so many units of P, so many units this ya know, they can put it in there and they will bring up options based on different products and their relative costs, they can do that.

4. SV That's Ravensdown is it?

5. DS Yeah

6. SV Is that comparing their products with other peoples products or is it just within their products?

7. DS No, its just in their products because they run a monopoly in their area, ya know, like the lower north island where you are is all Ravensdown, Taranaki is Fernz and up here is BOP and they don't cross over very much because of transport costs, that's what kills it. They had it, I don't know if they've still got it, they had it where you simply punch in some numbers and then the machine would come back and say if you use super phosphate here's the option, if you use this then here's the other option, on price. So that basically is the simplest. As I showed you here ours simply, we go to a database of fertiliser and say well we would like this fertiliser. I'll show you something else in this model, because you might want to know how did I get this, no ones ever seen this before, but I'll show you. We'll use that one, so if we just go cc we don't have to worry about this thing address we'll just put p for that, season doesn't matter we'll put s for that, crop k, block identification doesn't matter, we'll put d, age of vines is mature, right this we need to know, 5.5, yeah that's a good one to use, 5.5 my area's 25, herbicide strip was what, 13, bays per hectare 400, fruit load was 750, method was 2. Now we put in this application here, we use Hycane base mix at 85 that ones 56 and 85 grams. Now the first thing is if you are putting on 160 grams, or if you're putting on, you're putting on 166 grams on 13 squares so you're putting on, you're putting on about 12.5 grams, where's a bit of paper, we'll say there's a post there a post there and the vine's there, there's 10 squares, 4, 6, 8, 10, agreed, we're putting on 166 over 10, over 13 sorry, this is 13, we've divided this, this is 2.6 wide by 5m right so its 13, we're putting on 166 so that's about 12 grams of K per square

8. SV Over 13 squares?

9. DS We learnt from some of our early work that the maximum level to apply, the maximum loading to apply without getting sudden changes, right, trying to keep things reasonably constant was 15 grams a square of K, pure K. Now you could put these two on together then you would end up with 12.5 you would end up with 25, right, it won't necessarily do harm, but what you'll get is you'll get like spiking in the soil between the concentration before you started and then the concentration after it's, ya know, been brought into the soil, some of it is taken out because our soils are quite fixing so you would get, lets just say you would get something like this over time, so that would be time and that would be concentration, you would apply it here and ... [pause during incoming phone call] What will happen is these soils are interfering so people have put on all of it on in one hit, no question about that, what happens is they get a spike that looks like that, right, and then comes down, our soil are interfering because we have vermiculite in them and vermiculite has a strong attraction for potassium ions, so we don't believe in, we believe you're better off to have these three applications like that than to have one huge application and it doesn't quite come down like that, it comes down over time because we think there's more efficiency, there will be more efficiency in the three in an interfering soil than one big bash and that is why in essence our rates are always lower than theirs on K, they'll be probably at 250 when we'll be at 180, right, so we're going for efficiency because we're going for the little and often approach, which is here, three applications of K here and they've only got one big hit, right, they also apply theirs up to six weeks before bud burst we are applying as late as the 20th of the 8th first bit of bud burst will probably be in the first week of September so we are much closer to actual need they are earlier.

10. SV Yeah because with your nitrogen you're going to lose a lot.

11. DS Well yeah there's that too, nitrogen they used to say at bud burst, but other they used to put on earlier and when they were very high they used to put it on on the basis of early so they could wash out some of the chloride, which is not good agronomy either. So now you'll see here, so you can see here that there is 20, the total is 41, right, there's only going to be two applications total, so we put on half

of the P and 66 out of 180 a third of the K, a third of, then you've got sulphur doesn't really matter, magnesium and calcium. So those are the figures in the first application, that's not quite half, a third of this 66 is a bit more, right, that's the way we do it, now if you go to the second one, so you go 2, what was it? 56, 85 again and actually some of the growers don't like this, because it's more work, but we've always gone on the basis of the agronomy rather than work. So now you've got the same again, right, so you've got two applications, so now you've all your P in, right, by the 20th of the 9th and we know that most of the P is absorbed early, we know that from studies. In the case of K we try to get somewhere around two thirds in by the second application. And this application here which is the 30th of the 10th now the 30th of the 10th is about 7 weeks, you've probably only got your first bud burst about the 10th, about the 10th of September, so if you go back to this one, if you go back here, you're probably trying here, ok, we don't take a leaf test, if we did take a leaf test take it here, you can see while that is falling that is a natural, even if you applied some in here I don't think you are going to change this natural tendency, so now if you want to do a top up then you've got to try and get it in here so that when you move from 2 to 2.7 you can maximise that replenishment internally to carry you through to the end, so that is often timed in there. In the same way that's coming down very rapidly we target this for two reasons, you'll also see that half the nitrogen goes on here, later, part of the reason is that because the absorption of nitrogen is much governed by, sometimes we don't do this actually, sometimes this figures is not 50% it's higher, I can show you some others, this one is quite normal, this is usually, usually this is 220 and this is 170 as an example, now the reason for that is because that's initial when the vines are very young their needs are not high and there's still a lot of rainfall and then this one is just preflowering, flowering is a very stressful period in the vines and then we apply some nitrogen to carry them over potassium, to carry them over, some magnesium to carry them over and we like to target it somewhere here. This is volatile we want to start to, as it comes down here, to arrest this to hold these levels up to around 2 6 you see it's staying around there and also we want to maximise this, this change here so that we can keep the 2 7 perhaps longer and the 2 5 and so on because these all falling because the fruit are stealing it. So these things are planned around the physiology, they're not planned around ease or anything like that, they're planned around physiology.

12. SV Basically all your splitting of applications and that?

13. DS Yeah, that how this whole program works, this mixture's more expensive, we use sulphate of potash because um, its safer, the argument that sulphate of potash is bad for the vines that has been discounted, that was hue-ee anyway, we used to used to use Nitrophoska here as a matter of interest, but we didn't feel we used to get the value of the P because P demands are virtually ceasing towards the end of the season. The argument that we are servile to Nitrophoska is a nonsense because we used to use, we also went longer in the season, we've changed, so use nitrogen we always use CAN, so CAN here, CAN there for nitrogen, we don't use urea, not keen; there's a whole range of issues, that's all sulphate of potash, so that gives us a decent sulphur level and then that value there, the 2, we are very conscious in this district with um, in this district, these two buffer strongly, this is the weak link in our soils, there's very little mineral magnesium in our soils, no exchangeable, very low, we have to feed it. When you apply K to our soils you create magnesium deficiencies very rapidly. Calcium doesn't really impact much on magnesium, these two can fight, in our soils on occasions.

14. SV Calcium and magnesium?

15. DS Yeah, very high amounts of this one can actually hit that one, but our, I've done all this work, we presented the work, I don't know, ten years ago, a detailed analysis of all the different clays and their mineralogy, we know the exact percentages it was all done by soils we interpreted it. So these two are very sensitive, so in these things here you'll see that that ratio, 15 of K to 5 is 3 to 1 and even here we don't like, that's about as wide as we'll go 5 to 1 and that we've never, an we always try and make that around 4 to 1.

16. SV Which one's that, the K to Magnesium?

17. DS The K to Magnesium

18. SV The total K to the magnesium?

19. DS Another thing is that there is very little magnesium oxide in here, the magnesium oxide is only a little bit in here and here, no magnesium oxide in here.

20. SV That's for your Hycane is it?

21. DS Yeah, because these two are um, because the magnesium oxide is insoluble it's not available for this year, so we've got to be careful that we don't put an insoluble form on when we have a very soluble for of K. You can have the ratios right, but if this is soluble and that insoluble then you get the same problem again. So again we are creating the mixture around plant physiology and around the special nature of the Franklin soil. In the Coromandel we find exactly the opposite, I'll give you an example, just to show, how you address this in your model will not be easy, these are the special things. In the Coromandel we have trouble with magnesium, er sorry with phosphorus, we lose our phosphorus, I'll show you. So you can see here what we've done we've altered it, that Hycane base mix, so you've got 515 of supers and 300 of murate, in the Coromandel base mix we have more superphosphate and slightly less murate, you'll see here that we have 185 here we only have 150

22. SV That's a combination of keisrite and magnox?

23. DS Yeah, keisrite and magnox, do the same thing, that's the special mix, flavour. What we've done, what is happened is this and I'm going to show you, this one might give it to you, might get it in this one, we'll start from the back, here we go, we used to do them, they were more comprehensive, but you can see here are the numbers, 192, 48, see 4 to 1, 136 to 192 now what we had, now that was Hycane base mix, then we got this sort of problem.

24. SV So that was between 192 and 48 that was between your potassium and magnesium and 136 is ..

25. DS 136 is N, N is your nitrogen. So then we used to get this problem, this is 1990, this is 89, we've only seen him from 1991, so I've only been there, but this is what we used to, that's very low.

26. SV Low phosphorus.

27. DS But the phosphorus is only 16 there 0 to 6 and its 14 there, so we said right we want to lift that so then we started and we did this, and so now instead of this input, if we go back to this one, 50 you see. In fact, have you got a piece of paper there? Now you just write these down 136, 50, 192 ,103, 126, 48, now the following year we come along, we've got low P, these are soils, so we've got 142,

63, 194, 115, 156, 45, now what happens, lets have a look there it is, it's up 50, right, it's up 50 so 92/93 129 N, 63, 181, 106, 152, 42, now we come 92 see here see what happens.

28. SV It's up to 23.

29. DS Only, we've done very little remember, fractionally see, none of this bang it with two tonnes, I don't believe in it, now here we go again, so just leave that you don't need those figures, right, everything's getting about right um, ok we've put on some calcium so that's what's picked that up and this one, this is very traditional in Coromandel with this always struggling to get to here ok, now the following year, what have we got, lets have a look, I think that was the 92 recommendation, yep, so then we got this, ok, then we got this 17 come back again, the others are about right see, calcium again a fraction high, ya know, you look here 6.1, 6.2, 1.78, 0.68, 15, 14 nothing particular, this is the one, ya see, not to worry, right, so now you come along next year, ok it's gone down a bit, all right, now hold on a sec I just want to see what I've done here, yep, 93/94 so here we are 132, 65, 194, 140, 196, 56, this orchard's had consistent around 10000 trays, not very big, now the next year, what's that, 93/94, so, yep bang, look where we are now, 28 fractionally up from 87 it will go back to here, lets get them lined up 83, 92, 91, 93, where's 92, here it is, so what have we done, we've gone from 5.9, 6.1, 6.2, 6.3, 6.3 see nothing, this is the latest 95, now just to give you an idea see, here we've gone 15, 23, remember there's sampling error, 17, up to 28, 24, you'll always struggle in the Coromandel unless you want to go and hit it and all it will do is get absorbed into the soil system so you'll have a number, but you won't really have available P so ok there you have. K 64, 87, 68, 95, 88, ya know, remember there's sampling error, Calcium 13, 15, 14, 15, 17, magnesium 1.6, 2.35, 1.6, 2.1, 2.5 all these patterns if you have a look like that are all the same, see.

30. SV Same shapes.

31. DS That is good agronomy, not agronomy start a chopping and a changing each year like you think you're doing something good, you're doing no good. Believe you me I haven't selected one I've just taken the one off the top of the pack here.

32. SV There all in the right sorta, similar sorta ratios all the way through.

33. DS Yeah, yeah, that is what science that recommendations, and if you look at the recommendations, where are you up to now, 132, hold on.

34. SV I think it was the 93/94.

35. DS 1994 here it is, and now the last one we gave them, 94/95 that's the one you had was it?

36. SV 132, 58, no we haven't got that one.

37. DS Na that one you have 65, 194, what's the next number? 144 that was 95

38. SV That was 95

39. DS And the one before 94/95 is here, read it out 132, 59, 182, 131, 183, 52, that's what it's all about, it's got to be consistent, now, you wanta know what happens when you do this? The grower, this is a true story, there all there every year, grower takes this one he gets this one the new one, shit he says, you haven't changed anything, this is true what they do you haven't changed anything, right, sometimes a number fractionally, fractionally changes, I tell em, I say look boys why must I change it for, everything's going well in the orchard, why do you want to change for, why do you want to change for. I've told them they can take that program and run it for 10 years and nothing will happen, they don't need me, ya know, you can sack me now, I've told them, na, I've told them, the only time, I mean I don't need the work, now for someone else they might be quite excited to get involved in all this because it might engender additional work, but I've got no interest, so you can take that program now and run it for the next ten years, in fact the nitrogen's the same there almost the same that's Coromandel base mix and that's this. Now all we did was move that if you go to, if you go back to this one, hold on, that's 4.6 P, that's 5.4 P all I've done is slight change, I'm getting them up there, I've got some close to it, I struggle, I could bash it up I don't believe in it, we could make that 5.6 we could change the numbers around a bit and make the numbers a little bit more, but other than that, nothing. These growers have got no problems, growers as happy as larry, ya know, that's the way we take the approach. This thing where it just chops and changes from every bloody year, that's not science, that's just mickey mouse. And the growers come to me and

complain and say oh David ya know hasn't done much and I mean when you look at this test and go back, a year back and look at this test and then you go back and look at this test you wonder why you're doing it, there's nothing to do and they are there they come there with their files, got their files and they know what the soil test was the year before and they're watching me, David why isn't there any change, this guy's only a new guy, I'll get you another one, I can take anyone take this one, it doesn't matter, they're all the bloody same, here's one been here for ages, he doesn't listen to me even this one, he's a very lazy grower. Here we are, that's when they first come, we ask the to do it, we often ask them to do 6 inches and a deeper one so you can see all your fertility is in the top and there's the pattern, see same sort of thing, very low in phosphorus, you've got high calcium, you haven't really got high calcium because you haven't got high saturation, but on a map, ya know, because of the soil type it shows a really high here, ya haven't really got a high, you've got really low saturation, even these histograms are always a problem, we've got some difficulty because we think they give the grower the wrong fact. So that's 89, now we come along here we've done something for them, I don't know if I'll ever find it, na haven't got it and here we've already made some changes, nothing much but it's smoothed a little bit, see, that one's still bad the old block that's where the cows used to be and the other one was always worst I think and that was only 14 before stays where it is, then we put on the fertiliser, even when we've got lower K levels they don't rise appreciably so you've seen everything from about 180 to 200, here that was here for some reason, oh yes that's for one of the blocks and that's for the other block, so we've given him two different programs for two different blocks, a year later we've actually started putting them together, there it is there, yep that was 1990 there's 91. If you apply lime and we have here, in this case we've brought it up, these particular soils have gone from 45 to 69, these soils do this, so that's not really high, that's about as high as we'll get it, when you apply lime you get this instant reaction in terms of your extraction. So now we're up to there, he gets his program much the same again, ok, 92 here it is there, pH has dropped again, got him up a little bit, that's taken off one, that's the more fertile block. We give him another program there brought it down a little bit because of the fertility here it is there now it's slightly down, 31 was it? What was it, 37, now it's 28, ya know, but again same pattern, that's creeping up a little bit 1.39, now we're down a little bit

1.74, where we go to next, that's 1.57, 1.39 down to 1.33 again very gentle see, 31, staying in the thing, 6.2, 5, now we go to next year, K we think is still a little high we brought him down 170, we won't go much lower than that, other numbers are much the same. There we are that's last seasons, 124 down again from 133 to 124 that stayed up, that stayed steady, the calcium's back in balance. That's his other one, forget about the calcium 1.12 see staying there staying there balance 38 virtually the same these two now 39, 38, 1.12, 16 to 20, 2.53 to 3 and I go out of a job so actually I'm leaving I've offered them for this year programs, I used to out to the orchard twice a year and I've said no more boys I'm not going. I've got other things to do in life, I've to them you don't need me, some of them have gone to lease and they'll do their own thing up there it's got nothing to do with me. Here's another one, same bloody thing, same pattern, this one's always a little high in K this particular one 9.7, 1.9, we want to get him down 124, 164, 136, 136, 118, 136 and so forth, so the number here for K, we've brought K very low although it's low it's still 450 grams a bay, but he's got less bays so in some ways you're still applying the same amount per bay, but because he's got less bays you're getting a lower number and so it goes on, these are the Coroandel growers and you can go through them one after another boy and then, ya know, some of them are very very even, you look at this one, look at that one, it's high there, now it's back there 93, 92, 91, same sort of thing now, this is when they started, when they start they're usually a bit lower. That's a good orchard, it's 8000, so this one here then you put your nitrogen in and then you put your other, again it's, we want, we don't want equal amounts because we feel you need to get more on before something like a 66, 33, ya know, ya saw from the recommendation, now look here Stephen, ya know that sort of thing, those numbers and then it comes down, that sometimes is different, it depends on the orchards, sulphur's usually higher than it needs to be, but sulphur's never a problem up here.

40. DS You'll find that some advisors are high, just heavy handed, I don't know why, I think fear, they have a fear of deficiencies more than toxicity's, but they produce. They don't understand that as you put in more and more fertility that you've got other management problems that surround it particularly in summer management, just to grow leaves is silly. In a lot of our cases its not fertility that's the problem, but whether the spring is favourable or not. You also find, this season

we've actually cut down, some of the growers have asked for, because the prices are so poor, they've asked for reductions and we find that if you have a lot of rainfall after flowering in December then you often have a very good growing season, a longer growing season, if you have a very dry spell then you are more dependent to maintain the fruit load with less leaves because your growth will slow with the onset of fruiting, but in some seasons where there is a lot of rain the fruiting doesn't act as the same degree of break on leaf growth so you end up with, this year we end up with canopies with plenty of growth carrying good loads of fruit, other years we can end up with less canopy carrying the same loads of fruit because we are drier. So its not a fertility issue its a climate issue is very much a factor and the second factor is in my view is that a lot of people are applying more fertiliser because they are simply not sure of their ground. So they say ok well you need 200, well I think I'll put on 250, nothing will happen and I'll be more comfortable, but its because they're not certain of their ground. And the less certain you are the heavier you get and the more certain you are you start to come down. Then you get people that use American soil tests and stuff like that and they put on virtually nothing just trace elements and the end result with them is that they deplete the reserves and they get chucked off the land, in the short term its acceptable and its very low inputs, but in the longer term the vines go backwards. So you've got to find a medium balance and so long as our soils are in some sort of equilibrium we don't worry. We used to leaf tests, but no more.

41. SV So what, if could you just run through the process you'd go through if someone rings you up and says I need a soil recommendation, a fertiliser recommendation, what

42. DS If I haven't seen the orchard we virtually never do it.

43. SV So you always go and visit the orchard?

44. DS Nowadays, the orchards we're doing, there's about forty plus, we know each orchard and we give them recommendations and those recommendations are now quite historic as you can see they're all, in this district what's happening is that the orchards are being leased by orchards. The biggest packhouse leasing orchards, I do them all, there's fourteen or fifteen of them. The other packhouse that competes with them, they asked me to do theirs and I said I've got a difficulty

here because there's a conflict of interest, because sometimes growers will ask me who should I lease to and then if you've got to many irons in the fire then, then you're, its very difficult, I might say well he's better than him and he finds out he says I'm you're client and your saying I'm not as good, I don't want to get into that. We've actually been asked to do all of them, there are three packhouses basically that compete, we've been asked to do all three, I work for two of them, but one isn't very big and the third one they've pestered me for years and I came back last year and said no again its too much potential conflict of interest. If you took an orchard and you said how would you go about it, if they've got historical soil tests I'll take it. I often ask for two profiles initially 0 to 6 or 0 to 8 and 8 to 16 just to get a feel of what's up there and what's lower down.

45. SV Within your soil profile?

46. DS Yeah, we know that most of the roots are in the top 8, probably 40% at least are in the top 4, we know in our kiwifruit, not in the Bay of Plenty where they are very deep, but in our soils they are like that. We'll take two soil tests and take a look at it. We never put on lime at more than 2.5 tonnes per hectare in this district. Never put on much more than half of that rate on the pumice soils we saw their affinity, saw what happened.

47. SV Over on the Coromandel?

48. DS A tonne to the hectare and it all over the place its that quickly.

49. SV That's over on the Coromandel?

50. DS Yeah, so we put on less. Sometimes its difficult for growers to understand that we prefer them to apply less fertiliser more often, but we've found over the years that growers when they got themselves organised they could, even on big orchards, they could run a vicon all day and come within a bag, at the end of the day, they had it so finely done. We band the fertiliser more than broadcast, some orchards are broadcast in this district, some are, peat soils are usually banded, some of the light soils are banded, the heavy soil are not. So we've sort of made up these different parameters and then we've simply created the test around it and these have been going, I don't know, earliest kiwifruit growers in 1985 and we've never exceeded I think 220 of K and in normal situations never been below 170 of

K and then nitrogen, we've never exceeded 160 in my life and we down about as low as about 120 when we first started and we've accepted a little bit of the nitrogen need with high yields and we've gone to 160. So now it absolutely boring, I have to get motivated to do them. Now this year we've said that's it boys, you'll not get another visit from me, you can have a program from me if you want $130 plus GST and you can have a phone line if there's a query, if you call me out you'll get charged for time and mileage, so this is my last year. So now I'm doing other work. We've got a lot of trail work, these potato trails, pasture trails, we're introducing a new fertiliser into New Zealand called ammonium sulphate nitrate, lots of things

51. SV That's with BASF?

52. DS That's with BASF. Its a question of how far you try and make it, how far do you go to ask the computer to the decisions for you as against how far you go just to use it, to use the computer as a sort of a calculation agency, which that is [referring to the computer program he uses].

53. SV That's all it should be used for.

54. DS Well that's all that is, with all due respect, all it does is I choose the fertiliser, I choose the rate, it finishes off like that you press that button, it prints it, you send it to the grower. It has a problem, this is a bit of a problem, this rate per grams, farmers would like you to say Hycane base mix, so that's 880 kg per hectare for two applications, so they like me to write down there 440 kg, but its not per hectare, its only over the herbicide strip, 440, so they often come, we actually put that in afterwards, we never used to do that, we put that in afterwards so that they could go to the spreader and say you've got to put that a 400 kg because that's two applications, 440 just over the herbicide strip.

55. SV As you're putting it into your model there you are setting up how you're going to split your different applications?

56. DS Well the um, what's happened here is that in this particular case you've got the dates, right, so we tell him so those two are put on at the same time, down here he's told that on a hectare basis he needs 884, that two applications so he knows that. CAN is one application 260, kf special mix, they won't order 442 they'll

order 440 you know and then they'll multiply by their hectareage that they've got. How do you decide to make it one two or whatever, in kiwifruit we feel comfortable with this, in kiwifruit there is a lot of pressure for me to put the first two together, and that's a problem in itself because nitrogen is separate from the other. I went to one the other day and they asked me to look at it and I've said all right later in the season come back to me and I'll have a look at because what we'll do is exceed the minimum, the acceptable loadings in our, but there have been orchards that have been brining the two together and they've been manageable. But the growers today, the growers they get two soil tests that are different and they want to know why and they completely forget about the potential for sampling error, completely forget about it. They go to different sites, I don't know how they do it, you give a proposal of how many samples to take over a given area although we've done that we know that we need one to a tenth of an acre to get most of the variability out. Whether they do it or not we don't know, just don't know. But nowadays I'm absolutely worthless because I'm only there for insurance, they don't me, and that why we are very different from MAF in that respect because once you've got it into reasonable equilibrium what does he need you for.

57. SV Yeah he's producing the same amount of crop each year.

58. DS But if every year you come along and say this is down and that's up, I mean we don't even talk like that, we don't go to a grower and say last year you had 1.1 milli equivalents of K and this year you've got 1.17 and we think that a, we don't talk like that, na, they talk like that.

59. SV MAF?

60. DS Yeah, and all that they talking about how its improved might be all sampling error, it might actually have gone to hell. I don't think they have any idea as to how much variation that, overseas they've done it where they've taken plots, a hectare and then split it up into ten metre squares and then gone a sampled every one and then colour coded them for different values. Take P, for instance, and it looks like a checker board, yeah, we've got the slides. So sometimes people talk about how we've done some good work, its gone from 11 MAF units to 13 and I don't believe it has, often its just, we don't know what it is. So we don't work on

that, we just work on reasonable equilibrium year to year so you put in so much, you start with this, you put in so much the crop takes it out over the growing period you come back nine months later, twelve months later and take another sample you find there's very little variation then you come again and put on stuff and you find we don't have health problems so we stopped the leaf tests because often the leaf test will show something and then, show something, it might show something low and then everybody can't wait to put on this and to put on that. Another problem is that because, I mean, what the others are doing is they're putting it on very earlier, long before bud burst, they put nitrogen on at bud burst and then they take it six weeks later and they check out if everything's ok, but six weeks later we're putting on our final mixture, so what is the point? And we do that because flowering is very stressful, flowering is a very stressful time on nutrients in kiwifruit, a lot of activity going on, a lot of change going on, all of a sudden after flowering with the cell division and everything else. And so to give the plant, if the plant is in any way short at that point put on that application about one or two weeks before flowering, by the time of flowering it's in the system if the plants need a little bit of boost there it is, that's it. So we're putting on a bit of K putting, on a bit of magnesium, putting on nitrogen and close the door and I'm out of a job. Ya know you've got to think what you want to allow the model to do and what you feel you have to do and secondly you have to look at the outcome, the hopeful outcome you will have for your model because it's only really successful if you can take an orchard and bring it into some sort of static equilibrium and leave it there and the vines seem to be well rythmed, fruit crops are all like that they need to be well rythmed, the yields are satisfactory and you're getting no real problems and that's all we're doing, that's it and there's no change. I'd like to do other crops, but we're doing some potato work now. And kiwifruit also, its an industry where there's been a great deal of heart break and not a lot of enthusiasm, I don't know what you've found?

61. SV Yeah, it comes across like that.

62. DS But the pleasure for me is to go back into a grower, we've got one grower here, you wouldn't believe it, a very high yielding grower, let me show you something, let me show you one more just to show you how close we can get this thing and believe you me this is high yielding this is not, this is 11,000.

63. SV 11,000! That's better than a lot of the ...

64. DS This is a grower that just all out go, all out, he wants to be the best, wants to stay the best and he does everything boy, here it is here, have a look at this. We even fertigate, we fertigate here. This is before I came. There's 86, 87 all right, quite high rates, I don't know what they put on, this is not me. I wasn't here then. Now we come along, here's 88 see this is sent in by someone else this is not me, here we start, Sher, this is 88, so here's the, 6.5, 105, 12.3, 2.08 it low in phosphorus we know that. Here's a year later, 6.7, 105 becomes 104, 12.3 becomes 12.3, 2.08 becomes 2.21. Now we go a year later 105 back 12.4, 12.3, 2.39, 2.29, 18's gone up from 14, 6.7 dropped back to 6.5. This is an interesting one, this is the top grower, this guy is. We've put on, as you can see we've put on a bit more K, we had 214, now we've gone to 20, 1, 12 1.24 so three years in a row, nothing, we're at 8000 here this is at 8 then. Lets take another year, we got a little bit of variability after that time. With fertigation it's a little bit harder to control, ok, because he's putting it on right through the growing season, so what happens is we're even applying as late as February so some of that may be picked up in the next soil test. No longer are we applying it all by, ya know, by November, but anyway 20, we don't put P in it, 28, 136, 1, 12, 13, 2.24, 2.25, right, go to the next one, back to 21, its back here 0.85, don't know why, 12.4 same 2.26 the same, all the rest are the same. Go back to the next one, 94, now we got, we went down, pH is the same, these are sliding a little bit, so then we upped the rate I think, yes we have, we've now got a bonnar special that his name, so here we said that's too low so now we're using a triple super phosphate mix so it's higher in P, you can be sure of that, that's 94. We did that especially, we said that this is no longer acceptable, so you can see, I'll just show you this, this is quite important, if you look at 94, 93/94 so that would have been the fertiliser we would have applied, 93/94, then he took this test, we had 59, and I'm looking for 94/95, here it is 94/95 you see that here its a bit low so here we changed it you see, we said no, no, no, look we've gotta to do something better that was 60, 59 in the year before it was 63 we're not winning so we said ok we're going to change that we've now brought in triple, we've still got the 15% potash, but brought in special so we've now got here, we've lifted the P quite significantly 10.5 so we've gone, because these are high yields, I mean I'm talking well over 10, so I've said no, no,

no, so we've said we've really got to lift this, so we've lifted it, here's last years results, so what has happened, if you go back to 94, the K is up slightly, but we've now got the phosphorus, but we haven't gone crazy, we've just quietly changed the mixture, we haven't even done to much to cost we had 947, the year before we had 879.

65. SV It's not a lot is it.

66. DS We've also gone here from 187, 199, done it, remember there's a bit of fertigation on top of this. So we never know just how much he's doing, last year was a very big year when they pulled out very big yields and he was about 11 he was really high and so we've still raised his levels. Now we'll go back, you want the 95/96 one, here we are, we've maintained it and again we've pushed it up a little bit, same N, we've maintained this, there we are, so we got it to rise, we've told him we're going to continue for one more year because what happened was he got, we rose this in 95, but he also had this enormous crop ten eleven thousand he's another big there this year so we said ok we'll maintain it, that's gone up slightly from 199 I think it was there, its gone up slightly, N's the same, rest are much the same. All we've done is this and we've said to him after this year if you're up we're going to bring you back onto the old system.

67. SV Back onto the Coromandel base mix?

68. DS Yeah, we will not do this thing where a guy gets a low figure, er yeah need two tonnes of super phosphate don't do that. So there's one and that's the best one so that's the toughest one because this ones the highest removal and he's got fertigation, fertigation's very difficult, with fertigation to control all the nutrient values in the soil. But basically they don't need me. And as soon as I stop going there they will forget me, they'll say oh yeah I remember that guy who used to visit, ya know they'll do that, yeah three years down the track they'll say I used to know him, but all of them now, very, ya know, we don't have any crop failures, we haven't had a crop failure for I don't know how many years and again it's all come from this approach and that's really just a mathematical tool, isn't it.

69. SV Yeah, just something to aid your decision making.

70. DS Yes, well we're only using a few fertilisers, we use a kiwifruit special mix and the hycane, the CAN and the coromandel base mix. We don't need to go outside because we don't have any special situations, we don't have particularly low sulphur, particularly low phosphorus, particularly high this, we don't have it. Ya know I can bring out ten Franklin orchards and they've all got the same patterns. It's here, to give you an idea, if you look here, so this one I wasn't doing, this is one I've been called into do, so this one for some reason they've got it high, too high for our soils, Manering we've been doing for quite a while, there you are, these are Raymond Hull we haven't been doing for too long, it's also, you see that's been put on in the past, people have been pouring the stuff on we're down to 140, this one we did for a couple of years, Evans, this is another one, we try and keep the things in here, nothing too high, not too low, there's not much point and so it goes on.

71. SV Are all your fertilisers based on the stuff from BASF?

72. DS Na, na,

73. SV Or do you just buy from whoever?

74. DS Well that's not from BASF, that's a BOP mixture of 15% pot super mixture with a little bit of kieserite, that's the same, that's sulphate of potash, kieserite and CAN, na, hell no, na, it all comes out of ex BOP store.

75. SV What ever's local?

76. DS Yeah. In the old days we used to put it on much more often, this is the old program, ya see it doesn't have these bits here. There we put on 515 of K, its now 450, 280 we now put on 350, this is donkeys old. We've never ever had a failure, these are the very old ones we used to go as long as this, we used to put one on the 15th of the 8th then 15th of the 9th, those two are basically put together, those two are put together, those two could be basically put together, so we had four and then we had, so we had August, September, October, November we used to do it that way. We used to used potash of magnesia it's a very fine product. But we've told the growers, we are the rolls royce, we don't deny it, if you want a bloody Japanese copy from the other side you go and fetch it, we're absolutely adamant, but when they had all these problems with toxicity's and they wouldn't

acknowledge it all that happened was that more and more growers came to us. And you find that growers talk amongst themselves, they say who is doing yours. What I found was that in some cases, I don't give growers options I tell them this or this I'm very, not blunt, but I, you don't get waffle you get told, if you don't do something you get told you fix that, I'm not there to come along and spend time and be nice and give you ten different options and you go and pick, I don't work like that, some growers don't like it, they don't like the fourth-rightness, so you got some growers that wouldn't. I had growers challenge me over the model [KNMS] told me the model was right, they had no scientific knowledge at all, but they were convinced I was mocking the model was MAF and I don't particularly like MAF, but it's not MAF that I don't like it's the unprofessionalism I don't like. So I've got some very good friends in MAF who I regard as fine consultants, so when I attacked the model and said that's rubbish and they went off to me, it wasn't because I was attacking MAF I was attacking the science. I was also concerned about the way they defended the model, which was unrelated to its scientific credibility. It's like when they attacked us in the kiwifruit journal, they said he doesn't understand this and this, at the end of the day go to the Bollard review and the Bollard review said exactly what I said. And there's still people now that say it's personality driven against Smith and Bawalda, I have very little respect for them as scientists, very little respect, it's the same with Hendrikse. There were something like 60 consultants around the country when KNMS was released, only the Hawkes Bay conservatory refused to accept the model and it was only one person in there, a chap named Wilson who said that model's not coming, it's flawed and they pushed him out, they made life so uncomfortable for him that he left, he works for Montana. They tried the model and he said no, they came up here and they tried to persuade him and he said no and then they just made life uncomfortable for him and he left and as soon as he left the Hawkes Bay crowd took up the model. They said give the model some time perhaps it will get better, the model's flawed. Now through that period every single other MAF consultant who regards themselves as educated, gone to university and everything else, adopted that model, every one of them, there was no question about it, and that why I said its published can't you read it, can't you see it, it's flawed.

77. SV There ideas behind it originally I think were ...

78. DS There ideas were to make money. It was during that transition when they were going to make DSIR and MAF Tech and everything pay as you, ya know, pay its' way. They thought well models were the ideal way, they even wrote there that they were so inundated with requests for advise we had to find a vehicle to process all these requests and they weren't fooling anybody and the outcome at the end was just that. And when I went to see professor Lense at the university of Bond said that a simple mass balance approach like that will not work, it won't work and DSIR put up their model and you can still get it I think, Noel Turner would be the person to talk to, 625-4864, he lives in 2a Gorrie Ave, Epsom. The DSIR formed a thing like this were you have a number of databases, which you can go into, but at the end of the day you make the decision and he ran it, they then sold it to Yates, but that fell over, they then sold it to consultants Stevens and Mulagan, I don't even know if it's alive today. Instead of doing what MAF did, which was to say if you give me some numbers I'll be able to churn it out and tell you, they refused to do that, they worked with a consultant and they worked like my model has that parameter 800 fruit per whatever, they can do it that way or in tonnes, it comes up and it says that is your estimated need so if you go far in excess or far below there should be a reason, so what it's doing is saying don't get to far off this track unless it's justified and in turn if we found that we had underestimated a particular nutrient then we can just go into the machine and change those numbers and start running it again. You will find when you look now back at models that have been presented in a whole range of crops over the years, none of them have endured when you think about it. There is no simple apple model or kiwifruit model it has to be an element of human input into it and then you have to build your systems like you are around that so there can be cost, they can be like you said they can allow for idiosyncrasy of the crop, not too much chloride, not too much this, they don't like a lot of boron, ya know, different things, those ya can build around, you can build a generalised requirement, ya know, a box that sort of thing you can do, on the basis of an understanding, after that you've got o do things like, in the Bay of Plenty of instance we would use more K perhaps a little bit less N, in this district we've got it now, for our district, but over there they do it slightly different, so it's definitely different, and in the Coromandel like you saw very responsive to, the soil is very responsive to calcium, very low levels of P in our soils here and how do you, how do you deal with that? Because the model was

very simplistic, it's made physiological assumptions, if you take the yield from this to this then you need this, but it doesn't, seasonal influences you ignore, you say it has to go from here to here it needs this, better management, you don't say that, you say well if you, if I planned you for 5000 last year and I'm up to 7000 this year all I've got to do is shunt this thing up by a hundred of N. Well we've gone at Coromandel up 2000 trays on 10 units of N, we've not found that at all. Now what professor Bollard said was how do you know that if you put on nothing you won't get three quarters of the yield you got before, or all of the yield? How do you know how much of the nutrients in the soil or in the plant is able to be recycled. The cost thing is not sill because there are farmers that are concerned about cost.

79. SV What I'm trying to aim with my model is the idea of minimising cost plus the idea of minimising excesses, trying to get what fertilisers you use as close as possible to your requirements and I've allowed for the ability to maintain relationships between nutrients or between fertilisers and any minimum's or maximums of any particular ones. So that's sorta where it's at at the moment.

80. DS And you're doing it for kiwifruit?

81. SV At this stage it's not specific, a lot of the work I've been doing is looking at kiwifruit and that's what I've been talking to people about.

82. DS Kiwifruit's not bad, but the model made a lot of false assumptions.

83. SV It's a good one because it's got a lot of other industry information about which I can draw on especially it other sort of models that people have used to look at and take into account and see how mine differs from there sort of angles of attack

84. Well there were only two, I mean ours is really a simplified version of DSIR's. DSIR had other databases with more information probably than ours. We liked it like this because will liked to tell that farmer what he was putting on per bay in each of these, you could change it, you could tell the computer put that into kilograms per hectare for me, it no big deal, it grams of nutrients per bay, it no big deal, I mean we could have, I didn't write the program, someone wrote it for me some long time ago. Its relatively unsophisticated because there are management decisions you can't translate into computer language. How far do you take the

model? How far do you allow these assumptions, even yield, what they found in there's' was that, ya know, someone would come along and tell them that yield is potentially this or that and they quoted well we can measure the stem, you can't, it's bullshit, the only way you had any degree of accuracy was measuring the base, so you could say well I've laid down 600 winter buds, but the fruitfulness per bud can vary enormously from 1 to as much as 2.5, so again you just don't know, so what we've said is well these orchards are reasonably rhythmed they aim for 7000 we'll work it at 7, now they didn't do that, they said you give us this figure and we'll just ram it through and do it, if you go from 5000 to 7000 well we'll allow for the extra nutrient and they talk about deficits carry over of deficits, I mean I don't know where they get this from, it's not soil science.

[Tape ends]

Appendix 2

Evidence of the fertiliser service offered by consultants

2.1. Introduction

This appendix contains the evidence for the description of the fertiliser recommendation service of the horticultural consultants studied in chapter two. The evidence relating to each consultant is presented one after the other. For each consultant the evidence of each category is presented, which is then followed by the evidence for the links between the categories. The evidence follows a common layout throughout the appendix, an excerpt from the transcript is preceded by a number that denotes the paragraph in the transcript from where the excerpt is taken from and the excerpts are in the order from which they were taken from the transcript.

2.2. Consultant one

2.2.1. Categories

2.2.1.1. Collection of information

41. say its a new crop, like flowers, the floricultural consultants are constantly in touch with the research people on that, basically the research people are doing nutritional work, you say, this is what we're doing in the field, is it right, should we be doing something different.

2.2.1.1.1. Nutrient tests

25. If they're market gardeners they may test [soil] between crops

25. if they're greenhouse growers they'll usually test, depending on what they're doing, they may be growing in the soil, most of them are starting to grow in peat pumice mixes, in bags and so on, they may get an analysis done of that before they start

25. because the plants are virtually reliant on what you are putting through your irrigation system. So you are very heavily leaf testing all the time, maybe leaf testing as often as once a month, to track how well things are going.

25. Horticulturalists generally soil test, if they're fruit crops, permanent crop type situation they'll soil test at least once a year, usually only once a year.

92. the next winter, some more soil tests

2.2.1.1.2. Talk to growers

3. Second thing, definitely talk grower observation, so, in, they quite often say, historically have this problem or have this difficulty.

3. We'll also talk to them about any preferences in terms of the fertilisers that they wish to use.

5. some people think that there is a chloride problem.

2.2.1.2. Knowledge

82. this is historical rec.s from one of my colleagues

Information system

49. It's all hard copy, client files.

49. We've got in those little hard copy client files, we haven't got an electronic system that we think is reliable enough

49. clients go across consultants as well, so, I might be working with a client on the fruit side and they'll have a greenhouse as well, which another consultant will be working on so it's important that we do store information at one central place, and keep access to it

51. Keeping a copy of all the recommendations.

53. Keep the whole presentation that we've given to the grower. We'll sometimes keep our calculation sheets as well.

53. So if we print a least cost run, to the grower, usually to them we'll present the first 4 or 5 options, but for us we'll keep the whole printout.

65. being able to store more info by client [would be useful] so you don't have to wade through the historical folder of information that you've got

2.2.1.2.1. Literature

41. most of the crops, someone has done detailed nutritional work on it, somewhere, either reported in the scientific or public magazines

2.2.1.3. Analysis of information

3. we'll look at historical soil tests, historical leaf tests, and see if there are any problems or trends that are showing

46. you can go back, look at the past several years what you've done for that grower

55. we definitely go through again and look at the historical problems, trends there.

82. when I first went and saw him I got hold of as many of his historical soil test results as I could, so I got all those back, 1991, 1992

82. looked at his [the grower] historical recommendations and what fertilisers he'd put on

2.2.1.3.1. Nutrient trend

3. like round here, for instance, we quite often find there is a potassium or magnesium trend.

55. A good example is phosphate levels, can build up round here

2.2.1.4. Nutrient requirements

35. plus your wastage factor, because not everything that you put on is going to be taken up by the plant.

35. you've got that [a wastage factor] plus my sort of expected yield, my annual maintenance, plus any deficiencies.

63. you work up to that [the list of required nutrients], that's time, time is taken to develop how many kgs are of each of the nutrients is required.

63. It's working it out [nutrient requirements], you know, we've got to allow this for that, that for that, taking into account historical factors, expected yields, the grower factor, those types of things

2.2.1.4.1. Corrective levels

23. look at correction levels, to get that from where they are currently up to what we consider to be the base levels

23. there's very few people that we're looking at large levels of corrective fertilisers unless they're looking at going into market gardening out of pasture, which your pasture is generally lower than, so you're looking at a lift.

23. If you're looking at that, you then have to consider how long they're going to go into pasture as well, because to lift some of the base levels may take 4 to 5 years of the fertiliser programs to lift it otherwise you're putting it on to excess and its going out in the drains and in the water.

2.2.1.4.2. Maintenance levels

9. we'll look at estimated yield, so we'll do a calculation on the total tonnage of fruit that's going to be taken out, how much nutrients are actually going to be removed from the orchard

9. how much nutrients are actually going to be removed from the orchard, and we have some sort of guidelines that we work through

11. a little bit of that [prunings] as well [when determining maintenance levels]

11. yield is the part mainly removed from the orchard

11. most of the prunings are mulched and put back in. Kiwifruit particularly. Apples they tend to sweep them out

23. look at annual maintenance [when determining nutrient requirements]

23. in most instances here, we're looking at annual maintenance [as the main component of nutrient requirements]

35. of Kiwifruit, for instance, you're taking out 6000 trays, when that goes out for every thousand trays there's so much N P K Mg, sulphur, calcium going out, so you work out that's your maintenance

2.2.1.5. Select fertilisers

82. This here is an interesting sample of my fertiliser selection based on least cost.

2.2.1.5.1. Ability to meet nutrient requirements

11. more and more now what I'm taking into account to is that some of the models actually, when least cost, it actually has excesses of some nutrients, and we're trying to avoid that if we can, so we're trying to look at fertiliser programs that supply what we want, but not a hell of a lot more.

13. it [reduction of excesses] is particularly important when you get into some of the vegetable crops and the greenhouse crops and indoor crops particularly because you don't have the rain flushing the soil and so on, and you can get built up sulphur that goes through the roof, sulphur readings as high as 300 - 400, you know, which is absolutely ridiculous, and you then have to look at products like potassium nitrate, which are a lot more expensive.

31. when you are making the mixes up you generally take into account the cost of the products that are going in, but it is more important to get the mix right.

2.2.1.5.2. Cost

17. when they run a special you may go in there and alter the model price

17. deferred payments and stuff like that, sometimes you have to take those into account. There's a lot of the companies will allow you to put on a product and pay for it in 3 months or 4 months, and that can be quite important, particularly for market gardeners putting a crop in and waiting for it to come through

88. In this case here, its showed that a mix of, for that particular mix of nutrients, mix of D.A.P, Muriate, Magnox, gave a total of $495 per hectare, compared to, there's another one, a hort fertiliser, a special one that one of the companies here does, with muriated potash was 549, and so on up, and he is, a historical user of a 12:10:10 product, which is a lot more expensive, so he was able to save, in this

case, about 125 bucks per hectare over his whole orchard, through going back to a program like this.

2.2.1.5.3. Grower fertiliser preferences

3. Some of them may have a preference for organic type fertilisers

11. but if the client has said they don't want potassium chloride and the first one that punches out has potassium chloride in it then we keep on going down 'til we find an option that fits.

2.2.1.5.4. Least cost model

11. then from there we'll run a recommendation which may be on the old least cost fertiliser program, and that will then print out a range of options for us

11. how much nitrogen, potassium, magnesium, phosphate, sulphur are required and punch in what we can into the model

17. [The model currently used is a] Least cost one, yes. Its put out by the soil fertility service, probably about 7 or 8 years ago

17. what you do is you will punch in, for your nearest depot, you will punch in all the fertilisers and put in all the N P K Mg analysis of it and the sulphur analysis of it, and the price.

17. And so you can put in your complete list of fertilisers in there [in the model]

21. you just put in [to the model] you want 60 kg per hectare of N and 80 of P or whatever and it just mathematically goes through and makes a selection on it.

84. I punched in, this is my requirement here, it processes them and puts the total of each of those N P K S and Magnesium down here, and that's the first option, that's the second, third, fourth.

86. you can specify how many [fertiliser mix options] you want.

88. I usually specify 4 or 5, [fertiliser mix options] it usually gives you enough.

2.2.1.6. Fertiliser recommendation

2.2.1.6.1. Application suggestions

31. you have quite complex mixes of them they make up, and you can't mix certain products because the coagulate or crystallise or whatever. So you have basically A and B mixes for those particular ones

35. I don't so much do [split application of] the traces

37. For most of your elements like your phosphate, your relatively immobile elements like phosphate, calcium, lime, those sorts of products we tend to broadcast, get 100% ground cover, we put them on early in the season, because we know that they're not going to wash down the drain in the first shower of rain.

37. elements like potassium and nitrogen, potassium for Kiwifruit we generally apply early, and in bulk, we may apply 100%, or we may split, depending on the history of the property, in terms of its ability to retain potassium in the soil.

37. if we know it's a property where we've had a history of low potassium leaf tests we'd probably apply it in 2 or 3 applications.

37. So, nitrogen we definitely split. Nitrogen we'll put on almost every case we'll do 2 applications.

41. we have worked with scientists, in terms of the history of it, they'll generally say you put on a third here or two thirds here, general scientific information that we have based it on in the first instance.

2.2.1.6.2. Recommendation report

43. It depends on what the grower wants. [regarding a recommendation report]

43. Some growers, all they want, you just put it down and I'll go off and get on the phone and ring up Wrightsons or AnchorMart, order my fertiliser and its done. They don't want any of the sort of the rational behind it, so they don't want to understand why you have said what you do, they just want to understand this is what I've got to do

43. other growers like to see the results, so we present the results as they are, the desirable or target levels, the trends that we have picked up, so we can say right,

this has moved since last year, it's gone down or up, as a result of that we're going to take that into account in terms of the nutrient side of it.

43. So you might get a bit of a introduction, these are the results, here's some of the things that we've got to consider, and as a result of and your estimated crop, here's what our recommendation is in terms of amounts of N P K , in kg per hectare or kg per square meter depending on what your crop is, and as a result of that, by our calculations this is the least cost fertiliser option, so we then put in a recommendation in on that.

53. So if we print a least cost run, to the grower, usually to them we'll present the first 4 or 5 options

84. it's [recommendation report] got the elements [nutrients]

88. he'd get a letter, so, this one here I'd gone over his fertiliser history, so I didn't actually have any soil test results, and see what the recommendation was, chemical, N P K, magnesium, [can't understand a couple of seconds] and, what I'd allowed for in terms of the model, what it'd spat out

92. We've just made some comments about the magnesium, what could be suppressing it. So we're still working on that.

2.2.2. Links between categories

2.2.2.1. Knowledge / Analysis of information

3. we'll look at historically what information is available

3. And that [trend] has come through from historical soil and leaf tests and observations of the grower and what a growers

55. we can get phosphate levels as high as 100, 120, and in some of the soils the desirable target levels might be about 30

65. it would be great if you could electronically pull up for that client, their history, and it has some notes there, and it says has a history of high phosphate, or whatever, like that, has difficulty in getting magnesium levels up, you know, historically shows low magnesium.

65. [Would like the information system] So that without having to wade through it just pops up, and then you can put in historical yield figures, like 1990, this many trays per hectare, so it shows the sort of trends that are coming through there.

2.2.2.2. Knowledge / Nutrient requirements

7. its [leaf necrosis in kiwifruit] a nitrogen problem as far as I'm concerned.

9. But we definitely have to take that into account with the grower, and we can discuss that, you know, we consider its a nitrogen problem, but if they are quite insistent that they wish to apply potassium sulphate as opposed to potassium chloride we will take that into account when we do a recommendation.

11. apples are a much lower nutrient requirement crop [than kiwifruit]

2.2.2.3. Knowledge / Select fertilisers

3. others may have a preference for avoiding products with chloride in, because there has been a bit of a stigma

17. we'll have an AnchorMart and a Wrightsons price list on there

31. For the greenhouse, intensive cropping, type scene, we go to a lot wider range of suppliers, because there's Vegegrow supplies, Fruitfed supplies and so on, who supply small volumes of the trace element mixes

31. the big guys, you can only buy it in 40 or 50 kg bag, and a 40 kg bag of some trace element may last a green house grower 20 years, because you are talking such small amounts

65. Does not want to use these sorts of fertilisers, whatever, so if you had a lot of that there on a one page summary as you started off, it'd short cut it probably 10 minutes.

2.2.2.4. Analysis of information / Nutrient requirements

23. you have got to interpret that [soil and leaf test results] and work out on the basis of that, how many kilograms of product you have to put on per hectare to get a lift

55. you may have a policy of trying to knock your phosphate levels back down, because it may be suppressing copper or zinc

55. And so, if you don't recommend phosphate for a couple of years and the levels start to come back down again, down to a level where you say, all right, I'll start putting some more in as a standard maintenance that you put in. If you've got the historical information there you might think twice about that.

55. Might say well I've had historically a phosphate problem, lets not get too carried away with it, lets just leave it out for a little bit longer.

2.2.2.5. Analysis of information / Select fertilisers

3. Because you can sometimes have a perfectly normal soil test in terms of some of the nutrients, but in terms of the leaf test can be a difficulty so we may alter our actual recommendation on the basis of that.

25. if there has been a trace element problem has been identified, you may add it to your bulk fertiliser

25. if you have identified you have got a boron deficiency you may add a little bit of boron to your phosphate as it goes on.

29. unless they were just off the scale in terms of, it's only a minor deficiency, we might say that the traces, the impurities should be enough to cater for it. But generally you would make a firm recommendation for adding a trace to it.

92. low magnesium, and we recommend here you put on extra Epsom salts or Kieserite, basically just to kick the magnesium along.

2.2.2.6. Analysis of information / Fertiliser recommendation

3. will take account of that [a trend] when we're putting recommendations together.

43. We'll also look at the leaf test so we might go back later on, having Kiwifruit for instance leaf testing at the moment, we may take that into account when we do the rec., soil fertility rec. in August we'll say right, going back to your summer leaf test it showed this, so we're taking that into account.

2.2.2.7. Nutrient requirements / Select fertilisers

63. Once you've got that [nutrient requirements] it's two minutes to get your fertilisers sorted out

2.2.2.8. Fertiliser recommendation / Knowledge

55. Most consultants are pretty keenly aware of what's going on with their clients in terms of fertiliser history.

2.3. Consultant two

2.3.1. Categories

2.3.1.1. Collection of information

9. where we know we've got to learn about things. We're doing some, for example, with, with carrots at the moment we've been monitoring every week or two weeks just, just to get a fix on what is happening

21. we've got some pretty switched on growers now and they take note, they're around their paddock each day and they just jot things down.

49. or there's something happened and his orchards water logged and tile drains blocked up and the roots are rotting or something like that, something's happened

128. It started off, they didn't grow particularly well, and they were shy at bearing, and we were getting a lot of blind budding.

128. So it's a balance of looking at what's happening in the field, looking at monitoring your levels from year to year, and maintaining a balance.

2.3.1.1.1. Literature

23. there's not a lot of data [in the literature] that's available to latch into.

122. I keep in mind, um, anything I can find about volatilisation rates, and the work that Sherlock did, Canterbury, bring in data from Germany and have a look at it, other stuff that's been done in the North Island.

2.3.1.1.2. Nutrient tests

3. So I start off by saying well I need to have soil test data for each paddock.

5. Previous as well as what the current stuff

7. I monitor with leaf test data

7. we get leaf tests as the season goes on

7. it [leaf tests] gives you added information for next years crop

122. we sample [for nutrient tests] according to variety, rather than a mix.

134. I did a sample off the better area, and a sample off the poorer area.

2.3.1.1.3. Talking to growers

17. what I try and do is monitor, by monitoring and keeping in touch with the grower, I ring my main clients and so Ok this is what we did, given the season we've had, the weather conditions we've had, what are your thoughts.

21. And then we just sit down together, when they've gone through their harvest, and say, okay, what were the problems and lets see if we can relate them to any aspect of the fertiliser program

49. I'll say to the guy well look Ok um, here's what I suggested you do last year, did you do it? Gosh we were a bit short of funds or we were a bit late, no we never got round to putting that on and I look for reasons,

49. if he says yes I did everything you did, said, I then have to re-evaluate and say oh gosh I didn't put enough in because we're not keeping up, we're not sustaining the levels in the soil or the leaf and then I'll say well are there any possible reasons and he'll say well I'm hanging a hell of a crop this year and I'll have a look at the crop and Ok I'll say gosh ya know, good size, good crop, obviously we're heading for a bumper season, we've got a bigger crop than the average that I've sorta worked on, there's got to be a reason somewhere.

93. It may be part of the reason that his fruit looked to be a wee bit smaller at that stage than normal.

124. Talking to him, how did you get on with your fruit tests, you know, for the board, they're always testing, yep, fine. He can pack all count sizes.

134. you're asking questions like, you know, did you have a shelter belt here, and did you have a rubbish pile and, did you use it as a dump, is the soil compacted for some reason

140. I've just made some notes and I've been talking to these guys, um, too much nitrogen in the early season, need to space out the side dressings. These are the

sort of things that, you know, I forget about if I don't jot them down when I'm talking to them during the season

2.3.1.1.4. Visit property

55. I know a lot of the blocks, but if I'm not sure I'll have a look

65. the cropping levels good, although I did note a slightly smaller size than normal, but the numbers of fruits are good.

93. I did note in his vines signs of magnesium deficiency so we could pick it up in the leaves, if its getting to a point where its starting show and if you ever see anything its starting to obviously its causing damage.

134. when I looked at them, the leaf size is very small, and they were yellowish. They didn't actually have distinct magnesium deficiency signs, but they were showing symptoms of it. Compared to the rest of the block, which are nice big leaves, healthy green.

2.3.1.2. Knowledge

128. we've been gradually building those magnesium levels up, to the point now we've got good leaf magnesium, and we've got very good fruit set.

2.3.1.2.1. Crops

21. So instead of having a tomato programme, we'll have a tomato variety programme in the future.

21. Instead of having a potato fertiliser, we'll have potato variety, and what you do with Rua's, you may not do with Agrea.

21. these sort of programmes are going to get more refined to variety

21. that works well for this variety, but my observations are that you've got a hell of a lot of vine here, and bugger all fruit, and he says, yeah, I'm disappointed in my yield in this one, you know, from day one they've grown like crazy, and obviously the nutrient input for those are different for this. So we have to look at refining by variety.

23. So these guys come in, and they plant them, and they say, okay well, we're aware that they are a hybrid, we're aware that we're going to get growth vigour, so we've got to moderate in terms of nitrogen inputs, we think we've got the phosphate level about right for our current varieties, we've got to really go through a season and see how they go.

25. I try and take note of what's going on around the world, try and pick up comments from visiting people, and when I travel, have a look, you make note of what's said, really, from a whole range, from the scientists to the growers, and the field men for the different companies. You know, you just have to take note of comments that they make. They don't necessarily apply here, but you can gauge from what they say that all right, that's a more vigorous variety than that one. So when it comes in to being here you're fairly cautious.

128. I know that because I've done work, not only the texts tell you that, but I've done work with blocks where we have problems. And we've been spraying boron on at flowering. At different times, and we've set fruit or allowed it to frizzle up and drop off. And then done calcium tests on the resultant fruits, and we've found we've changed the levels. So I've actually been through that, with the board, with actual field work.

128. one of the symptoms of low magnesium is blind budding.

128. You have to watch the amount of nitrogen you put on fuji. Of all the apples, they're the best at picking up nitrogen in the soil.

130. what happens is the fruit doesn't colour. If you have too high a nitrogen, it doesn't colour up enough. So they, the grower's waiting and waiting and waiting for his colour requirement to come up, before he can pick them. And the longer you leave them, the more risk you run of getting water core.

130. I've actually put some in, because he's at the low end, and the trees, because they're now carrying a larger crop, they're, these trees are now about 5 or 6 years old, we've got to make sure we actually regenerate some good growth for the next years wood, fruiting wood.

130. So we put a little bit in, to maintain where we are, but, I, normally with fuji, don't use any nitrogen on heavy soils. This is a wee bit lighter soil.

2.3.1.2.2. Information system

3. they're [fertilisers] needed in different quantities, different rates, different times, different ways of applying them

45. I file according to, in just alphabetical order

45. this guys name is Ericson and he's not the only Ericson

2.3.1.2.3. Soils

7. year in year out you're dealing with a whole range of soils you do build up ya know a picture and I can get a soil test come over my desk and a maybe not dealt with that paddock before or, or that block of land, but I know from where it is what characteristics are that I would be looking for and what I've got to be mindful of in terms of inputs so that influences the way I think

7. on the Heratunga plains there are differences in terms of how much P you need to shift the soil test values depending on the soil types, you go from the Meanee silts here to the Havelock clay and its quite different and you go down to the high P retention soils and its quite you're different again

7. P retention is probably a good starting point if you've got that you know straight away what sort of quantity of input of phosphate is going to be and you're going to know what the sulphur level in the soil is going to be in terms of high P retention soil you've got high retention of sulphur, so you don't need to worry to much about putting sulphur in. Low P retention soils it is the other way around.

7. These things [knowledge of soils] all help me, um, formulating here how many kg's of, of K for example, I will put on.

41. you've got things like P retention, so your phosphate requirements are huge, compared to low P retention soils on the plains here. Your K reserves are quite different

43. And, paddocks coming out of grass, obviously have got a good organic matter content, whereas paddocks which have been cropped and cropped in the nineties, these ones over here, got bugger all organic matter, so you have to take that into account when you're looking at your inputs.

2.3.1.3. Analysis of information

5. So over a period of time I build up a picture of what they [soil test data] are doing

5. if I am linked in year-to-year and I can pick up trends as to what is happening

47. We've got an idea of removals, yeah crop removals and we've got an idea of what's happening from one year to the next.

49. I'll have a look over the past two or three years and see where the trends lie, what's getting out of balance in the soil and then I'll have a look at the leaf

124. the mid to upper part of the medium is where I'm looking at. Some of these get influenced by what they do, rather than what the plant takes up. By that I mean that, with calcium, you see it's quite high, for a variety like braeburn, the board, the Apple and Pear Board and Enza, insist that they apply, x sprays of calcium, because of bitterpip problems, storage problems in varieties like braeburn, cox's orange, in particular. So, they have to buy, by being dictated to by the board. They have to submit their spray diaries, they have to put on what ever it is, 13, 19 sprays of calcium chloride, or whatever. And as a result you do get leaf contamination of, that, which does influence it.

134. when I looked at the soil, and there wasn't much there, to be quite honest, ah, between the two.

151. see the trends, well, that's what I'm looking at, but, you know, you end up with ah, when I'm doing them you end up with stuff everywhere.

2.3.1.3.1. Current position

49. here's my little arrows, [on the soil test results] you can see that things aren't too good here, things are slipping

126. Even though they're middle of the range, they're fine.

2.3.1.3.2. Nutrient trends

5. what happens to the P level over time

47. So this guy I've got data here, same sort of data, and I go back and I look and I say Ok what's happened in terms of pH, phosphorous, calcium etc.

124. Some of them [leaf test results] come back and they're quite low. Which sets alarm bells going in my mind. Gosh, if you've got levels like that, and you've applied all these calcium sprays, you got a problem with uptake into the fruit.

134. he's got a very high calcium, ah, potassium level, and quite a low magnesium level. Compared to the better area, where the potassium level is a lot lower, and the magnesium level is higher

134. both got heaps of phosphorous.

134. nothing much between them in the calcium or the magnesium levels, but, both of them very high potassium's. 33 is a very high soil potassium.

134. what seems to be happening is that in this one particular area, the trees aren't getting enough magnesium.

134. the leaf level's very high.

2.3.1.3.3. pH trends

5. I can see whether the pH is dropping going up

5. Now over the years I've built up a picture of, of those [response rates and changes in pH] in my mind

47. So this guy I've got data here, same sort of data, and I go back and I look and I say Ok what's happened in terms of pH, phosphorous, calcium etc.

134. Much the same pH, 6.2, 6

2.3.1.3.4. Response rates

5. get an idea of response rates on those particular soils.

5. Now over the years I've built up a picture of, of those [response rates and changes in pH] in my mind

151. And then you've got to look at response rates

2.3.1.3.5. Yield trends

11. If the yields are declining well then we've got problems

2.3.1.4. Nutrient requirements

3. in the horticultural scene in inverted commas, we're dealing with nitrogen, phosphorous, potassium, magnesium, sulphur, calcium, trace elements

11. what we aim for is an equilibrium a balance between what we're putting in and obviously looking at yield

11. we aim for that equilibrium and after about three years you can slot in quite nicely to, inputs equalling what's been taken out or lost or fixed in the soil

13. We've got an idea from the type of soil, from crop removals, what sort of nutrient inputs are needed

41. different areas have different [nutrient] requirements.

41. what people use in, say, for example, Ohakune to grow carrots, we wouldn't use in Hawkes Bay. You know, the inputs are vastly different for the same crop.

41. Nitrogen requirements vary tremendously, you know, in Invercargil I'd be growing carrots without any Nitrogen, whereas here I'm putting it in.

45. The aim is to replenish the nutrients that are taken out in the season and ensure the buds that are being set up now for next season are well nourished.

51. I'm more interested in sustaining things as they are to maintain a good crop because if I let them slip he's going to come back to me in a couple of years and say why the hell didn't you tell me to do something about this two years, now look at me I've only got half of the crop and sure I've saved fifty bucks on fertiliser, but he's not going to thank ya.

67. you get down to, well even get down to Opotiki and you get into the heavier soils and those sort of N inputs can lead to problems and you get fruit drop and soft fruit

67. I've gone as high as I dare, I have to rely on my own experience for this.

67. We are particularly careful with chlorine on our heavy soils

89. I work on 10 kg's of magnesium per hectare to get a lift of one of one MAF unit.

122. And again I've gone back to previous years and looked at what we've put in

126. I've used, in this case, some boron, prior to flowering, and I've done that on the basis that we've done this each year, and the levels aren't increasing, we're maintaining them, and I know that because he's on a high pH soil, boron uptake is not going to be flash, so what we're doing is overcoming that by putting it on as a foliar, and keeping his levels up, and that's also influencing the uptake of calcium ... very strong relationship between those two.

128. He's got a very low level of magnesium, in the soil, so I've supplemented by saying, if we put potassium in we must put some magnesium in at the same time.

140. in this particular instance, the maize planting of this particular grower, he told me that he wanted to put a lot of phosphate on ... I wouldn't normally put as much in, but he wanted to go that way, so I had to fall in line with his, request.

2.3.1.4.1. Corrective levels

49. anyway in this case the nitrogen dropped, everything's dropped basically um so, then I start saying Ok what have I got to put in um, that's my scratchings at the time, but um, righto I've decided in this case that um, I'm going to increase the nitrogen to what I've put in in previous years, because his N levels dropped um, its still Ok

53. I adjust them [maintenance requirements] up or down depending on the soil and leaf levels

55. if the nitrogen level comes back in the leaf and its very high say for apples it should be around 2% and it comes back at nearer three, well I'll drop nitrogen out of the program, all right, um, as long as they're cropping trees and they're doing well and they're is plenty of vigour in the trees.

55. if I see he's got heaps of vigour or adequate vigour and if I go and add to that nitrogen that, that problem is already high by putting more nitrogen on now I'm going to stimulate excessive vigour I'll cause him a problem with fruit yield so I'll drop it out

67. all I've done is step it up slightly to make sure that we keep that level from dropping further, we're not in dire straits or anything.

67. so I've gone up above our maintenance input because we were dropping

91. so what I'm doing is bumping it up so we overcome this drop and bring this level up again.

2.3.1.4.2. Maintenance levels

53. I've got some ball park figures I work around in terms of a maintenance input for an average crop

57. I would normally be working in Hawkes Bay around 120 to 140kg's of N as a maintenance type Nitrogen

65. If we looked a maintenance for kiwifruit in the Bay of Plenty, or through Ag Research Ag MAF, Ruakura, the suggested maintenance rate for nitrogen is around 180 to 200 kg's of N, very high,

67. a normal maintenance level of potassium would be around 150 kg's of K again it bit lighter than the Bay of Plenty, but for this area, for average crops of around 6000 trays a hectare that maintains the size maintains level in the soil so our losses versus removals are pretty well in, in sink

122. all I'm working on there is maintenance

2.3.1.4.3. Nutrient relationships

13. you've gotta look at your relationships between nutrients and what happens if you go wrong.

128. when you put potassium in, you've got to be very careful you don't upset the balance with calcium and magnesium.

2.3.1.5. Select fertilisers

67. I've used pot sulphate because we accelerate the chloride content with potassium chloride

67. I've used in this case 35% potash gold super, which is simply superphosphate and potassium sulphate blended to provide, I've put some phosphate in because again his phosphate level has dropped and potash, which has again dropped

110. I figure that if growers come to me and want me to tell them what to do, so that they are sustaining their fertility, and getting the best production, I tell them what I would use if I was in their position.

120. if he's got a dripper irrigation system which is not wide spread, so he can't water the urea in, if it's a fairly light sandy soil, um, conditions, and, um, I'll use CAN in that case, even though it's September, and we're expecting perhaps reasonable rainfall. Um, if it's November, and generally by then it's quite dry, we're putting it on to bare ground, and it gets hot, as it can do in Hawkes Bay, you can expect volatilisation.

122. product selection is based on a study of the factors presented and knowledge of the property, knowledge of his management system.

2.3.1.5.1. Cost

108. what I do is I look at what's needed, and then I look at the best form of putting that on to get the results that the grower wants. I ignore the cost at that stage.

110. if a product costs $80 a ton more, that's neither here nor there, generally you're not using a ton, you're using a portion of a ton, so it might end up costing for a, one product versus another product, a like product but made up of a different composition, it might be 25 or 30 dollars per hectare, more.

114. It's [fertiliser cost as a portion of operating costs] absolutely bugger all, and most of them say to me, look, don't bother discussing that, it's neither here nor there, I've only got to put on only one extra fungicide spray if it rains, and I wouldn't event think about the cost of doing that, it's got to be done, and it blows out

116. what they want is the best for their plants, and that's why I disagree with the least cost approach. It's what's best for the plant is what the growers wanting. He wants that plant to perform to its maximum. So, I endeavour to put the right amount of nutrient in, and I tend to ignore the actual cost per unit of N or K or P, bearing in mind that the difference between the highest and lowest priced products is very little.

2.3.1.5.2. Effect on pH

87. I've used dolomite because the calcium wasn't flash either, so I've put a bit of calcium in, put a bit of magnesium in, 1500 kg's a hectares' not going to influence the pH unduly.

93. dolomite lime I find doesn't shift the pH as much as straight lime. and on a soil like he's got there, I wouldn't expect much more than about 0.2 shift in pH from that application of lime.

120. I'll use urea if the pH is pretty well up, and the acidic action of urea, the ultimate acidic action of urea is not going to affect the pH, it's fine, if it's going in at a time of the year when there's adequate moisture, and his volatilisation losses are not high, they're basically negligible, that's fine.

120. I'll use CAN if he's got a moderately acid soil, we don't want to lower the pH, we want to maintain it at its around the 5.8 to six, and we don't want to go dropping it down, and create the need for lime which may not be needed

2.3.1.5.3. Grower preferences

79. I get dictated to now, growers say there's no way I want chloride.

2.3.1.5.4. Nutrient uptake

3. What we're trying to do is use products which are the right products to allow the uptake of nutrient

3. for a vegetable crop where you are trying to grow it quickly you've got to use a quick, more quickly available type of product than you would use perhaps in a pastoral scene

128. when you put potassium in, you've got to be careful that potassium's taken up very easily by the plant.

128. I've used a magnesium product which is quickly available to the plant. In fact, it's the only one that's really able to be taken up by the plant at that pH. If I was to put dolomite lime in, it's alkaline, very very little of it will go up into the plant. You shift that level up, but it's not available. It is over a period of time, soil acids will work on it and you can, you'll get some uptake

134. I've gone in with some, this time of the year, some quickly available, um, magnesium, and in the winter time, some dolomite lime, much longer term magnesium source, to provide enough magnesium to counter the rapid uptake of potassium that is occurring.

2.3.1.6. Fertiliser recommendation

17. the way we work is to tell them to the best of our knowledge what the tree of the plant needs and how best to apply it.

53. I don't give them a list of so many kg's of N, P, or K, I convert it into product type

55. and I'll say to him look we're going to leave nitrogen out this year and explain why

57. but I find that now um, you could spend all day writing letters and people, they look at the, oh yeah that's all the crap to start with, right what have I got to do? they're into the bones of it and so, this particular one I haven't written anything um, some of them I'll do a brief explanation depends on how well I know them, how long I've been working with them for, but in this case I talked to the people, on site, run through the things with his son and this is the program that they work off.

140. I generally, I'm under a fair bit of pressure to get them out.

140. But in the cropping season, and I get these guys coming in, and they've got quite a few samples, I'll say to them, okay, well, I can't get them all done today, but, which paddocks are you getting into tomorrow and the next day, because, um, you know, I've got, on there you'll see, this divided up into pre plant dressings, ridging, side dressing 1, 2, and 3, that one there is the key one, they've got to get it on. So, ah, they'll just tell me and I'll whip through.

2.3.1.6.1. Application suggestions

13. the time of when it [fertiliser] should be put on

53. product type and split it according to the best time to apply it in terms of the growth stages of the tree, vegetable

97. I'm giving them a post harvest spray, so they can take some back into the wood, and I'm coming back in next spring, after the fruit's set, I don't like putting things on around flowering, just in case you upset the fertilisation process. Bring them in after that. Flowering's in November, so come in after flowering, and just spray them.

101. You've got to be a bit careful, but putting them on at that rate, which is a very light rate for manganese, you won't get any fruit damage or spray marking.

103. what it does is leave a black sticky mess on the fruit, that can last there all season. So, its not good to be putting it on in that form, and the other thing is that it leaves a hell of a mess in your spray tank, terrible job to get out.

103. there's no way I'd tell growers to do something I wouldn't be doing myself.

122. All I've put into his apples is a bit of nitrogen, a post harvest application.

128. And I've split the potassium, between there, and there, October, given that we want to get some up into the wood, so that we're setting up these buds for next year, get some into the, into the sink within the tree, but if we put it all on now, and we get a hell of a wet winter, some of that will leach. And that's on a pretty light soil, this particular block. It's much lighter than where that kiwifruit is, so I'm conscious of the fact that we don't wanta loose nutrients, so I've split applying it

134. Because they're young trees I've put the nitrogen in in the spring, rather than the autumn. They'll have a small crop on them, but we're trying to grow the tree, if you put nitrogen on in the autumn, you'll get it into the sink of the tree and it's used for fruit development, as well as growth. Put nitrogen on in the spring, and it goes into canopy, goes into canopy growth.

134. I've concentrated on putting nitrogen on in the spring. Young trees.

144. Well, we do look at segregation, so obviously we don't like blending a very fine material with a coarse chip, because you can get segregation occurring. So that's the major problem, is trying to get materials of a similar size so that you get an even spread if they're broadcasting. And the other one is compatibility.

2.3.1.6.2. Gower education

3. getting the growers to manage their application so that they can gain as much effectiveness from them as possible without using, without loosing through leaching any large quantities and that's applicable mainly to nitrogen, it does apply slightly to potassium, nitrogen is the key one.

15. Well sometimes they don't understand that you've got to have certain things at a certain level and um, ya know, they may say oh no, I want those trees to grow, I want them to grow faster than they are and also hang a crop so their throwing heaps of nitrogen at them

17. yeah wonder why they end up with very small fruit set and the ones that do set are like pumpkins which are no good for anything and you have to explain to them why you are trying to keep things in balance.

17. they just think oh year that's what I'll double it or on the other hand they may halve it and say that you told me to do that and your selling it so, therefore, your putting in too much.

2.3.2. Links between categories

2.3.2.1. Collection of information / Knowledge

9. we'll do annual monitoring of leaf testing and soils so we get a idea as to whether we are putting enough in or not.

2.3.2.2. Knowledge / Analysis of information

67. We run into problems with chlorine, chloride in the soil, it should be chloride, um, very easily here they don't leach out as quickly because our drainage is not that good.

2.3.2.3. Knowledge / Select fertilisers

151. how much boron do you add into mixes, so that's when you start pulling out textbooks, and, how much you should be putting in

2.3.2.4. Analysis of information / Nutrient requirements

7. I've got to be mindful of [soil test data] in terms of inputs [nutrient requirements] so that influences the way I think

7. On those same soils you can say right we know we are going to run into a manganese problem [trend] here so lets get in and put on manganese [nutrient requirements] on at the right time

7. we know we're got an uptake problem with potassium [trend] so we've got to increase our inputs [nutrient requirements].

63. I bumped it up um, as far as I dare given that we've got a reasonable level, he's got good production, but its dropping because I've looked at my trends.

126. they're not dropping, so I've not put anything in.

126. in this case, I see no need to put in, he's maintain his phosphorous level, he's maintained his potassium level, things are sitting right

128. I've just kept pace with magnesium, no, we don't have to put much in

128. we're putting it in in a form which will allow the roots to take up and maintain that level there, without causing a problem.

128. I've just carried on with the, keeping his boron's up. And I put in some manganese, to maintain that

128. I've put in manganese, it's a bit on the low side, um, and again because of a high pH soil, you get lock up of manganese.

128. Now I know he's got a low K, so I've had to put some in, because as these trees have aged, the crop load gets heavier, but if you don't keep the potassium up, the fruit size gets smaller.

128. And in this case, he's on a high pH soil, it's very difficult for the plant to take up magnesium.

134. the balance between the two is a long way out. So, what I've suggested to him is that, he should be putting magnesium onto these poor trees

2.3.2.5. Analysis of information / Select fertilisers

93. I didn't want to change to pH too much because it was already 6.5, okay. Um, dolomite lime I find doesn't shift the pH as much as straight lime, and on a soil

like he's got there, I wouldn't expect much more than about 0.2 shift in pH from that application of lime.

128. pretty simple programme for him on that one, the fuji block, I've treated slightly differently, um, because he's got a very low magnesium, in the soil, the leaf's not bad, potassium's quite low, um, what I've done there is I've put in some potassium

122. in his main block of apples I've used ammonium sulphate. And that's because he's got a very high pH, using an acidic nitrogen form, try and help bring that down, it's a wee bit high.

134. I can use dolomite because the pH allows it, 6. It's not low.

136. young trees, very small canopy area, um, sunshine's getting in, bare weed strips, I've used CAN. All right. He's at the bottom end of, ah, sort of, pipfruit, really, the ideal is up round 6.5, pH. But he's got good calcium levels, I haven't worried about bumping that up with lime. So, I've used CAN for the apples. For those young ones.

2.3.2.6. Analysis of information / Fertiliser recommendation

134. So you try and search for reasons, and in the end I did suggest that he should try and look in this area, although the soil test didn't show any difference in bulk density, um, to any great degree, .8, .85, um, that he should look at putting some rippers through, and just opening it up, and making sure that there's no barrier.

134. I'm not dead certain on the reason. I did suggest to him that there may be something in terms of soil structure, which is perhaps causing the water to sit around the roots of these particular trees, whereas the rest of the soil will be free draining.

2.3.2.7. Nutrient requirements / Select fertilisers

13. We've got an idea from the type of soil, from crop removals, what sort of nutrient inputs are needed, and then its just a matter of selecting the right type of fert

87. I've used dolomite because the calcium wasn't flash either, so I've put a bit of calcium in, put a bit of magnesium in, 1500 kg's a hectares'

2.3.2.8. Select fertilisers / Fertiliser recommendation

118. that all comes into my discussion with the grower. I may work out a program that says well this is going to cost you 500 dollars a hectare, for your kiwifruit fertiliser for the year, and, he says oh look, you know, I'm in dire straits, I can't afford any more that 400 dollars, so I say okay, where I've suggested CAN, we'll take it out and use urea. And we'll cut out that cost or we'll, whatever. So, um, on occasion, where a guy is in economic difficulties, I'll moderate the program accordingly.

2.4. Consultant three

2.4.1. Categories

2.4.1.1. Collection of information

29. this orchard's had consistent around 10000 trays

39. that's the more fertile block.

50. we've found over the years that growers when they got themselves organised they could, even on big orchards, they could run a vicon all day and come within a bag, at the end of the day, they had it so finely done.

62. just to show you how close we can get this thing and believe you me this is high yielding this is not, this is 11,000.

66. last year was a very big year when they pulled out very big yields and he was about 11 he was really high

2.4.1.1.1. Nutrient tests

11. we don't take a leaf test, if we did take a leaf test take it here

39. when they first come, we ask the to do it, we often ask them to do 6 inches and a deeper one so you can see all your fertility is in the top

44. If you took an orchard and you said how would you go about it, if they've got historical soil tests I'll take it.

46. We'll take two soil tests [when first starting with an orchard]

60. we stopped the leaf tests because often the leaf test will show something and then, show something, it might show something low and then everybody can't wait to put on this and to put on that.

60. Another problem is that because, I mean, what the others are doing is they're putting it [fertiliser] on very earlier, long before bud burst, they put nitrogen on at bud burst and then they take it [leaf tests] six weeks later and they check out if everything's ok, but six weeks later we're putting on our final mixture, so what is the point?

2.4.1.1.2. Visit property

39. I used to out to the orchard twice a year and I've said no more boys I'm not going.

2.4.1.2. Knowledge

40. In a lot of our cases its not fertility that's the problem, but whether the spring is favourable or not.

44. Nowadays, the orchards we're doing, there's about forty plus, we know each orchard and we give them recommendations and those recommendations are now quite historic as you can see they're all, in this district

46. A tonne [of lime] to the hectare [on Coromandel soils] and it all over the place its that quickly.

2.4.1.2.1. Crops

40. we find that if you have a lot of rainfall after flowering in December then you often have a very good growing season, a longer growing season, if you have a very dry spell then you are more dependent to maintain the fruit load with less leaves because your growth will slow with the onset of fruiting

40. in some seasons where there is a lot of rain the fruiting doesn't act as the same degree of break on leaf growth so you end up with, this year we end up with canopies with plenty of growth carrying good loads of fruit, other years we can end up with less canopy carrying the same loads of fruit because we are drier.

46. we know that most of the roots are in the top 8, probably 40% at least are in the top 4, we know in our kiwifruit, not in the Bay of Plenty where they are very deep, but in our soils they are like that.

2.4.1.2.2. Fertilisers

19. Another thing is that there is very little magnesium oxide in here [the Hycane fertiliser]

21. because these two are um, because the magnesium oxide is insoluble it's not available for this year

21. in the Coromandel base mix we have more superphosphate and slightly less murate

2.4.1.2.3. Soils

9. what happens is they get a spike that looks like that, right, and then comes down [due to one application on interfering soils]

9. our soil are interfering because we have vermiculite in them

11. we know that most of the P is absorbed early, we know that from studies.

13. this is the weak link in our soils, there's very little mineral magnesium in our soils, no exchangeable, very low, we have to feed it.

13. When you apply K to our soils you create magnesium deficiencies very rapidly.

13. Calcium doesn't really impact much on magnesium

13. these two [magnesium and calcium] can fight, in our soils on occasions.

15. I've done all this work, we presented the work, I don't know, ten years ago, a detailed analysis of all the different clays and their mineralogy, we know the exact percentages it was all done

21. In the Coromandel we have trouble with magnesium, er sorry with phosphorus, we lose our phosphorus

29. 17, up to 28, 24, you'll always struggle in the Coromandel unless you want to go and hit it and all it will do is get absorbed into the soil system so you'll have a number, but you won't really have available P

39. sulphur's never a problem up here. [at Coromandel]

39. If you apply lime and we have here, in this case we've brought it up, these particular soils have gone from 45 to 69, these soils do this, so that's not really high, that's about as high as we'll get it, when you apply lime you get this instant reaction in terms of your extraction.

2.4.1.3. Analysis of information

29. remember there's sampling error

39. These growers have got no problems, growers as happy as larry, ya know, that's the way we take the approach.

56. But the growers today, the growers they get two soil tests that are different and they want to know why and they completely forget about the potential for sampling error, completely forget about it. They go to different sites, I don't know how they do it, you give a proposal of how many samples to take over a given area although we've done that we know that we need one to a tenth of an acre to get most of the variability out. Whether they do it or not we don't know, just don't know.

60. So sometimes people talk about how we've done some good work, its gone from 11 MAF units to 13 and I don't believe it has, often its just, we don't know what it is.

64. Lets take another year, we got a little bit of variability after that time.

70. know I can bring out ten Franklin orchards and they've all got the same patterns.

2.4.1.3.1. Current position

39. these histograms are always a problem, we've got some difficulty because we think they give the grower the wrong fact.

44. I often ask for two profiles initially 0 to 6 or 0 to 8 and 8 to 16 just to get a feel of what's up there and what's lower down.

46. We'll take two soil tests [when first starting with an orchard] and take a look at it.

2.4.1.3.2. Nutrient trend

25. So then we used to get this problem [a nutrient deficiency of phosphorus]

29. everything's getting about right um, ok we've put on some calcium so that's what's picked that up and this one

29. this [low phosphorus] is very traditional in Coromandel with this always struggling to get to here

29. ok there you have K 64, 87, 68, 95, 88, ya know, remember there's sampling error, Calcium 13, 15, 14, 15, 17, magnesium 1.6, 2.35, 1.6, 2.1, 2.5 all these patterns if you have a look like that are all the same, see.

39. there's the pattern, see same sort of thing, very low in phosphorus

39. We give him another program there brought it down a little bit because of the fertility here it is there now it's slightly down, 31 was it? What was it, 37, now it's 28, ya know, but again same pattern, that's creeping up a little bit 1.39, now we're down a little bit 1.74, where we go to next, that's 1.57, 1.39 down to 1.33 again very gentle see, 31, staying in the thing

39. There we are that's last seasons, 124 down again from 133 to 124 that stayed up

39. staying there balance 38 virtually the same these two now 39, 38, 1.12, 16 to 20, 2.53 to 3

64. this is 88, so here's the, 6.5, 105, 12.3, 2.08 it low in phosphorus we know that. Here's a year later, 6.7, 105 becomes 104, 12.3 becomes 12.3, 2.08 becomes 2.21. Now we go a year later 105 back 12.4, 12.3, 2.39, 2.29, 18's gone up from 14, 6.7 dropped back to 6.5.

66. we've maintained it and again we've pushed it up a little bit, same N, we've maintained this, there we are, so we got it to rise

2.4.1.3.3. pH trend

39. pH has dropped again

2.4.1.3.4. Response rate

23. now that was Hycane base mix, then we got this sort of problem.

2.4.1.4. Nutrient requirements

9. We learnt from some of our early work that the maximum level to apply, the maximum loading to apply without getting sudden changes, right, trying to keep things reasonably constant was 15 grams a square of K, pure K.

9. Now you could put these two on together then you would end up with 12.5 you would end up with 25, right, it won't necessarily do harm, but what you'll get is you'll get like spiking in the soil between the concentration before you started and then the concentration after it's, ya know, been brought into the soil, some of it is taken out because our soils are quite fixing

9. that [three applications rather then one] is why in essence our rates are always lower than theirs [Ag New Zealand] on K, they'll be probably at 250 when we'll be at 180

11. So these [nutrient requirements] things are planned around the physiology, they're not planned around ease or anything like that, they're planned around physiology.

40. You'll find that some advisors are high, just heavy handed, I don't know why, I think fear, they have a fear of deficiencies more than toxicity's

40. They don't understand that as you put in more and more fertility that you've got other management problems that surround it particularly in summer management, just to grow leaves is silly.

40. this season we've actually cut down, some of the growers have asked for, because the prices are so poor, they've asked for reductions

40. Then you get people that use American soil tests and stuff like that and they put on virtually nothing just trace elements and the end result with them is that they deplete the reserves and they get chucked off the land, in the short term its acceptable and its very low inputs, but in the longer term the vines go backwards.

2.4.1.4.1. Computer model

7. We'll use that one, so if we just go cc we don't have to worry about this thing address we'll just put p for that, season doesn't matter we'll put s for that, crop k, block identification doesn't matter, we'll put d, age of vines is mature, right this we need to know, 5.5, yeah that's a good one to use, 5.5 my area's 25, herbicide strip was what, 13, bays per hectare 400, fruit load was 750, method was 2.

78. it comes up and it says that is your estimated need so if you go far in excess or far below there should be a reason, so what it's doing is saying don't get to far off this track unless it's justified

84. Well there were only two, I mean ours is really a simplified version of DSIR's. DSIR had other databases with more information probably than ours. We liked it like this because will liked to tell that farmer what he was putting on per bay in each of these, you could change it, you could tell the computer put that into kilograms per hectare for me, it no big deal, it grams of nutrients per bay, it no big deal, I mean we could have

2.4.1.4.2. Corrective levels

29. we've done very little remember, fractionally see, none of this bang it with two tonnes, I don't believe in it

39. Now all we did was move that if you go to, if you go back to this one, hold on, that's 4.6 P, that's 5.4 P all I've done is slight change, I'm getting them up there, I've got some close to it

39. I struggle, I could bash it up I don't believe in it, we could make that 5.6 we could change the numbers around a bit and make the numbers a little bit more, but other than that, nothing.

2.4.1.4.3. Maintenance levels

60. we just work on reasonable equilibrium year to year so you put in so much, you start with this, you put in so much the crop takes it out over the growing period you come back nine months later, twelve months later and take another sample you find there's very little variation then you come again and put on stuff and you find we don't have health problems

2.4.1.4.4. Nutrient relationships

15. So these two are very sensitive, so in these things here you'll see that that ratio, 15 of K to 5 [of magnesium] is 3 to 1 and even here we don't like, that's about as wide as we'll go 5 to 1 and that we've never, an we always try and make that around 4 to 1.

2.4.1.4.5. Quantity guidelines

50. we've never exceeded I think 220 of K and in normal situations never been below 170 of K

50. nitrogen, we've never exceeded 160 in my life and we down about as low as about 120 when we first started and we've accepted a little bit of the nitrogen need with high yields and we've gone to 160.

2.4.1.5. Select fertilisers

13. we used to used to use Nitrophoska here as a matter of interest, but we didn't feel we used to get the value of the P because P demands are virtually ceasing towards the end of the season.

13. we always use CAN, so CAN here, CAN there for nitrogen

13. we don't use urea, not keen

46. We never put on lime at more than 2.5 tonnes per hectare in this district. Never put on much more than half of that rate on the pumice soils

64. we haven't gone crazy, we've just quietly changed the mixture, we haven't even done to much to cost we had 947, the year before we had 879.

66. we've said to him after this year if you're up we're going to bring you back onto the old system.

70. we're only using a few fertilisers, we use a kiwifruit special mix and the Hycane, the CAN and the Coromandel base mix.

70. We don't need to go outside [of the few fertilisers used] because we don't have any special situations, we don't have particularly low sulphur, particularly low phosphorus, particularly high this, we don't have it.

78. The cost thing is not silly because there are farmers that are concerned about cost.

2.4.1.5.1. Nutrient uptake

21. we've got to be careful that we don't put an insoluble form [of magnesium] on when we have a very soluble form of K.

21. You can have the ratios right, but if this is soluble and that insoluble then you get the same problem again.

2.4.1.6. Fertiliser recommendation

11. we've always gone on the basis of the agronomy rather than work.

31. That is [referring to his fertiliser recommendation] good agronomy, not agronomy start a chopping and a changing each year like you think you're doing something good, you're doing no good.

39. that's what it's all about, it's got to be consistent [the fertiliser recommendations you give to a grower]

39. now, you wanta know what happens when you do this? The grower, this is a true story, there all there every year, grower takes this one he gets this one the new one, shit he says, you haven't changed anything

39. this is true what they do you haven't changed anything, right, sometimes a number fractionally, fractionally changes

39. I tell em, I say look boys why must I change it for, everything's going well in the orchard, why do you want to change for, why do you want to change for.

39. I've told them they can take that program and run it for 10 years and nothing will happen, they don't need me, ya know, you can sack me now, I've told them

39. so you can take that program now and run it for the next ten years

39. that's for one of the blocks and that's for the other block, so we've given him two different programs for two different blocks, a year later we've actually started putting them together

39. he gets his program much the same again

42. If I haven't seen the orchard we virtually never do it. [Provide a fertiliser recommendation]

50. Sometimes its difficult for growers to understand that we prefer them to apply less fertiliser more often

60. all that they [Ag New Zealand] talking about how its [soil test results] improved might be all sampling error, it might actually have gone to hell. I don't think they have any idea as to how much variation

60. it's [a model] only really successful if you can take an orchard and bring it into some sort of static equilibrium and leave it there and the vines seem to be well rythmed, fruit crops are all like that they need to be well rythmed. the yields are satisfactory and you're getting no real problems and that's all we're doing, that's it and there's no change.

2.4.1.6.1. Application suggestions

7. in this application here, we use Hycane base mix at 85 that ones 56 and 85 grams. Now the first thing is if you are putting on 160 grams, or if you're putting on, you're putting on 166 grams on 13 squares so you're putting on, you're putting on about 12.5 grams, where's a bit of paper, we'll say there's a post there a post there and the vine's there, there's 10 squares, 4, 6, 8, 10, agreed, we're putting on 166 over 10, over 13 sorry, this is 13, we've divided this, this is 2.6 wide by 5m right so its 13, we're putting on 166 so that's about 12 grams of K per square

9. there will be more efficiency in the three [applications] in an interfering soil than one big bash

9. we're going for efficiency because we're going for the little and often approach

9. three applications of K here and they've [Ag New Zealand] only got one big hit

9. they [Ag New Zealand] also apply theirs up to six weeks before bud burst we are applying as late as the 20th of the 8th first bit of bud burst will probably be in the first week of September so we are much closer to actual need they are earlier.

11. nitrogen they [Ag New Zealand] used to say at bud burst, but other they used to put on earlier and when they were very high they used to put it on on the basis of

early so they could wash out some of the chloride, which is not good agronomy either.

11. there's only going to be two applications total, so we put on half of the P and 66 out of 180 a third of the K, a third of, then you've got sulphur doesn't really matter, magnesium and calcium.

11. you've got two applications, so now you've all your P in, right, by the 20th of the 9th

11. In the case of K we try to get somewhere around two thirds in by the second application.

11. if you want to do a top up then you've got to try and get it in here so that when you move from 2 to 2.7 you can maximise that replenishment internally to carry you through to the end, so that is often timed in there.

39. we don't want equal amounts because we feel you need to get more on before something like a 66, 33, ya know, ya saw from the recommendation

50. We band the fertiliser more than broadcast

50. some orchards are broadcast in this district, some are, peat soils are usually banded, some of the light soils are banded, the heavy soil are not.

56. How do you decide to make it one two or whatever, in kiwifruit we feel comfortable with this, in kiwifruit there is a lot of pressure for me to put the first two together, and that's a problem in itself because nitrogen is separate from the other.

56. CAN is one application 260

60. we do that because flowering is very stressful, flowering is a very stressful time on nutrients in kiwifruit, a lot of activity going on, a lot of change going on, all of a sudden after flowering with the cell division and everything else. And so to give the plant, if the plant is in any way short at that point put on that application about one or two weeks before flowering, by the time of flowering it's in the system if the plants need a little bit of boost there it is, that's it. So we're putting on a bit of K putting, on a bit of magnesium, putting on nitrogen

64. so what happens is we're even applying as late as February [because of fertigation]

64. we don't put P in it [fertigation]

64. we fertigate here.

76. we used to put one on the 15th of the 8th then 15th of the 9th, those two are basically put together, those two are put together, those two could be basically put together, so we had four and then we had, so we had August, September, October, November we used to do it that way.

2.4.1.6.2. Computer model

52. Its a question of how far you try and make it, how far do you go to ask the computer to the decisions for you as against how far you go just to use it, to use the computer as a sort of a calculation agency, which that is [referring to the computer program he uses].

54. Well that's [his computer program] all that is, with all due respect, all it does is I choose the fertiliser, I choose the rate, it finishes off like that you press that button, it prints it, you send it to the grower.

54. It [his computer program] has a problem, this is a bit of a problem, this rate per grams, farmers would like you to say Hycane base mix, so that's 880 kg per hectare for two applications, so they like me to write down there 440 kg, but its not per hectare, its only over the herbicide strip, 440, so they often come, we actually put that in afterwards, we never used to do that, we put that in afterwards so that they could go to the spreader and say you've got to put that a 400 kg because that's two applications, 440 just over the herbicide strip.

55. As you're putting it into your model there you are setting up how you're going to split your different applications

2.4.1.6.3. Recommendation report

23. we used to do them, they were more comprehensive, but you can see here are the numbers, 192, 48, see 4 to 1, 136 to 192

56. you've got the dates, right, so we tell him so those two are put on at the same time, down here he's told that on a hectare basis he needs 884, that two applications so he knows that.

76. I don't give growers options I tell them this or this I'm very, not blunt, but I, you don't get waffle you get told, if you don't do something you get told you fix that, I'm not there to come along and spend time and be nice and give you ten different options and you go and pick, I don't work like that, some growers don't like it, they don't like the fourth-rightness

2.4.2. Links between categories

2.4.2.1. Knowledge / Analysis of information

39. you've got high calcium, you haven't really got high calcium because you haven't got high saturation, but on a map, ya know, because of the soil type it shows a really high here, ya haven't really got a high, you've got really low saturation

39. that one's still bad the old block that's where the cows used

2.4.2.2. Knowledge / Nutrient requirements

11. this one is quite normal, this is usually, usually this is 220 and this is 170 as an example, now the reason for that is because that's initial when the vines are very young their needs are not high and there's still a lot of rainfall and then this one is just preflowering

40. So its not a fertility issue its a climate issue is very much a factor

40. the second factor is in my view is that a lot of people are applying more fertiliser because they are simply not sure of their ground.

40. So they say ok well you need 200, well I think I'll put on 250, nothing will happen and I'll be more comfortable, but its because they're not certain of their ground. And the less certain you are the heavier you get and the more certain you are you start to come down.

2.4.2.3. Knowledge / Select Fertilisers

7. we go to a database of fertiliser and say well we would like this fertiliser.

2.4.2.4. Knowledge / Fertiliser recommendation

9. What will happen is these soils are interfering so people have put on all of it on in one hit

9. vermiculite has a strong attraction for potassium ions, so we don't believe in, we believe you're better off to have these three applications like that than to have one huge application and it doesn't quite come down like that, it comes down over time because we think there's more efficiency

21. we are creating the mixture around plant physiology and around the special nature of the Franklin soil.

2.4.2.5. Analysis of information / Collection of information

40. So you've got to find a medium balance and so long as our soils are in some sort of equilibrium we don't worry. We used to leaf tests, but no more.

Analysis of information / Nutrient requirements

11. while that is falling that [nutrient levels] is a natural, even if you applied some in here I don't think you are going to change this natural tendency

27. But the phosphorus is only 16 there 0 to 6 and its 14 there, so we said right we want to lift that so then we started and we did this

39. K we think is still a little high we brought him down 170, we won't go much lower than that

64. pH is the same, these [nutrient levels] are sliding a little bit, so then we upped the rate

66. so [because of the high yields last year] we've still raised his levels.

66. we've told him we're going to continue for one more year because what happened was he got, we rose this in 95, but he also had this enormous crop ten eleven thousand he's another big there this year so we said ok we'll maintain it

2.4.2.6. Analysis of information / Select fertilisers

64. we've now got a bonnar special that his name, so here we said that's too low so now we're using a triple super phosphate mix so it's higher in P

64. if you look at 94, 93/94 so that would have been the fertiliser we would have applied, 93/94, then he took this test, we had 59, and I'm looking for 94/95, here it is 94/95 you see that here its a bit low so here we changed it you see, we said no, no, no, look we've gotta to do something better that was 60, 59 in the year before it was 63 we're not winning so we said ok we're going to change that we've now brought in triple, we've still got the 15% potash, but brought in special so we've now got here, we've lifted the P quite significantly 10.5

2.4.2.7. Analysis of information / Fertiliser recommendation

58. if every year you come along and say this is down and that's up, I mean we don't even talk like that, we don't go to a grower and say last year you had 1.1 milli-equivalents of K and this year you've got 1.17 and we think that a, we don't talk like that, na, they talk like that.

we will not do this thing where a guy gets a low figure, er yeah need two tonnes of super phosphate don't do that.

Appendix 3

Example fertiliser recommendation reports

3.1. Consultant One

27 March, 1995

Joe Bloggs
RD 1
Hastings

Dear Joe

Please find attached your leaf test resukts for your kiwifruit and apples.

1. Comments on Kiwifruit results

   Key points to note are:

   - Magnesium levels continue to track lowly
   - Potassium levels are back to a better level than last year
   - Calcium levels are higher than last year, but still slightly lower than desirable (not worth panicing about)
   - Chloride levels have dropped significantly probably as a result of using potassium sulphate rather than potassium chloride. Levels are such that use of potassium chloride would do no harm, and would save you some money.

   The only thing you need to do is continue with application of magnesium as per our original programme.

   Overall these results present a fairly balanced nutrition situation.

2. Comments about apple results

   Key points to note are:

   - Magnesium is slightly low, and given your history of problems on kiwifruit will need watching. Apply approximately 25 grams/tree of kieserite once now, and once again at the end of January to keep on top of this.
   - Manganese is ridiculously high which probably reflects maganese in one of your sprays - Have you used mancozeb?
   - Iron is slightly high, but not worth worrying about

	kg/ha
Urea all blocks	200
Kieserite all blocks	333
Super Phosphate House/West South/East	 Nil 600
Sulphate of Potash House/West/East South	 150 350

3. Prunung

The amount and quality of cane available to tie down was plaesing, particularly in the blocks which normally have vigour problems.

Your biggest challenge is to get the job completed before budburst. You may need a few extra workers to complete this.

4. Apples

These were looking great. I would certainly start putting a light loag onto the older trees, particularly where you want to get some branch angles better. Avoid allowing any fruit to develop on your main leader.

5. Shelter Trimming

The person I use is Bob Smith from Tauranga, phone (07) 123-4567 or (025) 123-456. He does a very tidy job, moves alaong at good speed and has reasonable rates. I phoned him to check availablity. He will phone me back soon to confirm a time to get up to West Auckland, and will probably want more work then.

I suggest a visit around flowering to take a leaf test and check flower numbers. I will give you a call then.

Yours sincerly

3.2. Consultant Two

Ref: 5/3/4
27 March, 1996

Mr Joe Bloggs
RD 1
Hastings

Dear Joe

FERTILISER RECOMMENDATIONS 1996

1. **COXES BLOCK**

Autumn 1996

Immediately After Harvest	:	250 kg Kieserite, plus
	:	250 kg CAN/hectare
Plus a foliar Boron Spray	:	250 grams Solubor (or Hydrabor)/100 litres

Spring 1996

October	:	A further 250 kg Kieserite/ha
1-2 weeks preflowering	:	100 grams Solubar (or Hydrabor)/100 litres Apply twice a week apart
November/December	:	100 grams Manganese Sulphate, plus 200 grams Urea/100 litres Apply 3 times at fortnightly intervals

2. **MAIN BLOCK (Breaburn Sampled)**

Autumn 1996

Immediately After Harvest	::	250 kg CAN/hectare
Plus a foliar Boron Spray	:	250 grams Solubor (or Hydrabor)/100 litres

Spring 1996

October	:	A further 250 kg Kieserite/ha
1-2 weeks preflowering	:	100 grams Solubar (or Hydrabor)/100 litres Apply twice a week apart

3. **CREEK BLOCK (Royal Gala Sampled)**

Autumn 1996

Immediately After Harvest	:	250 kg CAN/hectare 200 kg Potassium Sulphate/hectare
Plus a foliar Boron Spray	:	250 grams Solubor (or Hydrabor)/100 litres

Spring 1996

1-2 weeks preflowering	:	100 grams Solubar (or Hydrabor)/100 litres Apply twice a week apart
Early October	:	125 kg Nitrophoska 12-10-10, plus A further 125 kg Kieserite/ha
3-4 weeks after fruitset	:	250 grams Solubor (or Hydrabor)/100 litres
EarlyDecember	:	125 kg Nitrophoska 12-10-10, plus 125 kg Kieserite/ha

4. **YOUNG TREES - Planted 1994**

Same programme as last year.

September	:	100 grams CAN, plus 100 grams Kieserite/tree
November	:	A further 100 grams CAN, plus 100 grams Kieserite/tree
1-2 weeks preflowering	:	100 grams Solubar (or Hydrabor)/100 litres Apply twice a week apart

Kind regards

Consultant two
HORTICULTUAL ADVISOR

3.3. Consultant Three

JOE BLOGGS | AGE OF VINES (YRS): MATURE
RD 1, HASTINGS | VINE SPACING M: 5X5
SEASON: 1995/96 | BAY AREA SqM: 25
CROP: KIWIFRUIT | HERBICIDE STRIP AREA SqM: 15
BLOCK: A123 | BAYS/Ha: 400
APPL. METHOD: BROADCAST HERBICIDE STRIP | FRUIT LOAD/BAY: 750

DATE	FERTILISER/ANALYSIS	RATE	N	P	K	S	Ca	Mg	COST
ddmm		grms	(grms of nutrient per bay)						/BAY
2008	HYCANE BASE MIX 0-4.6-15-8.8-11-5	1125	0	52	169	99	124	56	0.46
2009	HYCANE BASE MIX 0-4.6-15-8.8-11-5	1125	0	52	169	99	124	56	0.46
2009	CAL. AMM. NITRATE 27-0-0-0-8-0	675	182	0	0	0	54	0	0.32
3010	KF SPECIAL MIX 16-0-11-8-5-2	1050	168	0	116	84	53	21	0.63
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
0		0	0	0	0	0	0	0	0.00
total grms/bay:			350	104	454	282	355	133	$1.87
estimates need:			330	75	450	100	400	100	
grms excess/deficiency:			20	29	4	182	-45	33	
TOTAL Kg/Ha:			140	42	182	113	142	53	

FERTILISER	Kg/Ha	$/Ha
HYCANE BASE MIX	900.0	369.0
CAL. AMM. NITRATE	270.0	126.9
KF SPECIAL MIX	420.0	251.2
TOTAL COST $/Ha:		747.1

Appendix 4

An introduction to databases

4.1. Database fundamentals

A database is a structured collection of data that a person or organisation stores for some later use. Databases are replacing the traditional paper filing systems of offices due to the less room required to store information, the speed at which data can be accessed and the ease of generating reports based on analysis or aggregation of information in the database. Databases are not new and have evolved since the dawn of the computer age. This evolution has seen the development of three main database models; the hierarchical, network and relational models. The hierarchical and network models have declined in popularity in recent years, while the relational data model has gained popularity and is the most commonly used model for contemporary database application (McFadden & Hoffer, 1991).

In 1970 Codd introduced a method of describing both the structure and data manipulation operations of databases known as the relational data model. In the relational data model, data is stored in tables; the columns have names and are referred to as attributes, while the rows in a table consist of values for each of the attributes (Manila & Raiha, 1992). The set of all rows in a table is called a relation and a relational database is the combination of several tables (Manila & Raiha, 1992).

In the framework of the relational model, the main task of database design is to find suitable tables for storing the data (Manila & Raiha, 1992). Peckham and Maryanski (1988) comment that many database designers believe that the relational model does not offer a sufficiently rich conceptual framework for problems that do not map onto tables in a straight forward fashion. Semantic models were developed to over come this problem by providing a higher level of abstraction for modelling data. This allows database designers to think of data in ways that correlate more directly to how the data arises in the view of the world that users have (Hull & King, 1987). The use of semantic models are primarily as schema design tools, which allow designers to create a schema at a high level and then translate it to one of the traditional models such as the relational model for implementation (Hull & King, 1987).

This use of semantic modelling is common in industry and research (see, for example, Date, 1986), of the semantic modelling techniques available the most widely used is the entity-relationship model (Manila & Raiha, 1992). As with the relational model, the entity-relationship model has only a few simple concepts and are easily learnt, contributing to its popularity (Manila & Raiha, 1992). In this study the relational model and the entity-relationship model are used to express the methods of database design.

4.2. Database design

A database needs organising in a manner that allows the user to store, update and query the data they desire, without posing restrictions other than those necessary for maintaining the consistency of the data (Manila & Raiha, 1992), achieving this task is the goal of database design. In the literature it has become standard to divide the database design process into four phases: requirements analysis, conceptual design, logical design, and physical design (Batini, Ceri, & Navathe, 1992; Manila & Raiha, 1992; McFadden & Hoffer, 1991).

The first phase, requirements analysis, produces an operationally-orientated description of the database. Its purpose is to ensure that the database contains the data necessary for the functions and applications that database users will require (Manila & Raiha, 1992). There exists no commonly accepted notion of how requirements analysis should be done and how its results should be represented, however, Manila and Raiha (1992) suggest a general description of the purpose of the database and the tasks users require it to perform. This description should be presented in plain language so it can be easily understood by everyone involved in the project.

Requirements analysis is a knowledge acquisition problem: knowledge needs transferring from users to designers. Chen (1980) has noted that as databases have evolved the communication gap between users and designers has worsened. An approach to help overcome this problem is participatory design, where the users and designers together construct a description of the database and its usage (Manila &

Raiha, 1992). A popular method, used by McFadden and Hoffer (1991) to elicit what data needs storing in the database, is to describe the user views. User views refer to ways in which the intended users of the database currently view the data, for example, forms that are currently filled in, reports that are written and other information that comes into the organisation.

The result of conceptual design is a description (in the form of a conceptual data model) of the database using some form of semantic modelling technique. A conceptual data model provides a representation of the structure of a database independent of the software that will be used to implement it. The main task of the conceptual design process is to find the essential concepts from the operational description that was produced by the requirements analysis (Manila & Raiha, 1992). Of the various semantic modelling techniques many authors in the literature use the entity-relationship model for creating the conceptual data model, the technique is used in this study and is discussed further in section 4.3 An entity-relationship approach. With regard to user and designer interaction Manila and Raiha (1992) suggest that it is advisable to merge the two steps, requirements analysis and conceptual design, and have the users participate in both (Manila & Raiha, 1992).

Logical design is the process of transforming the conceptual database model into a logical database model. This process involves transforming the semantic data model (in this case an entity relationship model) into normalised relations (McFadden & Hoffer, 1991). Normalisation involves constructing table structures that are free from various update anomalies and avoid redundant data storage (Manila & Raiha, 1992). Normalisation was introduced by Codd (1972) and then improved by Codd (1974) and Fagin (1977, 1979). For a good description of normalisation see chapter fifteen of Date (1986) or chapter six of McFadden and Hoffer (1991).

Physical design is the last stage of the database design process. During physical design the particular database program that the database is to be implemented with is considered in conjunction with table indexing, referential integrity constraints and denormalisation (McFadden & Hoffer, 1991). Denormalisation, the opposite of normalisation, is a process that may or may not be required and involves consciously sacrificing some the desirable properties of the database schema for the sake of efficiency (Manila & Raiha, 1992). A good file structure is found by trying to optimise the overall performance of the system, so that most frequently executed queries can be handled fast (Manila & Raiha, 1992).

4.3. An entity-relationship approach

The entity-relationship model was introduced by Chen (1976) in which he described the main constructs of the entity-relationship model - entities and relationships - and their associated attributes. Some authors refer to relationships as associations and refer to attributes as properties. Although similar modelling constructs had appeared in earlier semantic data models, the work of Chen (1976) is generally considered to be the starting point of the development of the entity-relationship model.

Along with the entity-relationship model Chen (1976) also introduced a diagramming technique (entity-relationship diagrams) for representing the structure of a database in a pictorial manner. These diagrams are useful as a documentation aid, especially during the database design process (Date, 1986). Date (1986) suggests that the popularity of entity-relationship modelling as an approach to database design can probably be attributed more to the existence of that diagramming technique than to any other cause. Currently there is no single, standardised entity-relationship model (Kroenke, 1992) so one that uses common notation and conventions used by McFadden and Hoffer (1991) and used in this study is presented in Figure 35 Entity-relationship diagram notation. and described within this section.

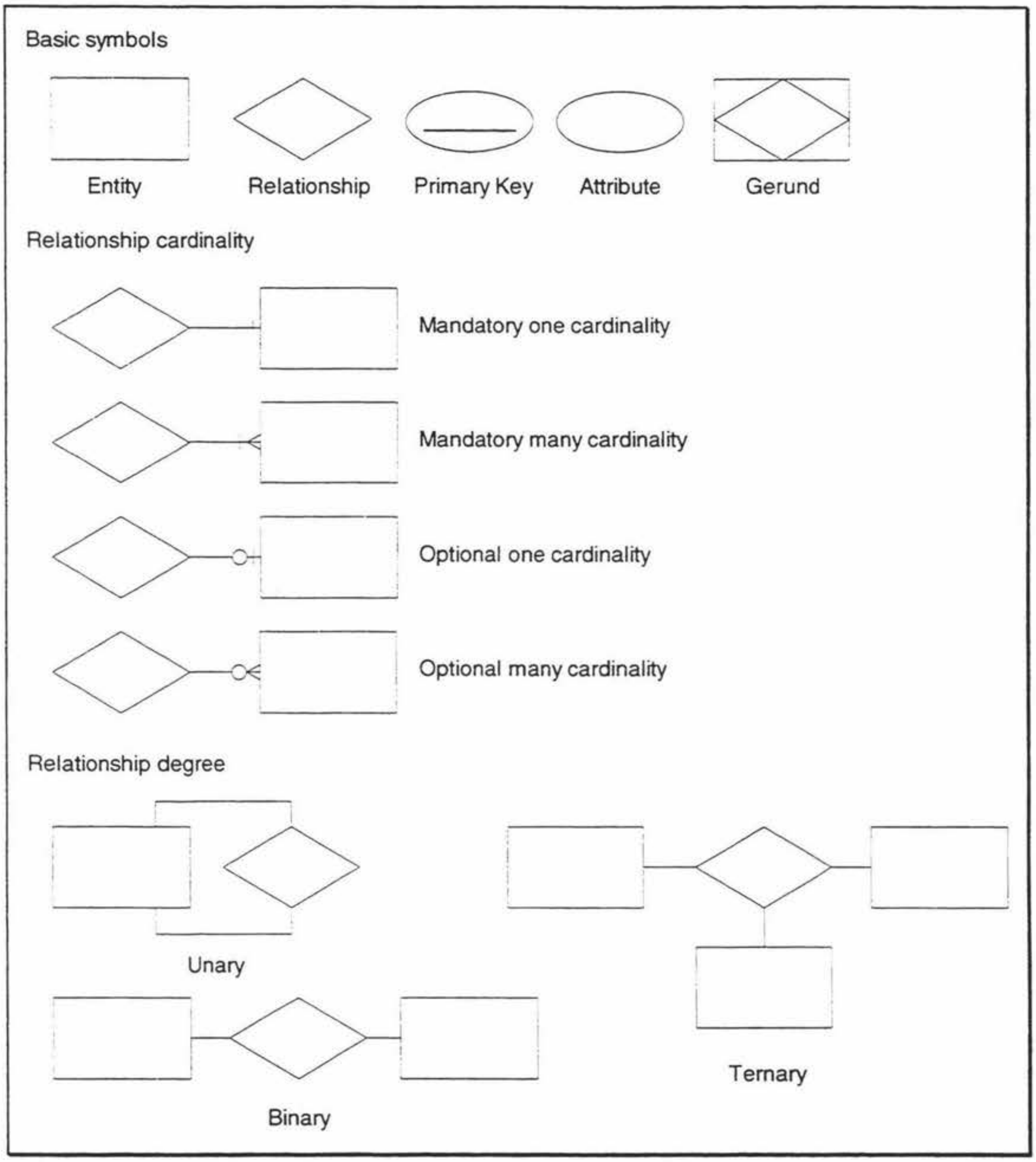


Figure 35 Entity-relationship diagram notation.

4.3.1. Entities

Entities are either a person, place, object, event, or concept in the user environment about which an organisation wishes to maintain data (McFadden & Hoffer, 1991). Entities are referred to in two ways, as entity types (or classes) and as entity instances. An entity type is a collection of entities that share common properties or characteristics (McFadden & Hoffer, 1991), while an instance of an entity type is the representation of a particular entity (Kroenke, 1992). There are usually many instances of an entity in an entity type (Kroenke, 1992), for example, within the entity type, FERTILISER, there are many instances, one for each fertiliser represented in the database. A weak entity is an entity type that has an existence dependency, thus, an instance of a weak entity cannot exist independently, but depends on the existence of an instance of another entity type (McFadden & Hoffer, 1991). In an entity-relationship diagram a rectangle symbol represents an entity and the name of the entity appears inside the shape in capital letters.

4.3.2. Relationships

A relationship is an association between instances of one or more entity types that is of interest to the organisation (McFadden & Hoffer, 1991). There are relationship types and relationship instances, relationship types are associations among entity types, while relationship instances are associations among entity instances (Kroenke, 1992). The number of entities involved in a relationship is referred to as the degree of the relationship (Kroenke, 1992). The three most common relationships in entity-relationship model are unary (degree one), binary (degree two), and ternary (degree three) (McFadden & Hoffer, 1991), see Figure 1 for an example of each. In an entity-relationship diagram a diamond shape represents a relationship. A relationships name is written as an adjective and in lowercase with an initial capital letter.

4.3.3. Attributes

Each entity type has a set of attributes associated with it (McFadden & Hoffer, 1991). An attribute is a property or characteristic of an entity that is of interest to the organisation (note that relationships may also have attributes) (McFadden & Hoffer, 1991). Capital letters are used in naming an attribute. In entity-relationship diagrams attributes are represented by placing its name in an ellipse with a line connecting it to its associated entity.

4.3.4. Candidate keys, primary keys and foreign keys

Every entity type should have a set of attributes that uniquely identify and clearly distinguishes an instance from other instances of the same type (McFadden & Hoffer, 1991). A candidate key is an attribute (or combination of attributes) that uniquely identifies each instance of an entity type (McFadden & Hoffer, 1991). Some entities may have more than one candidate key, when this occurs the designer must choose one of the keys as the primary key (McFadden & Hoffer, 1991).

A primary key is a candidate key that has been selected as the identifier for an entity type (McFadden & Hoffer, 1991). For each entity, the name of the primary key is underlined on the entity-relationship diagram. Bruce (1992) suggests the following criteria for selecting primary keys.

Choose a candidate key that will not change over the life of each instance of the entity type.

- Choose a candidate key such that for each instance of the entity, the attribute is guaranteed to have valid values and not be null.
- Avoid the use of so-called intelligent keys, whose structure indicates, for example, classifications or locations because such codes often change as conditions change, which can render the primary key values as invalid.
- Consider substituting a single-attribute surrogate keys for large composite keys.

Weak entities often do not have a natural identifier (or candidate key) (McFadden & Hoffer, 1991). Instead , the primary key of the parent entity (on which the dependent entity depends) is often used as part of the primary key of the dependent child entity (McFadden & Hoffer, 1991).

A foreign key is an attribute that appears in an entity that is the primary key of another entity McFadden & Hoffer, 1991). A foreign key is used to link together two entities.

4.3.5. Gerunds

A gerund (sometimes called a composite entity) is a combination of an entity and a relationship (McFadden & Hoffer, 1991). Gerunds appear in the entity-relationship diagram when modelling a many-to-many relationship between two entities. The relationship, instead of just being a description, has attributes and these attributes include the primary keys from the many-to-many related entities. The primary keys from the related entities are required to maintain the uniqueness of each instance of the gerund and to match which instances from each entity are related to each other. Both entities and gerunds are implemented the same in a database, as a database table (McFadden & Hoffer, 1991).

4.3.6. Cardinality

The cardinality of a relationship refers to the number of instances of a particular entity that can (or must) be associated with each instance of a related entity (McFadden & Hoffer, 1991). The minimum cardinality of a relationship is the minimum number of instances of a specific entity that may be associated with each instance of a specific related entity, while the maximum cardinality is the maximum number of instances (McFadden & Hoffer, 1991). The symbols used to denote the minimum cardinalities of a relationship are usually zero (0) or one (|) and for maximum cardinalities, one or many (□), these are also shown in Figure 1. The maximum cardinality can take on any value, and not just the one or many, for example, it could have the values of 2 or 3, which means a maximum of only two or three instances of a particular entity can be related to the other related entity. The participation in a relationship is either optional or mandatory for the entities involved. If the minimum cardinality is zero the participation is optional; if the minimum cardinality is one, participation is mandatory (McFadden & Hoffer, 1991).

4.3.7. Business rules

Business rules are specifications that preserve the integrity of the logical data model (McFadden & Hoffer, 1991). There are four basic types of business rules as stated by McFadden and Hoffer (1991).

- Entity integrity: Each instance of an entity type must have a unique identifier (or primary key value) that is not null.
- Referential integrity constraints: Rules concerning the relationships between entity types.
- Domains: Constraints on valid values for attributes. A domain is a set of all data types and ranges of values that attributes may assume (Flemming & von Halle, 1990). Domain definitions typically specify some (or all) of the following characteristics of attributes: data type, length, format, range, allowable values, meaning, uniqueness, and null support (whether the attribute value may or may not be null).
- Triggering operations: Other business rules that protect the validity of attribute values.

4.4. References

Bruce, T. A. (1992). Designing quality databases with IDEF1X information models. New York: Dorset House.

Batini, C., Ceri, S., & Navathe, B. C. (1992). Conceptual database design: An entity-relationship approach. Redwood City, California: Benjamin/Cummings.

Chen, P. P. (1976). The entity-relationship model: Toward a unified view of data. ACM Transactions on Database Systems, 1(1), 9-36.

Chen, P. P. (Ed.). (1980). International Conference on Entity-Relationship Approach to Systems Analysis and Design: Entity-relationship approach to systems analysis and design. Amsterdam: North-Holland.

Codd, E. F. (1970). A relational model of data for large shared data banks. Communications of the ACM, 13(6), 377-387.

Codd, E. F. (1972). Further normalisation of the data base relational model. In Data base systems, Courant Computer Science Symposia Series, Vol. 6. Englewood Cliffs, New York: Prentice-Hall.

Codd, E. F. (1974). Recent investigations into relational data base systems. Proceedings of the IFIP Congress.

Date, C. J. (1986). An introduction to database systems (4th ed., Vol. 1). Reading, Massachusetts: Addison-Wesley.

Fagin, R. (1977). Multivalued dependencies and a new normal form for relational databases. ACM Transactions on Database Systems, 2(3).

Fagin, R. (1979). Normal forms and relational database operators. Proceedings of the 1979 ACM SIGMOD International Conference on Management of Data.

Flemming, C. C. & von Halle, B. (1990). An overview of logical data modelling. Data Resource Management 1(Winter), 5-15.

Hull, R. & King, R. (1987). Semantic database modeling: Survey, applications, and research issues. ACM Computing Surveys, 19(3), 201-260.

Kroenke, D. M. (1992). Database processing: fundamentals, design, implementation (4th ed.). New York: Macmillan.

Manila, H. & Raiha, K. (1992). The design of relational databases. Workingham, England: Addison-Wesley.

McFadden, F. R. & Hoffer, J. A. (1991). Modern database management (4th ed.). Redwood City, California: Benjamin/Cummings.

Peckham, J. & Maryanski, F. (1988). Semantic data models. ACM Computing Surveys, 20(3), 153-189.

Appendix 5

Fertiliser descriptions

5.1. BOP Fertilisers

The following table contains the fertilisers available for selection and thus inclusion in a fertiliser recommendation by consultants one and three.

Table 33 Nutrient analysis and price fertilisers available from BOP Fertilisers.

Name	Price	Nutrient Analysis							
		N	P	K	S	Mg	Ca	Cl	Mn
Superphosphate	155.00		9		12		22		
Super Plus	287.00		15		7		18		
Triple Super	427.00		21		2		14		
Reactive Rock	167.50		13				34		
Reactive Rock + S	171.50		12		7		31		
15% Potash Super	184.50		8	8	10		19	8	
20% Potash Super	193.00		7	10	10		18	10	
30% Potash Super	209.50		6	15	8		15	15	
50% Potash Super	243.00		5	25	6		11	25	
20% Potash Super Plus	298.50		12	10	5		14	10	
15% Potash RPR	195.00		11	8			29	8	
30% Potash RPR	218.00		9	15			24	15	
Muraite of Potash	340.00			50				50	
Sulphate of Potash Bagged	608.50			42	18				
Sulphate of Ammonia	279.00	21			24				
N-Rich Urea Bulk	442.50	46							
Calcium Ammonium Nitrate	430.00	27					8		
Nitrophoska Blue Bagged	601.00	12	5	14	4	1	6	10	
Nitrophoska Blue 12-10-10 Bagged	605.50	12	10	10	1		6	7	
Ammo-Phos/Hycrop 9-18-7	496.50	9	18	7	2				
Ammo-Phos/Hycrop 8-14-16	475.50	8	14	15	1				
Sulphur Super	165.50		8		20		20		
15% Potash Sulphur Super	193.50		7	8	17		17		
30% Potash Sulphur Super	218.00		6	15	14		14		
50% Potash Sulphur Super	250.00		4	25	10		10		
Durasul	399.00				100				
Sulphur Super 30	167.00				30		20		

Name	Price	Nutrient Analysis							
		N	P	K	S	Mg	Ca	Cl	Mn
Serpentine Super	151.50		7	0	9	5	17		
15% Potash Serpentine Super	181.50		6	8	8	4	14		
30% Potash Serpentine Super	207.00		5	15	6	4	12		
50% Potash Serpentine Super	241.00		3	25	4	3	9		
Magphos	200.50		8		11	5	19		
15% Potash Magphos	230.00		7	8	9	5	16		
30% Potash Magphos	255.00			15	7	5	13		
Granmag	437.50				6	30			
Magnox	434.60					51			
Crop Fertiliser	209.00	5	4	5	12	3	10		
Ammoniated Super	197.500	5	7		15		17		
DAP	485.00	18	20		2				
DAP Sulphur Super	357.50	11	15		13		7		
Dolomite	274.00					11	23		
Magnesium Sulphate (Kieserite)	829.85				20	15			
Kiwifruit special mix	400.98	16.2	2.5		5.8	1.8	11		
Hycane base mix	315.58		4.6	15	8.9	4.6	11.3	15	
Coromandel base mix	282.72		5.4	12.5	9.2	4.1	13.2	12.5	

The fertiliser Kiwifruit special mix, Hycane base mix and Coromandel base mix are blends created by consultant three. Their constituents are shown in Table 34.

Table 34 Fertiliser blends designed by Consultant Two and blended by BOP Fertilisers.

Blended fertiliser name	Constituent fertilisers	Percentage used in the blend
Kiwifruit special mix	C.A.N.	60%
	Super phosphate	28%
	Keserite	12%
Hycane base mix	Super phosphate	30%
	Keserite	30%
	Murate of Potash	30%
	Magnox	10%
Coromandel base mix	Super phosphate	60%
	Keserite	10%
	Murate of Potash	25%
	Magnox	5%

5.2. Ravensdown Fertiliser Co-operative fertilisers

The following table contains the fertilisers available for selection and thus inclusion in a fertiliser recommendation by Consultant Two.

Table 35 Nutrient analysis and price fertilisers available from Ravensdown Fertiliser Co-operative.

Name	Price	Nutrient Analysis							
		N	P	K	S	Mg	Ca	Cl	Mn
Superphosphate	166.40		9.1		12		20		
Magnesium Super	193.27		8.3		11	4.2	18.4		
Sulphur Super	175.34		8.2		19.8		18.2		
Sulphur Super Extra	181.32		7.3		28.3		16.1		
Maxi Sulphur Super	190.32		5.1		50		11		
TSP 15% S	364.10		16		15.5		14.5		
N C Reactive Rock	171.60		13		1		33		
RPR 8 S	178.57		11.8		8.4		29.7		
RPR 11 S	179.50		11.4		10.8		28.6		
RPR 17 S	181.94		10.3		17.3		25.7		
RPR/Sulphur Super	177.27		10.8		11.1		26.5		
Potassium Chloride	348.30			50				50	
15% Potash Super	193.96		7.7	7.5	10.2		17	7.5	
20% Potash Super	201.76		7.3	10	9.1		16	10	
30% Potash Super	217.36		6.4	15	8.4		14	15	
50% Potash Super	248.56		4.6	25	6		10	25	
15% Potash Sulphur Super	198.03		7.1	7.5	17		17	7.5	
30% Potash Sulphur Super	220.71		5.8	15	13.7		14	15	
Higro 7-5-7	238.38	7	5.1	7	14		11.2	6.5	
Potassium Sulphate	531.44			42	18				
Potash Gold 15-10-10	478.19	14.7	10	9.7	11.1				
Potash Gold 8-15-13	549.43	7.7	15.4	12.6	6.1				
20% Potash Gold Super	243.57		7.2	8.4	13.2		16		
35% Potash Gold Super	298.32		5.9	14.7	14.1		13		
55% Potash Gold Super	371.33		4.1	23.1	15.3		9		
Dolomite	216.32					11	23		
Magnesium Oxide	450.32					52			
N-Rich Urea	471.12	46							
Ammonium Sulphate	313.04	21			24				
Ammonium Sulphate Nitrate	376.48	26			14				
Calcium Ammonium Nitrate 27-0-0 (CAN)	400.40	27					8		
Cropmaster DAP	534.56	18	20		1				
Cropmaster 20	427.96	20	10		13				
Cropmaster 15	429.83	15	10	10	8				
Cropmaster 13	475.07	12.6	14	15	1				
DAP 13 S	452.66	13.5	16.2		2.2				
Ammo-Phos MAP	551.20	11	22		1				
Ammo-Phos/Hycrop 9-19-7	521.040	9.4	18.7	7.5	0.9				
Ammo-Phos/Hycrop 8-15-15	486.72	7.7	15.4	15	0.7				
Ammo-Phos/Hycrop 8-12-22	448.24	7.8	11.6	22.5	0.6				
Nitrophoska 12-10-10	543.92	12	10.4	10	1		6	10	
Nitrophoska Blue TE 12-5-14	532.48	12	5.2	14	4	1	6	7	

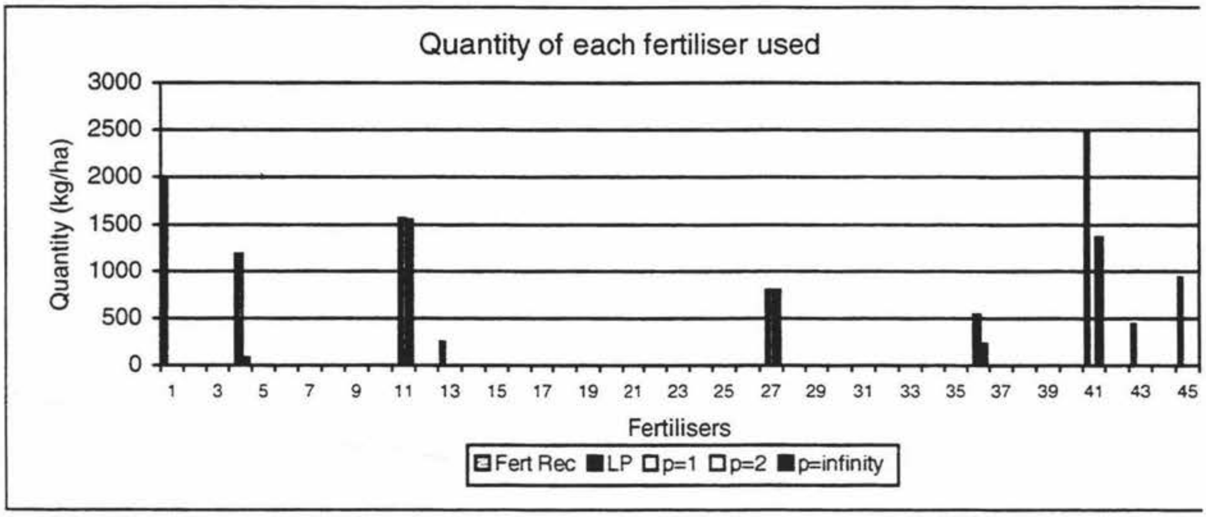
Name	Price	Nutrient Analysis							
		N	P	K	S	Mg	Ca	Cl	Mn
Manganese Sulphate	928.00				13				32
Potassium Nitrate	1243.00	13		38					

Appendix 6

Results

This appendix contains the output from the decision support system.

6.1. Consultant One example one

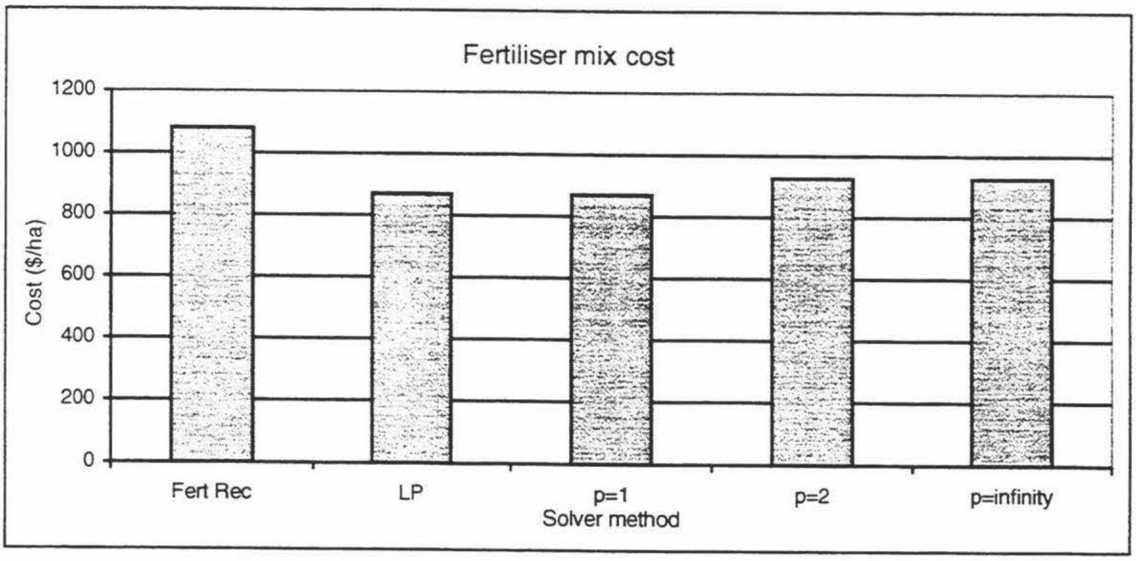


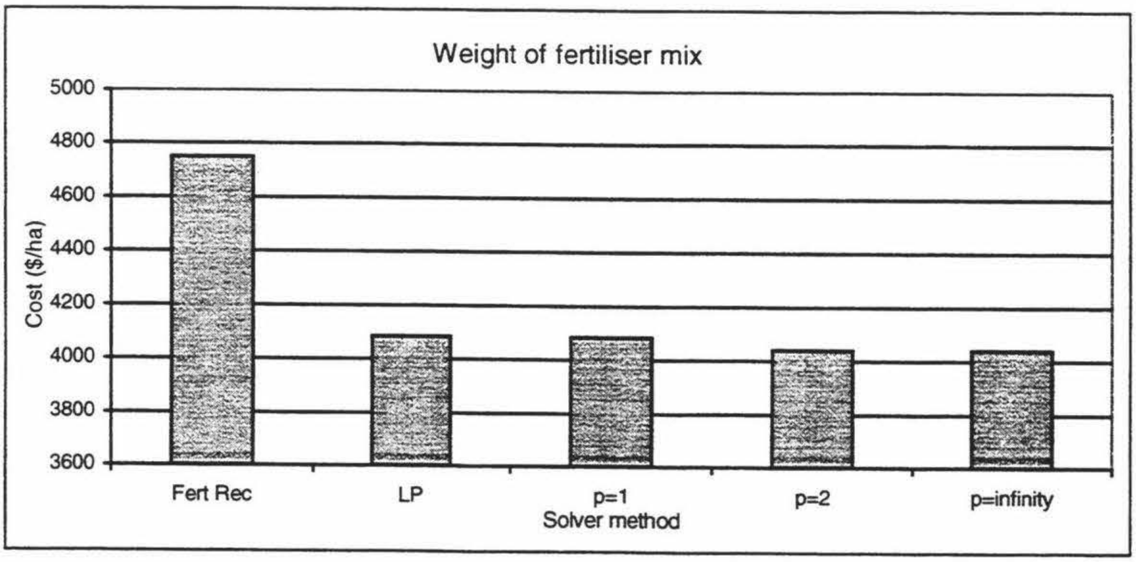
	Fertiliser	Fert Rec	LP	p=1	p=2	p=infinity
1	Superphosphate	2000				
2	Super Plus					
3	Triple Super					
4	Reactive Rock		1182	1182	84	84
5	Reactive Rock + S					
6	15% Potash Super					
7	20% Potash Super					
8	30% Potash Super					
9	50% Potash Super					
10	20% Potash Super Plus					
11	15% Potash RPR		1563	1563	1552	1552
12	30% Potash RPR				3	3
13	Muraite of Potash	250				
14	Sulphate of Potash Bagged					
15	Sulphate of Amonia					
16	N-Rich Urea Bulk					
17	Calcium Ammonium Nitrate					
18	Nitrophoska Blue Bagged					
19	Nitrophoska Blue 12-10-10 Bagged					
20	Ammo-Phos/Hycrop 9-18-7					
21	Ammo-Phos/Hycrop 8-14-16					
22	Sulphur Super					
23	15% Potash Sulphur Super					
24	30% Potash Sulphur Super					
25	50% Potash Sulphur Super					
26	Durasul					
27	Sulphur Super 30		800	800	800	800
28	Serpentine Super					
29	15% Potash Serpentine Super					
30	30% Potash Serpentine Super					
31	50% Potash Serpentine Super					
32	Magphos					
33	15% Potash Magphos					
34	30% Potash Magphos					
35	Granmag					
36	Magnox		539	539	234	234
37	Crop Fertiliser					
38	Ammoniated Super					
39	DAP					
40	DAP Sulphur Super					
41	Dolomite	2500			1369	1369
42	Magnesium Sulphate (Kieserite)					
43	Kiwifruit special mix					
44	Hycane base mix					
45	Coromandel base mix					

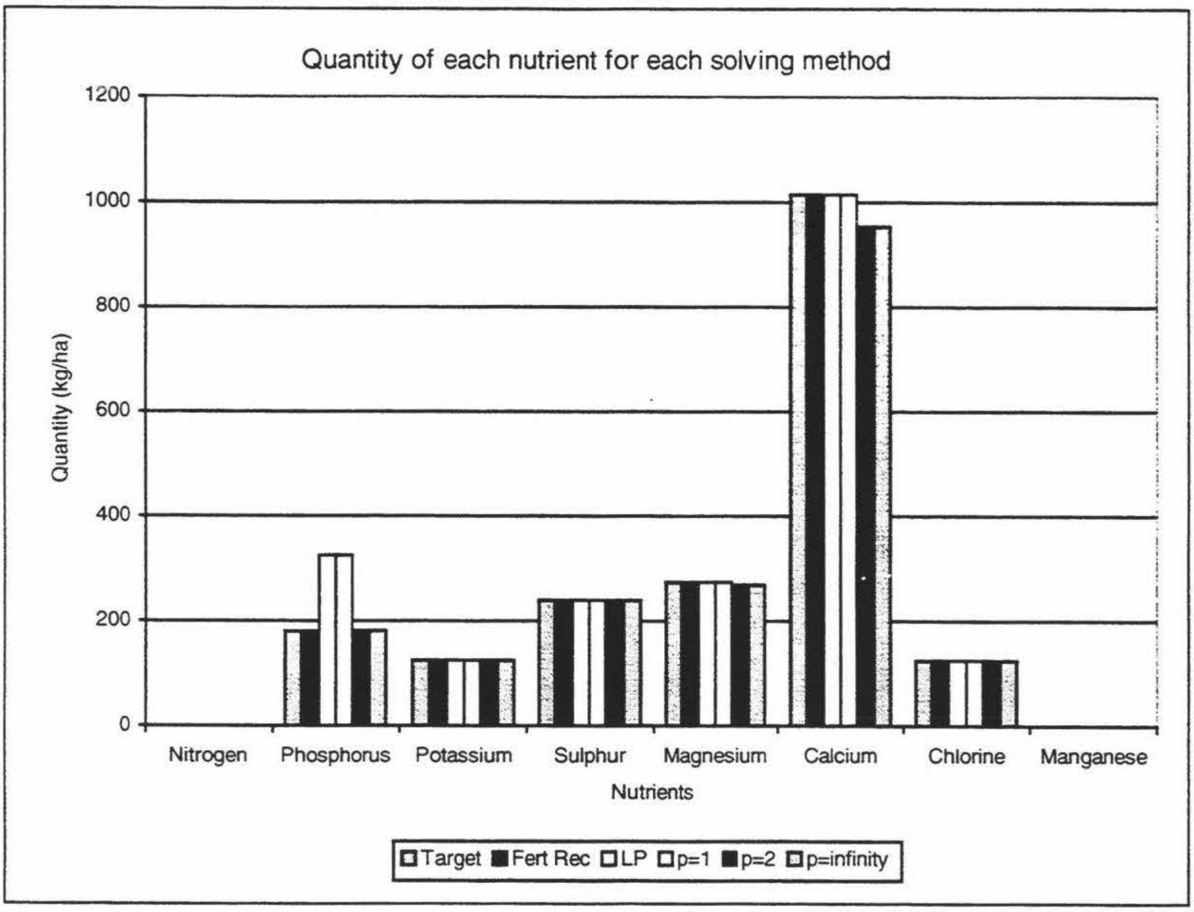
Nutrient usage (kg/ha)								
	N	P	K	S	Mg	Ca	Cl	Mn
Target	0.0	180.0	125.0	240.0	275.0	1015.0	125.0	0.0
Fert Rec	0.0	180.0	125.0	240.0	275.0	1015.0	125.0	0.0
LP	0.0	325.5	125.0	240.0	275.0	1015.0	125.0	0.0
p=1	0.0	325.5	125.0	240.0	275.0	1015.0	125.0	0.0
p=2	0.0	181.9	124.6	239.9	270.1	954.0	124.6	0.0
p=infinity	0.0	181.9	124.6	239.9	270.1	954.0	124.6	0.0

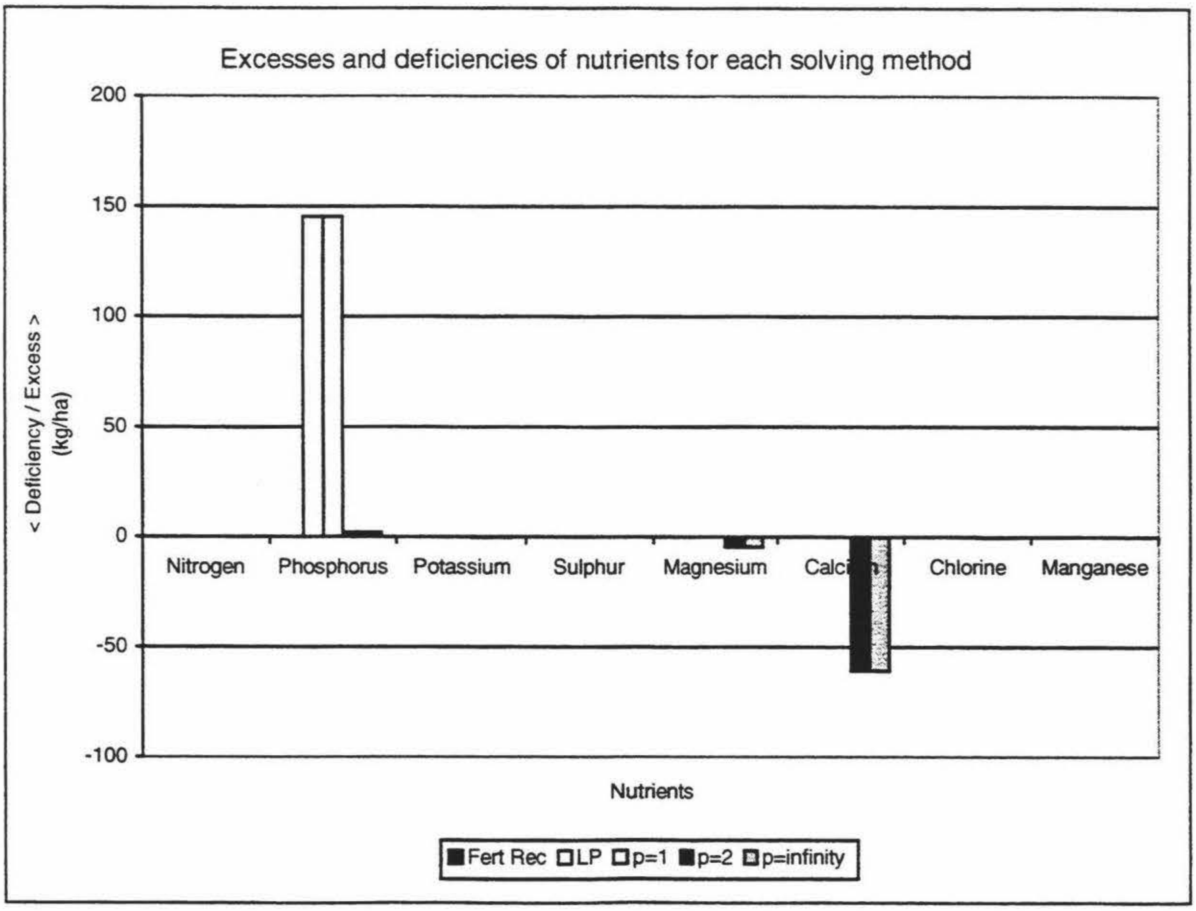
Nutrient excesses from target (kg/ha)								
	N	P	K	S	Mg	Ca	Cl	Mn
Fert Rec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LP	0.0	145.5	0.0	0.0	0.0	0.0	0.0	0.0
p=1	0.0	145.5	0.0	0.0	0.0	0.0	0.0	0.0
p=2	0.0	1.9	-0.4	-0.1	-4.9	-61.0	-0.4	0.0
p=infinity	0.0	1.9	-0.4	-0.1	-4.9	-61.0	-0.4	0.0

Cost and weight of each fertiliser mix					
	Fert Rec	LP	p=1	p=2	p=infinity
Cost ($/ha)	1080.00	870.61	870.61	927.83	927.83
Weight (Tonnes/ha)	4750.00	4083.70	4083.70	4041.69	4041.69

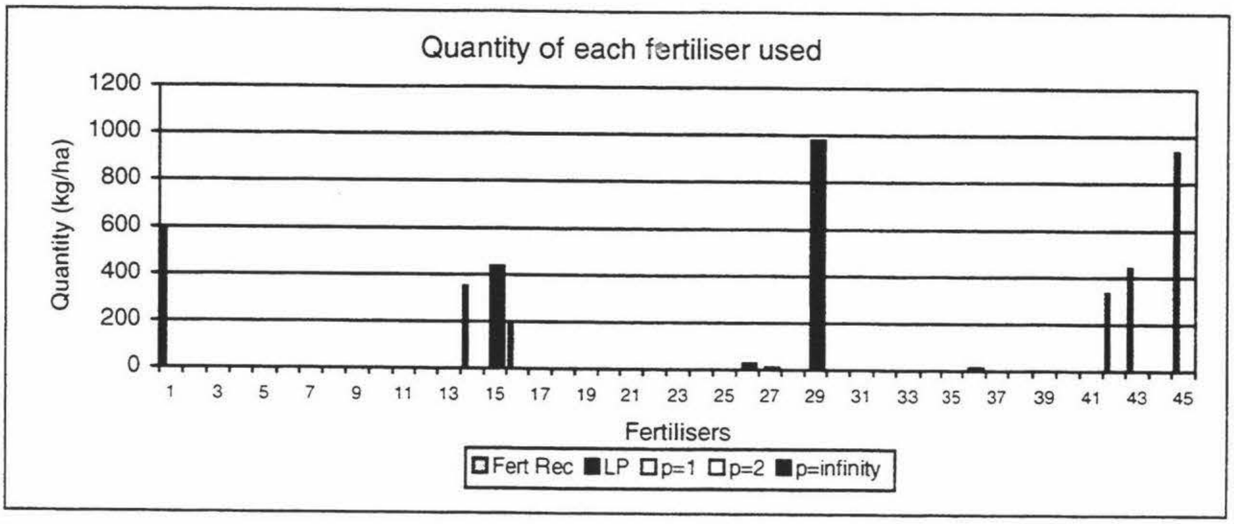





Quantity of each nutrient for each solving method
Quantity (kg/ha)
1200
1000
800
600
400
200
0
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Target
Fert Rec
LP
p=1
p=2
p=infinity


Excesses and deficiencies of nutrients for each solving method
< Deficiency / Excess >
(kg/ha)
200
150
100
50
0
-50
-100
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Fert Rec
LP
p=1
p=2
p=infinity

6.2. Consultant One example two

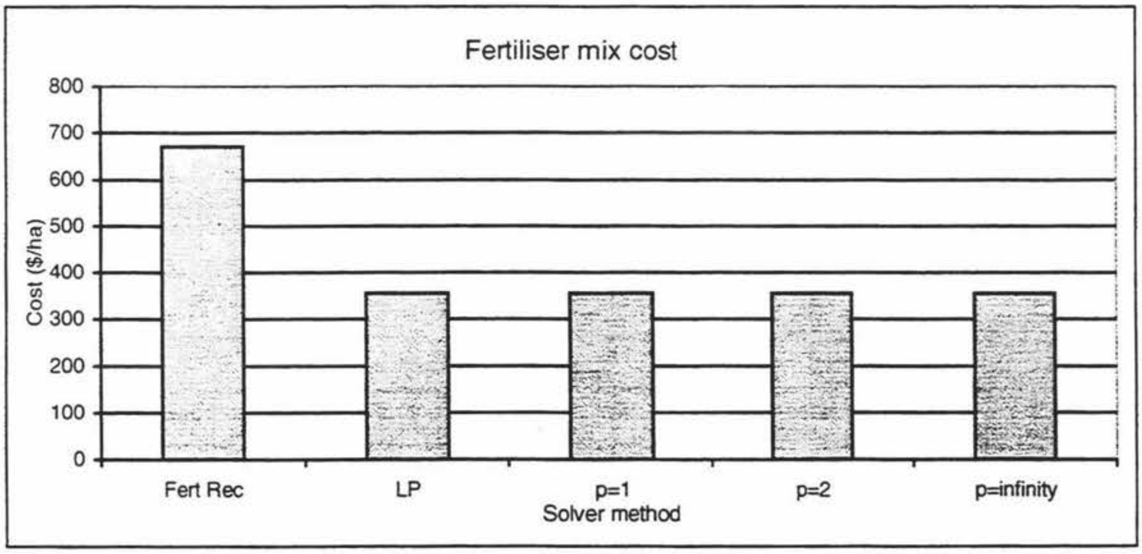


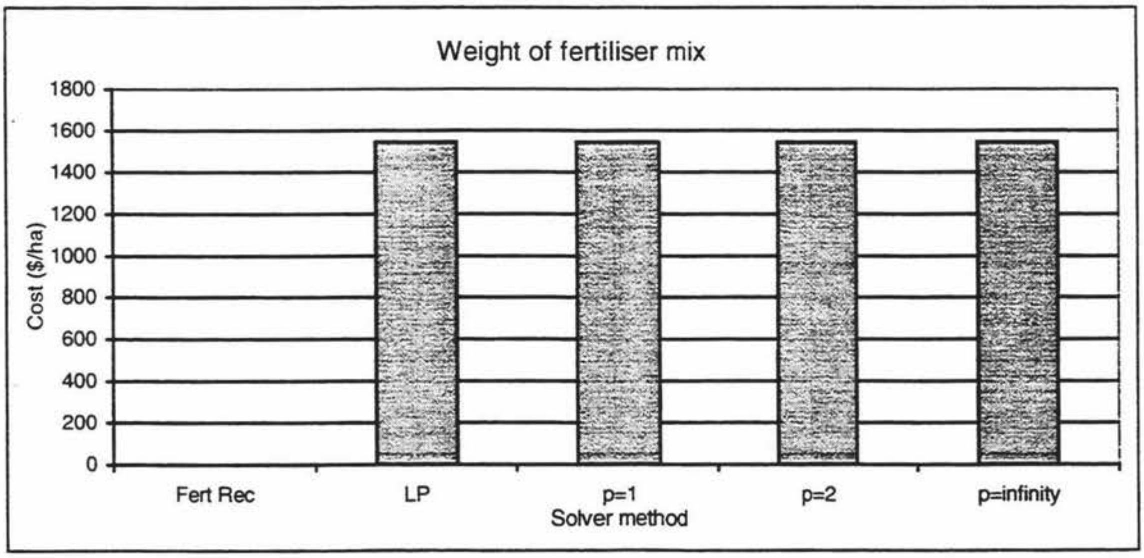
	Fertiliser	Fert Rec	LP	p=1	p=2	p=infinity
1	Superphosphate	600				
2	Super Plus					
3	Triple Super					
4	Reactive Rock					
5	Reactive Rock + S					
6	15% Potash Super					
7	20% Potash Super					
8	30% Potash Super					
9	50% Potash Super					
10	20% Potash Super Plus					
11	15% Potash RPR					
12	30% Potash RPR					
13	Muraite of Potash					
14	Sulphate of Potash Bagged	350				
15	Sulphate of Amonia		438	438	438	438
16	N-Rich Urea Bulk	200				
17	Calcium Ammonium Nitrate					
18	Nitrophoska Blue Bagged					
19	Nitrophoska Blue 12-10-10 Bagged					
20	Ammo-Phos/Hycrop 9-18-7					
21	Ammo-Phos/Hycrop 8-14-16					
22	Sulphur Super					
23	15% Potash Sulphur Super					
24	30% Potash Sulphur Super					
25	50% Potash Sulphur Super					
26	Durasul		28	28	28	28
27	Sulphur Super 30		11	11	11	11
28	Serpentine Super					
29	15% Potash Serpentine Super		980	980	980	980
30	30% Potash Serpentine Super					
31	50% Potash Serpentine Super					
32	Magphos					
33	15% Potash Magphos					
34	30% Potash Magphos					
35	Granmag					
36	Magnox		14	14	14	14
37	Crop Fertiliser					
38	Ammoniated Super					
39	DAP					
40	DAP Sulphur Super					
41	Dolomite					
42	Magnesium Sulphate (Kieserite)	333				
43	Kiwifruit special mix					
44	Hycane base mix					
45	Coromandel base mix					

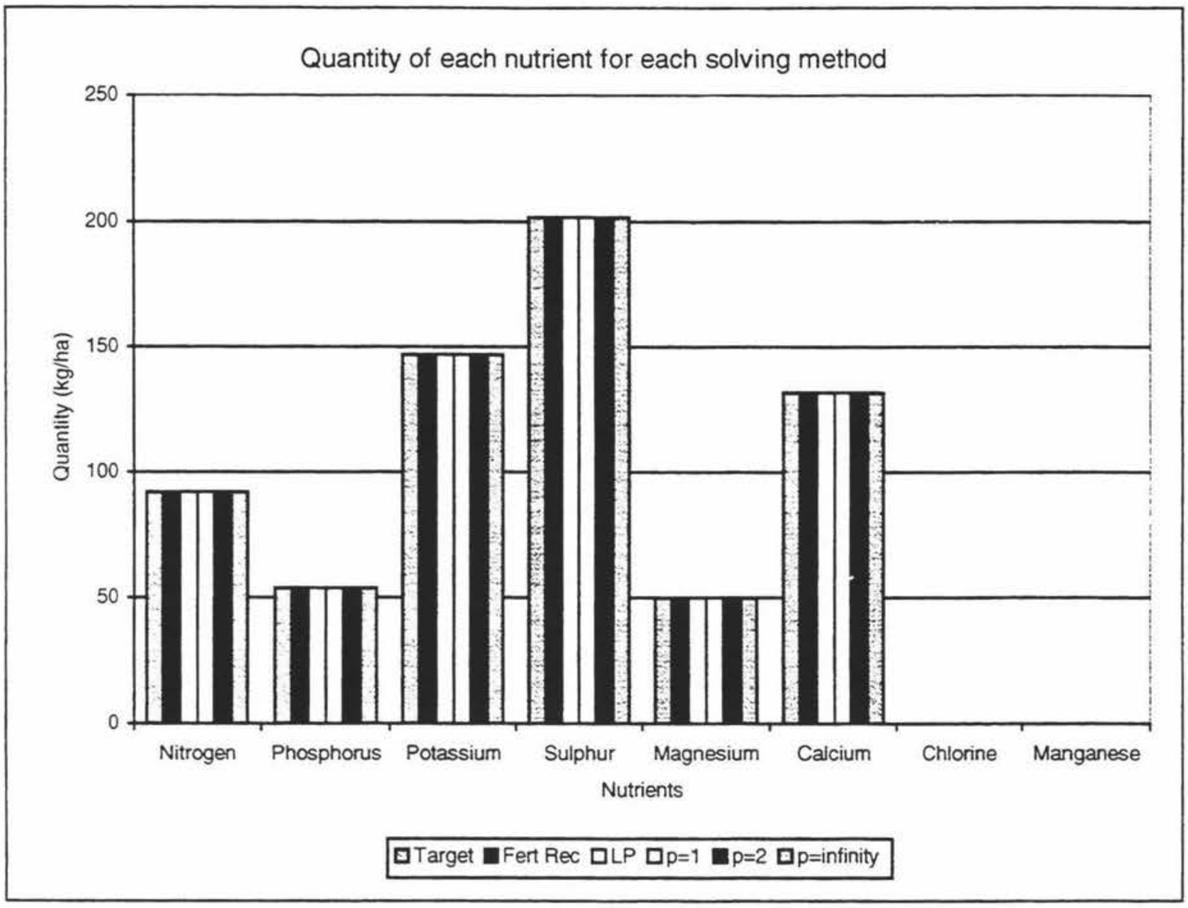
Nutrient usage (kg/ha)								
	N	P	K	S	Mg	Ca	Cl	Mn
Target	92.0	54.0	147.0	201.6	50.0	132.0	0.0	0.0
Fert Rec	92.0	54.0	147.0	201.6	50.0	132.0	0.0	0.0
LP	92.0	54.0	147.0	201.6	50.0	132.0	0.0	0.0
p=1	92.0	54.0	147.0	201.6	50.0	132.0	0.0	0.0
p=2	92.0	54.0	147.0	201.6	50.0	132.0	0.0	0.0
p=infinity	92.0	54.0	147.0	201.6	50.0	132.0	0.0	0.0

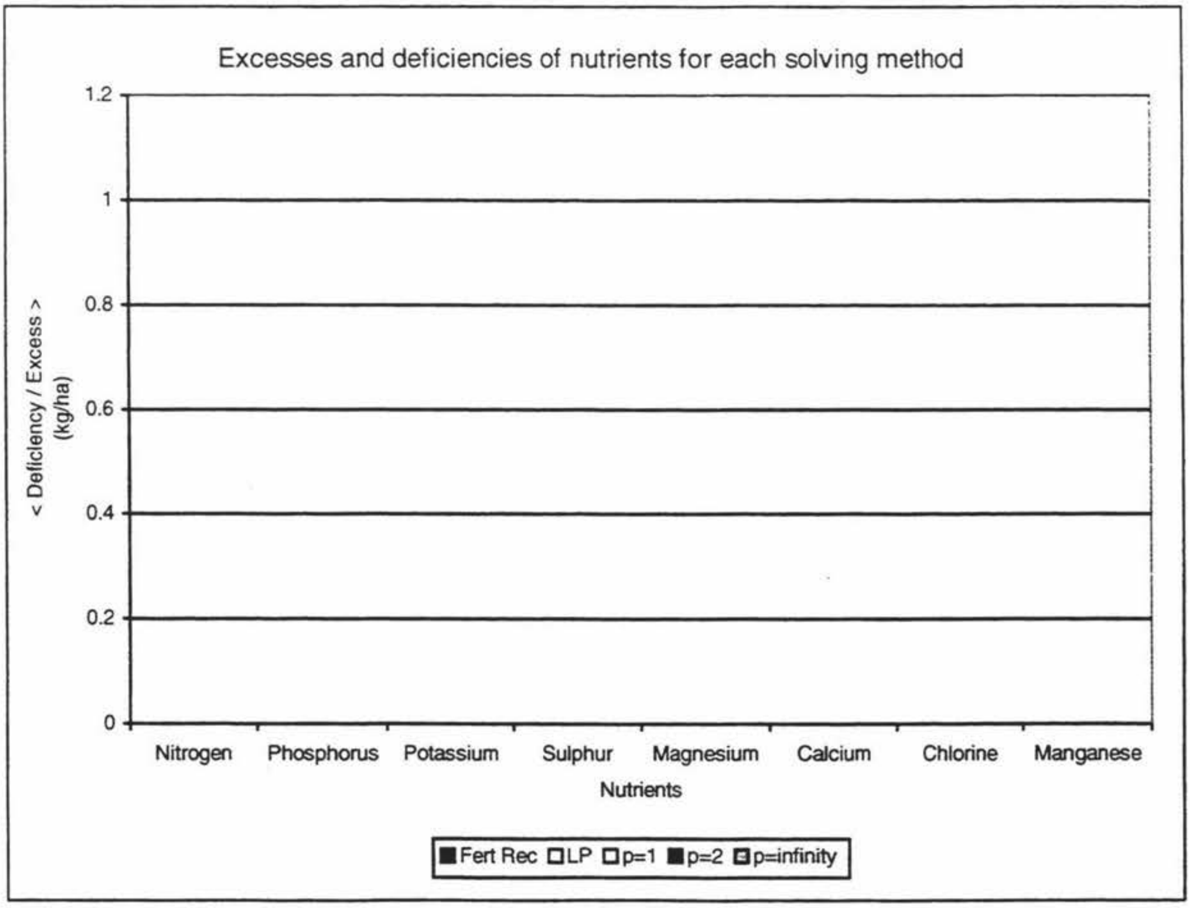
Nutrient excesses from target (kg/ha)								
	N	P	K	S	Mg	Ca	Cl	Mn
Fert Rec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
p=1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
p=2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
p=infinity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Cost and weight of each fertiliser mix					
	Fert Rec	LP	p=1	p=2	p=infinity
Cost ($/ha)	670.82	355.02	355.02	355.02	355.02
Weight (Tonnes/ha)	14.83.00	1542.73	1542.73	1542.73	1542.73

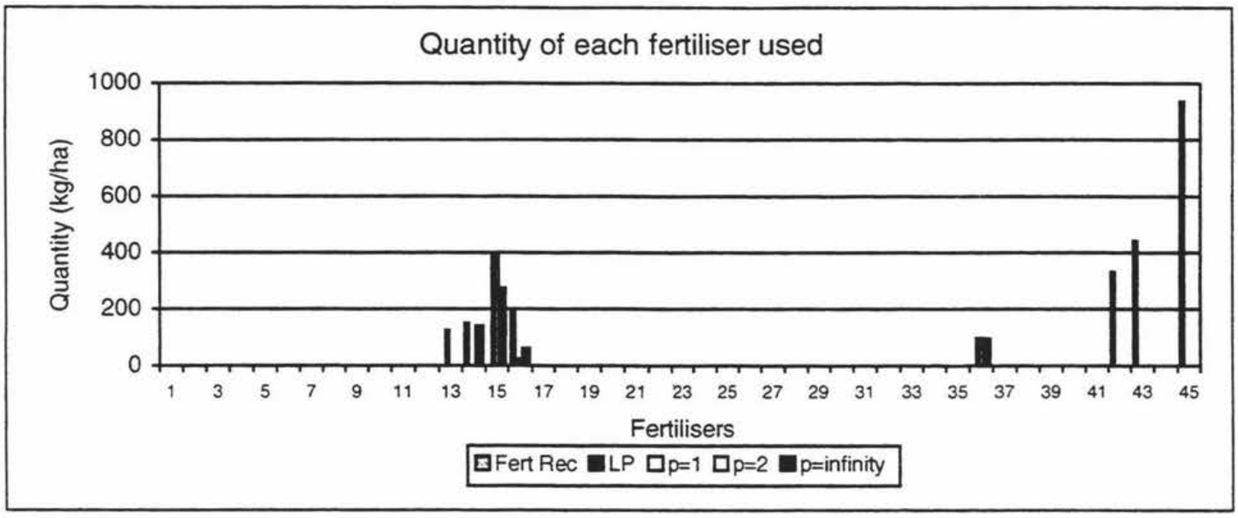





Quantity of each nutrient for each solving method
250
200
150
100
50
0
Quantity (kg/ha)
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Target
Fert Rec
LP
p=1
p=2
p=infinity


Excesses and deficiencies of nutrients for each solving method
1.2
1
0.8
0.6
0.4
0.2
0
< Deficiency / Excess > (kg/ha)
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Fert Rec
LP
p=1
p=2
p=infinity

6.3. Consultant One example three

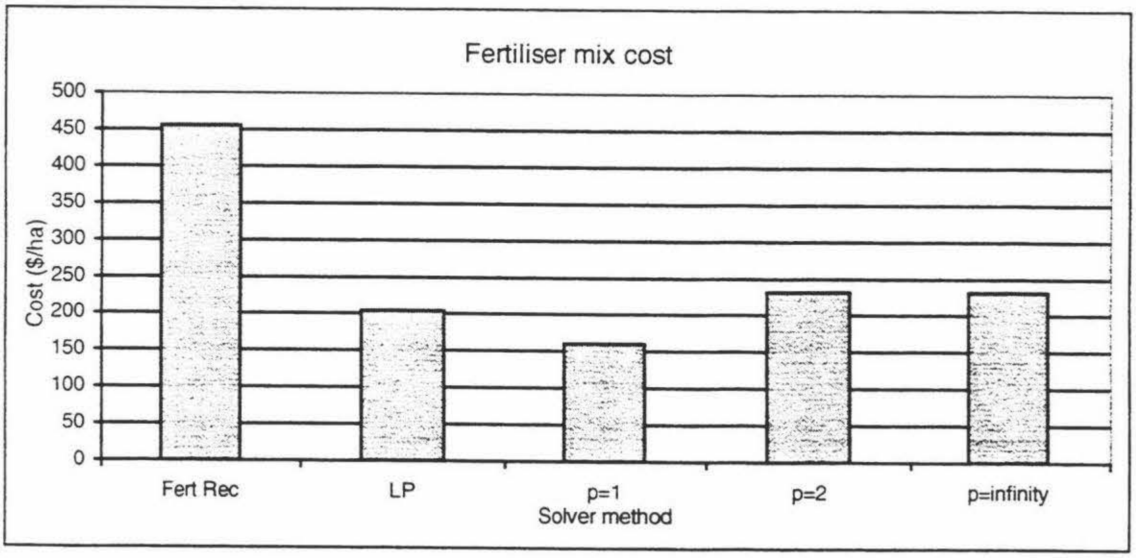


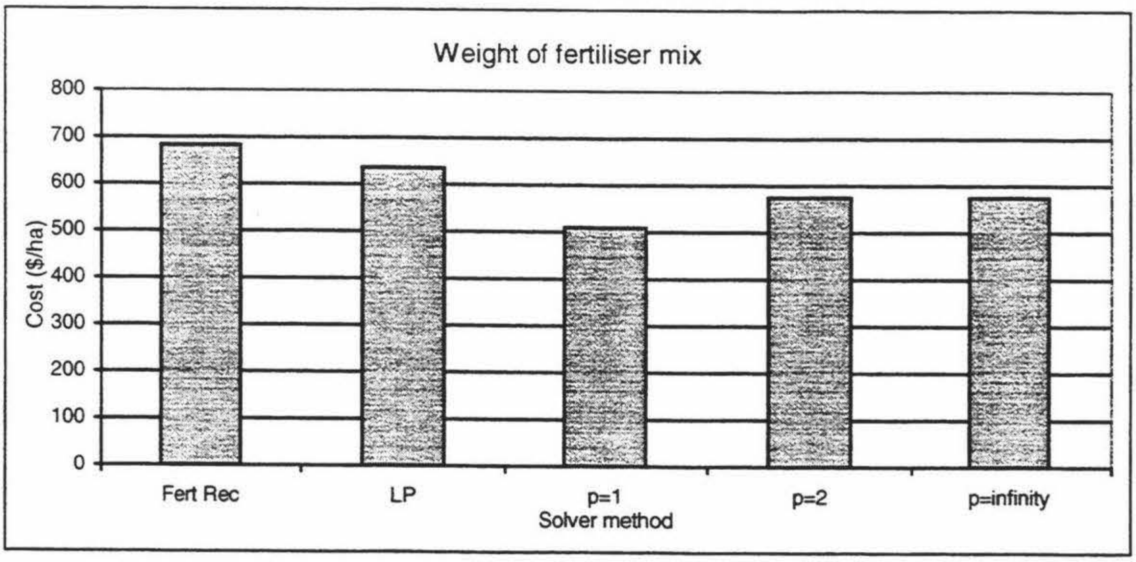
	Fertiliser	Fert Rec	LP	p=1	p=2	p=infinity
1	Superphosphate					
2	Super Plus					
3	Triple Super					
4	Reactive Rock					
5	Reactive Rock + S					
6	15% Potash Super					
7	20% Potash Super					
8	30% Potash Super					
9	50% Potash Super					
10	20% Potash Super Plus					
11	15% Potash RPR					
12	30% Potash RPR					
13	Muraite of Potash		126			
14	Sulphate of Potash Bagged	150			142	142
15	Sulphate of Amonia		390	390	276	276
16	N-Rich Urea Bulk	200	22	22	62	62
17	Calcium Ammonium Nitrate					
18	Nitrophoska Blue Bagged					
19	Nitrophoska Blue 12-10-10 Bagged					
20	Ammo-Phos/Hycrop 9-18-7					
21	Ammo-Phos/Hycrop 8-14-16					
22	Sulphur Super					
23	15% Potash Sulphur Super					
24	30% Potash Sulphur Super					
25	50% Potash Sulphur Super					
26	Durasul					
27	Sulphur Super 30					
28	Serpentine Super					
29	15% Potash Serpentine Super					
30	30% Potash Serpentine Super					
31	50% Potash Serpentine Super					
32	Magphos					
33	15% Potash Magphos					
34	30% Potash Magphos					
35	Granmag					
36	Magnox		98	98	95	95
37	Crop Fertiliser					
38	Ammoniated Super					
39	DAP					
40	DAP Sulphur Super					
41	Dolomite					
42	Magnesium Sulphate (Kieserite)	333				
43	Kiwifruit special mix					
44	Hycane base mix					
45	Coromandel base mix					

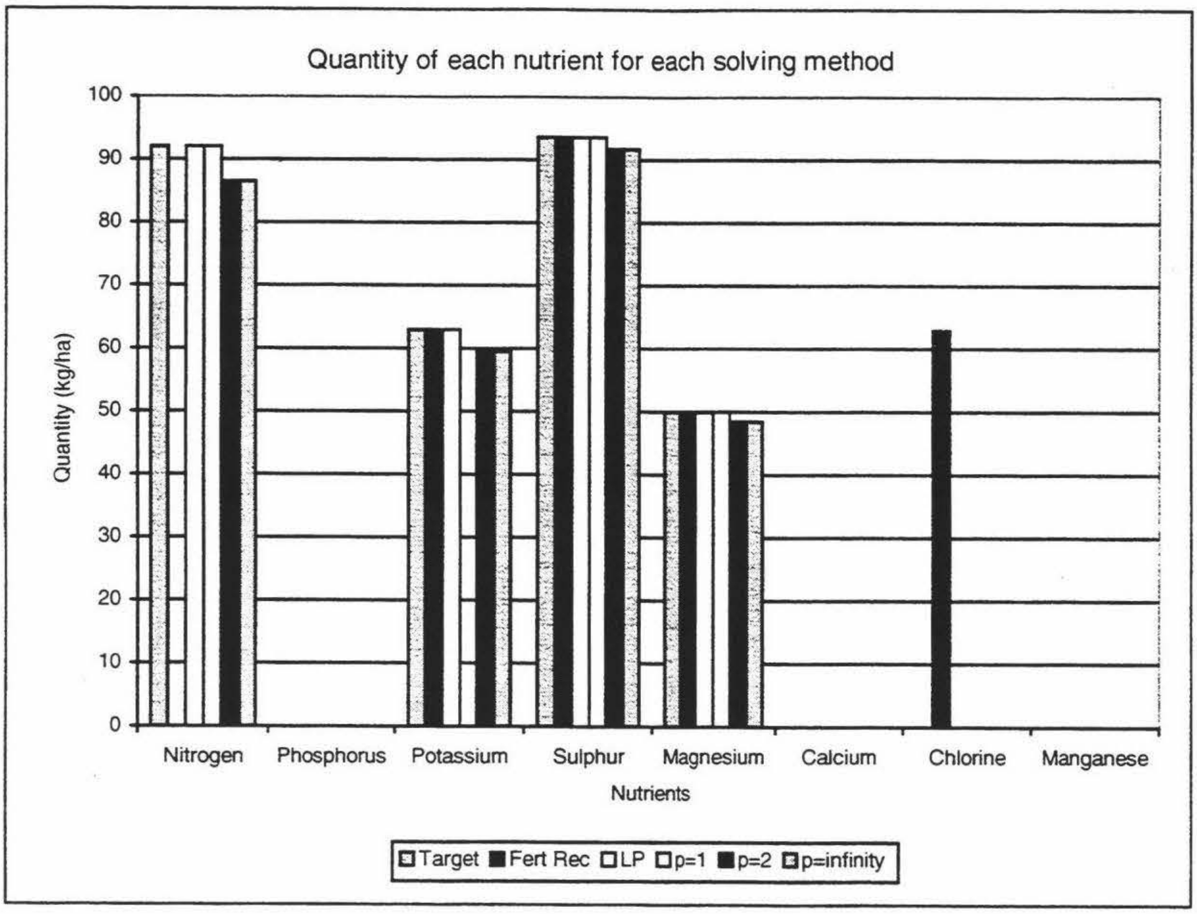
Nutrient usage (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Target	92.0	0.0	63.0	93.6	50.0	0.0	0.0	0.0
Fert Rec	92..0	0.0	63.0	93.6	50.0	0.0	63.0	0.0
LP	92.0	0.0	63.0	93.6	49.9	0.0	0.0	0.0
p=1	92.0	0.0	0.0	93.6	50.0	0.0	0.0	0.0
p=2	86.5	0.0	59.5	91.7	48.5	0.0	0.0	0.0
p=infinity	86.5	0.0	59.5	91.7	48.5	0.0	0.0	0.0

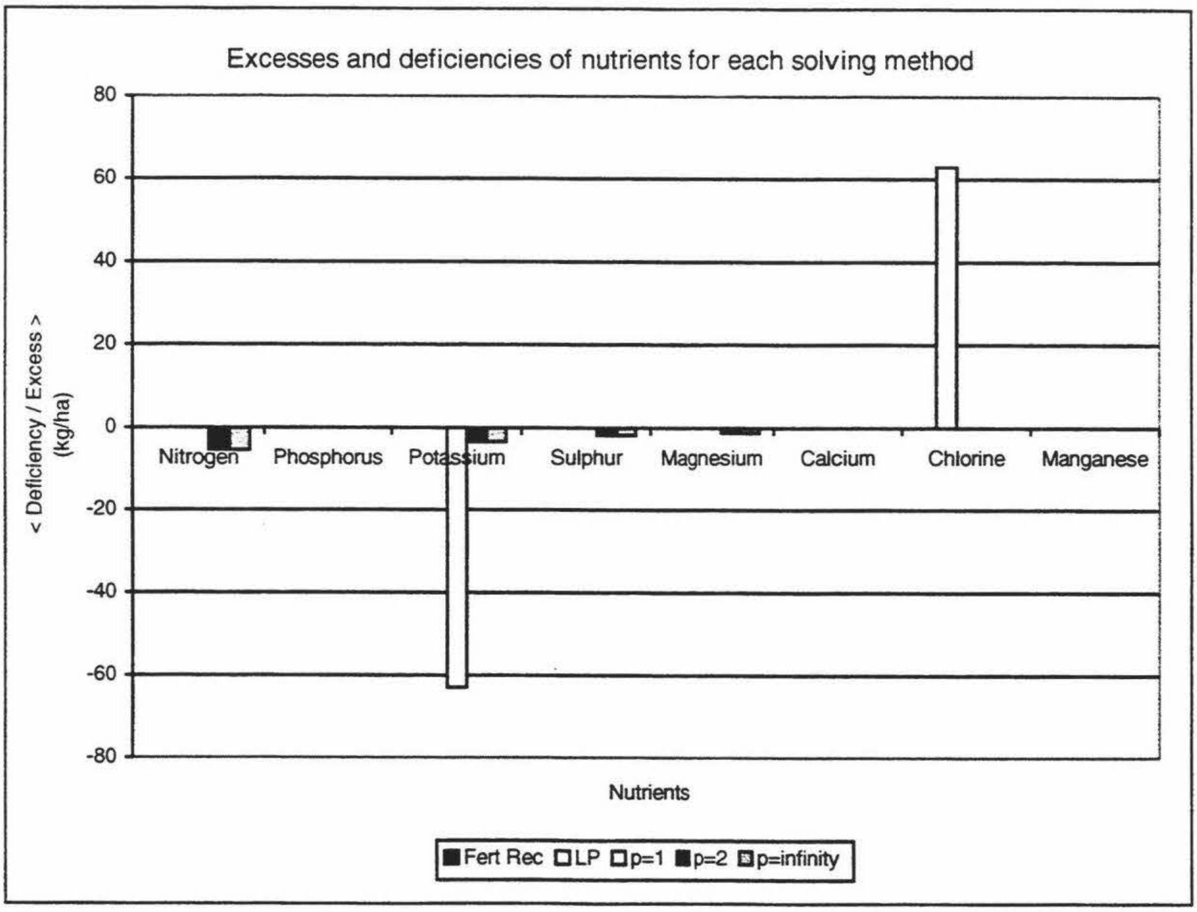
Nutrient excesses from target (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Fert Rec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LP	0.0	0.0	0.0	0.0	0.0	0.0	63.0	0.0
p=1	0.0	0.0	-63.0	0.0	0.0	0.0	0.0	0.0
p=2	-5.5	0.0	-3.5	-1.9	-1.4	0.0	0.0	0.0
p=infinity	-5.5	0.0	-3.5	-1.9	-1.4	0.0	0.0	0.0

Cost and weight of each fertiliser mix	Fert Rec	LP	p=1	p=2	p=infinity
Cost ($/ha)	456.12	203.93	161.09	231.99	231.99
Weight (Tonnes/ha)	683.00	635.90	509.90	574.76	574.76



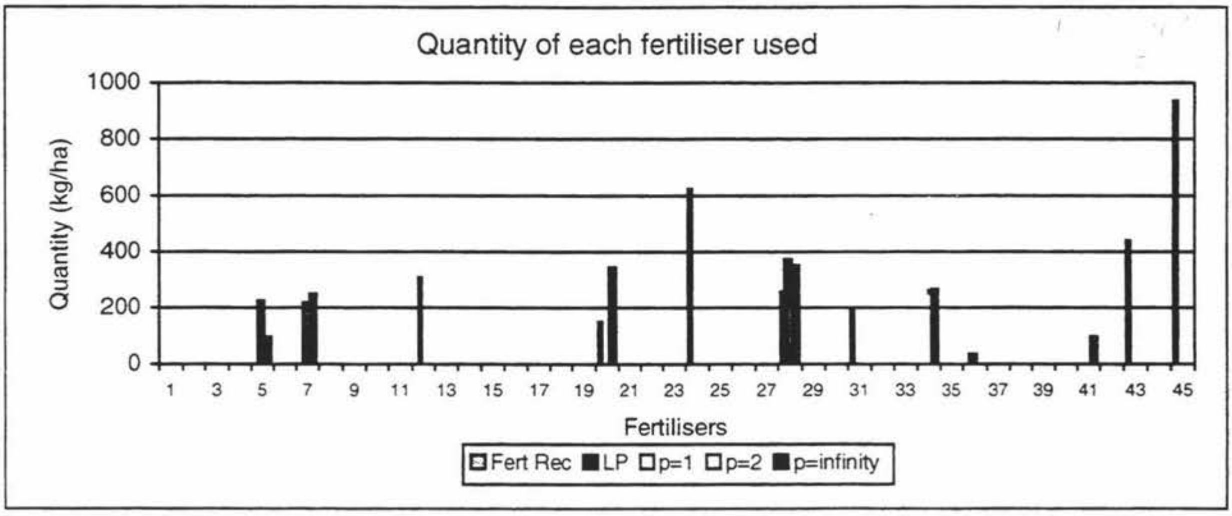






Can't see separate bars for LP and p=1

6.4. Consultant Two example one

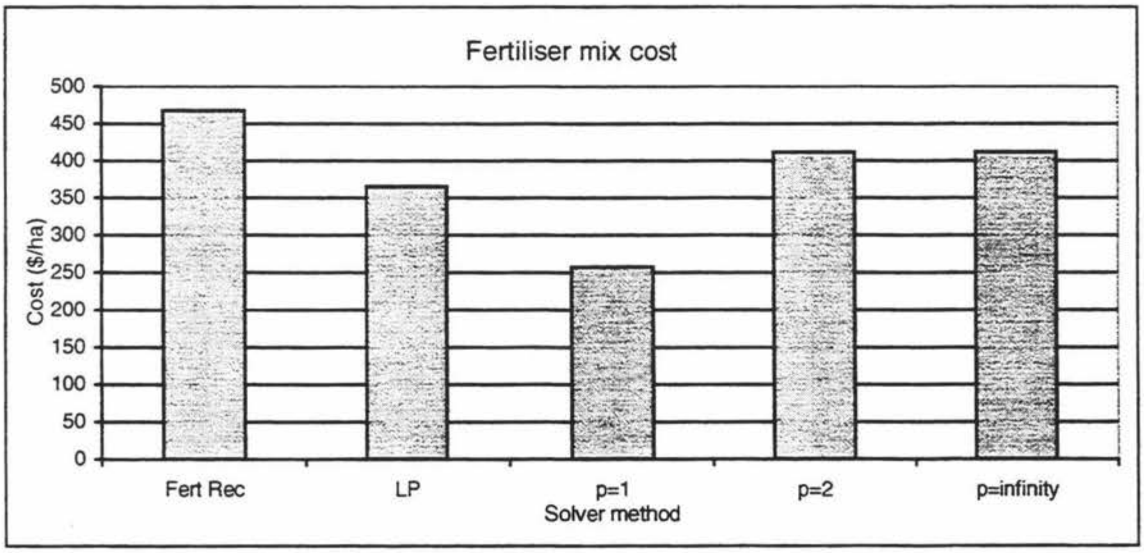


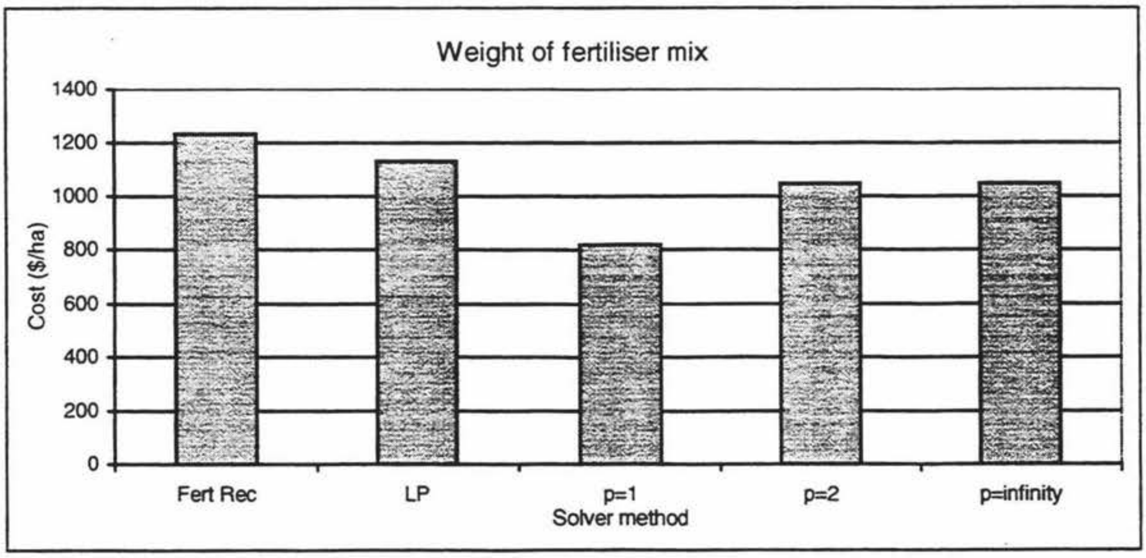
	Fertiliser	Fert Rec	LP	p=1	p=2	p=infinity
1	Superphosphate					
2	Magnesium Super					
3	Sulphur Super					
4	Sulphur Super Extra					
5	Maxi Sulphur Super		226	226	98	98
6	TSP 15% S					
7	N C Reactive Rock		219	219	251	251
8	RPR 8 S					
9	RPR 11 S					
10	RPR 17 S					
11	RPR/Sulphur Super					
12	Potassium Chloride		310			
13	15% Potash Super					
14	20% Potash Super					
15	30% Potash Super					
16	50% Potash Super					
17	15% Potash Sulphur Super					
18	30% Potash Sulphur Super					
19	Higro 7-5-7					
20	Potassium Sulphate	150			346	346
21	Potash Gold 15-10-10					
22	Potash Gold 8-15-13					
23	20% Potash Gold Super					
24	35% Potash Gold Super	625				
25	55% Potash Gold Super					
26	Dolomite					
27	Magnesium Oxide					
28	N-Rich Urea	258	375	375	352	352
29	Ammonium Sulphate					
30	Ammonium Sulphate Nitrate					
31	Calcium Ammonium Nitrate 27-0-0 (CAN)	200				
32	Cropmaster DAP					
33	Cropmaster 20					
34	Cropmaster 15					
35	Cropmaster 13					
36	DAP 13 S					
37	Ammo-Phos MAP					
38	Ammo-Phos/Hycrop 9-19-7					
39	Ammo-Phos/Hycrop 8-15-15					
40	Ammo-Phos/Hycrop 8-12-22					
41	Nitrophoska 12-10-10					
42	Nitrophoska Blue TE 12-5-14					
43	Manganese Sulphate (Monohydrate)					
44	Potassium Nitrate					
45						

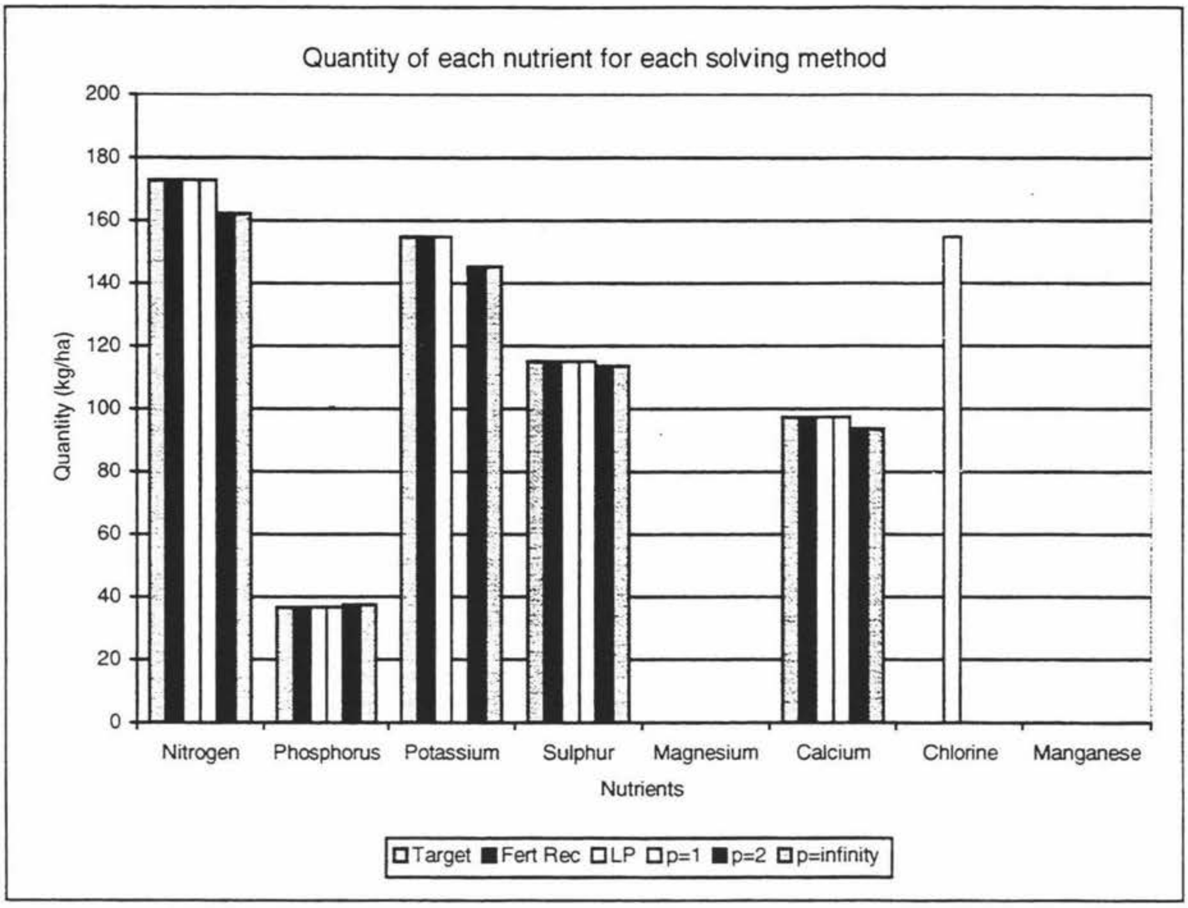
Nutrient usage (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Target	172.7	36.9	154.9	115.2	0.0	97.3	0.0	0.1
Fert Rec	172.7	36.9	154.9	115.2	0.0	97.3	0.0	0.1
LP	172.7	36.9	154.9	115.2	0.0	97.3	154.9	0.1
p=1	172.7	36.9	0.0	115.2	0.0	97.3	0.0	0.1
p=2	162.1	37.6	145.4	113.8	0.0	93.6	0.0	0.1
p=infinity	162.1	37.6	145.4	113.8	0.0	93.6	0.0	0.1

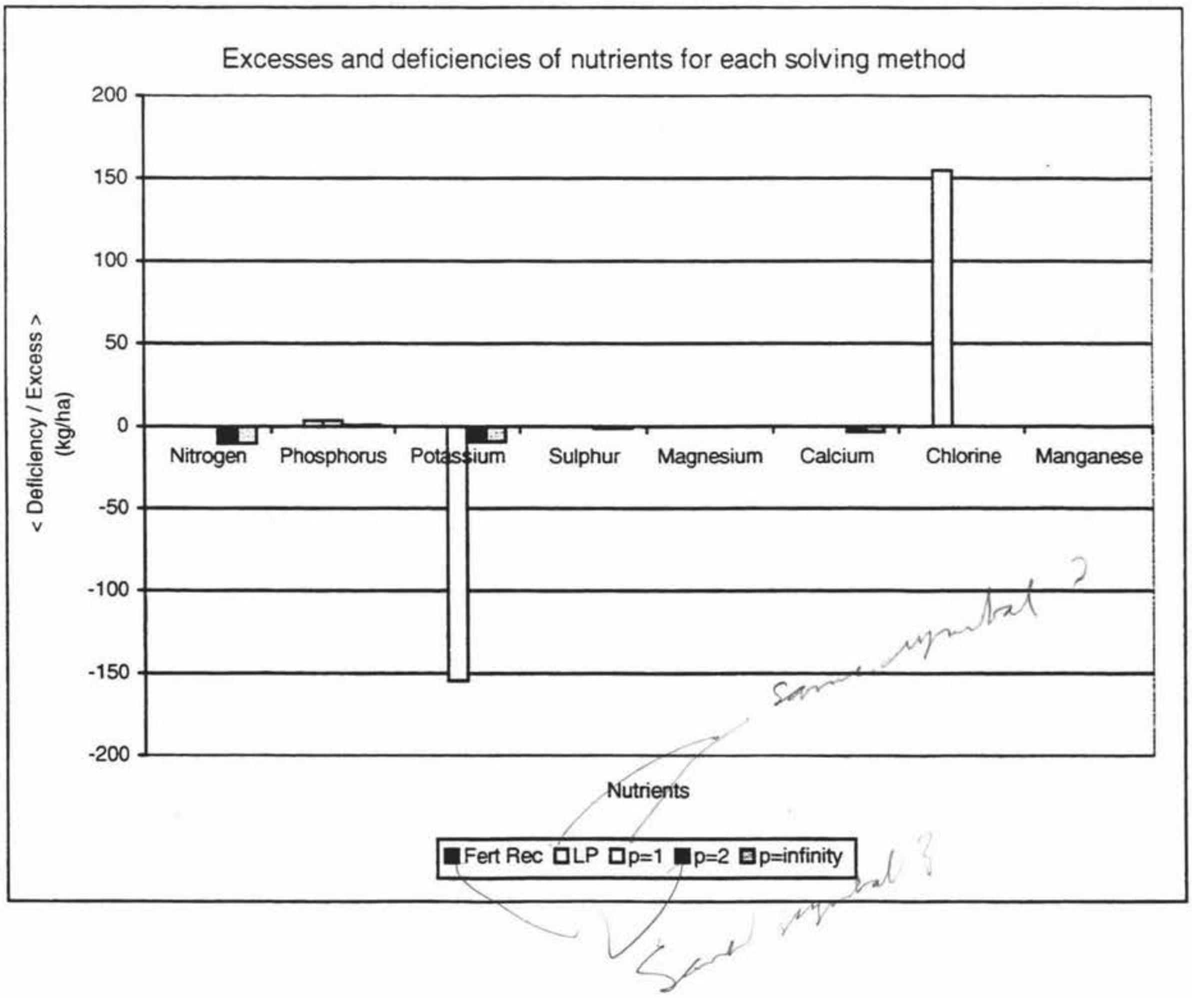
Nutrient excesses from target (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Fert Rec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LP	0.0	3.2	0.0	0.0	0.0	0.0	154.9	0.0
p=1	0.0	3.2	-154.9	0.0	0.0	0.0	0.0	0.0
p=2	-10.6	0.7	-9.5	-1.3	0.0	-3.7	0.0	0.0
p=infinity	-10.6	0.7	-9.5	-1.3	0.0	-3.7	0.0	0.0

Cost and weight of each fertiliser mix	Fert Rec	LP	p=1	p=2	p=infinity
Cost ($/ha)	468.17	365.75	257.86	412.07	412.07
Weight (Tonnes/ha)	1233.40	1130.81	821.03	1047.81	1047.81

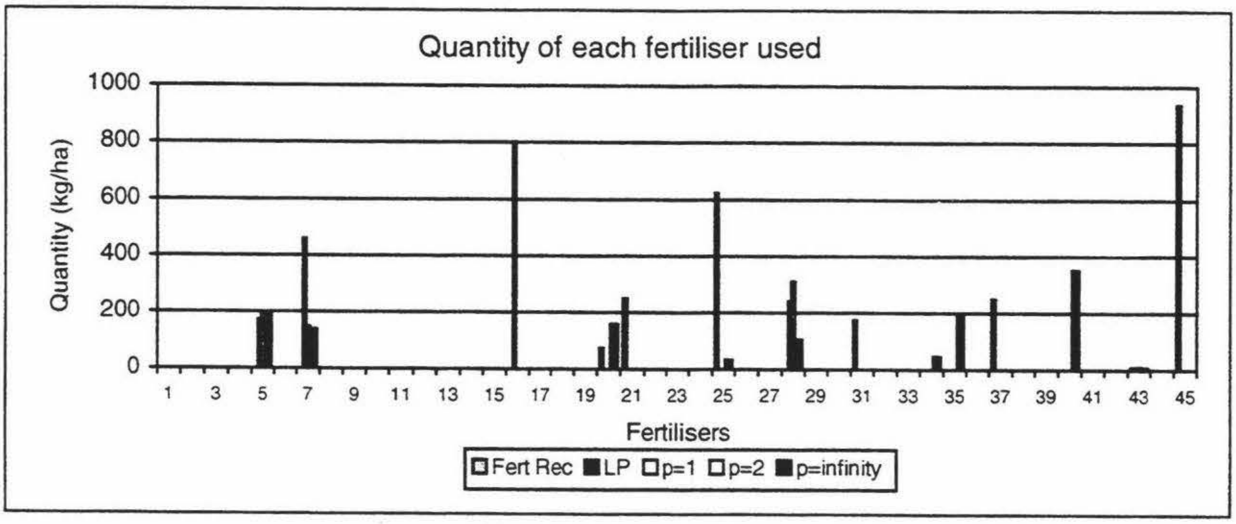





Quantity of each nutrient for each solving method
Quantity (kg/ha)
200
180
160
140
120
100
80
60
40
20
0
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Target
Fert Rec
LP
p=1
p=2
p=infinity


Excesses and deficiencies of nutrients for each solving method
< Deficiency / Excess > (kg/ha)
200
150
100
50
0
-50
-100
-150
-200
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Fert Rec
LP
p=1
p=2
p=infinity

6.5. Consultant Two example two

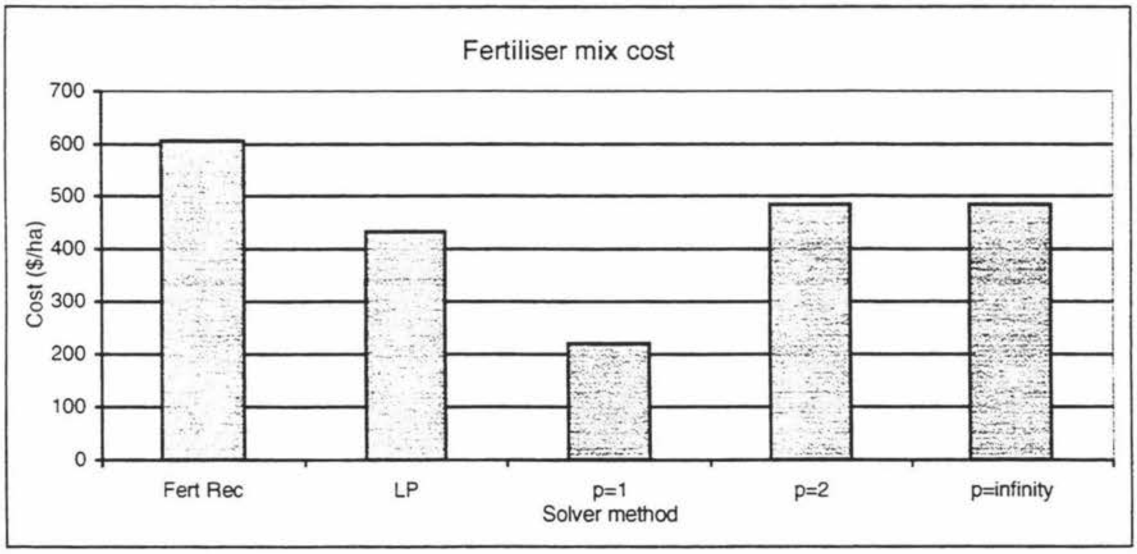


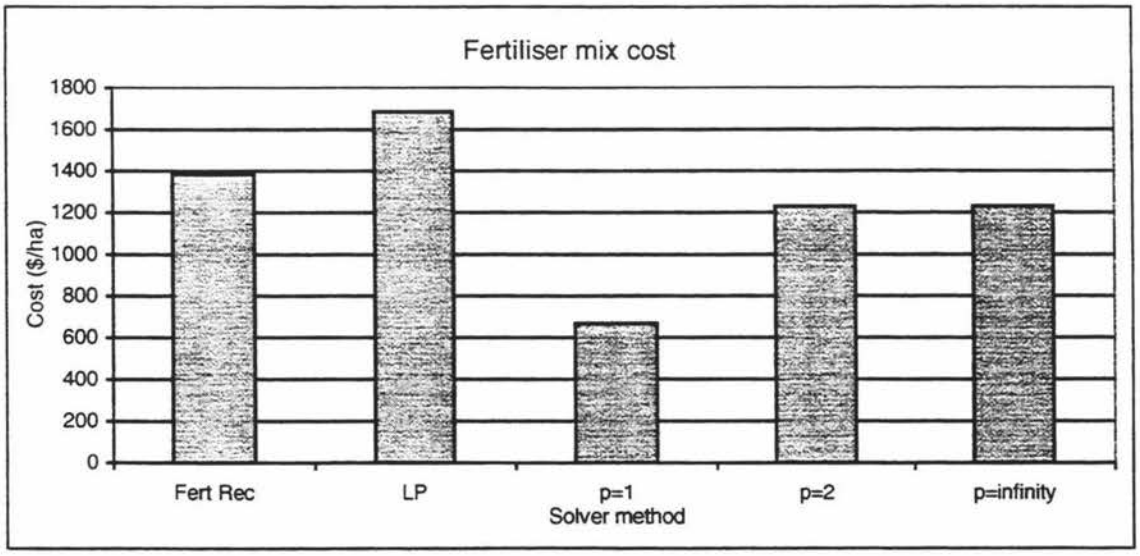
	Fertiliser	Fert Rec	LP	p=1	p=2	p=infinity
1	Superphosphate					
2	Magnesium Super					
3	Sulphur Super					
4	Sulphur Super Extra					
5	Maxi Sulphur Super		173	197	190	190
6	TSP 15% S					
7	N C Reactive Rock		461	147	140	140
8	RPR 8 S					
9	RPR 11 S					
10	RPR 17 S					
11	RPR/Sulphur Super					
12	Potassium Chloride					
13	15% Potash Super					
14	20% Potash Super					
15	30% Potash Super					
16	50% Potash Super		801			
17	15% Potash Sulphur Super					
18	30% Potash Sulphur Super					
19	Higro 7-5-7					
20	Potassium Sulphate	75			159	159
21	Potash Gold 15-10-10	250				
22	Potash Gold 8-15-13					
23	20% Potash Gold Super					
24	35% Potash Gold Super					
25	55% Potash Gold Super	625			35	35
26	Dolomite					
27	Magnesium Oxide					
28	N-Rich Urea		242	312	107	107
29	Ammonium Sulphate					
30	Ammonium Sulphate Nitrate					
31	Calcium Ammonium Nitrate 27-0-0 (CAN)	175				
32	Cropmaster DAP					
33	Cropmaster 20					
34	Cropmaster 15				47	47
35	Cropmaster 13				191	191
36	DAP 13 S					
37	Ammo-Phos MAP	250				
38	Ammo-Phos/Hycrop 9-19-7					
39	Ammo-Phos/Hycrop 8-15-15					
40	Ammo-Phos/Hycrop 8-12-22				352	352
41	Nitrophoska 12-10-10					
42	Nitrophoska Blue TE 12-5-14					
43	Manganese Sulphate (Monohydrate)	8	8	11	8	8
44	Potassium Nitrate					
45						

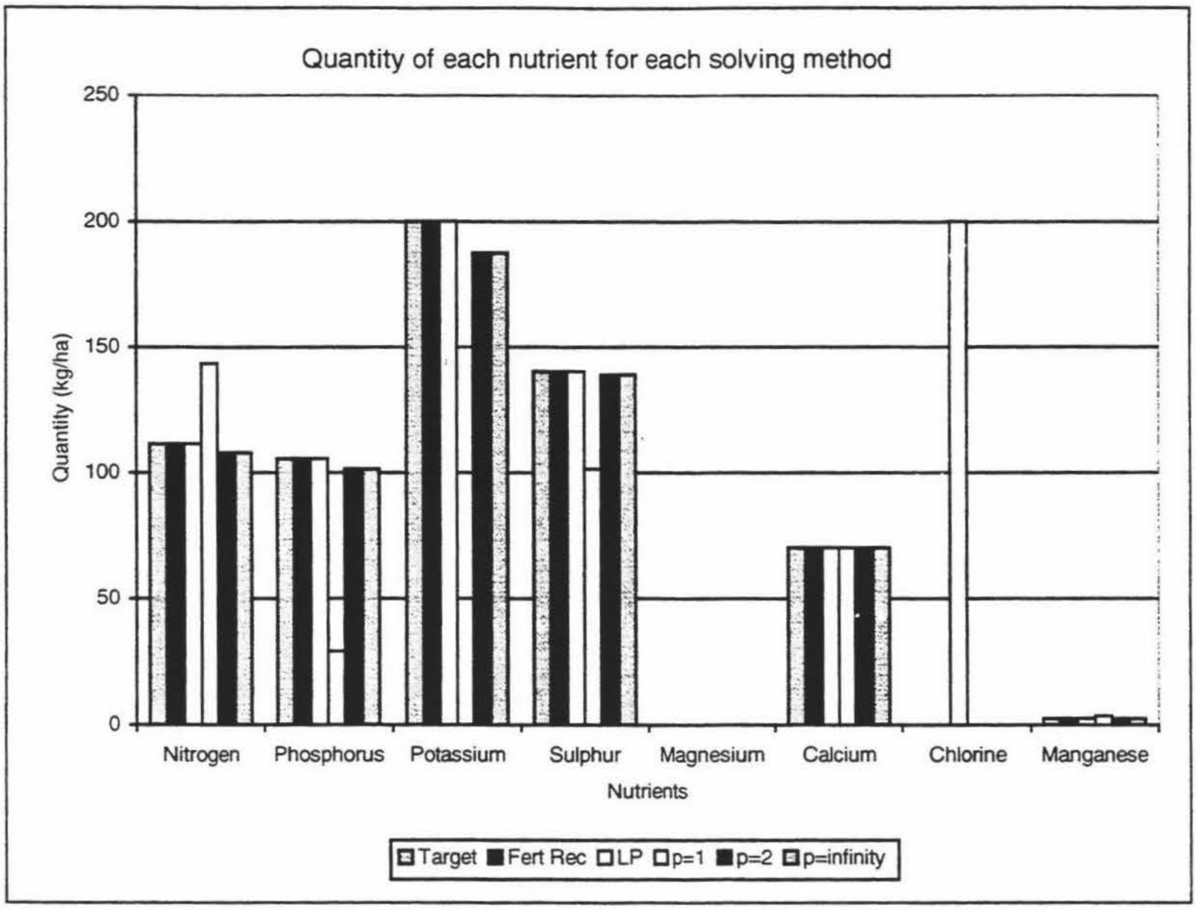
Nutrient usage (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Target	111.5	105.6	200.1	140.4	0.0	70.3	0.0	2.6
Fert Rec	111.5	105.6	200.1	140.4	0.0	70.3	0.0	2.6
LP	111.5	105.6	200.1	140.4	0.0	70.3	200.1	2.6
p=1	143.4	29.2	0.0	101.6	0.0	70.3	0.0	3.5
p=2	108.0	101.6	187.7	139.1	0.0	70.2	0.0	2.6
p=infinity	108.0	101.6	187.7	139.1	0.0	70.2	0.0	2.6

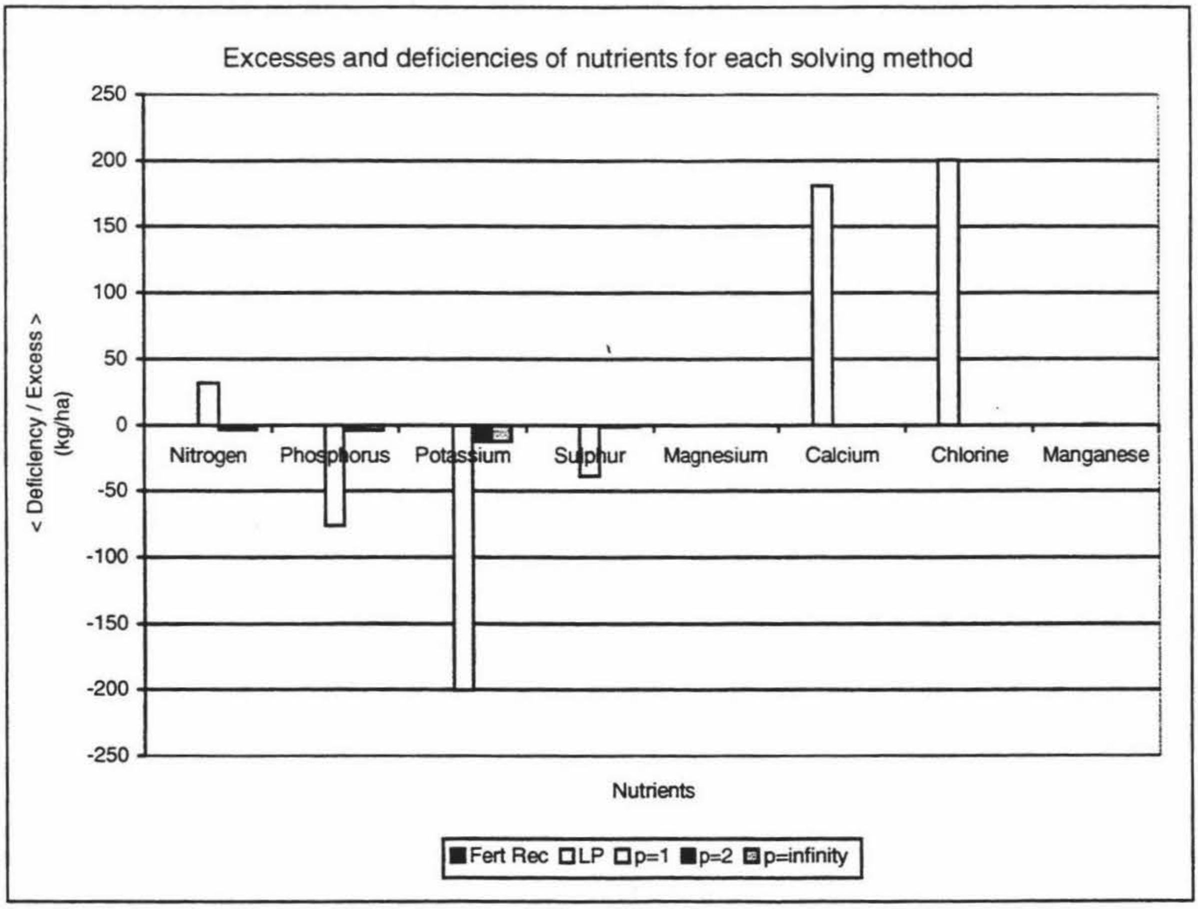
Nutrient excesses from target (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Fert Rec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LP	0.0	0.0	0.0	0.0	0.0	181.1	200.1	0.0
p=1	31.9	-76.4	-200.1	-38.8	0.0	0.0	0.0	0.1
p=2	-3.5	-4.0	-12.4	-1.4	0.0	0.0	0.0	0.0
p=infinity	-3.5	-4.0	-12.4	-1.4	0.0	0.0	0.0	0.0

Cost and weight of each fertiliser mix	Fert Rec	LP	p=1	p=2	p=infinity
Cost ($/ha)	606.78	432.76	219.98	484.74	484.74
Weight (Tonnes/ha)	1383.00	1685.61	667.35	1229.84	1229.84

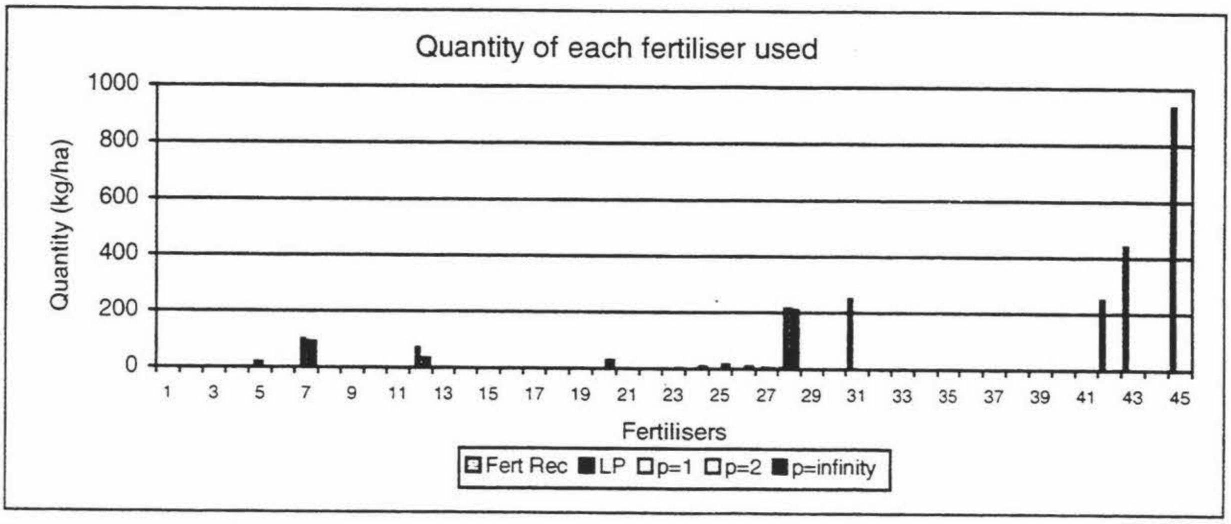





Quantity of each nutrient for each solving method
250
200
150
100
50
0
Quantity (kg/ha)
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Target
Fert Rec
LP
p=1
p=2
p=infinity


Excesses and deficiencies of nutrients for each solving method
250
200
150
100
50
0
-50
-100
-150
-200
-250
< Deficiency / Excess > (kg/ha)
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Fert Rec
LP
p=1
p=2
p=infinity

6.6. Consultant Two example three

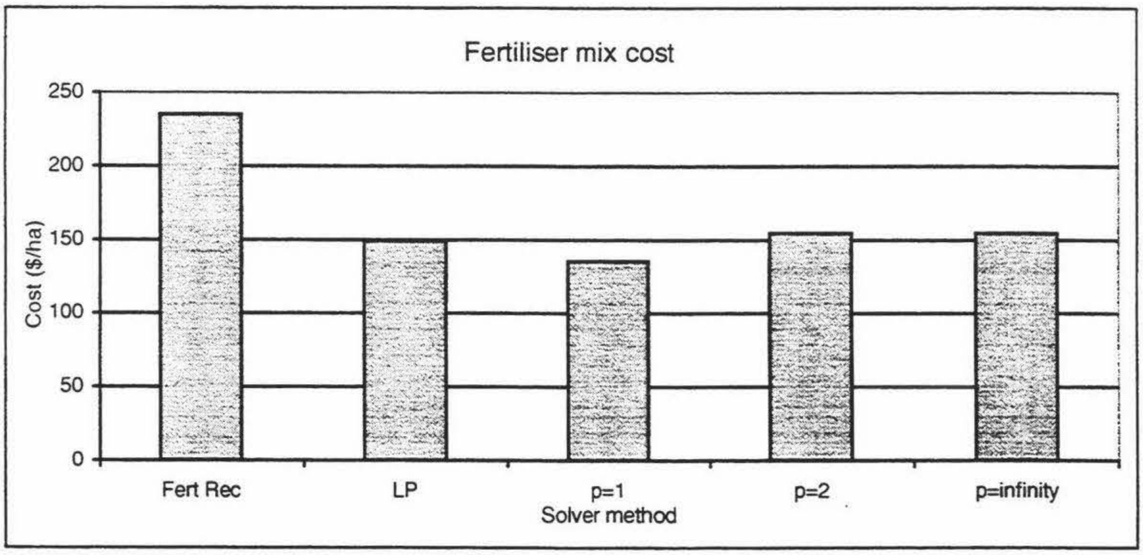


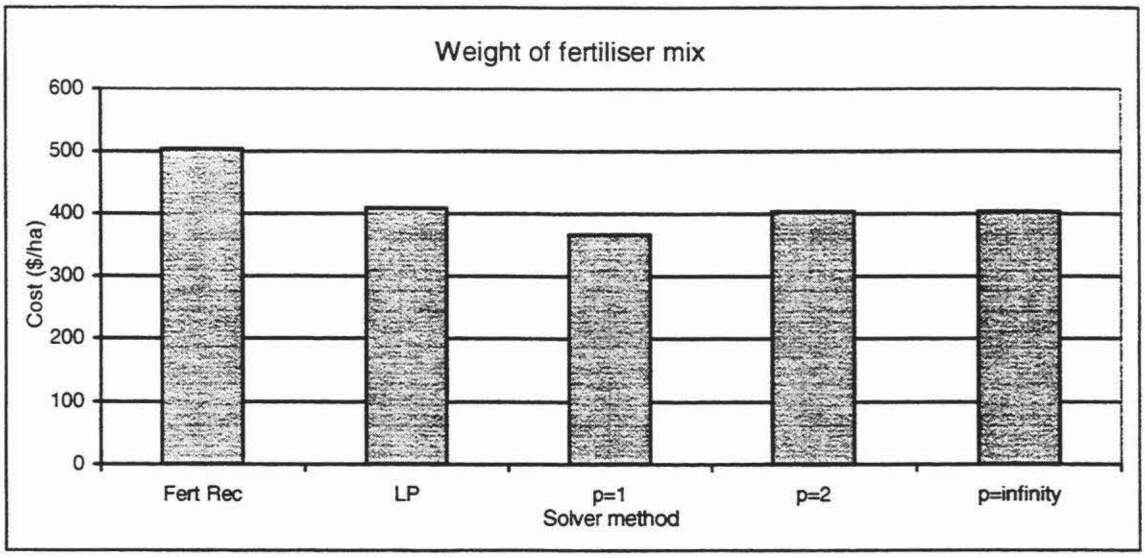
	Fertiliser	Fert Rec	LP	p=1	p=2	p=infinity
1	Superphosphate					
2	Magnesium Super					
3	Sulphur Super					
4	Sulphur Super Extra					
5	Maxi Sulphur Super		18	18		
6	TSP 15% S					
7	N C Reactive Rock		100	93	90	90
8	RPR 8 S					
9	RPR 11 S					
10	RPR 17 S					
11	RPR/Sulphur Super					
12	Potassium Chloride		70	35	35	35
13	15% Potash Super					
14	20% Potash Super					
15	30% Potash Super					
16	50% Potash Super					
17	15% Potash Sulphur Super					
18	30% Potash Sulphur Super					
19	Higro 7-5-7					
20	Potassium Sulphate				29	29
21	Potash Gold 15-10-10					
22	Potash Gold 8-15-13					
23	20% Potash Gold Super				3	3
24	35% Potash Gold Super				8	8
25	55% Potash Gold Super				15	15
26	Dolomite				10	10
27	Magnesium Oxide		5	5	3	3
28	N-Rich Urea	4	216	216	211	211
29	Ammonium Sulphate					
30	Ammonium Sulphate Nitrate					
31	Calcium Ammonium Nitrate 27-0-0 (CAN)	250				
32	Cropmaster DAP					
33	Cropmaster 20					
34	Cropmaster 15					
35	Cropmaster 13					
36	DAP 13 S					
37	Ammo-Phos MAP					
38	Ammo-Phos/Hycrop 9-19-7					
39	Ammo-Phos/Hycrop 8-15-15					
40	Ammo-Phos/Hycrop 8-12-22					
41	Nitrophoska 12-10-10					
42	Nitrophoska Blue TE 12-5-14	250				
43	Manganese Sulphate (Monohydrate)					
44	Potassium Nitrate					
45						

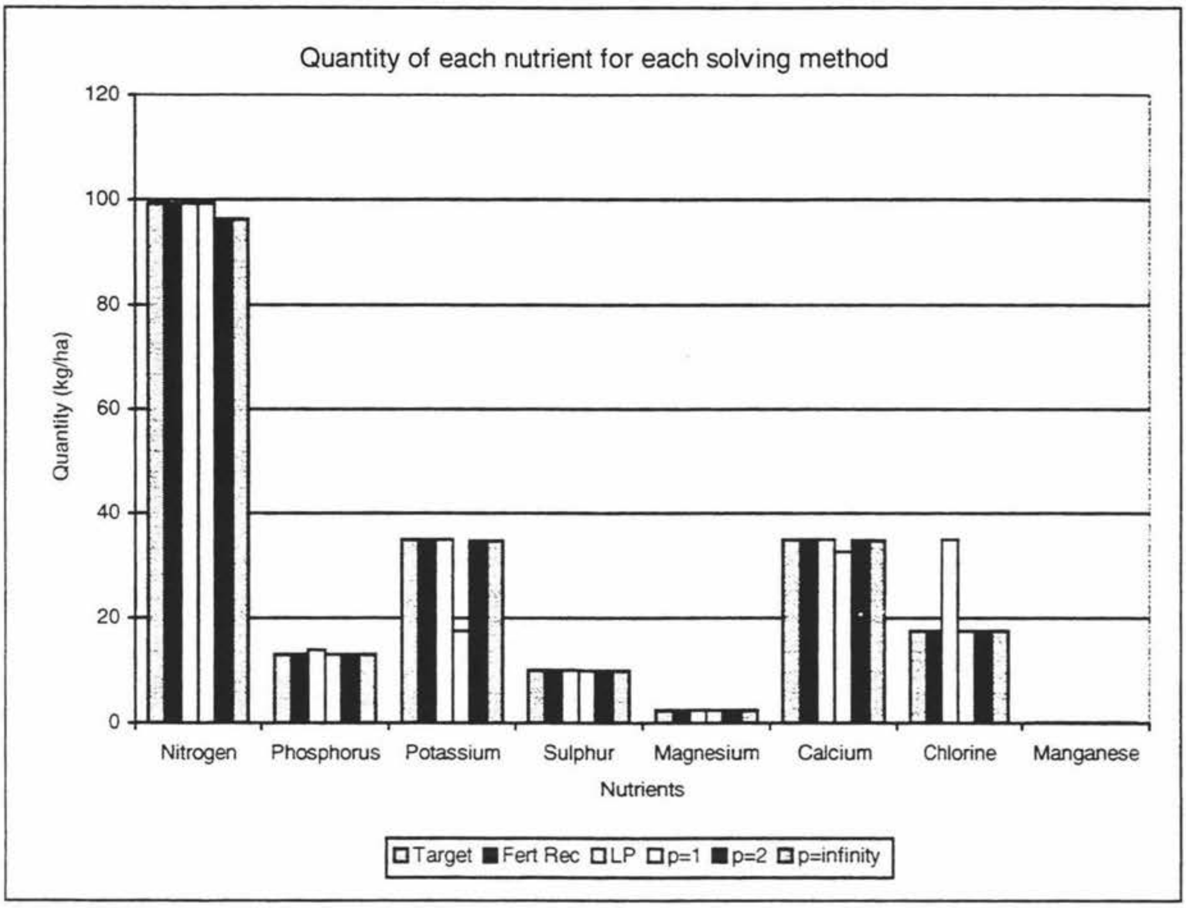
Nutrient usage (kg/ha)								
	N	P	K	S	Mg	Ca	Cl	Mn
Target	99.3	13.0	35.0	10.1	2.5	35.0	17.5	0.1
Fert Rec	99.3	13.0	35.0	10.1	2.5	35.0	17.5	0.1
LP	99.3	13.9	35.0	10.1	2.5	35.0	35.0	0.1
p=1	99.3	13.0	17.5	10.0	2.5	32.6	17.5	0.1
p=2	96.3	13.0	34.7	10.0	2.5	34.8	17.5	0.1
p=infinity	96.3	13.0	34.7	10.0	2.5	34.8	17.5	0.1

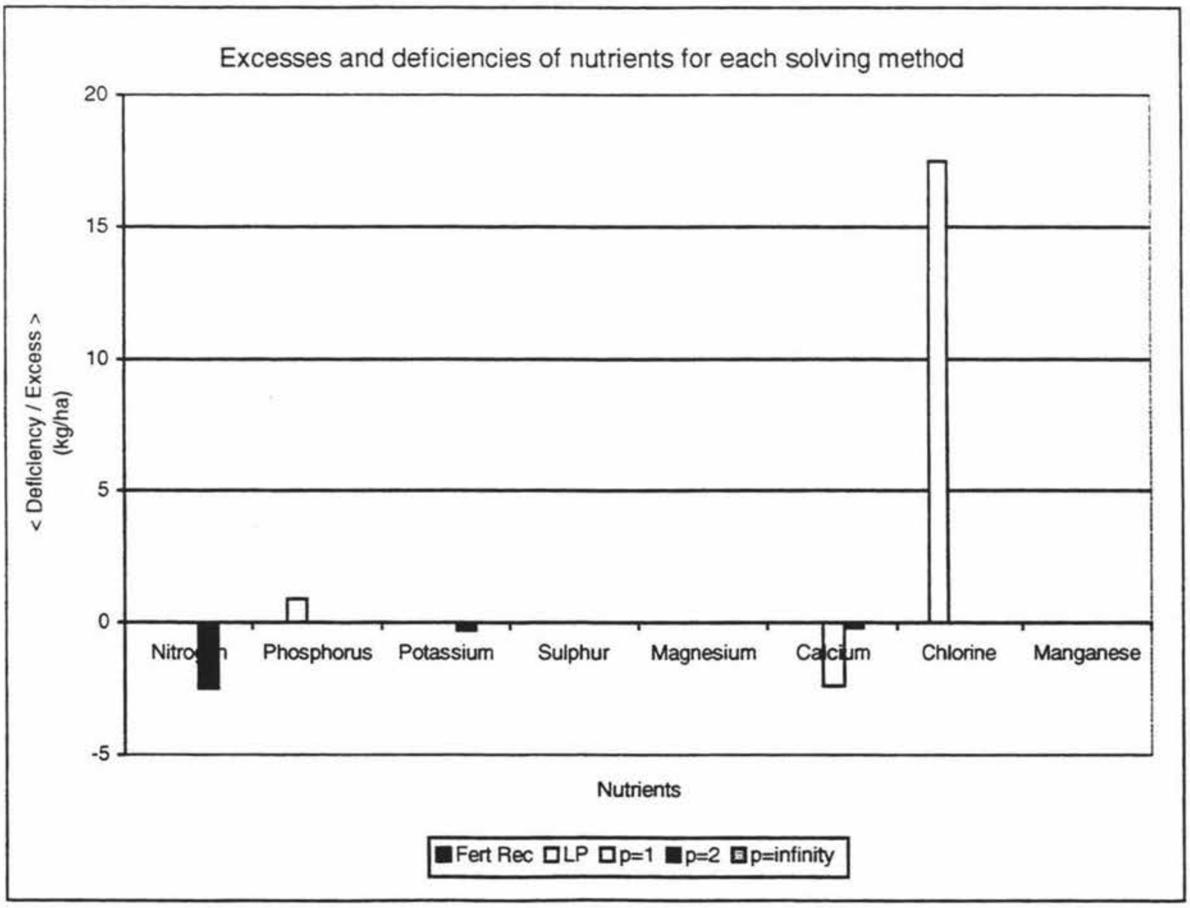
Nutrient excesses from target (kg/ha)								
	N	P	K	S	Mg	Ca	Cl	Mn
Fert Rec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LP	0.0	0.9	0.0	0.0	0.0	0.0	17.5	0.0
p=1	0.0	0.0	0.0	0.0	0.0	-2.4	0.0	0.0
p=2	-2.5	0.0	-0.3	0.0	0.0	-0.2	0.0	0.0
p=infinity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Cost and weight of each fertiliser mix					
	Fert Rec	LP	p=1	p=2	p=infinity
Cost ($/ha)	235.48	149.25	135.85	154.78	154.78
Weight (Tonnes/ha)	504.40	409.22	367.15	403.79	403.79

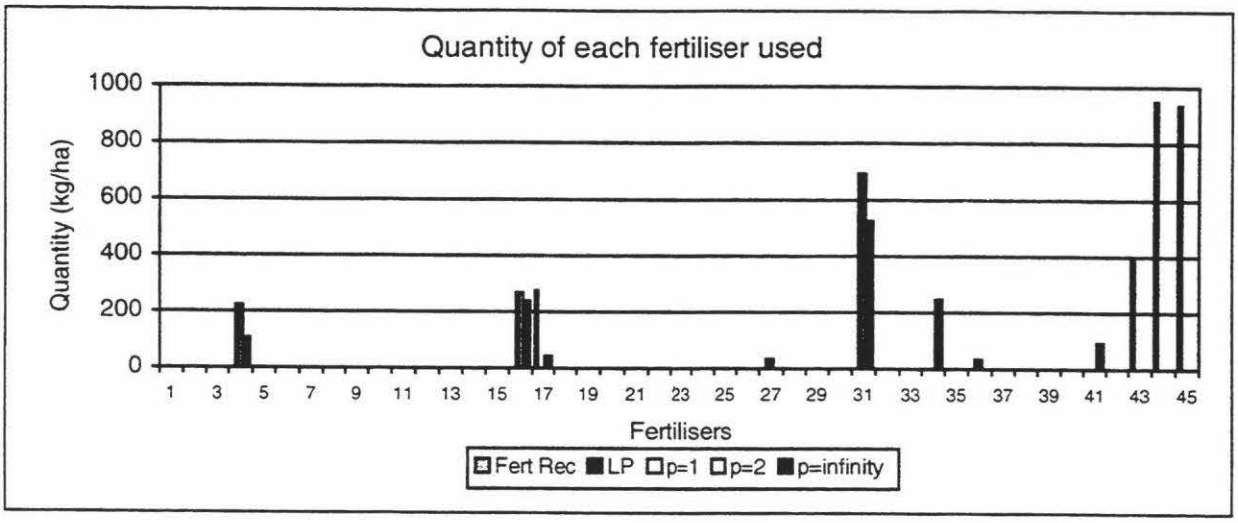





Quantity of each nutrient for each solving method
120
100
80
60
40
20
0
Quantity (kg/ha)
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Target
Fert Rec
LP
p=1
p=2
p=infinity


Excesses and deficiencies of nutrients for each solving method
20
15
10
5
0
-5
< Deficiency / Excess >
(kg/ha)
Phosphorus
Potassium
Sulphur
Magnesium
Chlorine
Manganese
Nutrients
Fert Rec
LP
p=1
p=2
p=infinity

6.7. Consultant Three example one

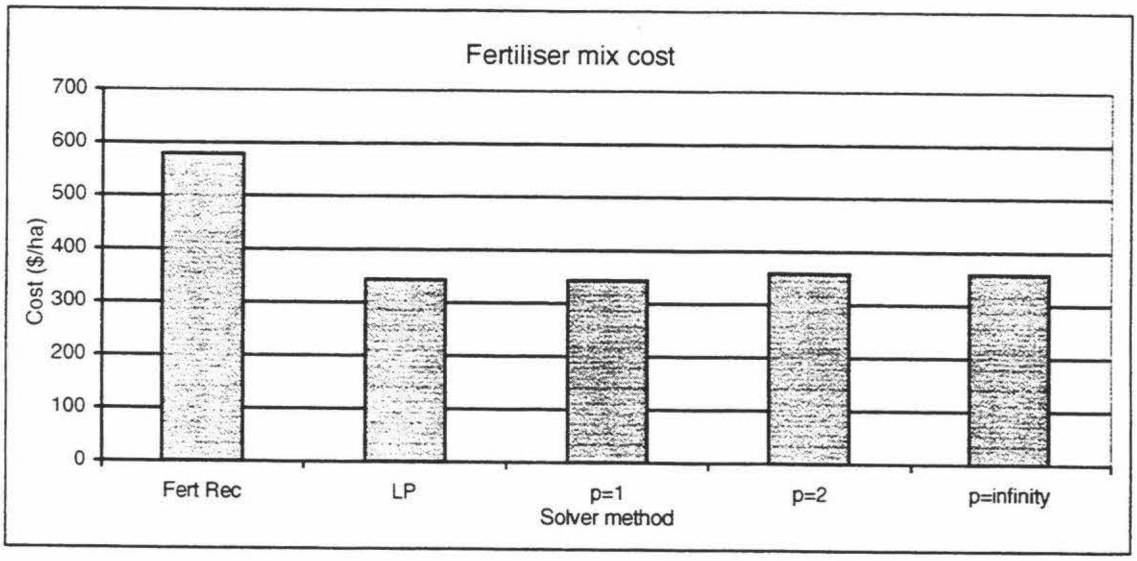


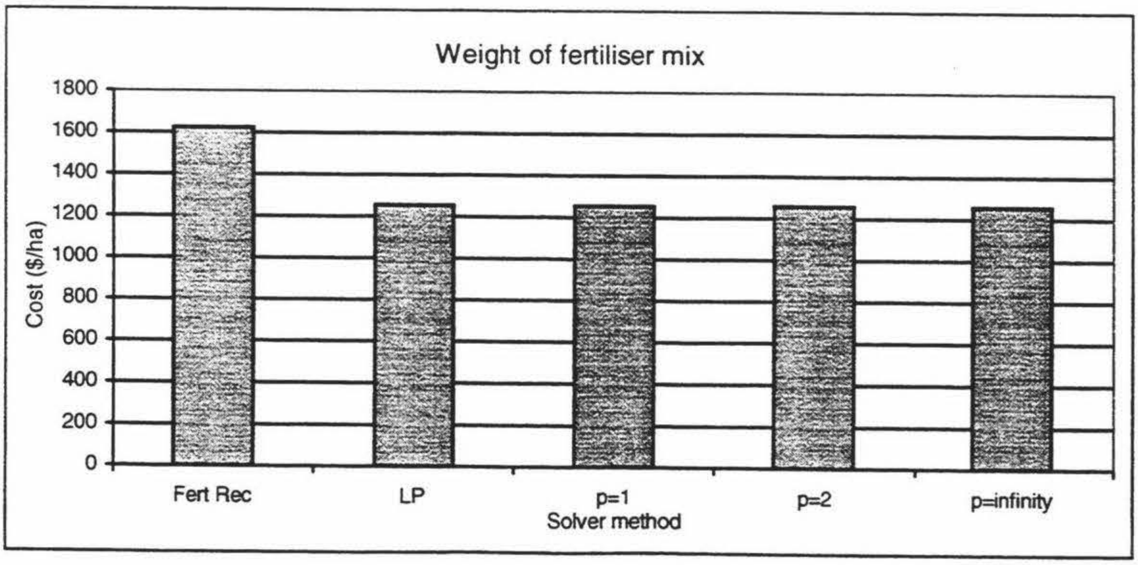
	Fertiliser	Fert Rec	LP	p=1	p=2	p=infinity
1	Superphosphate					
2	Super Plus					
3	Triple Super					
4	Reactive Rock		224	224	106	106
5	Reactive Rock + S					
6	15% Potash Super					
7	20% Potash Super					
8	30% Potash Super					
9	50% Potash Super					
10	20% Potash Super Plus					
11	15% Potash RPR					
12	30% Potash RPR					
13	Muraite of Potash					
14	Sulphate of Potash Bagged					
15	Sulphate of Amonia					
16	N-Rich Urea Bulk		269	269	240	240
17	Calcium Ammonium Nitrate	275			43	43
18	Nitrophoska Blue Bagged					
19	Nitrophoska Blue 12-10-10 Bagged					
20	Ammo-Phos/Hycrop 9-18-7					
21	Ammo-Phos/Hycrop 8-14-16					
22	Sulphur Super					
23	15% Potash Sulphur Super					
24	30% Potash Sulphur Super					
25	50% Potash Sulphur Super					
26	Durasul					
27	Sulphur Super 30		35	35		
28	Serpentine Super					
29	15% Potash Serpentine Super					
30	30% Potash Serpentine Super					
31	50% Potash Serpentine Super		692	692	526	526
32	Magphos					
33	15% Potash Magphos					
34	30% Potash Magphos				249	249
35	Granmag					
36	Magnox		34	34		
37	Crop Fertiliser					
38	Ammoniated Super					
39	DAP					
40	DAP Sulphur Super					
41	Dolomite				93	93
42	Magnesium Sulphate (Kieserite)					
43	Kiwifruit special mix	400				
44	Hycane base mix	950				
45	Coromandel base mix					

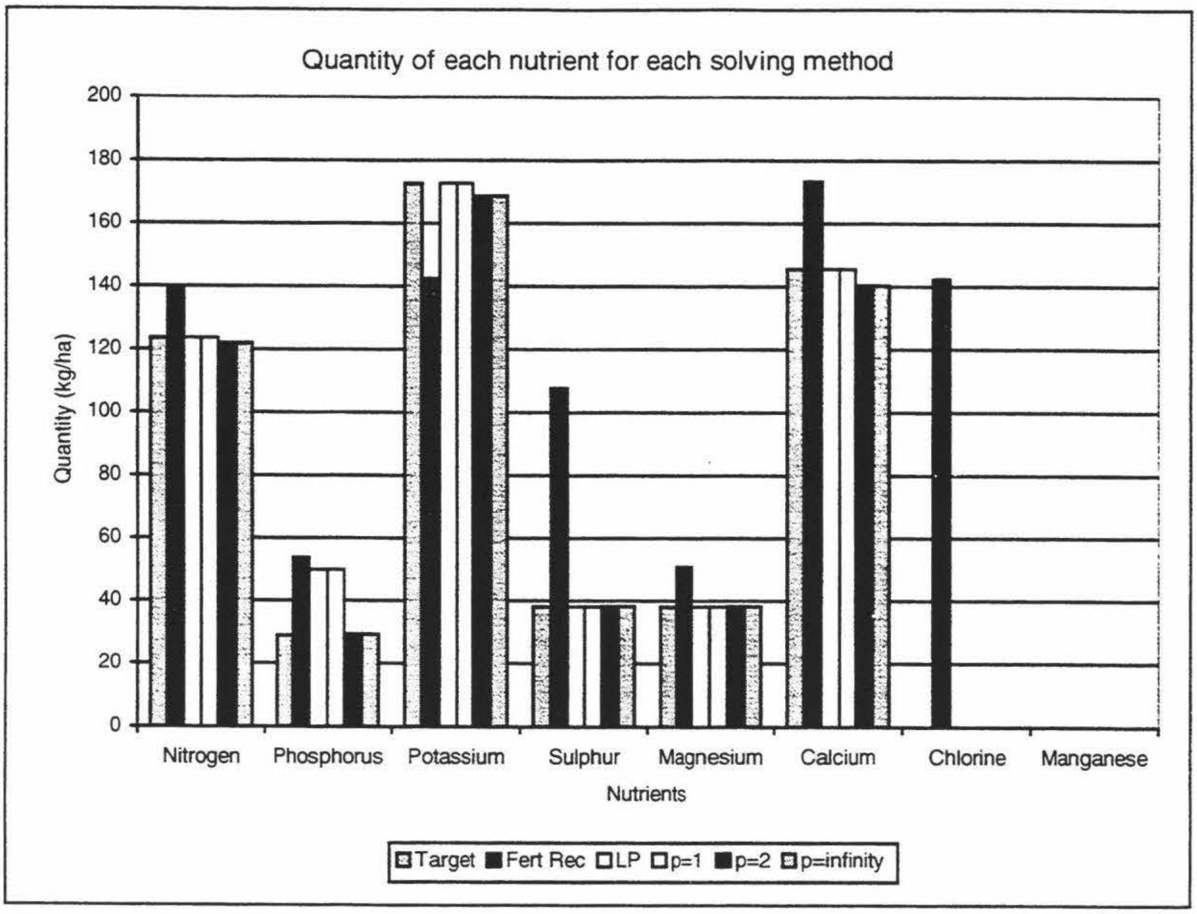
Nutrient usage (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Target	123.8	29.1	172.9	38.2	38.2	145.6	0.0	0.0
Fert Rec	139.1	53.7	142.5	107.8	50.9	173.4	142.5	0.0
LP	123.8	49.9	172.9	38.2	38.2	145.6	0.0	0.0
p=1	123.8	49.9	172.9	38.2	38.2	145.6	0.0	0.0
p=2	122.0	29.5	168.8	38.5	38.5	140.5	0.0	0.0
p=infinity	122.0	29.5	168.8	38.5	38.5	140.5	0.0	0.0

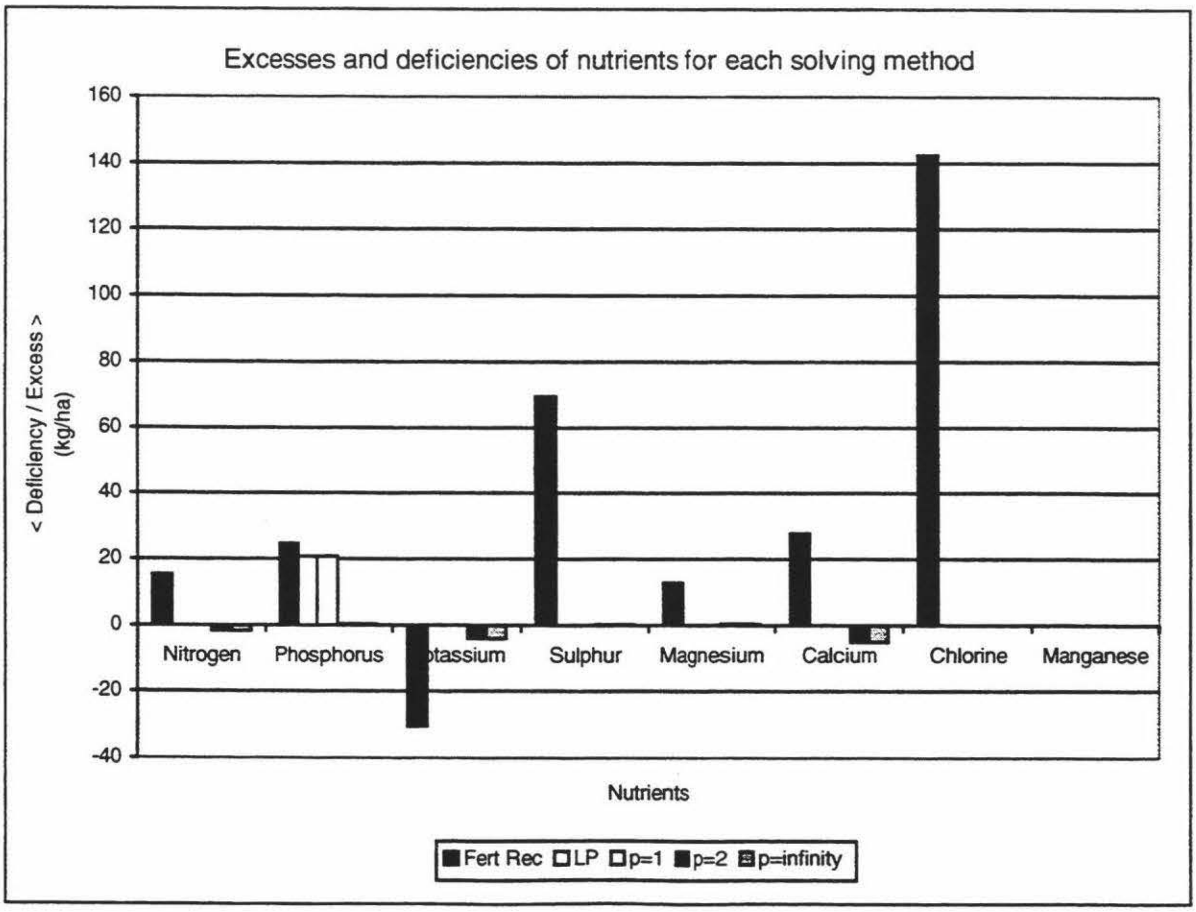
Nutrient excesses from target (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Fert Rec	15.3	24.6	-30.4	69.5	12.7	27.8	142.5	0.0
LP	0.0	20.8	0.0	0.0	0.0	0.0	0.0	0.0
p=1	0.0	20.8	0.0	0.0	0.0	0.0	0.0	0.0
p=2	-1.8	0.4	-4.1	0.2	0.3	-5.1	0.0	0.0
p=infinity	-1.8	0.4	-4.1	0.2	0.3	-5.1	0.0	0.0

Cost and weight of each fertiliser mix	Fert Rec	LP	p=1	p=2	p=infinity
Cost ($/ha)	578.44	344.09	344.09	358.20	358.20
Weight (Tonnes/ha)	1625.00	1254.56	1254.56	1256.95	1256.95

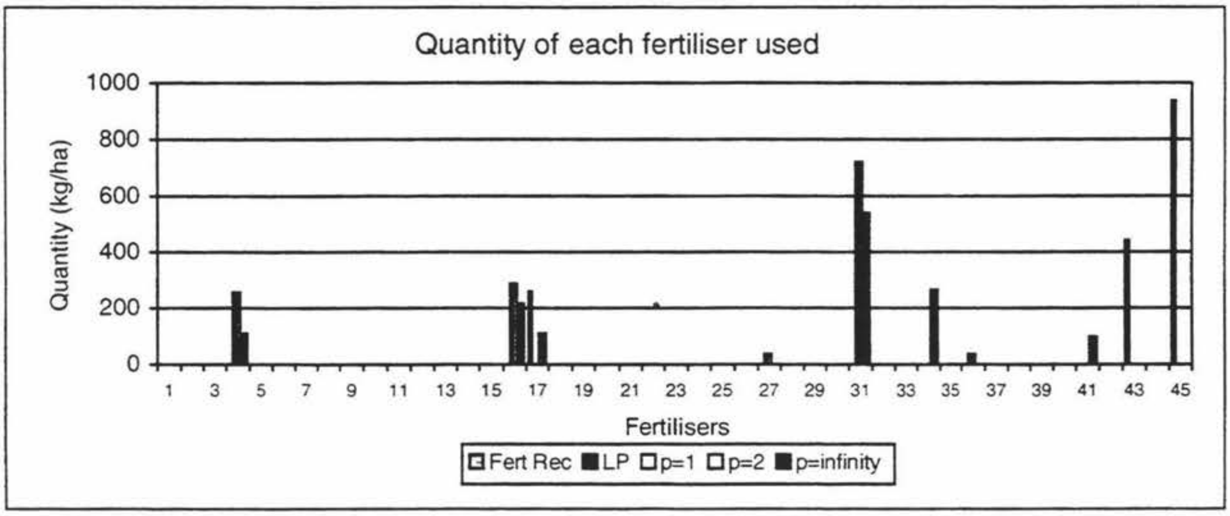





Quantity of each nutrient for each solving method
Quantity (kg/ha)
200
180
160
140
120
100
80
60
40
20
0
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Target
Fert Rec
LP
p=1
p=2
p=infinity


Excesses and deficiencies of nutrients for each solving method
< Deficiency / Excess >
(kg/ha)
160
140
120
100
80
60
40
20
0
-20
-40
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Fert Rec
LP
p=1
p=2
p=infinity

6.8. Consultant Three example two

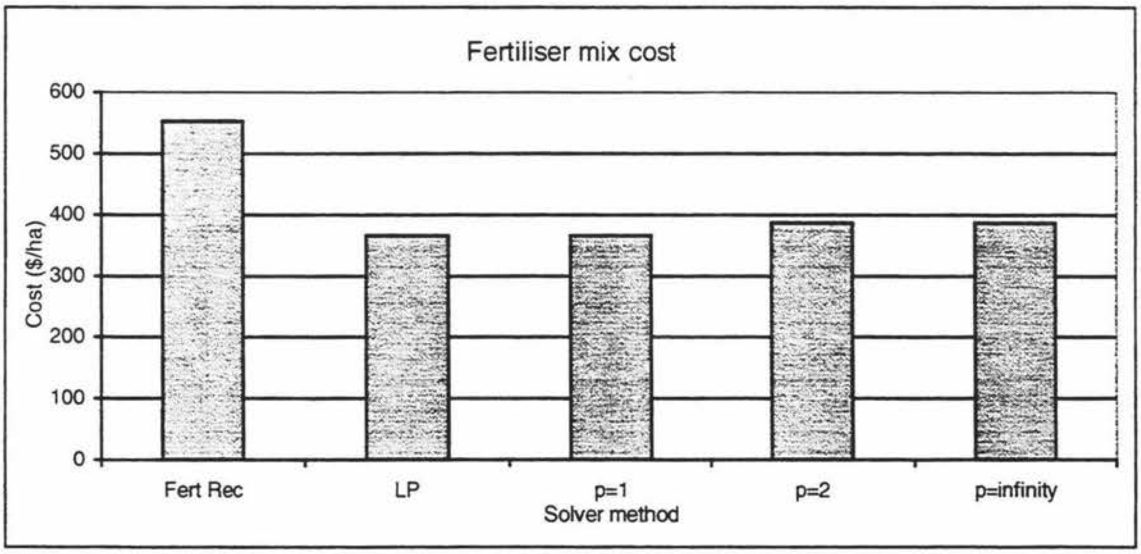


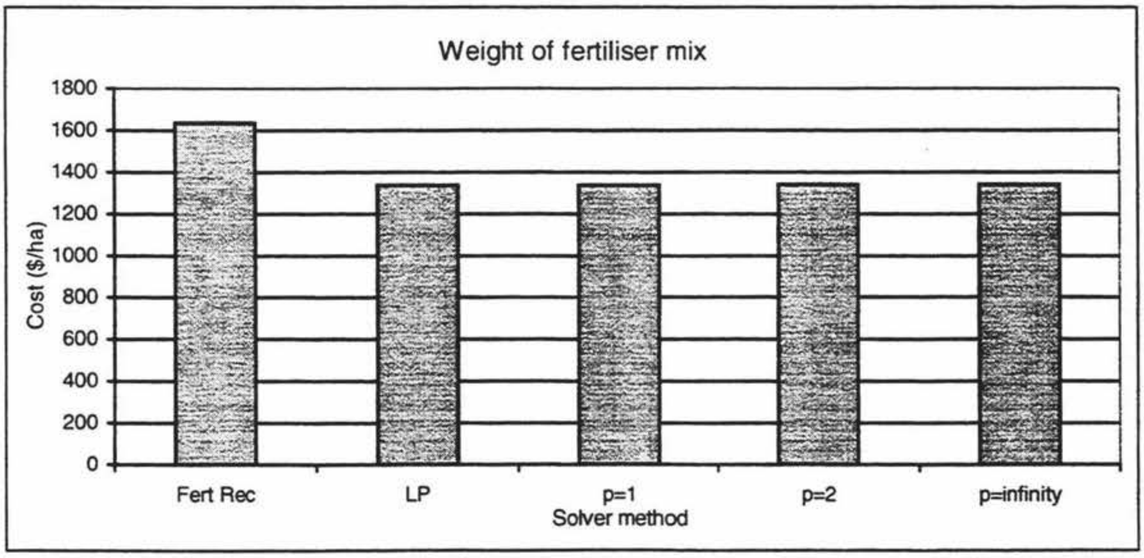
	Fertiliser	Fert Rec	LP	p=1	p=2	p=infinity
1	Superphosphate					
2	Super Plus					
3	Triple Super					
4	Reactive Rock		258	258	110	110
5	Reactive Rock + S					
6	15% Potash Super					
7	20% Potash Super					
8	30% Potash Super					
9	50% Potash Super					
10	20% Potash Super Plus					
11	15% Potash RPR					
12	30% Potash RPR					
13	Muraite of Potash					
14	Sulphate of Potash Bagged					
15	Sulphate of Amonia					
16	N-Rich Urea Bulk		287	287	217	217
17	Calcium Ammonium Nitrate	260			109	109
18	Nitrophoska Blue Bagged					
19	Nitrophoska Blue 12-10-10 Bagged					
20	Ammo-Phos/Hycrop 9-18-7					
21	Ammo-Phos/Hycrop 8-14-16					
22	Sulphur Super					
23	15% Potash Sulphur Super					
24	30% Potash Sulphur Super					
25	50% Potash Sulphur Super					
26	Durasul					
27	Sulphur Super 30		37	37		
28	Serpentine Super					
29	15% Potash Serpentine Super					
30	30% Potash Serpentine Super					
31	50% Potash Serpentine Super		720	720	539	539
32	Magphos					
33	15% Potash Magphos					
34	30% Potash Magphos				266	266
35	Granmag					
36	Magnox		36	36		
37	Crop Fertiliser					
38	Ammoniated Super					
39	DAP					
40	DAP Sulphur Super					
41	Dolomite				99	99
42	Magnesium Sulphate (Kieserite)					
43	Kiwifruit special mix	442				
44	Hycane base mix					
45	Coromandel base mix	936				

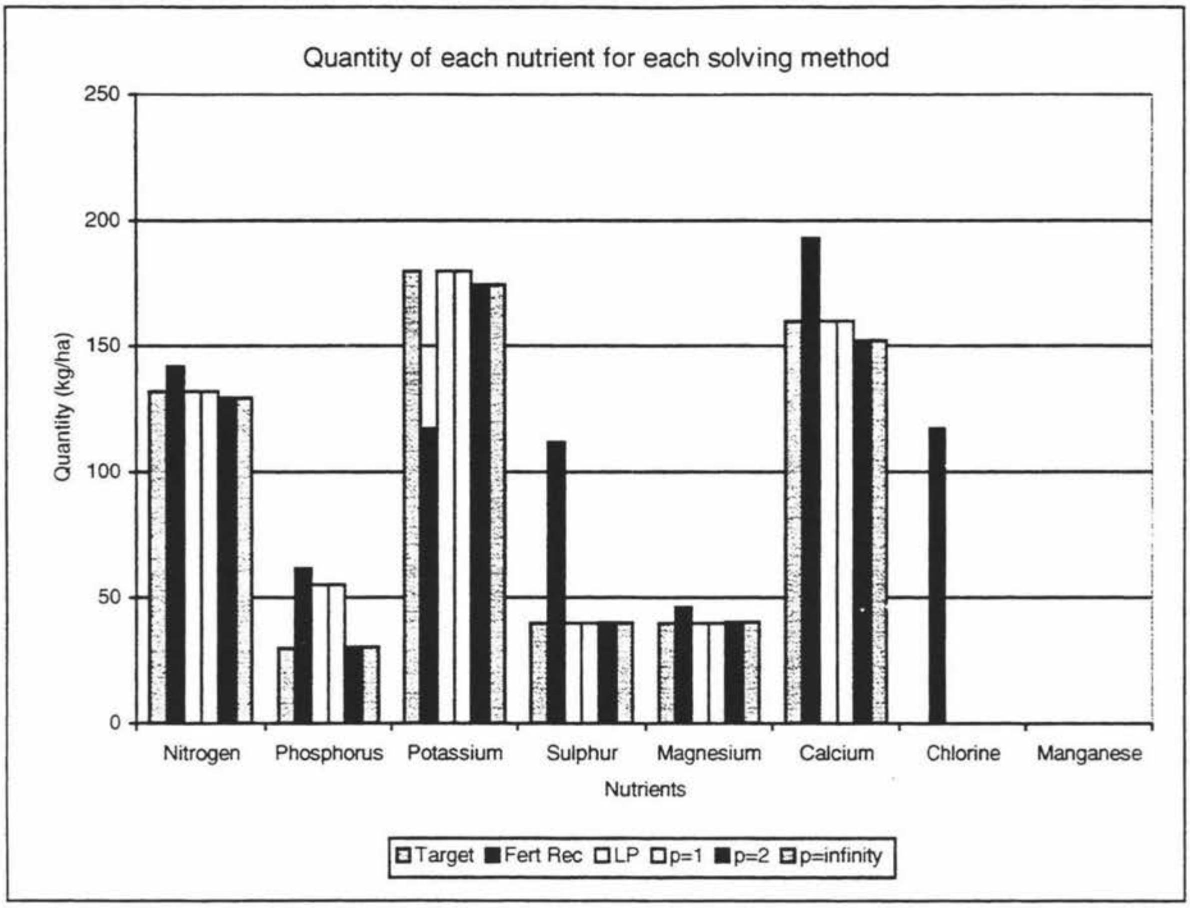
Nutrient usage (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Target	132.0	30.0	180.0	40.0	40.0	160.0	0.0	0.0
Fert Rec	141.8	61.6	117.0	111.7	46.3	193.0	117.0	0.0
LP	132.0	55.1	180.0	40.0	40.0	160.0	0.0	0.0
p=1	132.0	55.1	180.0	40.0	40.0	160.0	0.0	0.0
p=2	129.4	30.5	174.7	40.2	40.4	152.2	0.0	0.0
p=infinity	129.4	30.5	174.7	40.2	40.4	152.2	0.0	0.0

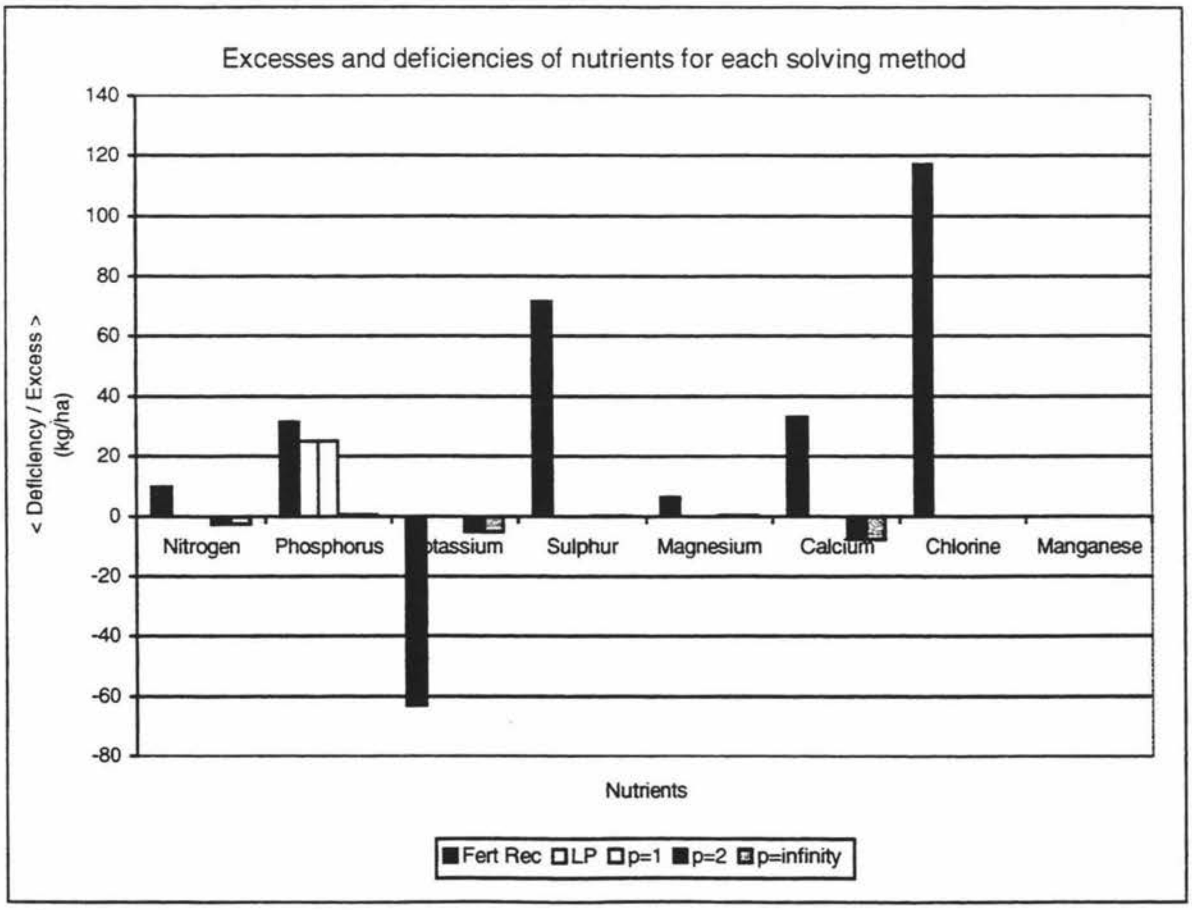
Nutrient excesses from target (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Fert Rec	9.8	31.6	-63.0	71.7	6.3	33.0	117.0	0.0
LP	0.0	25.1	0.0	0.0	0.0	0.0	0.0	0.0
p=1	0.0	25.1	0.0	0.0	0.0	0.0	0.0	0.0
p=2	-2.6	0.5	-5.3	0.2	0.4	-7.8	0.0	0.0
p=infinity	-2.6	0.5	-5.3	0.2	0.4	-7.8	0.0	0.0

Cost and weight of each fertiliser mix	Fert Rec	LP	p=1	p=2	p=infinity
Cost ($/ha)	553.66	365.63	365.63	386.53	386.53
Weight (Tonnes/ha)	1638.00	1338.41	1338.41	1341.36	1341.36

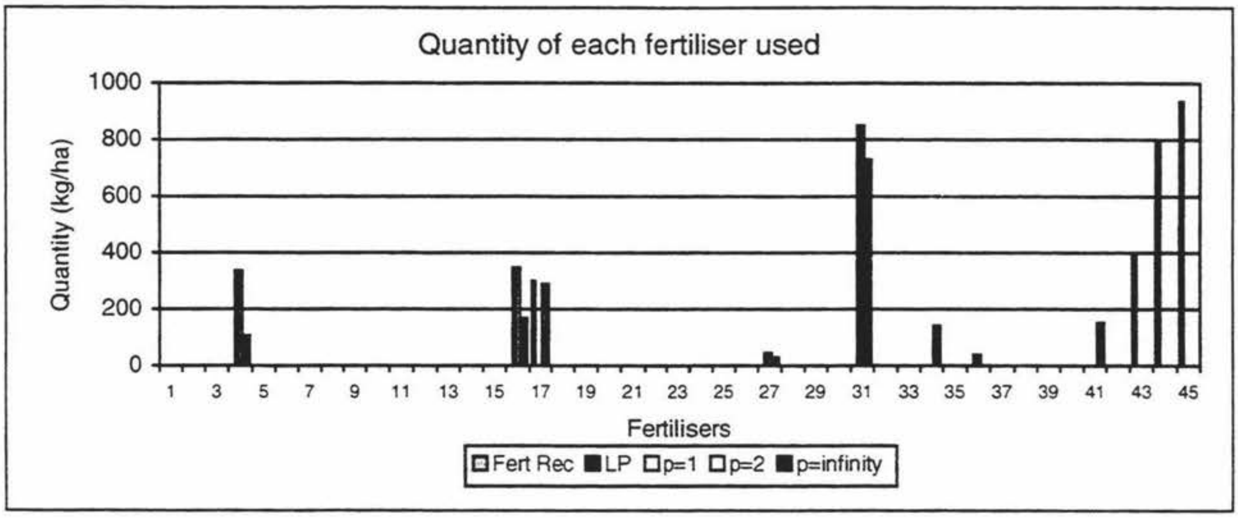





Quantity of each nutrient for each solving method
Quantity (kg/ha)
250
200
150
100
50
0
Nitrogen
Phosphorus
Potassium
Sulphur
Magnesium
Calcium
Chlorine
Manganese
Nutrients
Target
Fert Rec
LP
p=1
p=2
p=infinity


Excesses and deficiencies of nutrients for each solving method
< Deficiency / Excess >
(kg/ha)
140
120
100
80
60
40
20
0
-20
-40
-60
-80
Nitrogen
Phosphorus
Sulphur
Magnesium
Chlorine
Manganese
Nutrients
Fert Rec
LP
p=1
p=2
p=infinity

6.9. Consultant Three example three



	Fertiliser	Fert Rec	LP	p=1	p=2	p=infinity
1	Superphosphate					
2	Super Plus					
3	Triple Super					
4	Reactive Rock		337	337	108	108
5	Reactive Rock + S					
6	15% Potash Super					
7	20% Potash Super					
8	30% Potash Super					
9	50% Potash Super					
10	20% Potash Super Plus					
11	15% Potash RPR					
12	30% Potash RPR					
13	Muraite of Potash					
14	Sulphate of Potash Bagged					
15	Sulphate of Amonia					
16	N-Rich Urea Bulk		348	348	168	168
17	Calcium Ammonium Nitrate	300			290	290
18	Nitrophoska Blue Bagged					
19	Nitrophoska Blue 12-10-10 Bagged					
20	Ammo-Phos/Hycrop 9-18-7					
21	Ammo-Phos/Hycrop 8-14-16					
22	Sulphur Super					
23	15% Potash Sulphur Super					
24	30% Potash Sulphur Super					
25	50% Potash Sulphur Super					
26	Durasul					
27	Sulphur Super 30		45	45	29	29
28	Serpentine Super					
29	15% Potash Serpentine Super					
30	30% Potash Serpentine Super					
31	50% Potash Serpentine Super		850	850	729	729
32	Magphos					
33	15% Potash Magphos					
34	30% Potash Magphos				142	142
35	Granmag					
36	Magnox		38	38		
37	Crop Fertiliser					
38	Ammoniated Super					
39	DAP					
40	DAP Sulphur Super					
41	Dolomite				152	152
42	Magnesium Sulphate (Kieserite)					
43	Kiwifruit special mix	400				
44	Hycane base mix	800				
45	Coromandel base mix					

Nutrient usage (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Target	160.0	35.0	212.5	47.5	45.0	200.0	0.0	0.0
Fert Rec	145.8	46.8	120.0	94.4	44.0	158.4	120.0	0.0
LP	160.0	69.3	212.5	47.5	45.0	200.0	0.0	0.0
p=1	160.0	69.3	212.5	47.5	45.0	200.0	0.0	0.0
p=2	155.4	35.9	203.5	47.8	45.7	184.8	0.0	0.0
p=infinity	155.4	35.9	203.5	47.8	45.7	184.8	0.0	0.0

Nutrient excesses from target (kg/ha)	N	P	K	S	Mg	Ca	Cl	Mn
Fert Rec	-14.2	11.8	-92.5	46.9	-1.0	-41.6	120.0	0.0
LP	0.0	34.3	0.0	0.0	0.0	0.0	0.0	0.0
p=1	0.0	34.3	0.0	0.0	0.0	0.0	0.0	0.0
p=2	-4.6	0.9	-9.0	0.3	0.7	-15.2	0.0	0.0
p=infinity	-4.6	0.9	-9.0	0.3	0.7	-15.2	0.0	0.0

Cost and weight of each fertiliser mix	Fert Rec	LP	p=1	p=2	p=infinity
Cost ($/ha)	541.86	439.30	439.30	475.37	475.37
Weight (Tonnes/ha)	1500.00	1617.83	1617.83	1617.79	1617.79