SOIL MANAGEMENT IN VEGETABLE GARDENS IN THE EASTERN FREE STATE AND ITS IMPACT ON SUSTAINABLE PRODUCTION

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SOIL MANAGEMENT IN VEGETABLE GARDENS IN THE EASTERN FREE STATE AND ITS IMPACT ON SUSTAINABLE PRODUCTION

by

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DECLARATION

I, Griffith Petrus Hadebe, declare that the dissertation herewith submitted for the degree of Master of Technology (Agriculture) at the Technikon Free State, has not previously submitted by me for a degree at any other university or institution of higher learning.

Signature..

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SUMMARY

The Free State Province has a population of about 2.9 million people (7% of the national population), growing at 1.5% per annum, with a density of 22 persons per km². Before 1994, agricultural research and development efforts in South Africa were focused mainly on commercial farmers, neglecting small-scale farmers to a large extent. The challenge now lies in redirecting research and development, as well as extension efforts, to include this new clientele. The areas requiring attention include vegetable gardens in urban and peri-urban areas, small farmers, community farmers and reserve settlement areas (Saunderson, 1995:165-165). This study investigates the vegetable farming practices of small-scale farmers in the Eastern Free State. A questionnaire survey was administered to 30 randomly selected small-scale vegetable farmers. In addition, trials using carrots and potatoes were also conducted in two locations (Mpho and Leratong) to assess the impact of soil compaction on the preparation of seed-beds for vegetable crops.

The demographic information collected indicated that the average age of farmers engaged in vegetable farming was 53 years. Most of the respondents (21%) were in the age group 60 to 69 years. Most of the farmers had occupied the land for less than six years. With regard to the different farming activities described, 58.6% of the farmers had some experience related to agriculture. Of the farmers, 48% had a qualification lower than grade seven. The average size of land allocated for vegetable farming was 3 ha. Of the respondents, 86% planted their vegetable crops in seed-beds, while the rest made no use of seed-beds. Land resting was practised by 69% of the farmers studied. The majority of the farmers (41%) irrigated their vegetable crop once per day. Mulching was not practised widely by the farmers interviewed. Farmers also indicated that they applied salt to vegetable seedbeds for moisture retention. Based on this information, soil samples were collected from non-salted, recently salted and old salted soils and measured for bulk density and porosity percentage. However, there were no significant differences with regard to both bulk density and porosity percentage between the three soil types measured.

There were no significant differences with regard to carrot length, diameter and mass between the two locations studied. The carrots from the loosened seedbeds were significantly longer (1.7 cm) than the carrots from the compacted seed-beds, while the differences with regard to carrot diameter and mass were not significant. Location as well as compaction had no influence on the mass of the potatoes harvested. In conclusion, this study shows that farmers need training in soil management and modern vegetable production techniques.

OPSOMMING

GRONDBESTUUR IN GROENTETUINE IN DIE OOS-VRYSTAAT EN DIE INVLOED DAARVAN OP VOLHOUBARE PRODUKSIE

Die Vrystaat Provinsie het 'n bevolking van ongeveer 2.9 miljoen mense (7% van die nasionale bevolking), wat teen 1.5 % per jaar groei, met 'n digtheid van 22 persone per km^2. Vóór 1994 was landbounavorsing en ontwikkelingspogings in Suid-Afrika grootliks gefokus op kommersiële boere, terwyl kleinskaalse boere in 'n aansienlike mate verwaarloos is. Die uitdaging lê nou daarin om navorsing en ontwikkeling sowel as uitbreidingspogings in 'n nuwe rigting te stuur om hierdie nuwe kliënte in te sluit. Dit is veral groentetuine in stedelike en buitestedelike gebiede, kleinboere, kommunale boere en nedersettingsgebiede in reservate wat aandag benodig (Saunderson, 1995:165). Hierdie studie ondersoek die bestuurspraktyke van kleinskaalse groenteboere in die Oos-Vrystaat. 'n Opname m.b.v. 'n vraelys is onder 30 kleinskaalse groenteboere, wat ewekansig geselekteer is, gedoen. Proefnemings met wortels en aartappels op twee persele by Mpho en Leratong is ook uitgevoer ten einde die invloed van grondkompaksie op die voorbereiding van saadbeddings vir die aanplant van groente te bepaal.

Die demografiese inligting wat ingesamel is, dui aan dat die gemiddelde ouderdom van groenteboere 53 jaar was. Die grootste groep respondente (21%) was in die ouderdomsgroep 60 tot 69 jaar. Die meeste van die boere het die grond vir minder as ses jaar bewoon. 'n Beduidende aantal respondente (58.6 %) het oor die een of ander vorm van landbouverwante ondervinding beskik. 'n Groot aantal boere (48%) het nie graad sewe voltooi nie. Die gemiddelde grootte van groenteplase was 3 ha. Ses en tagtig persent van die respondente het hulle groente in saadbeddings geplant, terwyl die ander respondente nie van saadbeddings gebruik gemaak het nie. Die braak lê van grond is deur 69 % van die boere toegepas. 'n Groot aantal boere (41%) het hulle groentegewasse een maal per dag besproei en grondbedekking (bv. met strooi) is deur baie min boere gebruik. Boere het ook aangedui dat hulle sout toedien met die oog op waterretensie. Gebaseer op hierdie inligting is grondmonsters van nie-gesoute beddings, onlangs gesoute beddings en ou gesoute beddings geneem en getoets vir massadigtheid en persentasie poreusheid. Daar was geen betekenisvolle onderlinge verskille tussen die drie grondtipes wat getoets is met betrekking tot beide massadigtheid en die mate van poreusheid nie.

Daar was geen beduidende onderlinge verskil met betrekking tot die lengte, deursnee en massa van die wortels in die twee areas wat bestudeer is nie. Die wortels uit die los saadbedding was beduidend langer (1.7 cm) as die wortels uit die kompakte saadbedding, terwyl die verskille ten opsigte van worteldeursnee en –massa nie beduidend was nie. Die area sowel as die kompaktheid van die grond het geen invloed op aartappelmassa gehad nie. Die studie het bevind dat boere 'n groot behoefte aan opleiding in grondbestuur en moderne groenteproduksietegnieke het.

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INTRODUCTION

1.1 BACKGROUND

The Free State Province has a population of about 2.9 million people (7% of the national population), with a growth rate of 1.5% per annum and a density of 22 persons per km². The province's contribution to the national economy has declined by 7% since 1970. In 1997 vegetables contribute only 6% to the economy, whereas wheat contributed 50% (Venter, Du Toit and Bunyasi, 1997:14). Vegetable production is influenced by a large number of factors, including soil, climate, markets and the availability of water. Before 1994, agricultural research and development efforts in South Africa focused mainly on commercial farmers, neglecting small-scale farmers to a large extent. Consequently, the challenge now lies in redirecting research and development efforts, as well as lending a helping hand to bring this new clientele into the fold. The range of areas/farmers requiring attention includes vegetable gardens in urban and peri-urban areas, small farmers, community farmers and reserve settlement areas (Saunderson, 1995:165). The draft integrated development plan (2002-2003) proposes that more attention should be paid to poverty eradication programmes, which involve the development of food gardens. Research must be initiated, mostly in previously disadvantaged areas; to investigate the causes of low vegetable production, apart from the role played by the above-mentioned production factors. Marsh (1998:4), Ojeifo (1989:6) and Davidson (1990:169) state that the promotion of gardening as a nutrition or community development strategy is controversial, since it is generally believed that the disappointing results of gardening projects stem from a failure to understand the existing gardening system within the context of changing household objectives. If the improvement of gardens could be based upon the characteristics and objectives of traditional gardens, many problems would be avoided because home gardening contributes to household food security and nutrition by providing direct access to diverse food sources that can be harves served to family members, often on a daily basis.

Before 1994, as part of the land reform programme, the Free State Provincial Department of Agriculture established vegetable gardens without determining whether the soil was conducive to sustainable vegetable production. The land reform programme aims to reduce the risk of land degradation, it should reduce poverty, diversify sources of income and give people more control over their lives and their environment (Department of Land Affairs, 1998:vii). For land reform to be successful, it is essential that land with suitable potential be allocated to beneficiaries. A vegetable garden should therefore be located in a sunny area, with loamy, well-drained soil. However, fertile soil and a good climate are of little use if ineffective or inefficient management practices are applied. Soil management, a critically important activity, is therefore the focus of this study.

Communal vegetable gardens are subdivided into plots and each member has his or her own plot for production purposes, although in some areas members work together as a group. In some cases, individual farmers work on their own piece of land within the context of a group, whereas in other areas groups join forces to work on one garden.

1.2 PROBLEM STATEMENT

The overall problem statement is that improper soil management practices are followed in vegetable gardens in the Eastern Free State area (Qwaqwa).

Subproblem 1

Movement of project beneficiaries between the rows during ploughing, sowing, irrigation and weeding.

Subproblem 2

Over-irrigation by members results in soil sealing and crusting, which inhibits water penetration, leading to a shortage of available water for vegetable growth.

Subproblem 3

Application of sodium chloride by respondents for moisture retention purposes.

Since cultivation methods are not optimal, surface sealing occurs in some of the vegetable gardens. Together with crusting it inhibits or limits water penetration, resulting in a shortage of available water for vegetable growth. Possible secondary effects of compacted subsoil can be minimised through the careful administration of nutrients to the soil (Montangu *et al.*, 1997). Improper soil management practices in and around gardens may lead to water run-off and soil erosion, resulting in a reduced yield and a decline in production potential. Some of the irrigation practices (e.g. using of a basket) limit the sprouting of seeds.

The gardens used in this study are situated in Qwaqwa in the villages of Mangaung, Makwane, Phuthaditjhaba, Hasethunya, Boiketlo and Thaba Bosiu, as well as in Clarens. Since the research focused on soil management, trials were also conducted in some of the aforementioned villages to demonstrate the effects of soil compaction to the local garden farmers.

1.3 OBJECTIVES OF THE RESEARCH

The overall objective of this study was to determine management practices in vegetable gardens in the Eastern Free State.

1.3.1 Main objectives

1. Determination of management practices applied by farmers with regard to their vegetable gardens.
2. Trial plantings to demonstrate the effects of soil compaction.

1.3.2 Secondary objectives

1.3.2.1 Management practices

Determination of the following with regard to management practices:

- Cultivation methods
- Irrigation methods
- Fertiliser application
- General management skills and perceptions
- Physical and financial records of previous years.

In addition to the above-mentioned, soil texture class, bulk density and the porosity of samples taken from the gardens, will be determined.

1.3.2.2 Trials

The underground layer of the present gardens will be loosened (treated), and the growth of various types of vegetables will be monitored and compared to those growing in unloosened soil (control).

1.4 HYPOTHESES

The following two main hypotheses will be tested in this study:

1. If the farming practices of farmers on vegetable gardens are researched, it will be found that optimal farming practices are executed to varying levels on vegetable gardens, while meaningful differences will also occur between farmers.

2. The trials will show a significant difference between compacted (untreated) and loosened (treated) garden soils.

2

LITERATURE REVIEW

2.1 INTRODUCTION

The physical properties of soil and its management for optimal production is the basis of this study. Consequently, these aspects are discussed in depth in this chapter.

2.2 DEFINING SOIL

Soil is the habitat of plants, and the farmer depends on it for a living. The farmer therefore has no choice but to pay specific attention to its characteristics (Cooper, 1990:108; Hemy, 1964:15 and Brady, 1984:3). White (1997:4) refers to soil as having a direct influence on the growth of crops and the health of livestock, even though the nutrients in soil occur mainly in the topsoil, the upper 20 – 25 cm that is tilled by a plough.

Foth (1984:2), Wood (1989) and Hillel (1982:5) define soil as "unconsolidated mineral matter on the surface of the earth that has been subjected to, and influenced by genetic and environmental factors of parental material, climate (including moisture and temperature effects), macro and micro-organisms and topography, all acting over a period of time and producing a product soil that differs from the material from which it is derived". Soil is a mixture of inorganic material (sand, silt and clay particles), non-living organic matter and living organisms (biomass), with the particles arranged into a solid structure and with spaces between the particles containing air and soil solution (Wood, 1989). Since soil and moisture are the most important requirements for successful crop production, the conservation of both should be a priority for any farmer (Matchett, 2001:22).

2.3 SOIL MANAGEMENT

Davis *et al.* (1993:1) state that soil management has three goals: (1) to grow crops for profit, (2) to maintain or improve soil fertility and (3) to avoid contaminating the environment and water supplies with nutrients and other chemicals. The soil phase of conservation requires an inventory of the soil, qualitative measurements of its physical characteristics and information on soil response to various treatments (Schwab *et al.*, 1993:1). Soil management can be performed by collecting data via soil and plant analysis to determine the nutrient status of the soil and plants, which affect the quality and yield of crops. Good soil will help the plants in a garden to grow strong and healthy. If soil contains a lot of organic matter, it will hold more water (Kendrick, 1971:12). Soil management in vegetable production is characterised by frequent and intense activation of the topsoil (Montagu *et al.*, 1998:89). Good soil management, however, plays an important role in cultivating vegetables of a good quality. Since the function of the soil is to give support and anchorage to plants, it must supply water, oxygen and nutrients needed for plant growth, be relatively free of toxic elements such as soil-borne pests and diseases, harmful bacteria and fungi, and permit plants to produce vigorous, healthy and unrestricted root systems (Hemy, 1984).

Most vegetable crops are heavy feeders, and to obtain satisfactory yields it is essential that the gardener has some knowledge of the capacity and limitations of his particular soil type. Any soil can be modified to become a suitable medium for crop production (Hadfield, 1995:16). The growth of plants depends upon many factors, including the way in which soil solids are arranged to provide channels approximately 0.2 mm in diameter. The supply of nutrients such as nitrates to a plant, depends upon the activity of micro-organisms (Wood, 1989).

The aim of soil management is to reduce and minimise soil compaction to the greatest possible extent, and to alleviate or rectify the inevitable compaction caused by traffic and tillage (Hillel, 1982). Compaction is a common problem in vegetable production systems, since farming activities must often be carried out within narrow time frames that do not allow for adequate soil drying before making use of the field's capacity (V . The upper limit of a soil's plasticity is ascertained either by determining the water content level at which a groove formed in the soil will begin to close up again in response to standardised impacts, or by the method preferred by the British Standards Institution, namely using a cone penetrometer (Marshall *et al.*, 1996).

The concepts of soil productivity and fertility should be taken into account when dealing with soil management. Soil productivity can be defined as the capability of a soil to produce a specified plant or sequence of plants under a specified system of management; it is basically an economic concept, and not a soil property. Soil fertility is defined as the quality that enables soil to provide the proper nutrients in the right amounts and the correct balance for the growth of specified plants to occur when temperature and other factors are favourable (Foth, 1984:18). According to Matchett (2001:22), limiting tillage of the soil as much as possible and planting the seed in a narrow tilled area, will mean that plant residues from previous crops will only be minimally disturbed on the soil surface.

Soil used for intensive vegetable production is more prone to loss of organic matter, which may result in reduced enzyme activity and microbial biomass carbon, as well as the degradation of the physical condition of the soil (Gagnon *et al.*,1999:91). Soil management can be facilitated by laying out the garden in the right place, i.e. in the location that gets morning sun and afternoon shade (Kendrick, 1971). Soil management entails the manipulation of the soil to enhance certain properties such as the infiltration, porosity and nutrient-retaining capacity of the soil (Upchurch,1999:1049). Traditional soil management in the central Free State involves late summer and autumn cultivation pertaining to crop residue, weed control, seedbed penetration and reduction of surface compaction (Steyn *et al.*, 1994). A steep slope can also have a detrimental effect on some plots, depending on their location; nutrients may be eroded from the topsoil by water runoff during heavy rains, and then deposited in valleys.

2.4 SOIL PROFILE

Davies *et al.* (1993:3), Kramer (1949:23), Hillel (1982:12), Brady (1984:8) and Marshall (1996) define soil profile as the soil layers that are exposed when a pit is dug to a depth of about one metre. The colour of various layers or horizons shows whether the soil is well or inadequately drained. Examination of a vertical section of soil in the field reveals the presence of more or less distinct horizontal layers; such a section is called a profile, and individual horizons are regarded as layers (Brady, 1984:8). The properties of a soil's profile differ greatly from place to place on the earth's surface, and from top to bottom through the succession of horizons or layers that constitute the soil profile. Horizons or material generally occur in the first 1,5 metres from the soil surface (Soil Classification Working Group, 1991).

2.5 SOIL STRUCTURE AND TEXTURE

2.5.1 Introduction

Soil texture refers to the proportion of particles of various sizes in a given soil, whereas soil structure refers to the arrangement of soil particles into groups or aggregates (Brady, 1984). Baver *et al.* (1972:140), Hillel (1971:24), Davies *et al.* (1993:5), Foth (1984:21) and Kramer (1949:20) define soil texture as the mixture of gravel, coarse sand, medium sand, fine sand, silt and clay present in a particular soil. The texture of the soil determines its drainage, water storage, working properties and suitability for different crops, and it can also influence soil structure.

Soil structure is the arrangement of individual particles into larger units or aggregates. Its importance lies in the size and extent of the pore system between the structural units. Soil structure refers to the size, shape and arrangement of voids and aggregates, and the combination of voids and aggregates into various types of structure. The average sand, silt and clay content of various texture classes can be shown or determined by a textural triangle. Soil structure refers to the combination or arrangement of primary soil particles, i.e. sand, silt and clay, into secondary particles or [illegible] aggregates, which are separated by surfaces of weakness (Foth, 1984:30; Hillel, 1971:25; Baver *et al.*, 1972:136).

There are two methods for determining soil texture class. The field method can be used in the field by wetting the soil. The accuracy of this method depends on the experience of the individual concerned. The second method is the laboratory method, which is based on particle size analysis (Brady, 1984:43). Soil structure grades relate to the degree of inter-aggregate adhesion and to the aggregate stability. Four aggregates are recognised as being without structure, i.e. their particles are not arranged into peds or aggregates and are not bound together, as in coarse sand (Brady, 1984:48; Thompson, 1978:54).

2.5.2 Particle density of mineral soil

The unit volume of soil solids is called particle density. Particle density is defined as mass/weight of a unit volume of particles (Tan, 1996:87; Brady, 1984:50).

$$\text{Particle density} = \frac{\text{weight of soil solids (oven-dried)}}{\text{volume of solid particles}}$$

The unit for measuring particle density is g/cc or mg/cm^3 Thus, if 1 cm^3 of soil solid weighs 2.6 mg, the particle density is 2.6 mg/cm^3 (Brady, 1984). The particle density of any soil is constant and does not vary according to the size of the spaces between the particles (Foth, 1984:30).

2.5.3 Bulk density of mineral soils

Over a ten-year period the bulk density of the soil in the top 15 centimetres increases significantly due to reduction during tillage. Numerous studies have shown that bulk densities near the topsoil are higher under zero tillage than under conventional tillage (Campbell, Selles, Lafond, Biederbeik and Zentner, 2001:157). Density refers to the mass of soil per unit volume of soil (Tan, 1996:3; Hillel, 1971:10; Little *et al.,* 1998:80; Zhang *et al.*, 1997:106), and bulk density to the mass or weight of soil per unit volume of undisturbed soil or bulk soil volume. Brady (1984:50) describes bulk density as the weight of solid particles in a standard volume of field soi [illegible] spaces occupied by air and water). A very compact soil may have a bulk density of 2,0 mg/cm or more. Bryane *et al.* (1993) states that the density of a soil in the field decreases or increases according to the amount of air space in the soil, since the effect of traffic is to close up some of the larger air-filled spaces in the soil. Research has demonstrated that disc harrowing or raking reduces bulk density and improves total porosity and macro porosity, as well as volumetric moisture content and soil phosphorus availability in the topsoil layer of phosphorus-fixing oxisols (Phiri, Amezquita, Rav & Sigh, 2001).

$$\text{Bulk density} = \frac{\text{weight of oven-dried soil}}{\text{volume of soil (solids and pores)}}$$

2.5.4 Pore space of mineral soils

Pore space is the portion of soil volume not occupied by solid particles, but by air and water (Tan,1996:94; Foth,1984:39). Finer-textured soils have a greater total porosity than coarse, sandy soil. There are two types of pores with different functions, viz. the macro-pores, which accommodate mostly air, and the micro-pores, which retain or hold soil moisture.

The simplest method of determining pore space is by measuring bulk density and particle density (Tan, 1996). The pore space percentage can be calculated by using the following equation:

$$\text{Pore space \%} = \frac{100 \times \text{particle density - bulk density}}{\text{particle density}}$$

The above-mentioned procedure is the same as the one used by Brady (1984:53) and Foth (1984:40). The pore space percentage of different soils depends on or differs according to the soil texture. Research showed that intensive disc harrowing improved a macro-porosity value of 0-5 cm by 59% (Phiri *et al.*, 2001:131).

2.6 SOIL AND WATER

2.6.1 Introduction

Brady (1984:16) and Kramer (1949:41) state that two major concepts concerning soil water emphasise the significance of this component of the soil in relation to plant growth. Water is held within the soil pores with varying degrees of tenacity, depending on the amount of water present and the size of the pores. Together with dissolved salts, soil water makes up the soil solution, which is so important as a medium for supplying nutrients to growing plants. Shainberg *et al.* (1996:1) mentions that, when water is supplied to the soil surface, whether by precipitation or irrigation, some of the water penetrates the surface and flows into the soil, while some may fail to penetrate and instead accumulates on the surface or flows over it. Infiltration is the term applied to the process of water entry into the soil, usually by flowing downward through the soil surface (Shainberg *et al.*,1996:1). Foth (1984) and Wild (1993:95) mention that the movement of water in soils and from the soil into plant roots, takes place from a region of high-energy water to a region of low-energy water. Brady (1984) also declares that water movement in soils takes place from a zone where the free energy is high, to one where the free energy is low. All plant growth depends upon a supply of water, and this water must be transported by the action of roots that extract water from the soil in which the plants grow (Davies *et al.*, 1993:46). Water in soils at field capacity is only loosely held and easily extracted by plant roots, but as more and more water is removed from the soil from progressively smaller pores, the point is reached at which the maximum suction that roots can exercise, balances the energy at which water is held by the soil (Davies *et al.*, 1993:47).

The variable amount of water contained in a unit mass or volume of soil and the energy state of water in the soil, are important factors affecting the growth of plants. Numerous other soil properties depend very strongly upon water content. These include mechanical properties such as consistency, plasticity, strength, compatibility, penetrability, stickiness and traffic ability (Hillel, 1982). At field capacity, the soil contains the maximum amount of water readily available to plants (Tan, 1996). Total soil water content can be conducted either directly or indirectly. Direct determinat nt percentage takes place by means of the gravimetric method, which in principle involves the measurement of water lost by weighing a soil sample before and after it has been dried at 105°C to 110°C in an oven (Tan, 1996). The water content of soil can be measured by determining the mass of water lost after drying the soil sample in an oven at 105 degrees Celsius, to form a constant mass. Since the amount of water lost increases with the drying temperature in any soil that contains dry or organic matter, the oven temperature must be controlled within the range of about 100°C to 110°C for routine work (Marshall *et al.*, 1984:10). The available water capacity (AWC) defines the amount of soil water that is normally available for growth. The upper limit is set by the field capacity (FC), and the lower limit by the point at which the plant loses turgor and wilts (the permanent wilting point - PWP) (White, 1997).

2.6.2 Soil irrigation and drainage

Marshall *et al.* (1984:22) state that the movement of water through the soil to the plant and then through the plant to the atmosphere, is called adsorption of water by the roots. The cohesion theory of the transmission of water through plants, so named because it requires the water column to be continuous from the roots to the leaves, is firmly established. Watering methods should be adapted according to the season and local conditions. As far as seedlings are concerned, the critical time is between sowing and emergence of the seedling. The soil in contact with the seed must be moist at all times. The period that elapses until the seedling emerges, will vary according to the kind of vegetable, the soil temperature and the sowing depth.

Watering should be done before and after transplanting. Zone watering has proved to be effective in reducing the amount of water used while still maintaining good plant growth (Hemy,1984). Hatfield (1984) states that most gardeners tend to over-water container plants - a mistake that has serious consequences, particularly if the soil is compacted or if the container has no crocking material and few drainage holes. Controlled rain-water runoff from an irrigation field protects the soil and prevents the degradation of river water (South African Irrigation

Magazine, July 2000). Acc[illegible] 34), surface drainage is the collection and removal of water from the surface of the soil. Irrigation is an ancient agricultural practice that was used 7000 years ago in Mesopotamia, and today about 11% of the world's crop land is irrigated. The choice of various methods of applying irrigation water is influenced by seasonal rainfall, the slope and general nature of the soil surface, the supply of water and how it is delivered, crop rotation and infiltration rate. The methods of distributing water can be classified as surface, sub-surface, sprinkler and drip or trickle. Irrigation is practised predominantly on soils that are reasonably permeable (White, 1997).

Increasing the degree and the extent of drainage in humid areas has both negative and positive impacts on hydrology and water quality. Sub-surface drainage lowers the water table, thus increasing the pore space, which allows for greater infiltration and storage of water in the soil profile (Schwab *et al.,* 1996). Most vegetables grow well when they get about two to three centimetres of water every week. When watering plants, the soil should be moist to a depth of 15 to 18 centimetres. The best time to water is in the evening. Try to water thoroughly once or twice a week, rather than lightly every day. Deep watering is beneficial because it can prevent salts from building up in the soil around plant roots. A buildup of salts can prevent growth or even kill plants (Kendrick in *Developing African Farming*, May/June, 2000).

Soil aggregation, which is a natural result of the shrinkage of soil during drying as well as during the cultivation of arable land, has a profound effect on the water and solute transport behaviour in soil profiles. The macro-pores surrounding aggregates provide very conductive channels that act as a source of water uptake, but become practically non-conductive and a barrier to the transport of water and solutes when empty (Youngs *et al.*, 1994:127).

Effective irrigation scheduling must supply water at the right time and in the right volumes. The frequency of irrigation depends on the specific requirements of plants, the growth stage, the size of the plants and the type of growth medium

(Bosman, 2002:28). The [illegible] lures should be used to facilitate irrigation:

- Test the water quality
- Use correct filtration systems
- Regularly flush out filters to remove irrigation limes
- Check pump pressure
- Check for and repair leakages

Tunnels made by worms and cavities left by decomposed (but undisturbed) roots of the previous crop, are extremely useful. They reduce water runoff after heavy thunderstorms, improving the drainage of your fields and crops. The water is then absorbed rapidly and stored underground (Russell, 2001:14).

A major problem with irrigation in regions with a high rainfall is the accumulation of salts in soils, especially sodium salts, which can render the soil too saline for crop growth (Wild, 1993:268). Soils with a high hydraulic conductivity can be irrigated satisfactorily with sprinklers and by flooding (Marshall *et al.*, 1996:268). Efficient surface irrigation requires grading of the soil surface to control the flow of water (Schwab *et al.,* 1993:288). Basher *et al.* (2001:117-130) state that, when cultivating the wheel tracks, infiltration will increase and runoff will be reduced, resulting in a 95% erosion reduction.

2.7 SOIL AIR AND AERATION

Soil aeration is a process of O_2 and CO_2 exchange with the atmosphere (Hillel, 1982:136; Kramer, 1949:221; Nielsen *et al.*, 1984:17; Hillel, 1971:125). Soil air has a higher concentration of carbon oxide and a lower concentration of oxygen than the atmosphere above the soil. The volume of air in soil is determined by the soil water content (Wild, 1993:28). Brady (1984:17) and Davies *et al.* (1993:6) state that there must be a balance between pore spaces containing air and pore spaces storing water, since growing roots require oxygen and constantly give off carbon dioxide. Aeration of the upper part of the soil profile is necessary for the growth of most terrestrial plants. Oxygen is used in respiration to provide the energy for roots to extend, e o nutrient ions selectively (Marshall *et al.,* 1996:362).

2.8 SOIL CULTIVATION AND COMPACTION

Cultivation refers to all gardening and farming operations that disturb the soil, including digging and ploughing. The term is usually reserved for tillage of the soil after the seeds have been sown (Hadfield, 1967:40). Soil tillage is a basic management tool, which has a great impact on crop establishment and growth (Elsevier, 2001:2; Govers *et al.*, 1994:469; Thompson, 1978:416). Tilth is the physical condition of the soil in relation to plant growth, which depends on granite formation and stability, as well as factors such as moisture content, degree of aeration, rate of water infiltration, drainage and capillary water capacity (Brady,1984:65).

As far as the physical and chemical soil environment is concerned, the formation of organic soil matter provides feedback on the activity of decomposers and the plant community by affecting the retention of water and nutrients, the germination of seeds and the distribution and activity of plant roots, while the regulation of turnover is the main feature of the decomposition subsystem (Christenson, 2001:345).

Optimal soil tilth is of great importance in organic farming systems. The research shows that it takes 3-5 years for results to manifest after a non-invasive tillage. Non-inversion deep tillage successfully loosens the compact and root-resisting pan. A conservation tillage system retains more residues and has a rougher soil surface than conventional systems. It also has a slower runoff and a slower rate of loss of particulate phosphorus (Ball *et al.*, 1997:48,599). Tillage has traditionally been associated with weed control and seedbed preparation; however, the availability of herbicides has greatly reduced the need for tillage to control weeds (Bhatnagar, 1982:27; Tolmay, 1995:1). A disadvantage of conventional tillage is that it leaves the soil exposed to wind and rain, thus making it prone to erosion (Wild,1993:140).

Maclay (1984:1) and Davies *et al.* (1993:111-138) state that the effect of traffic on soil is to close up some of the larger air-filled spaces. The measurement of bulk density gives an indication of soil compaction. The purpose of soil cultivation is to create sustainable physical conditions for crop plants. Wolfe *et al.* (1995:956-963) state that soil compaction on farms is most commonly caused by vehicle traffic, particularly the use of heavy equipment with poor weight distribution on wet soils. Consequently, soil compaction is common in vegetable production systems because farming activities must often be performed within narrow time frames that do not allow for adequate soil drying before working on the field. Fields left relatively undisturbed (by not tilling) develop a very porous structure, which promotes the unrestricted exchange of oxygen and carbon dioxide, improves moisture and nutrient movement and reduces the effect of compacted soil layers (Russell, 2001:14-15). The restricted root distribution in compacted soils can lead to a reduction in shoot growth and yield by limiting water and nutrient uptake (Wolfe *et al.*, 1995:956-963). Bennie *et al.* (2000:44-46) state that soil bulk density is an indicator of the compactness of a specific soil. Steyn *et al.* (1994), state that tillage may also lead to the breakdown of organic matter, loss of soil moisture and an increase in wind and water erosion. Compaction may restrict soil aeration and crop root development, limiting water uptake, nutrient availability and overall crop growth.

2.9 MULCHING

Kendrick (1991, in *African Farming* May/June 2000), Biamah *et al.* (1998:5-9), Yan li *et al.* (2001:137-142), Ghuman and Sur (2001:1-10), Groves (1979:402), Maclay (1984:26) and Hadfield (1967:25) define mulching as a good way of retaining moisture in your garden by covering garden soil with residue or leaves. Less water will evaporate, and moisture will therefore be retained for a longer period. The correct choice of cover crop is equally important. When making this choice, a sound knowledge of the different species and cultivars is necessary.

The mulch should suppress the growth of competitor plants adjacent to the production of growth inhibitors. Legumes condition the soil well, resulting in friable, well-aerated soil in which the next crops can easily be planted. Cover crops do not usually require additional fertilisation, as they grow successfully in the residual fertility of the previous crop (Stubbs: 2001:22).

2.10 SOIL FERTILITY

Serage (2000:13) describes soil fertility as the soil's ability to make nutrients available to the growing plant. Nutrients can become depleted as a result of poor practices such as over-cropping, constant cultivation without fertilisation and the breaking down of the soil structure. Manure from cattle feedlots could be valuable for its nitrogen fertiliser content, although half of that nitrogen never reaches the field. Microbes in animal manure and soil produce the enzyme urease, which converts the urea in urine into ammonia, which then evaporates into the air (Hardin, 1998). Research indicates that chisel ploughing also increases microbial activity and competition among saprophytic organisms, resulting in the suppression of pathogenic activity (Carter *et al.*, 2001:1-13). Adding fertiliser as an additional insurance when the soil nutrient supply is already adequate is uneconomical and environmentally unacceptable, since it is a potential source of pollution. There is no easily recognised nutrient balance indicator within the plant to determine whether conditions are conducive to best crop production, except when growth becomes stunted due to the unavailability of essential nutrients (Bennett, 1993:149). Aon *et al.* (2001:173) state that the ability of soils to maintain the integrity of nutrient cycles and energy flows in order to increase their capacity to recover from perturbations introduced by management systems for crop production, is crucial in the evaluation of soil health and quality. Soil condition or health is the ability of the soil to perform according to its potential, and this changes over time due to human use and management, or unusual natural events (Upchurch, 1999:1042). The nutrients needed by crops are taken by the roots from the soil. Three sources are important in replenishing the stock of soluble nutrients that the roots draw on, namely:

(i) rain,

(ii) soil reserves, and

(iii) fertilizers.

The total level of nutrients in soil is much higher than what crops require, but this is not a reliable indication of soil fertility. Only a small fraction of the total amount becomes soluble and useful to crops in any season (Cooke, 1982:85). Fertilizers are chemical (inorganic) manures containing plant foods in a concentrated, easily soluble form that is quickly absorbed by the roots. Nitrogen is the main nutrient required by the plant. It contributes to good growth and leaf colour, and also assists in breaking down organic matter in the soil (Tan, 1996:135; Hemy, 1994:10). While nitrogen fertiliser is important, its benefits can be lost if other nutrients, water or poor soil conditions limit growth. Under such conditions, any applied nitrogen is poorly utilised and potentially at risk from leaching (Rahn, 2001:34). Fertiliser mixtures containing two or more nutrients in varying proportions, are thus very convenient for farmers who wish to apply more than one nutrient. Instead of buying separate fertilisers, each containing a single nutrient, and then mixing them together on the farm, the required nutrients can be purchased ready-mixed at a lower cost (Lea, 1991:35).

Phosphorus fertilisers are manufactured from phosphate ores containing the mineral contents, which is triculcium orthophosphate with calcium fluoride. There are two forms of this ore. The first form is called igneous rock, which is solidified magma that was thrust up in a pipe from underneath the earth crust. The content in this rock is crystalline, and is only soluble in strong mineral acids. The second one is sedimentary rock, which is formed and deposited after the chemical breakdown of the bones and droppings of marine animals and birds. The content in this rock is less crystalline and of an amorphous nature, which renders it more easily soluble than igneous rock, so that the content can then be converted into phosphate concentrate (Nufamer, 2002:5).

In organic crop production, soil fertility plays an important role in ensuring the best possible growing conditions for plants in order to eliminate stress factors that might allow disease/pest infestation. Compost is employed because of its potential to provide nutrients to the crop, as well as to protect it from soil-borne diseases. Compost contains large numbers of organisms that are beneficial to the growth of plants. These numbers are much higher than those normally present in agricultural soils. Humus [illegible] il structure by binding soil mineral particles together to form water- stable aggregates, thereby increasing effective particle size and macro-pore volume and facilitating drainage and aeration. It is also a habitat and source of nutrients for soil micro-organisms, providing favourable conditions for a healthy micro-organism ecosystem to develop. Mature compost is a soil conditioner with qualities that benefit the performance of plants in soil were it has been developed, and where nutrient cycling occurs (Raath, 2001:43). Earthworm casts contain five to ten times as much organic matter and nutrients as soil (Russell, 2001:14). The manure practices for food production followed by poor rural families, are regarded as old-fashioned. It is, however, still common to see kraal manure being used in backyard gardens in these areas. Organic fertiliser needs to be promoted by focusing on the benefits of clean kraals, the disposal of kitchen litter and overall soil improvement, in a physical, chemical and biological sense. An application of about 10 tons/ha maize grain or 1,2 tons/ha sunflower is recommended. However, kraal manure has the disadvantages that it often harbours diseases and most of its boron content leaches out easily (Seobi, 1999).

CHAPTER 3

RESEARCH PROCEDURE

3.1 INTRODUCTION

In this chapter, the research procedure regarding the two main objectives, namely the analysis of the questionnaire on farm practices and the trial procedure, are discussed. The method used to determine the pore space percentage and the bulk densities of different gardens' soils, mostly where sodium chloride was applied, are discussed. Trial plantings were also made in two different vegetable gardens, namely at Mpho and Leratong. Since vegetable gardens in the sample area were also evaluated, they are discussed in this chapter.

3.2 QUESTIONNAIRES

3.2.1 Study location and participating farmers

The study was undertaken within the Qwaqwa and Clarens districts. In Qwaqwa, the villages of Phuthaditjhaba, Makwane, Namahadi and Hasethunya were included. From these villages, a total of 29 vegetable farmers were randomly selected to participate in the survey study. Five farmers from Phuthaditjhaba, four from Namahadi village, eight from Makwane, seven from Hasethunya and six from Clarens participated in the study.

Garden samples were taken in Boithatelo and Boiketlo and soil texture types were identified independently by both the farmers and the researcher. Open-ended and closed questions to investigate farming practices as well as vegetable production records, were used in data collection. Topsoil samples were taken from gardens to determine soil texture using field and laboratory procedures.

3.2.2 Structure of the ques

The questionnaire, used as a survey instrument in this study, is attached as Appendix A. The questionnaire is divided into the following headings and topics:

(a) Biographical information, consisting of the districts where the research was done, the province, the age of every farmer, for how long the farmer has been on the farm or land, farming experience expressed in years, and the highest academic qualification achieved per individual farmer.

(b) Information about the farm and farming practices. This part of the questionnaire includes the following: size of land, allocation of land or farm, beneficiaries, group farming, responsibility of the farmer with regard to the vegetable garden, seed supplier, planting in the seedbeds, duration of seedbed cultivation, number of trespassers, land resting, duration of resting period, traffic during resting period, and type of traffic in gardens or fields.

(c) Fertiliser and manure usage. Farmers were asked about the types of manure they were using, the method for measuring manure before application to the garden, reasons why they were using manure, the best kraal manure for the production of vegetables, mixing of fertiliser and manure, amount of fertiliser applied to vegetable gardens, over-application of fertiliser, types of fertiliser and crops to which the farmers were applying kraal manure, and observations after applying manure.

(d) Soil cultivation methods. The farmers were asked about the equipment or machines they were using to prepare their soil and the depth to which they were ploughing, and to compare the effectiveness of using a spade to work the soil versus ploughing with a tractor.

(e) Plant growth, soil compaction and irrigation. In this section, questions were asked about the compaction of the garden soil, determining compaction, the effects of soil compaction on seed germination, soil texture determination, the clay percentage of the garden soils, irrigation methods, effects of irrigation on soil structure, irrigation frequency, [illegible] oil during transplanting of seedlings, and mulching and its effects where it was used.

(f) Farmers were asked about their physical and financial records. Training needs, future plans and recommendations also featured under this subheading.

3.3 BIOGRAPHICAL INFORMATION OF RESPONDENTS

3.3.1 Districts

Table 3.3.1 shows the districts were the questionnaires were distributed and the number of respondents per district.

Table 3.3.1: Geographical distribution of respondents per district.

DISTRICT	NUMBER OF RESPONDENTS	PERCENTAGE
Phuthaditjhaba	5	16.7%
Namahadi	4	13.3%
Makwane	8	26.7%
Hasethunya	7	23.3%
Clarens	6	20.0%
Total	*30*	*100%*

Thirty questionnaires were completed by the farmers, most of whom were located in the Makwane (26.7%) and Hasethunya (23.3%) districts.

3.3.2 Distribution according to age of respondents

The age of individual farmers was investigated, and this information is represented in Figure 3.3.2 in the form of its distribution across certain age groups. The average age is 53.0 years, with a standard deviation of 16.4. One respondent did not know his age. The highest number of respondents (31%) was in the 60 to 69 years group, followed by 21% in the 50 to 59 years group.

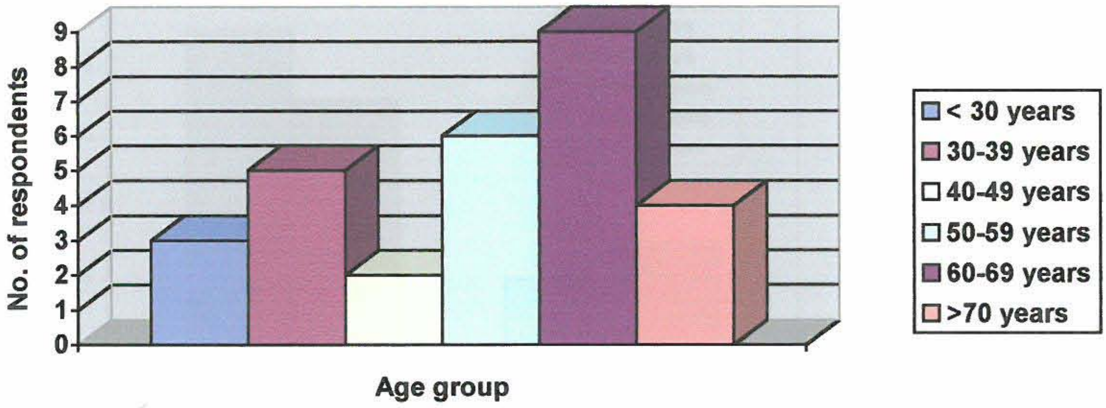

Figure 3.3.2: Age distribution of the respondents

3.3.3 Occupation of farming land in terms of years

Farmers were asked to state the number of years they had been occupying their current farming land. The average duration of land occupation was 15.4 years, with a standard deviation of 10.8 years. Of the respondents, one third (33.3%) had been occupying land for less than six years, 23.3% had been occupying land for a period of 19 to 24 years and one person had been occupying it for a period of 7 to 12 years, whereas 16.7% of the respondents had been occupying land for more than 25 years.

3.3.4 Experience

The experience of farmers with regard to farming and non-farming activities was determined via the questionnaire. Respondents were grouped into five-year categories according to their experience of farming, and this is shown in Figure 2.3.4. With regard to farming experience, most (34.5%) had worked as farm workers, 17.2% had poultry management experience, 10.3% had cooking and selling experience, one person had bookkeeping experience, 6.9% had gardening experience, 6.9% had worked as electricians and welders, one person had driving experience, one person had mechanical experience and one respondent had no experience other than working on a farm. Generally speaking, thus, 58.6% of the respondents had some form of experience related to agriculture.

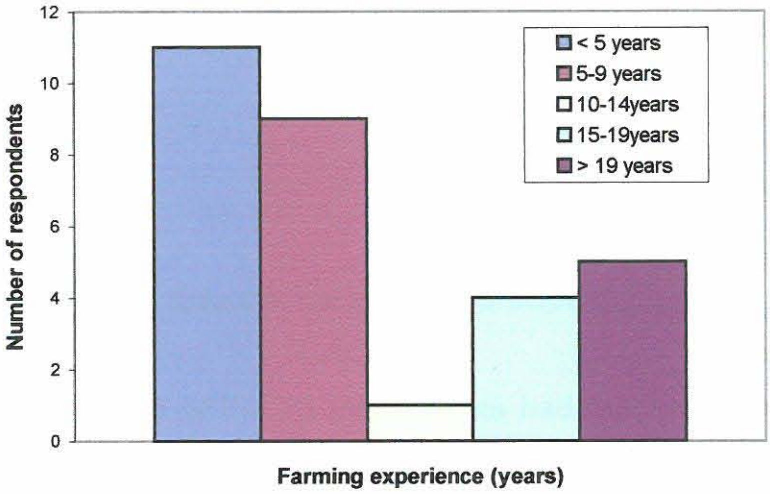

Figure 3.3.4: Farming experience of respondents

It is clear from the figure above that the largest portion of the respondents (36.7%) had less than five years' experience, while 30.0% had between five and nine years' experience. One third of the respondents had ten or more years of experience, and these were farmers aged between 53 and 60 years. The average period of experience was 9.4 years.

3.3.5 Educational qualifications of farmers

The highest academic qualification of each individual respondent was determined via the questionnaire, and this information is represented in Figure 2.3.5. Only 25 farmers responded to this question.

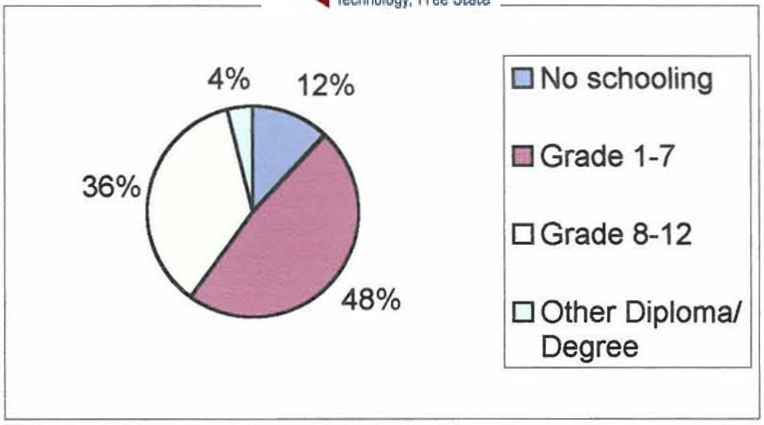

Figure 3.3.5: Educational level of participating farmers.

Most (48.0%) of the 25 respondents had reached an educational level between grade one and seven, 36.0% had reached a level between grade eight and twelve, 4.0% had completed either a diploma or a degree, and the remaining respondents (12.0%) had never attended school at all. Although some respondents had no formal school training, they were able to read and write.

3.3.6 Size of farming land

The respondents were asked whether they knew the size of their farming land. One third of the respondents did not know the size of their land, 20.0% of the respondents said they were farming on land of less than 1 hectare and 33.3% were farming on between 2 and 4 hectares of farming land, whereas 13.3% of the respondents were farming on an area of more than five hectares. The average size of the land or farm was 3.0 hectares with regard to 20 farmers only, since 10 farmers did not specify the size of their respective farms. This indicates a need for training - if farmers do not even know the size of their respective farms, it will be difficult for them to plan their cropping system.

3.3.7 Allocation of land

Table 3.3.7 illustrates the individuals or institutions that gave land to farmers.

Table 3.3.7: Allocators of la aries.

ALLOCATOR	NUMBER OF RESPONDENTS	PERCENTAGE
Chief	22	73.3%
Government	3	10.0%
Municipality	4	13.3%
Purchased	1	3.3%
Total	*30*	*100%*

Chiefs had allocated land to 73.3% of the respondents, implying that most respondents were farming on communal land. The government had allocated land to 10.0% of the respondents, 13.3% of the respondents had received land from a municipality and 3.3% had purchased their farmland.

3.3.8 Beneficiaries

Beneficiaries can be defined as people who benefit directly from farming activities. These individuals can be identified on the basis of the comments received from respondents. The farmers were asked about the number of people in their respective projects - if they were farming in groups - and these groups are represented in Figure 2.3.8. As mentioned above, beneficiaries in this context are not referring to dependants (because the respondent may not be the head of the household), but rather to the people who get direct benefits from the land they farm on.

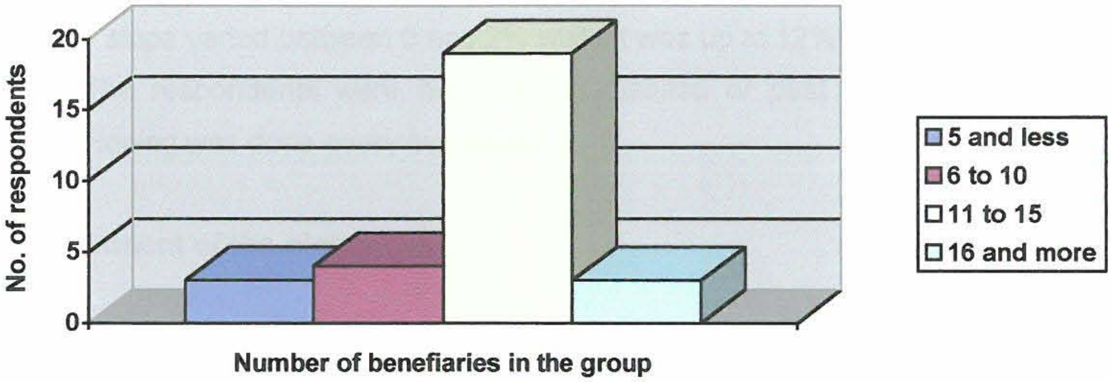

Figure 3.3.8: Number of beneficiaries in the group

From Figure 3.3.8 it is clear that most of the groups has between 11 and 15 people that benefits directly from their farming activities. Increased success in garden farming will therefore influence the lives of many people.

3.4 FIELD TRIALS

3.4.1 Location of the trials

Two gardens were used for the trials, namely the Mpho garden in the Mangaung ward and the Leratong vegetable garden in the Thaba Bosiu ward. The Leratong vegetable garden was 0.16 ha in size, and the Mpho garden 0.19 ha. In both the Mpho and Leratong vegetable gardens, potatoes and carrots were planted as trial crops. In each location, three identical plots, each covering an area of 14 m^2, were used. A randomized block design was used to assign either loosened (experiment) or compacted (control) areas before trial crops were planted.

3.4.2 Characteristics of the plots

Soil samples from the Mpho and Leratong projects were taken to the Glen soil laboratory for analysis. Although there were slight variations, in most cases the soil texture was classified a . 50% sand and 50% clay plus silt. With regard to alkalinity, the conductivity was 49 and the Standard Acid Ratio was 1.1. Soil reaction or pH (potassium chloride) was determined as 3.9. At Mpho the level of the slope varied between 0 and 2% while it was up to 12% at the Leratong garden. The respondents were not applying disease or pest control in their gardens. Hoeing was done every two weeks.

3.4.3 Treatment of the plots

Mixed fertilizer at the rate of 285kg/ha was applied to the plots planted with carrots. Through this practice, 17.9kg/ha nitrogen, 26.9kg/ha phosphorus and 17.9kg/ha potassium were applied. Mixed fertilizer at the rate of 153kg/ha was applied to the plots planted with potatoes, thereby applying 9.6kg/ha nitrogen, 14.4kg/ha phosphorus and 9.6kg/ha potassium. Plots were rested for two weeks before planting. The Table 3.4.3 below shows the different crops planted, fertilisers used, crop variety planted and the planting date of the experiment and control plots respectively.

Table 3.4.3: Treatments us ent and control plots respectively

MPHO VEGETABLE GARDEN			
	EXPERIMENT Loosened subsoil (non mechanised)		CONTROL Unloosened subsoil
1	Carrots plot 400g of 2:3:2(22) per 14 m² Variety: Ideal red Date planted: 14-09-2000	1	Carrots plot 400g of 2:3:2(22) per 14 m² Variety: Ideal red Date planted: 14-09-2000
2	Potatoes 215g of 2:3:2(22) per 14 m² Variety: Bp1 Date planted: 14-09-2000	2	Potatoes 215g of 2:3:2(22) per 14 m² Variety: Bp1 Date planted: 14-09-2000

LERATONG VEGETABLE GARDEN			
	EXPERIMENT Loosened subsoil (non mechanised)		CONTROL Unloosened subsoil
1	Carrots 400g of 2:3:2(22) per 14 m² Variety: Ideal Red Date planted: 14-09-2000	1	Carrots 400g of 2:3:2(22) per 14 m² Variety: Ideal Red Date planted: 14-09-2000
2	Potatoes 215g of 2:3:2(22) per 14 m² Variety: Bp1 Date planted: 14-09-2000	2	Potatoes 215g of 2:3:2(22) per 14 m² Variety: Bp1 Date planted: 14-09-2000

3.4.4 Layout of the plots

The Table 3.4.4 shows the random layout of the experimental and control plots respectively.

Table 3.4.4: Layout of the experiment and control plots for Mpho and Leratong vegetable farms.

MPHO VEGETABLE GARDEN

Carrots **control** plot	Carrots **experimental** plot	Carrots **control** plot
Carrots **experimental** plot	Carrots **control** plot	Carrots **experimental** plot
Carrots **control** plot	Carrots **experimental** plot	Carrots **control** plot
Carrots **experimental** plot	Carrots **control** plot	Carrots **experimental** plot
Carrots **control** plot	Carrots **experimental** plot	Carrots **control** plot
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Carrots **experimental** plot	Carrots **control** plot	Carrots **experimental** plot
Carrots **control** plot	Carrots **experimental** plot	Carrots **control** plot

Potatoes **control** plot	Potatoes **experimental** plot	Potatoes **control** plot
Potatoes **experimental** plot	Potatoes **control** plot	Potatoes **experimental** plot
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Potatoes **control** plot	Potatoes **experimental** plot	Potatoes **control** plot
Potatoes **experimental** plot	Potatoes **control** plot	Potatoes **experimental** plot
Potatoes **control** plot	Potatoes **experimental** plot	Potatoes **control** plot

LERATONG VEGETABLE GARDEN

Carrots **experimental** plot	Carrots **control** plot	Carrots **experimental** plot
Carrots **experimental** plot	Carrots **control** plot	Carrots **experimental** plot
Carrots **experimental** plot	Carrots **control** plot	Carrots **experimental** plot
Carrots **experimental** plot	Carrots **control** plot	Carrots **experimental** plot
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Potatoes **control** plot	Potatoes **experimental** plot	Potatoes **control** plot
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Potatoes **experimental** plot	Potatoes **control** plot	Potatoes **experimental** plot
Potatoes **experimental** plot	Potatoes **control** plot	Potatoes **experimental** plot

3.4.4.1 Carrot trials

For the purpose of establishing carrot length and mass, a plot of 14 square metres was subdivided into nine quadrants, and four carrots were harvested from each quadrant. Every sixth sprout in each row was measured. Twenty-four sprouts per block from both the treated and the control plots in two different locations, were measured. The length (in centimetres) and mass (in grams) of carrots from both the treated and control plots, were measured. The length and mass of carrots were compared, taking into account soil management practices and location effects. A comparison was made between the locations of the vegetable gardens, per block and per plot.

3.4.4.2 Potato trials

The potato trial was also conducted in the Mpho and Leratong vegetable gardens. As with carrots, the plot size of both the control and the treated plots was 14m^2. Each of the control and treated plots was subdivided into six columns, and two potatoes were picked from each column. This amounted to 12 potatoes being picked per block, from both the control and the treated plots. The mass of potatoes was measured to the nearest gram, and tests were conducted to determine the effects of soil management treatment and location.

3.5 DETERMINATION OF PORE SPACE PERCENTAGE IN RECENTLY SALTED, NON-SALTED AND OLD SALTED SOILS

Three different soil samples were taken from the three vegetable gardens. The clay content percentages differed. The aim was to determine the relationship between bulk density and pore space percentage, or porosity. Soils were weighed and dried in an oven, at about 100°C for fifteen minutes. The soils were weighed again after they were removed from the oven. This procedure was repeated five times, and is set out in Table 3.5.1.

Table 3.5.1 Determination [illegible] rcentage for both the treated and control plots

Treatments	Container volumes	Clay %	Soil Mass	Oven-dried Soil Mass
1) Recently salted	250cm^3	5	250g	240g
2) Non-salted	250cm^3	4	250g	245g
3) Old salted	250cm^3	25	310g	300g

All calculations were done according to the Brady procedure (1984:53).

Bulk Density (BD) was calculated as follows:

$$BD = \frac{\text{Mass of oven-dried soil}}{\text{Volume of container}}$$

Particle density (PD) is calculated as follows:

$$PD = \frac{\text{weight of soil solids (oven-dried)}}{\text{volume of solid particles}}$$

The pore space percentage was calculated as follows:

$$\text{Pore Space \%} = 100 - \frac{(\text{Bulk Density} \times 100)}{\text{Particle Density}}$$

4

RESULTS OF THE TRIALS

4.1 CARROT (*Daucus carota var. Sativas*) GROWTH AND YIELD

4.1.1 Plant growth

The carrot cultivar planted was Ideal Red. In the plots where soil was loosened, carrot seeds sprouted out of the soil after seven days, whereas very few sprouted in the control plots. After 14 days, the plant population in the experimental plots was denser than that of the control plots. In order to balance the plant population in both plots, the seedlings were thinned out. Plant population and density in the plots were assessed visually. Plants were given equal amounts of fertiliser. After one month, the vegetative growth in the treated plots was higher than in the control plots (see Table 4.1.1).

Table 4.1.1: Mean and standard errors (S.E.) for vegetative length of carrots

Soil management applied	Location	Mean (S.E.) in cm*
Control (compacted)	Leratong	2.11(0.29)a
Control (compacted)	Mpho	2.59(0.29)a
Treated (loosened)	Leratong	3.94(0.29)a
Treated (loosened)	Mpho	4.16(0.29)a

* Values in brackets are standard errors; means with the same letters in the same column, are not significantly different ($P<0.05$). Detailed ANOVA is available in Annexure C.

There was no significant ($P>0.05$) difference between the two soil management practices applied in all locations. The mean vegetative length of the carrots in the control plots was 0.48 cm shorter compared to the treated ones in the Mpho vegetable garden. There was a 0.22 cm difference in the mean length of carrots planted in loosened plots in the Mpho and Leratong vegetable garden locations respectively; however, this difference was not significant. It must be taken into account that factors such as climate (especially rainfall) and fertigation may also have influenced the experi situations (low rainfall/irrigation and fertilizer) it is expected that the loosened soil will have a significant advantage over the compacted soil. In general, the loosened subsoil had a positive effect on the vegetative growth of carrots in both locations; the assumption is therefore made that carrot seeds were restricted by soil compaction during sprouting.

4.1.2 Yield

When harvested, the carrots in the experiment plots were longer than the ones in the control plots, which were short and thick in diameter. The mean length, diameter and mass of carrots harvested from the treated and control plots, are indicated in Table 4.1.2.

Table 4.1.2 Mean and standard errors (SE) for carrot length, diameter and mass with regard to the control and treated plots.

Soil management treatments	Length in cm.	Diameter in cm.	Mean mass in g.
Control	13.61 (0.18) a*	3.95 (0.05) b	39.62 (0.33) c
Treated	14.71(0.18) b	3.36 (0.05) b	38.75 (0.33) c

* Values in brackets are standard errors; means with the same letters in the same column, are not significantly different (P<0.05). Detailed ANOVA is available in Annexure C.

The mean length of the carrots from the control plot was significantly shorter (1.7 cm) than that of the treated ones. The better growth of the carrots on the treated plots could be the result of the loosened topsoil. The mean carrot diameter for control plots was 0.59 cm more than that of the ones planted in the loosened soil. It was assumed that, in view of the unloosened subsoil, the carrot roots developed in a horizontal direction because of the root restriction associated with soil compaction. The mean mass of carrots harvested from control plots was 0.90g more than that of carrots harvested from loosened soil; however, this difference was not significant. The findings confirmed that the carrots from the control plots were shorter in length, thicker in diameter and heavier in mass than the ones planted in the loosened plots.

The carrots in the treated pl an those in the control plots due to the removal of compaction, improved drainage and the availability of nutrients due to more favourable growing conditions (Tomay, personal communication). In the control plots the soil was compacted and the nutrients were only available within 10 cm of the topsoil. Bennie *et al.* (2000:44) report that soil bulk density is an indicator of the compactness of the specific soil. Compaction is a common problem in vegetable production systems because farming activities are often conducted within a narrow time frame that does not allow for adequate soil drying before entering the field or garden. The restricted root distribution in compacted soils can lead to a reduction in shoot growth and yield by limiting water and nutrient uptake (Wolfe *et al.*, 1995:956). The fertiliser applied did not penetrate into the soil; it remained in the upper 10 cm of the soil due to soil compaction.

Table 4.1.3 illustrates mean and standard errors (SE) for carrot length, diameter and mass according to location and soil management treatments.

Soil management treatments	Location	Length in cm.	Diameter in mm	Mass in g.
Control	Leratong	14.15 (0.25)b*	3.98 (0.07)b	39.09 (0.47)ab
Control	Mpho	13.07 (0.25)a	3.93 (0.07)b	40.15 (0.47)b
Treated	Leratong	14.53 (0.25)b	3.31 (0.07)a	38.64 (0.47)a
Treated	Mpho	14.90(0.25)c	3.42 (0.07)a	38.86 (0.47)a

* Values in brackets are standard errors; means with the same letters in the same column, are not significantly different ($P<0.05$). Detailed ANOVA is available in Annexure C.

In the Leratong vegetable garden there was no significance difference in carrot length between the control group and the loosened soil group, whereas there was a significant difference (1.83 cm) between control and treated groups with regard to the carrots planted in the Mpho vegetable garden. In both locations there was a significant difference in carrot diameter between the control and treated groups. Carrots harvested from the loosened soil at the Mpho location were significantly ($P<0.05$) heavier (1.29 g) (Table 4.1.3.). It is postulated that the difference in carrot yield can be ascribed to the difference in soil type between the Leratong vegetable garden and Mpho vegetable gardens, as shown earlier in section 4.1.

4.2 POTATO (*Solanum tuberosum)* YIELD

The Bp1 potato variety was planted in the trials at the Mpho and Leratong vegetable gardens. The potato seedlings were planted in loosened (treated) and compacted (control) plots measuring 14m² each. After 14 days the potato plants sprouted, with a higher plant population in the loosened plots than in the control plots. Irrigation frequency was twice a day with regard to both the treated and control plots. A month after planting, the growth on the control plots was more prolific than on the treated plots. Because of the higher plant density, the plants on the treated plots were stunted and flowered earlier than the ones on the control plots, while they also matured sooner. Early maturity can be a sign that the soil is lacking nutrients such as nitrogen. It is therefore evident that the fertilizer application to the plots was too small, while total production per square meter on the treated areas was probably higher than the untreated areas.

The vegetative growth on the treated plots was stunted owing to a lack of nutrients and matured early, whereas the plants on the control plots grew well.

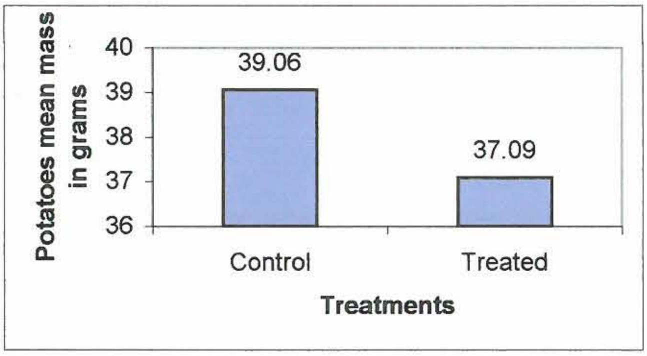

Figure 4.2.1 Mean mass of potatoes harvested from the two treatments.

There was no significant (P>0.05) difference in mass between the two treatments. Based on individual potatoes, it can therefore be postulated that loosened topsoil has no impact on potato mass, although total production for the treated plots could be more than that of the control plots.

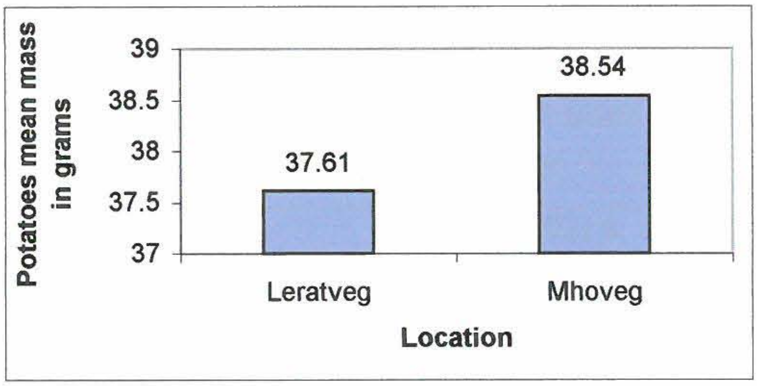

Figure 4.2.2: Mean mass of potatoes harvested from the Leratong and Mpho vegetable gardens.

There was no significant (P>0.05) difference in growth between the two locations, although the Mpho vegetable location mean was 0.93g more than the Leratong vegetable garden. Findings show that the growth of plants depends on many factors (supply of nutrients, the way soil solids are arranged, etc.), and these factors differ according to locations (Wood, 1989).

4.3 APPLICATION OF SODIUM CHLORIDE APPLICATION TO VEGETABLE GARDEN SOIL

During the interviews conducted with them, farmers reported that they were applying sodium chloride to their garden soils. It should be mentioned that the extension officer in their area was opposed to this practice. The farmers claimed that the radish yield increased dramatically on the soil where sodium chloride was applied, since the sodium chloride improved the moisture-retaining capacity of the soil. Soil bulk density (BD) and porosity percentage (porosity %) were measured on samples collected from recently salted, old salted and non-salted plots. These two measurements were taken from the fresh and oven-dried samples.

Table 4.3.1 Mean bulk density and porosity percentage of fresh and oven-dried soil samples.

Treatment	Mean BD in g/cm^3 (±SE)*	Mean porosity % (±SE)*
Fresh	1.04 (0.002) a	60.37(0.2) a
Oven-dried	1.08 (0.002) b	59.34 (0.2) b

* Values in brackets are standard errors; means with the same letters in the same column, are not significantly different ($P<0.05$). Detailed ANOVA is available in Annexure C.

There was a significant difference ($P< 0.01$) between the fresh and oven-dried soil with regard to mean bulk density. The observed difference in bulk density could have been caused by the loss of moisture in the pores due to the oven-drying process. There was a reduction of 1.03% ($P<0.05$) in soil porosity due to the oven-drying of the samples. The pore percentage space of different soils varies according to their soil texture. Research shows that intensive disc harrowing improved the soil macro-porosity value from 0 to 0.05 g/cm^3 for 59 % of the samples studied (Phiri, *et al.*, 2001:131)

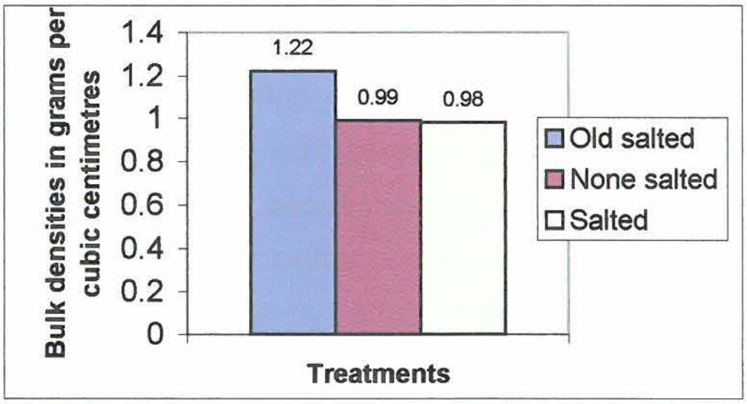

Figure 4.3.2 Mean bulk density for non-salted, old salted and recently salted treatments.

There was a significant difference ($P<0.001$) between the bulk density of non-salted, old salted and recently salted soils. The mean bulk density of old salted soil was 0.23 g/cm3 and 0.24 g/cm3 higher than that of the non-salted and recently salted soils respectively. The non-salted and recently salted soil's bulk densities were the same, since it takes a while for the detrimental effect of sodium chloride application to become evident, particularly with regard to irrigated land. Soils under zero tillage may have a high bulk density (Campbell *et al.,* 2001:157). Forth (1984:21) mentions that the clay content of soil can also have an effect on its bulk density. It was observed that the higher the clay content of the soil, the higher the bulk density and the lower the porosity of the soil, according to Buyeye (1996, personal communication). This trial was repeated several times, and its aim was to demonstrate to the respondents how porosity affects different types of soil texture.

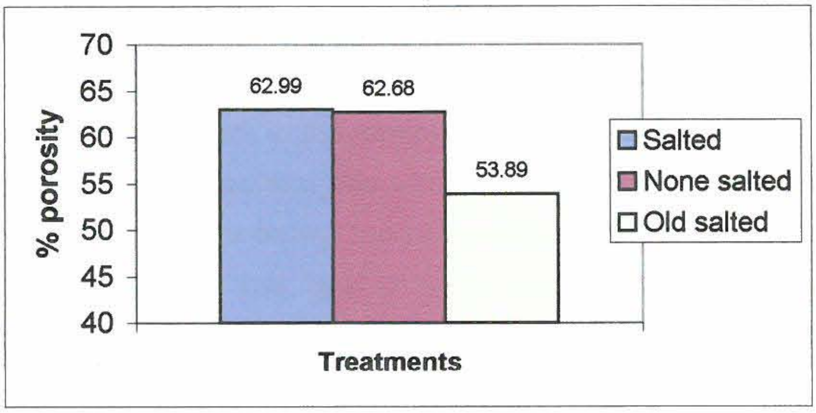

Figure 4.4.3 Mean porosity percentage of salted and non-salted treatments

There was no significant difference ($P>0.05$) between the salted and the non-salted treatment with regard to soil porosity percentage (Figure 4.4.3). This supports the statement made above, namely that the side effects of salt application are not immediately evident in soil which is under irrigation. On average, the non-salted and recently salted soils' porosity percentage was 8.9% ($P<0.05$) higher than that of the old salted soils. These results therefore demonstrate that the detrimental effects of salt application only manifest themselves after a long period of time. The majority of farmers decided to stop using the technique of salt application after these findings were presented to them. Two of them even won the province's Female Farmer of the Year award.

Farmers were unaware of the causes and consequences of soil compaction. The layout of some gardens was conducive to soil erosion, since they were situated on very steep slopes and had n g irrigation their soil was eroded and washed away, together with the planted seeds. It was not easy to tackle cultural issues which have a bearing on farming. Personal discussions revealed, for example, that most of the farmers were not using herbicides and pesticides. Weeds were controlled by hoeing and other mechanical means. Some of the farmers took the leaves of wild garlic, steeped them in water and then sprayed their pest-infested vegetables with the solution.

Over-application of fertiliser occurred in some of the gardens. Farmers also neglected to take soil samples in order to determine the amount of nutrients to be applied to the gardens. This resulted in kraal manure being over-applied because the nutrient requirements of the soil were not known. Kraal manure was also mixed with fertiliser.

Most of the members in the sample area were women. Home gardens place the spotlight on the important role women play in agriculture. Home gardens offer a direct opportunity for equity, food accessibility and support for community gardens (Torrens, 1989). The lack of skills among the farmers with regard to soil compaction and management has resulted in this research, after collection of the preliminary questionnaires from the farmers.

5

THE SOIL MANAGEMENT PRACTICES OF FARMERS

5.1 INTRODUCTION

In this chapter, the practices of the respondents will receive attention. The focus will be on the following aspects: the responsibilities of individual farmers within a group context, seedbed preparation, land resting, manures and fertilisers, soil-turning equipment, the definition and determination of soil compaction, irrigation methods, mulching and the economic records of farmers.

5.2 RESPONSIBILITIES OF INDIVIDUAL FARMERS WITHIN A GROUP CONTEXT

All the responsibilities assigned to individual farmers have been investigated and the results are listed below in percentage form, and according to the specific task. Of the 19 respondents, five were tasked according to the functions within the project, four were responsible for selling vegetables and managing the soil in the gardens, three were working as secretaries, three were additional members, one was working as a guardian in a group, one was a treasurer and another one was acting as chairman of the project. Project chairmanship appointment is not based on qualifications, as emerged during interviews with the beneficiaries. This could have had a negative impact on the success of projects. The ideal would be for farmers to elect literate management committees. Eleven people did not respond.

5.3 PROJECT MANAGERS

The various ways in which groups were formed to work on different projects, as well as their work procedures, were examined. Of the 30 respondents, 53.9% were ordinary members and 46.1% were project managers. Individual vegetable gardens were divided into p[illegible] shared by beneficiaries. Individuals were responsible for their own plots with regard to production. In a few cases groups of farmers who worked together and shared the resulting profit.

5.4 NUMBER OF PEOPLE WORKING IN A GROUP

The number of people working on plots in gardens, was determined and listed in Table 5.4.1.

Table 5.4.1: Number of people per plot.

NUMBER OF PEOPLE PER PLOT	NUMBER OF RESPONDENTS	PERCENTAGE OF RESPONDENTS
Unknown	4	13.3%
1-5 people	22	73.3%
6-10 people	1	3.3%
11-15 people	2	6.7%
16 or more people	1	3.3%
Total	*30*	*100%*

Of the 30 respondents, most (73.3%) were working in groups consisting of one to five people. They worked together during soil preparation and other vegetable management processes taking place on their plots. The respondents mentioned that the movement of their co-workers in the gardens compacted the soil to some extent. Respondents observed that, the higher the number of people who were working on a plot, the larger the volume of water lost during irrigation would be.

5.5 SEEDBEDS

Of the 28 respondents, 85.7% were planting in seedbeds, while the rest were planting in ordinary rows without seedbeds. Farmers hardly ever turned the seedbeds in which they we [illegible] bles. They kept on using the same seedbeds without making any changes. Of the 21 respondents, a third had been cultivating the same seedbeds since the establishment of their respective projects. About 9.5% of the respondents had been working on the seedbeds for a period of less than five years, 33,3% for a period of between six and ten years, 14.3% for 11 to 20 years, and 9.6% for a period longer than 21 years. It was noted that some of the above-mentioned farmers had not been turning their seedbeds for many years. This resulted in soil compaction, which was further compounded by animal traffic on their respective plots.

5.6 LAND-RESTING PRACTICE

The farmers were asked about their land-resting as a principle, the duration of the land-resting periods and the traffic on their land during the resting period. Land resting was practised by 68.9% of the 29 respondents; the rest were cultivating their land without any interruption. Of those resting their land, 45.0% rested it for a period of less than four months, 45.0% rested their land for between five and six months, and 10.0% rested their land for seven and more months. It also transpired that none of the respondents rested their land for more than one year. Of the 30 respondents, 60.0% believed that there was no traffic in their gardens during the resting period, and 40.0% were of the opinion that there was indeed traffic. Traffic was attributed to trespassers, crop pickers and cattle.

5.7 TYPES OF MANURE USED IN DIFFERENT GARDENS

The types of manure and fertiliser used by farmers was investigated, and the results are presented in Figure 5.7.1. Belay *et. al.* (2000:44-51) states that the decomposition of manure and the mineralization of the nutrients contained in it is normally a fairly slow process, and may take months or even several years to complete. Depending on environmental factors, this may have residual effects lasting for long periods.

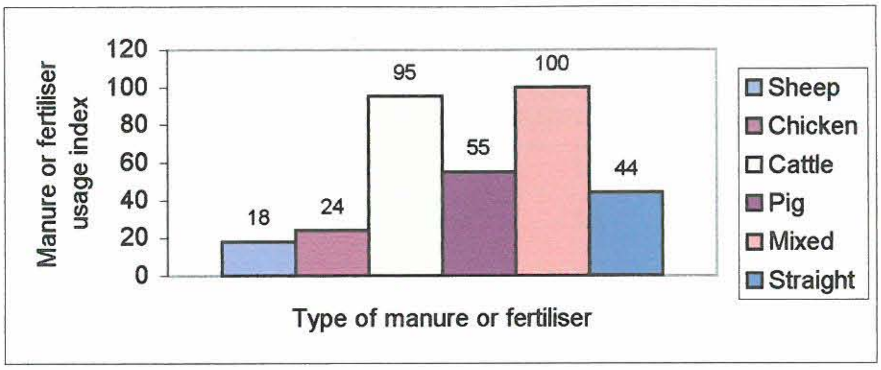

Figure 5.7.1: Manure usage by respondents

Cattle manure usage amounted to 95.0%, followed by pig manure at 55.0% and chicken manure at 24.0%. Nobody used rabbit manure. Of the respondents using fertilisers, all used mixed fertilisers, while 44.0% used straight fertilizers. Straight fertiliser contains only one component such as urea, which has nitrogen as its only nutrient. Cattle manure is the main source of plant nutrients and soil improvement in smallholder farming systems. The quality of manure from smallholder areas is often low, due to the inferior quality grazing available to cattle and poor storage and handling of manure (Nyamangara *et. al.*, 2001:157).

5.8 METHOD OF MEASURING KRAAL MANURE

The measurement of manure before application, was investigated. Of the 27 respondents, only 18.5% were measuring manure before application. Measuring was done with five-litre buckets for plots of between 14 m² and 24m².

5.8.1 Reasons for using kraal manure

The reasons for using manure are listed in Table 5.8.1.

Table 5.8.1: Reasons for m

REASONS	FREQUENCY OF RESPONSES	RESPONSE PERCENTAGE
Lack of funds to buy fertiliser	15	25.4%
To loosen the soil	12	20.3%
To retain moisture in soil	9	15.3%
It is cheap and easily available	7	12.3%
To improve soil structure	6	10.2%
To feed the plants	5	8.5%
To improve plant growth and production	3	5.1%
To produce nutrients	2	3.4%
Total	*59*	*100%*

Most of the responses (25.4%) reveal that respondents were using kraal manure due to its cheapness and easy availability; 20.3% said it fertilises the soil, whereas 10.2% of the respondents were of the opinion that it improves the soil structure. The literature consulted indicates that cattle manure significantly improves structural stability and water retention capacity at low suction values, in sandy and other soil. Cattle manure can be used effectively to improve the physical fertility of the soils with low levels of organic matter that are widely cultivated (Nyamangara *et al.*, 2001:157).

5.8.2 Kraal manure rated best for vegetable crops by the respondents

Farmers were asked about the kraal manure they rated highest, based on their experience. The findings are represented in Table 5.8.2.

Table 5.8.2: Rating of usefu y respondents.

MANURE	NUMBER OF RESPONDENTS	PERCENTAGE
Cattle	12	41.4%
Pigs	7	24.1%
Humans	4	13.3%
Goats and pigs	3	10.3%
Poultry and goats	1	3.4%
Cattle and pigs	1	3.4%
Sheep	1	3.4%
Total	*29*	*100%*

Most (41.4%) of the 29 respondents rated cattle manure as the best type of manure. The lowest-rated types of manure were combined poultry and goat manure, combined cattle and pig manure, as well as sheep manure, each rated by one respondent. It was mentioned that responses were influenced by the availability of certain types of animal per village or region.

The majority (53.3%) of the 30 respondents were mixing fertiliser with manure in their gardens without measuring it first or taking soil samples for analysis, while only 20.0% of the respondents were taking soil samples to the laboratory for analysis. Thirty percent of the respondents were able to interpret the soil recommendations from the laboratory, whereas the rest were not. Twenty-three respondents (60.9%) did not know the amount of fertilizer they applied per area.

5.8.3 Crops to which kraal manure is applied

Respondents were asked the names of crops to which they were applying kraal manure. They were also questioned about their observations after application. It was found that all the respondents were applying kraal manure to all the vegetables they were planting. The effect of manure on crops received due attention. The various resp vith regard to the effect of manure on vegetable crops, are represented in Table 5.8.3.

Table 5.8.3. Observations after application of manure

OBSERVATIONS	NUMBER OF RESPONDENTS	PERCENTAGE
Increase in yield	22	75,9%
Good growth of edible parts	5	17,2%
Normal growth	1	3,4%
Greener colour	1	3.4%
Total	*29*	*100%*

As shown in Table 5.8.3, 75.9% of the respondents observed an increase in yield after applying kraal manure to their gardens, 3.4% noticed a greener colour in their crops after application and 17.2% observed good growth of leaves and edible parts after application, while one respondent was of the opinion that there was no difference between plots where manure was applied and those where it was not applied. The majority of respondents based their answer to this question on their previous experience as farm workers.

5.9 SOIL-TURNING EQUIPMENT

The soil-turning equipment of the farmers was investigated, as well as the reasons for its utilisation. The following questions were asked to clarify the opinions of farmers in this regard: Why does the soil need turning? What ploughing depth is used? How does turning the soil with a tractor compare to turning it with a spade?

Most respondents (82.8%) were using forks, spades and rakes to turn and prepare their soil, while the rest were turning their soil with tractor-propelled equipment such as mould-board ploughs, disc harrows and chisel ploughs. Of the 29 respondents, 37.1% tilled their soil as a way of loosening it, 27.6% tilled or ploughed it to destroy weeds, 6.9% used the above-mentioned equipment for breaking up clods of earth, at using machines to plough saves time and labour, and 20.9% of the respondents used manual tillage because they thought it was cheaper. A large portion (36.7%) of respondents turned the soil to bury weeds, 6.7% to retain moisture, 13.8% to facilitate soil infiltration, and one respondent to mix fertiliser with the soil. Of the respondents, 10.3% were turning their soil to mix manure into the soil, while 6.9% were turning their soil to prepare it for planting and to kill pests. The infiltration rate measurement indicated that seedbeds covered by vegetative plants were relatively resistant to water runoff and sediment formation during storms, unless the soil in the beds became completely saturated. Disc harrowing could reduce bulk density and improve total porosity (Phiri *et al.*, 2001:131).

5.10 PLOUGHING DEPTH

Most respondents (66.7%) were ploughing the soil to a depth of 30cm, 18.5% to a depth of 25cm, 3.7% to a depth of 35cm and 11.1% to a depth of 60cm.

5.11 TRACTORS VERSUS SPADES

Of the respondents, 63.3% believed that ploughing with a tractor was better than using spades and forks, whereas 23.3% believed that using spades and garden forks was the best; 13.3% believed that both methods gave similar results.

Reasons respondents gave for not ploughing with a tractor are:

- The tractor disturbs irrigation pipes in the soil; and
- It destroys seedbeds in vegetable gardens.

Reasons given for ploughing with a tractor:

- Ploughing with a tractor saves time and labour;
- Good ploughing depth;
- It improves soil structure;
- It can be used for large-scale farming, and
- it removes weeds.

5.12 SOIL COMPACTION TIVE FACTORS

Respondents were asked whether their garden soils were compacted or not. Of the respondents, 50.0% were of the opinion that their garden soils were indeed compacted, while the rest did not think so.

Heavy rain was seen as a cause of soil compaction by 8.7% of respondents. These respondents reasoned that if the soil was compacted, high runoff and erosion would occur during heavy rains. Some of the respondents (26.0%) investigated this problem by checking the heaviness of the soil during ploughing, whereas 30.4% examined the structural development of the soil. Of the respondents, 8.7% accepted that their soil was compacted because it was not turned regularly. Only 4.3% of the respondents were of the opinion that traffic did not contribute to their soil compaction, while 13.0% believed that their soil was compacted because there was a lot of human and animal traffic on their plots. Some of the respondents (8.7%) believed that their soil was compacted because it consisted of clay.

Most of the respondents (96.7%) believed that soil compaction affected seed germination. Davies *et al.* (1993:111) and George (1984:1) state that traffic closes up some of the larger air pockets in the soil. The number of air pockets in the soil gave an indication of structural damage to the soil. The large pores that were closed by traffic, had previously acted as drainage channels in the soil. Of the respondents, only one was of the opinion that seed germination was not affected by compaction. Tillage practices which involve heavy machinery physically break up macro-aggregates into smaller units, leading to the creation of new surfaces. Pore size distribution is one sensitive physical property of soil that can be used to evaluate the influence of tillage on physical conditions, since it regulates the rate of water entry into the soil. It also influences the soil water fluctuation, which affects plant nutrition availability and plant growth (Phiri *et al.*, 2001:131).

The respondents were also asked about the effect of soil compaction on seed germination. Erosion was identified as one of the consequences of soil compaction by 11.1% of the respondents. They said that seeds were washed away by runoff water during he respondents, 44.4% were of the opinion that very heavy soil suppresses seed germination and hampers seed sprouting, 29.6% believed that soil compaction restricts seed development and growth, whereas 11.1% thought that it restricts root development. Of the respondents, 3.7% believed that soil compaction restricts air movement and water penetration to the seed in the soil. Soil organisms are very important in promoting the turnover of carbon molecules. Aerobic respiration involves the breakdown or dissemination of complex carbon compounds, as well as oxygen consumption and the release of carbon dioxide, water and energy for cellular growth (White, 1997:149).

5.13 SOIL TEXTURE CLASSES

Respondents were asked to classify their soils into different textural classes, and the results are set out in Table 5.13.1.

Table 5.13.1: Soil texture

TEXTURE CLASSES	NUMBER OF RESPONDENTS	RESPONDENT %
Sandy	8	27.5%
Sandy Loam	7	24.1%
Loamy	7	24.1%
Clay	4	13.7%
Clay Loam	2	6.9%
Unknown	1	3.4%
Total	*29*	*100%*

Most of the 29 respondents specified their garden soil texture as sandy, sandy loam or loamy types. This classification was correct to within 5% (plus or minus) when compared to the result of the laboratory analysis.

Respondents were asked about the methods they used to determine the texture class of their garden soil. Of the 29 respondents, 3.5% determined their soil's texture class by observing its swelling and shrinking behaviour, 13.8% by its stickiness, 75.9% through vi 3.5% by the degree of infiltration (some respondents mentioned that sandy soil is easily infiltrated), and 3.5% of the respondents determined their soil's texture class by colour. Most soils have a clay content of between 0-5% and 6-10%, as specified by 21 of the respondents; nine people did not respond. The actual clay percentages were 40%, 4%, 5% and 20% respectively, as determined by the Glen Soil Laboratory. This demonstrated to the farmers that there is not such a big difference between field and laboratory methods.

5.14 IRRIGATION PRACTICES

The farmers were asked about the irrigation methods they utilised for their crops, the effect of irrigation on soil structure and irrigation frequency in their gardens or fields. Of the respondents, 23.0% were irrigating with sprinklers, 23.0% were utilising buckets, 11.5% were using watering cans and 15.4% were irrigating with hosepipes. Four people did not specify the method they were using for irrigation.

5.14.1 Irrigation frequency

Irrigation frequency is set out in Table 5.14.1.

Table.5.14.1: Irrigation frequency in the vegetable gardens.

FREQUENCY	NUMBER OF RESPONDENTS	RELATIVE PERCENTAGE
Once a day	12	41.4%
Twice a day	10	34.5%
No irrigation	7	24.1%
Total	*29*	*100%*

Table 5.14.1 shows the response of farmers regarding irrigation frequency. The majority of the respondents (41.4%) irrigated once a day, 34% irrigated twice a day, and 24.1% did not irrigate their vegetables. Vegetables cannot grow well if they are not irrigated, since water and nutrients in the soil form a colloidal solution

(Phiri *et al.*, 2001:131). Of t ts, the majority (66.7%) believed that summer crops need more frequent watering than winter crops. Most of the thirty respondents (63.3%) were irrigating seedbeds before transplantation. Sixteen of the 29 respondents were of the opinion that clay soil could be watered less often than sandy soil.

5.14.2 Effect of irrigation on soil structure

Of the 28 respondents, 46.4% were of the opinion that irrigation methods had no effect on soil structure, 28.0% believed it compacted the soil, 14.3% believed that it had an effect on soil structure, 7.8% said that it increased growth and production, and 3.5% did not respond to this question. Over-watering can produce excessive leaf growth in vegetables, which makes the leaf inedible, restricts root growth and causes leaching of nitrogen from the soil (Hemy, 1984:24). The application of water to the soil is one of the oldest techniques to ensure an adequate food supply (Wild, 1993:162).

5.15 MULCHING

Project participants were asked to give their interpretation of mulching. Of the 29 respondents, 65.5% had a good understanding of mulching, whereas 34.5% were not familiar with the term. After explaining what the term meant, the respondents were asked about the effects of mulching on vegetables of which 25 people responded to this question. The effects were not known by 8.0%, 4.0% responded that it regulates soil temperature and 16.0% said that it protects against sun heat. Four percent believed that it prevents soil erosion and 12.0% believed that it improves soil fertility, while 56.0% of the respondents indicated that it reduces moisture loss. Gicheru *et al.* (1998:5) state that mulching conserves soil water and leads to better crop performance than conventional tillage and tied ridging. Crop performance was measured in terms of emergence, height, vegetative growth and yield.

5.16 FUTURE PLANS FOR PROJECT

The respondents were asked about the future of their respective projects. A large portion (45.0%) of the 20 respondents indicated that they wanted to produce more vegetables in the near future, 30.0% wanted to create a bigger market, 15.0% were planning to become commercial farmers in the near future, and one responded that he wanted to create employment opportunities. An old farmer wanted to be pensioned off.

5.17 TRAINING NEEDS

Information concerning the training needs of farmers was collected. The institution that offered training to the respondents and the value of the training the respondents received, were also investigated. Most of the respondents (63.3%) indicated that they still needed training, while the rest had already received training. Most of the latter (84.2%) had received training from the Department of Agriculture, 10.5% had received training from Boskop and 5.3% from Agriqwa. Of the 17 respondents, 35.3% regarded the training they received as worth their while, 17.7% rated it highly, 23.5% said it had increased their production, 17.7% were of the opinion that it had improved their skills, while 5.9% thought it was not good. A small portion of the respondents (5.2%) believed that they required no training because they had received a lot of training in the past.

The respondents identified the following training needs (in order of priority):

• Protection of crop against weeds	31.1%
• Pest control	22.4%
• Record-keeping	18.9%
• Fertiliser application	10.3%
• General project management	5.2%
• No training needed	5.2%
• Seed-planting method	3.5%
• Tractor maintenance	1.7%
• Marketing	1.7%

5.18 RECORD-KEEPI MICS

Most (68.0%) of the 25 respondents did not know what record-keeping meant, 8.0% thought it referred to the total value of everything on the farm or in the project, 16.0% believed it concerned physical and financial records, and the rest believed it had something to do with gains or losses. Of the 30 respondents, 26.9% kept financial records of their project activities while 16.7% kept physical records. Four respondents were subsistence farmers, two were unaware of the total amount of money they earned every season by selling their agricultural produce, and one sold all his products every season. Of the 26 respondents, 61.5% knew how to determine profit, 7.7% determined it by using records and 3.9% had no records to determine profit, while 26.9% were unable to calculate it.

Of the 29 respondents, most (93.1%) borrowed money for their input costs. Most of the respondents (66.7%) were storing seed from the previous years, whereas the rest were not. Of those who were storing seed, 60.0% stored them in tins and buckets, 20.0% stored them inside the original seed packets, and 20.0% dried them in the sun.

5.19 AVERAGE AREA UTILISED FOR DIFFERENT VEGETABLE CROPS, AND YIELD OBTAINED

Information regarding the production area, yield, input costs and units sold was collected from farmers, although only averages were taken into consideration, as set out in Table 5.19.1.

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Table 5.19.1: Average area utilised for different vegetable crops, average yield, average input cost and income earned.

Crops	Units	Average Area (m²)	Average total yield	Average price/ unit (R)	Average income(if all units were sold) (R)	Average input costs (R)	Average income on sold units (R)	Amount consumed in cash (R)	Average profit (R)
Cab-bage	Head	308.1	179.9	5.20	932.10	31.30	250.30	681.80	900.80
Beetroot	Bundle	620.7	55.4	7.50	415.50	29.10	139.50	276.00	386.40
Potatoes	10kg	29.8	102	13.30	1354.60	21.80	132.80	1215.80	1332.80
Beans	2kg	121.5	145.8	13.50	1968.70	47.00	151.90	1816.80	1921.70
Spinach	Bundle	122.3	23.3	2.40	54.80	19.20	6.10	48.70	35.60
Radish	Bundle	151.6	10	2.30	22.50	15.00	20.30	2.20	7.50
Peanuts	1kg	21.0	3	12.30	36.90	32.00	37.00	*	4.99
Carrots	1kg	30.0	*	*	*	*	*	*	*
Pumpkin	Head	75.0	81.5	8.50	692.80	*	229.50	463.30	692.80
Onion	1kg	30.0	*	*	*	*	*	0	*
Giant curl	1kg	267.0	*	*	*	*	*	*	*

* = CROP DAMAGED BY FLOOD

As shown in Table 5.19.1, the most popular vegetable crop was beetroot, followed by cabbage, whereas peanuts were the least cultivated crop. On average, maize and beans sold the most units. The highest price fetched per unit was for potatoes.

6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY

6.1.1 Introduction

In this chapter, a summary will be given and the study's recommendations will be discussed in detail. The focus will be on the trials, soil management and the information extrapolated from the distributed questionnaires.

6.1.2 Demography and geographical distribution

The sample was distributed well among the five locations, with Makwane marginally more represented with 26.7% of the respondents. The average age of the respondents was 53 years, indicating that most of the respondents were quite old. The highest number of respondents were in the group 60-69 years. The largest portion of respondents (36.7%) had less than five years' experience. Most (48%) of the 25 respondents had reached an educational level somewhere between grade one and seven. About 12% did not attend school at all, though some knew how to read and write. The chief allocated land to 73.3% of the respondents. Most (65.5%) of the respondents were working in groups of between 11 and 15 people.

6.1.3 Carrot trials

Bennie *et al.* (2000:44) regard soil bulk density as an indicator of the compactness of a specific soil. No significant ($P>0.05$) differences between the Leratong and the Mpho vegetable control plots were observed regarding bulk density. This implies that, although these plots were situated in different locations, their soil characteristics were much the same. There was no significant ($P>0.05$) difference between the soil management practices in all locations. In the loosened topsoil, the mean carrot growth was ording to Wolf *et al.* (1995:956), a compacted seedbed reduces aeration and limits water and nutrient movement in the soil, and as a result of this the shoot and root growth of vegetables is restricted. The significant (P<0.05) difference between the mean length of the carrots in the control group and the treated group respectively, is postulated to be the result of the loosened topsoil. Carrot mean diameter and mass were significantly influenced by soil compaction. This trial's findings showed that soil compaction has a negative effect on the production of carrots.

6.1.4 Potato trials

The potatoes in the unloosened topsoil emerged earlier, reflecting the importance of smooth seedbed preparation. However, there was no significant (P>0.05) difference between the control and treated soil in terms of the mean mass of the potatoes that were harvested. These results showed that the growth of plants depends on many factors such as the supply of nutrients, the way soil solids are arranged, and other factors that were determined by the location (Wood, 1989).

6.1.5 Application of sodium chloride to vegetable garden soils

A significant (P>0.01) difference was observed between the bulk density of the fresh and the oven-dried soil. This result is of vital importance to farmers, because it demonstrates that soil can actually retain more water than one would think possible. There was a significant (P<0.01) difference between the non-salted, old salted and recently salted soils, and the detrimental effects of salt on soils, were demonstrated. Based on this finding, it is clearly not advisable to apply salt to garden soils.

6.1.6 Soil management practices

The main objective of this study was to determine the soil management practices of farmers in the Eastern Free State. This was accomplished via two processes, namely the planting of trials in vegetable gardens to demonstrate the effects of soil compaction, and the determination of the management practices of farmers with regard to their vegetable ga 3%) of the respondents reported no traffic on their plots, while 13.0% believed that the textural characteristics of their garden soil affected vegetable production. Knowledge of soil texture enabled farmers to take account of the clay content of the soil before they planted the vegetable seeds. Soil compaction was a new term to some of the respondents. As a result, they were unable to identify certain features of soil compaction. Farmers did not make appropriate use of irrigation, while some of them did not loosen or prepare the soil properly before planting the seeds.

Of the total number of respondents, 73.3% were working in a group consisting of one to five people during soil preparation and other vegetable management activities on their plots. Slightly more than 85% of the 28 respondents were planting in seedbeds. Of the 29 respondents, 68.9% were resting their land while the rest were cultivating their vegetable gardens without interruption.

Most of the respondents (95%) used cattle manure, and a smaller number utilised pig manure. Of the 27 respondents, only 18.5% measured out the manure prior to application. Most of the respondents mentioned that they were using kraal manure because of its cheapness and availability. Most (41.4%) of the 29 respondents rated cattle manure as the best type of manure for application to vegetable gardens. Farmers observed that the application of cattle manure had increased their vegetable yield. The majority (53.3%) of the 30 respondents were mixing fertiliser with manure in their gardens without measuring it first or taking soil samples for analysis, while only 20.0% of the respondents were taking soil samples to the laboratory for analysis. Thirty percent of the respondents were able to interpret the soil recommendations from the laboratory, whereas the rest were not. Twenty-three respondents (60.9%) did not know the amount of fertilizer they applied per area.

Most respondents (82.8%) were using forks, spades and rakes to till the soil. Most of the respondents were tilling their soil to a depth of 30 cm. Almost all the respondents believed that soil compaction affects seed germination. Of the 29 respondents, 41.4% irrigated their plots once a day, while 46.4% were of the opinion that the irrigation method has no effect on soil structure. Of the regard to their vegetable ga [illegible] 3%) of the respondents reported no traffic on their plots, while 13.0% believed that the textural characteristics of their garden soil affected vegetable production. Knowledge of soil texture enabled farmers to take account of the clay content of the soil before they planted the vegetable seeds. Soil compaction was a new term to some of the respondents. As a result, they were unable to identify certain features of soil compaction. Farmers did not make appropriate use of irrigation, while some of them did not loosen or prepare the soil properly before planting the seeds.

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6.2 CONCLUSIONS

The following two main hypotheses were tested in this study:

1. If the farming practices of farmers on vegetable gardens are researched, it will be found that optimal farming practices are executed to varying levels on vegetable gardens, while meaningful differences will also occur between farmers.

2. The trials will show a significant difference between compacted (untreated) and loosened (treated) garden soils.

From the discussion in paragraph 6.1 it is obvious that both these hypothesis can be accepted.

6.3 RECOMMENDATIONS

Farmers should be trained in vegetable management as well as fertiliser and manure application techniques. This study has pointed out that fertiliser is applied to gardens without taking soil requirements into account. Knowledge of the textural characteristics of soil is important, since it would enable farmers to take cognisance of the clay content of the soil before planting any vegetables. If farmers were able to identify their soil texture, they would find it easy to plan production accordingly. Farmers are unaware of the moisture-retaining capacity and compaction of their soils. Farmers irrigate twice a day or more without determining the moisture-retaining capacity of their soils. Compaction is also a new term to most of the farmers. As a result, farmers are unable to identify certain features of soil compaction. T d be trained to measure their fields, since this will make it easier for them to plan their vegetable production. Record-keeping is not done properly; farmers should be advised to keep farming records. Farming records are useful for monitoring and identifying profitable and non-profitable farming activities. Such records can also be used for making decisions regarding future activities that will increase profit.

Farmers should be made aware of the effect of compaction on their garden soil. Soil management aspects such as mulching and irrigation must be explained to farmers. The application of proper management techniques to the running of vegetable gardens should have a positive impact on soil management. Fertiliser should be applied to soil on the basis of the recommendations received from soil laboratories after the soil was carefully analysed.

On average, farmers had been occupying land for 15 years. Most of the respondents (73.3%) had been farming on communal land for a period of almost 25 years. They should be advised to buy their own farms. Farmers who are currently working together in a group, should be advised to farm individually in order to avoid profit-sharing and possible conflict.

REFERENCES

Aon, M.A., Sarena, D.E., Burgos, J.L. and Cortassa, S. 2001. Microbiological, Chemical and Physical Properties of Soils Subjected to Conventional Or No Till Management: an assessment of the quality status. In: *Soil and Tillage Research*. 60:173-186.

Ball, B.C., Campbell, D.J., Douglas, J.T., Henshall, J.K. and O'Sullivan, M.E. 1997. Soil Structural Quality, Compaction and Land Management. In: *European Journal of Soil Science*. Eh26 Oph, Uk Volume 48, Edited by R Webster, Rothamsted Experiment station, Harpenden Herts, Al 2JQ UK.

Basher, L.R. and Ross, C.W. 2001. Role of Wheel Tracks in Runoff Generation and Erosion Under Vegetable Production on Clay Loam Soil At Pukekohe, New Zealand.In: *Soil and Tillage Research.* Volume 62, Publisher Elsevier: Amsterdam, 117-130.

Baver, L.D., and Gardner, W.R. 1972. *Soil physics*. John Wiley and sons, USA.

Belay, A., Classens, A.S., Wehner, F.C., and de Beer, J.M. February 2001. Influence of Residual Manure on Selected Nutrients Elements and Microbial Composition of Soil Under Long Term Crop Rotation.In: *Plant and Soil.* Volume 18, number 1. Edited by J.B.J. van Rensburg, Forum Press International.

Bennet, W. 1993. *Nutrient Deficiencies and Toxicities in Crop Plants*. Publisher: American Phytophological Society, United States of America.

Bosman, T. Dec 01 / Jan 02. Irrigation can make or break your crop in South Africa. In: *Vegetables and Fruits.* Number 84.

Brady, N.C. 1984. *Nature and properties of soil.* Macmillan: New York.

REFERENCES

Aon, M.A., Sarena, D.E., Burgos, J.L. and Cortassa, S. 2001. Microbiological, Chemical and Physical Properties of Soils Subjected to Conventional Or No Till Management: an assessment of the quality status. In: *Soil and Tillage Research*. 60:173-186.

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Baver, L.D., and Gardner, W.R. 1972. *Soil physics*. John Wiley and sons, USA.

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Bennet, W. 1993. *Nutrient Deficiencies and Toxicities in Crop Plants*. Publisher: American Phytophological Society, United States of America.

Bosman, T. Dec 01 / Jan 02. Irrigation can make or break your crop in South Africa. In: *Vegetables and Fruits*. Number 84.

Brady, N.C. 1984. *Nature and properties of soil*. Macmillan: New York.

Burger, D. 1999. *South Afri* *9.* Published in South Africa: ISSN O302-0681.

Campbell, C.A., Selles, F., Lafond, G.P., Biederbeck, V.O. and Zentner, R.P. 2001. Tillage fertiliser changes: Effect on some quality attributes under long term crop rotations in thin black chernozen. In: *Canadian Journal of soil science*. Volume 81, number 2(May 2001) edited by R R Simord (157-165

Carter, M.R. 1998. Penetration Resistance to Characterise the Depth and Persistance of Soil Loosening in Tillage Studies.In: *Canadian Journal of Soil Science*. 68:657-668.

Carter, M.R. and Sanderson, J.B. 2000. Influence of Conservation Tillage and Rotation Length on Potato Productivity, Tuber Disease and Soil Quality Parameters on A Fine Sandy Loam in Eastern CanadaIn: *Soil and Tillage Research.,* 63:1-13. Publisher: ISTRO.

Christensen, B.T. Sept. 2001. Physical Fraction of the Soil and Structural and Functional Complexity in Organic Matter Turnover.In: *European Journal of Soil Sciences*. Department of Crop Physiology and Soil Sciences, Danish Institute of Agricultural Sciences, Research Centre Forum, Box 50, 8830 Tjel, Denmark. Editor-in-chief: Webster, R. Published by Blackwell Sciences and the British Society of Soil Sciences on Behalf of the National Societies of Soil Sciences in Europe: 345-353.

Cooke, G.W. 1982. *Fertilizing for Maximum Yield*. Published in Greate Britain by Richard Clay (Press Ltd).

Cooper, E.L. *Agriscience Fundamentals and Applications*. Published by Delmar, USA.

Cruickshank, G.G. 1974. *Soil Geography*. Queens University. Publisher: Belfast David and Charles.

Davidson, F.R. 1990. Food Production At the Household Level. In: *Vegetable Research and Development in SADCC. Proceedings of Workshop Held At Amsha*. Tanzania, 9-13, July, 1990. Editor: Opena, R.T. and Kyomo, M.I. Taiwan: 169-172.

Department of Land Affairs. 1998. *White Paper on South African Land Policy*. Government Printer : Pretoria.

Foth, H.A. 1984. *Fundamentals of Soil Science*. Seventh Edition. Publisher: John Wiley and Sons, USA.

Gagnon, B., Lalande, R., Simard, R.R. and Roy, M. February, 2000. Soil Enzyme Activities Following Paper Sludge Addition in A Winter Cabbage Sweet Corn Rotation.In: *Canadian Journal of Soil Sciences.* Canada G1K74P. Edited by R.R. Simard, Agriculture and Agricultural food in Canada, Soils and crop research and development centre, Dante- Foy, Quebec, A.D.J. Canada, Volume 80, Number 1, 91-97.

Ghuman, B.S. and Sur, H.S. 2001. Tillage and Residue Management Effects on Soil Properties and Yields of Rainfed Maize and Wheat in Sub Humid Subtropical Climate.In: *Soil and Tillage Research*. 58:1-10.

Gicheru, P.T., Gachene, C.K.K. and Biamah, E.K. 1998. Effects of Tillage and Mulching on Soil Moisture Conservation and Crop Production.In: *Applied Plant Science.* Publisher: South African Weed Science Society. Volume12, Number 1: 5-9.

Govers, G., Vandaele, K., Desmet, J., Poesen, J. and Bunte, K. December, 1994. The Role of Tillage in Soil Distribution on Hillslopes.In: *European Journal of Soil Science.* Publisher: Blackwell Scientific Publications and the British Society of Soil Science. 45:469-479.

Groves, M.P. 1979. *Complete guide to gardening*. USA, Meridith Co-operative, Des-moines, Iowa.

Hadfield, J. 1967, *Vegetable gardening in South Africa*. Publisher: Purnell and Sons (SA)PTY, LTD. Keerom street, Cape Town.

Harden, B. 1998. Managing Manure Nitrogen to Curb Odours. In: *Agricultural Research Service*. USA, USADA:22.

Hemy, C. 1984. *Growing Vegetables in South Africa*. Publisher: Macmillan SA (Pty)Ltd.

Hillel, D. 1971. *Soil and Water, Physical Principles and Processes*. University of Jerusalem, Academic Press. New York.

Hillel, D. 1982. *Introduction to Soil Physics*. Published by Academic Press Inc., London Ltd, UK.

Huxley, A. 1975. *Garden Planning And Planting*. Blandford Press.

Kendrick, J. 1991. Reviewed by Soleri, D. of the Centre for People. Vegetable Ventures.In: *African Farming*. June/May 2000. Publisher: Allam Charles,12-13.

Kessler, K. 2002. Nitrogen: Use it or lose it. In: *The Furrow Summer* .Volume 107, Issue 1. Editor: Wolf F, 8:13.

Kramer, P.J. 1949. *Plant and soil water relationship*. New York, Torondo London, Mc Graw-Hill Book company.

Lea, J.D. 1991. *Maize Production in Kwa-Zulu - A Handbook for Extension Officers and Farmers.* Publisher: Montage Print.

Little, K M.; Metelerkamp, ; W. 1998,Compaction of Three Methods of Soil Water Content Determination.In: *South African Journal of Plant and Soil.* Publisher: South African Weed Science Society, Volume15, Number 2, 80-89.

Maclay, G,1984. *Encyclopedia of Gardening in South Africa*. Readers Digest, South Africa. Pty. Ltd., Cape town.

Marasas, C.N. May, 1999. *Socio-economic Impact of the Russian Wheat Aphid Integrated Control Program.* Ph.D in the Department of Agricultural Economics, Extension and Rural Development, Faculty of Biological and Agricultural Sciences, University of Pretoria.

Marsh, R. 1998. Building on Traditional Gardening to Improve Household Food Security. In: *Food Nutrition and Agriculture*. Number 22:4-14.

Marshall, T.J., Holmes, J.W. and Rose, E.W. 1996. *Soil Physics*. Cambridge University Press, USA.

Masiunas, J.B. 1998. Production of Vegetables Using Cover Crops and Living Mulches - A Review. In: *Journal of Vegetiable Çrop Production*. Volume 4, Number 1. University of Illinos(USA):11-31.

Matchett, T. 16 February 2001. Sustainable agriculture: no tillage. *Farmers Weekly.*

Mbuvi, J.P. and Wanjogu, S.N. 1998. Crusts and Their Influence on Soil Properties in Two Semi-arid Areas in Kenya, University of Nairobi.In: *Applied Plant Sciences.* Publisher: SAWSS, Sunnyside, Volume 12, No.3 :83-87.

Ministry for Agriculture. 1998. *Agricultural Policy in South Africa*. CPT Printers, Cape Town.

Montagu, K.D., Conroy, J.P. 1998. Root and shoot response of field grown lettuce and broccoli to a compact subsoil. *Australian Journal of Agricultural Research*, 49:7

Munkholm, L.J., Schojonning, P. and Rasmussen, K. J. Oct. 2001. Non-inversion Tillage Effects on Soil Mechanical Properties of A Humid Sandy Loam. In: *Soil and Tillage Research.* Danish Institute of Soil Sciences, Research Centre, P.O. Box 50 Dk-8830, Jjele, Denmark. Published in Collaboration with Nutritional Soil Tillage Research Organisation. Volume 62: 2-14.

Naude, S. and Van der Bergh, A. 1992. Beetroot, spinach and swisschard. In: *South African Plant Disease Control Handbook* edited by Wilkinson, D.J. and Esterhuysen, S.P. Publisher: Farmer support group, University of Natal.

Nhantumbo, D.C. and Bennie, A.T.P. 2001. A Procedure for Determining the Minimum Bulk Density of Soils.In: *South African Journal of Plant and Soil.* Department of Soil Science, University of the Orange Free State, February 2001, Volume 18 Number 1. Edited by J.B.J. van Rensburg. Publisher: South African Society of Crop Production, 44-46.

Nielson, D.R., Jackson, R.D., Cary, J.W. and Evans, D.D. 1984. *Soil Water.* American Society of Agronomy and Soil Science, 677 South Seqoe Road.

NUFARMER, April 2002 and AFRICAN ENTREPRENEUR, VOL:6 No. 11 :5, 1:28.

Nyamangara, J. Gotosa, J. and Mpofu, S.E. 2001. Cattle maintenance on structural stability and water retention capacity of an organic sandy soil in Zimbabwe. In *Soil and Tillage Research*, University of Zimbabwe, Volume 62. London, New York: 157-162

Ojeifo, I.M. 1989. The Pla [illegible] Production in Cropping Systems of Rural Communities. In: *Occasional Papers*. National Horticultural Research Institute, Abadania. Number 21:6.

Phiri, S., Amezquita, E. Rav, I.M. & Sigh, B.R. 2001. Disc harrowing intensity and its impact on soil properties and plant growth of Agro-pastoral systems. In *Soil and Tillage Research*. Vol 62:131-143

Raath, P.J. November 2001. The importance of compost in organic crop production. In: *Vegetables and fruit*. No. 763:43-46

Rahn, C. 2001. Reducing nitrogen losses from field crops. In *Fruit and Vegetables Tech*. Volume 1, No.1:34-35

Russell, B. 2001. Till systems nurture the earthworms which increase soil moisture, fertility and nutrients levels and production growth stimulants. *Farmers Weekly*: 9 March 2001.

Sauderson, M.D. 1995. Sustainable Agriculture and Rural Development in South Africa. In: *Outlook on Agriculture*. Vegetable and Plant Institute, Agricultural Research Council. Elsenburg, 7607.24(3),163-165.

Schwab, G.O., Fangmeier, D.D. and Elliot, W.J. 1996. *Soil and Water Management Systems*. Publisher: John Wiley and Sons, Canada.

Serage, K.L. 2000. *Possible Predictors Determining the Adoption of Potatoes (Solunum tuberosum) Into the Wheat (Triticum aestivum) Based Cropping System in Mokhothong, Lesotho*. University of the Free State, Centre for Agric. Management. M.Agric.-thesis.

Shainberg, I. and Levy, G. J. 1996. Infiltration and Seal Formation Processes.In: *Soil Erosion, Conservation and Rehabilitation*. Institute of Soils and Water, Bet-dagan, Israel. Edited by Menachem Agassi. Published by Marcel Dekker: 1-22.

Soil Classification Workgroup. 1991. Soil Classification – A Taxonomic System for South Africa. 2nd Revised Edition. Directorate Agricultural Information: Pretoria.

Sojka, R. E. and Upchurch, D.R. 1999. Preservation Regarding the Soil Quality concept.In: *Soil Sciences Society of American Journal.* Volume 63, no.5, SSSJD4 63(5): 1039-1484.

Somani, L.L. 1990. *Interactive Effect of Soil Compaction and Mixing of Heavy Textured Soil in Loamy Sand Soil on the Physical Properties of Sandy Soil and Yield of Clusterbean,* Yada V, BL. SKN College of Agriculture, Jobner, Rajasdam, India. Transactions of Indian Society of Desert Technology.

South African Irrigation, June/July 2000. The Official Journal of South African Irrigation Institute.Volume 22, Number 4. ISSN 0258-5081:21.

South African Yearbook 2001/2002. Edited by Burger, D. Publisher: GCIS

Steyn, J T. 1994,Die invloed van grondbewerkingsstelsels op grondwaterhoud en wortelontwikkeling van verskillende koringkultivars in die somerreënstreek. MSc Agric., University of the Free State.

Stirzaker, R.J. 1997. Processing Tomato Response to Soil Compaction and Fumigation. in *Australian Journal of Experimental Agriculture*, 37: 477-483.

Stubbs, R. 9 March 2001. Cover crop and no till production. In: *Farmer's Weekly.* 9 March, 2001.

Tan, K.H. 1996. *Soil Sampling, Preparation and Analysis*. Marcel Dekker, 270, Madison avenue: NY.

Thompson, L.M. Troeh, F.R. 1978. *Soils and soil fertility*. Publisher: McGraw-Hill, USA.

Tolmay, J. P. C. 1995. The influence of tillage methods on the utilisation of soil water by three winter wheat cultivars (Triticum aestivum L.) in the Eastern Orange Free State. Faculty of Agriculture, University of the Orange Free State.

Tshepiso, S. 1999. Farmyard manure as an alternative to inorganic fertiliser. Soil Science Directorate Technical Support Services, Department of Agriculture. in *Vegetables and Fruit,* no:70

Upchurch, D.R. & Sojka, R.E. 1999. Presentation regarding the soil quality concept. In *Soil Science Society of America Journal*, Vol. 63:5, 1039-1484

Van Ouwerkerk, C. 1983. Effects of tillage and residue management on properties of too coarse-textured soils and on yield of irrigated wheat and groundnut. In: *International Journal in Research and Development in Soil Tillage and Field Traffic*. Published in Collaboration with the International Soil Tillage Research Organisation. Volume 3.

Venter, L., Du Toit, P. and Bunyasi, 1999. *Free State Mission on Rural Investment*. Publisher: Rural Strategy Unit, Glen, South Africa.

Walker, S. 1999. Small scale farmer needs in Leliefontein community area. *Proceedings of 33rd conference of the South African Society for Agricultural Extension*., 11-13 May, 1999, President Hotel, Bloemfontein. SASAE Publications: Pretoria

White, R.E. 1997. *Principles and Practises of Soil Science. The Soil As A Natural Resource*. Third edition, University of Melbourne, Parkville, Australia. Publisher: Marston Book Services.

Wolfe, D.W., Topeleski, D.T, Gundersheim, N.A and Ingall, B.A. 1995. Growth and Yield Sensitivity of Four Vegetable Crops to Soil Compaction. In: *Journal of American Soc. Hort. Sci.* 120, (6):956-963.

Wood, M. 1989. *Soil Biology*. Chapman and Hall, New York.

YanLi, X., Liu, L.Y. and Gong, J.D. 2001. Influence of Peddle Mulch on Soil Erosion by Wind and Trapping Capacity for Wind Blown Sediment.In: *Soil and Tillage Research.* 59:137-142.

Young, E.G., Leeds-Harrison, B.P. and Garnett, R.S. 1994. Water Uptake by Aggregates.In: *European Journal of Soil Sciences.* Volume 45:127-134.

Zhang, B. Zhao, Q.G. Horn, R. and Baumgartl, B. 2001. Shear Strength of Surface Soil As Affected by Soil Bulk Density and Soil Water Content.In: *Soil and Tillage Research.* 59:97-106.

ANNEXURE A

QUESTIONNAIRE ON THE IMPACT OF SOIL COMPACTION ON THE SUSTAINABILITY OF VEGETABLE GARDENS IN THE EASTERN FREE STATE

QUESTIONNAIRE ON THE IMPACT OF SOIL COMPACTION ON THE SUSTAIN ABILITY OF VEGETABLE GARDENS IN THE EASTERN FREE STATE

Compiled by: G.P. HADEBE
September 2000

SCHOOL OF ENVIRONMENTAL DEVELOPMENT AND AGRICULTURE

TECHNIKON FREE STATE

BLOEMFONTEIN

OVERHEAD OBJECTIVES OF THE QUESTIONNAIRE:

- Management practices of the vegetable gardens in the Eastern Free State will be investigated.
- Factors which affect production in the vegetable gardens will also be researched.
- To determine whether farmers can identify soil compaction in their gardens

The information on this questionnaire will be confidential. Please write honest and frank answers.

Answer all questions

For office use

A. BIOGRAPHIC INFORMATION

A.1 DISTRICT : 1

A.2 PROVINCE : 2

A.3 AGE OF FARMER...years 3

A.4 YEARS ON THIS FARM / LAND :...................................... 4

A.5 YEARS IN FARMING : 5

A.6 OTHER EXPERIENCE : 6

A.7 HIGHEST ACADEMIC QUALIFICATION OBTAINED:........ 7

B. INFORMATION ABOUT THE FARM

B.1 Give the size of the land you farm on : .... ha 8

B.2 Who allocate the farm you farm on to you?

(Mark applicable option with X)

ALLOCATOR	OPTIONS	COMMENTS		
Chief	Yes	....		9
	No	....		10
Government	Yes	....		11
	No	....		12
Municipality property	Yes	....		13
	No	....		14
Legally Purchased and owned	Yes	....		15
	No	....		16
Rented	Yes	....		17
	No	....		18
Other specify	:..			19
	:..			20

B.3 How many beneficiaries are in your project ? (state) :.................... 21

B.4 Are you farming as a group ? : Yes/ No 22

B.5 If "not" specify 23

:..

:.. 24

:.. 25

B.6 If farming as a group, what are the responsibilities with regard to

vegetable garden ? :.. 26

: 27

: 28

B.7 Are you the only manager in the project ? Yes/ No 29

B.8 How many people are working on the plot in your garden ?

: 30

31

:..

:.. 32

B.9 Are you planting on seedbeds in your garden ? Yes/ No 33

B.10 If "not" specify how are you planting in your garden ?

34

:..

35

:..

B.11 If "yes" how long have you been planting on the same seedbeds

without changing or turning them ?

.... 36

B.12 How many people are trampling over the garden or seedbeds

everyday ? 37

B.13 Is your land or vegetable garden have a resting period ? Yes/ No 38

B.14 If "yes" for how long do you rest it ? :.. 39

B.15 Is the any traffic in your garden/ land during rest period ?

Yes/ No 40

B.16 If "yes" specify :.. 41

42

:..

43

:..

C. QUESTIONS ABOUT FERTILISERS AND MANURE.

C.1 To what level do you use the following types of manure/ fertiliser?
(Tick the relevant option with "X")

ITEM	Never	Minimum	Moderate	Maximum	
Sheep manure					44
Chicken manure					45
Cattle manure					46
Rabbit manure					47
Pig manure					48
Mixed fertilisers					49
Straight fertilisers					50

C.2 How do you measure the amount of kraal manure in your garden ?

: 51

: 52

: 53

C.3 If you use kraal manure, please give reasons for using it?

:.. 54

:.. 55

:.. 56

:.. 57

C.4 Which animal kraal manure do you think is the best for your soil?

: 58

: 59

: 60

C.5Are you mixing fertiliser and kraal manure ? :Yes/ No 61

C.6 If "yes", why, specify :.. 62

: 63

: 64

C.7 Do you take soil for analysis? Yes / No 65

C.8 If "yes" can you interpret the recommendations? Yes / No 66

C.9 If "not", how much fertiliser do you apply per hectares/
dimension/plot

: 67

....

C.10 Can you explain what over-application of fertilisers is ? 68

:.. 69

:.. 70

:.. 71

: 72

: 73

C.9 Which type of fertiliser do you apply in your soil ?

:.. 74

: 75

C.10 For which crops do you apply kraal manure? 76

: 77

: 78

C.11 Did you saw any change in growth after ?

: 79

: 80

C.12 What is the appearance of your carrots/ beetroot where you have applied manure ?

: 81

: 82

D. CULTIVATION METHODS.

D.1 What are you using to turn the soil on your farm ? : 83

: 84

....

: 85

....

D.2 Why are you using the abovementioned type of turning the soil?

: 86

: 87

: 88

D.3 Why do you turn or plough your soil? :.. 89

: 90

D.4 Up to which depth do you plough your soil? : .... ☐ 91

: .... ☐ 92

D.5 Do you think ploughing with a tractor is better than using spades?

Yes/No ☐ 93

D.6 Give reasons : .... ☐ 94

: ☐ 95

....

: ☐ 96

....

: .... ☐ 97

E. QUESTIONS RELATED TO PLANT GROWTH , SOIL , SOIL COMPACTION AND IRRIGATION.

E.1 Is your farm soil compacted? Yes/ No ☐ 98

E.2 How do you know the answer in E.1. ?

☐ 99

:..

☐ 100

:..

E.2 Does compacted soil have effects on the germination of seeds? Yes/No ☐ 101

E.3 If yes state the effects: .... ☐ 102

: .... ☐ 103

E.4 Mention its effects on growth ,root development and general growth
of vegetables if any ?

:.. 104

:.. 105

:.. 106

:.. 107

E.5 What is the soil texture of your soil ?:.. 108

E.6 How do you determine it ? *(Give reasons)* :....................................... 109

110

111

E.7 How much clay contents does it contains? :....................................% 112

E.8 Which method/equipments are you using to irrigate your soil ? :......... 113

114

E.9 Do you think it have effects on the soil? :... 115

116

E.10 How many times do you irrigate per day and when?:....................... 117

118

119

120

E.11 Summer crops need more frequent watering than winter crops?
Yes/No 121

E.12 When transplanting seedlings do you water the furrows first?
Yes/No 122

E.13 Clay soil can be watered less often than sandy soil? True/ False 123

E.14 Do you know what mulching is ? Yes? No 124

E.15 If "yes" do use mulching in you garden? Yes/ No 125

E.16 Give its effects :.. 126

:.. 127

:.. 128

F. QUESTIONS ABOUT THE FUTURE PLANS OF THE FARM.

F.1 What are your future plans regarding your farm? :............................. 129

: 130

....

: 131

: 132

G. TRAINING NEEDS.

G.1 Did you once receive training in soil/vegetable management? Yes/No 133

G.2 If "yes" from which institutions? :.. 134

G.3 Did you saw any increase/decrease in production after? Yes/No 135

G.4 List all your training needs for this year ? :.. 136

137

:...

138

:...

139

:...

140

:...

:... 141

:... 142

:... 143

:... 144

H. RECORD KEEPING AND ECONOMICS.

H.1 *(Fill all the spaces in the undermentioned table)* :

Type of veg.	Area	Total Yield/ Unit	Units sold	Veg. Price/ Unit	Input cost/ area		
eg Maize	100 square metre	200kg	150kg= 3 bags	R80/50kg	R200		145
Beetroot							146
Potatoes							147
Cabbage							148
Beans							149
Spinach							150
Raddish							151
Others:.....							152
....							153
....							154
....							155

H.2 Explain record keeping according to your understanding?

: .... ☐ 156

: .... ☐ 157

H.3 What is your total production per year? : .... ☐ 158

: .... ☐ 159

:... ☐ 160

H.4 Do you keep financial and physical records on your farm? Yes/No ☐ 161

H.5 If "yes" specify : .... ☐ 162

: .... ☐ 163

: .... ☐ 164

H.6 What is your annual inputs costs ? :.. ☐ 165

H.7 How much vegetables do you sell per season? :.................................. ☐ 166

:... ☐ 167

H.8 How do you know whether you are making profit ? :.......................... ☐ 168

:... ☐ 169

:... ☐ 170

:... ☐ 171

I. SEEDS.

I.1. Do you store seeds from previous years? Yes/ No ☐ 172

I.2 If "not" where do you buy your seeds ?specify : .... ☐ 173

: .... ☐ 174

I.3 If "yes" how do you store them? :... 175

: 176

: 177

: 178

J. COMMENTS

J.1 General comments from interviewer

.... 179

.... 180

.... 181

.... 182

.... 183

.... 184

.... 185

Questionnaire marks: 186

ANNEXURE B

CODE LIST

CODE LIST – GP HADEBE

A.1
Phuthaditjhaba = 1
Namahadi = 2
Makwane = 3
Hasethunya = 4
Clarens = 5
Leratong = 6
Lehlohonolo = 7

A. 2 Province = 1

A. 6 Other experiences:
Bookkeeping = 1
Gardening = 2
Farmworker = 3
Cooking, baking+selling = 4
Electric and welding = 5
Management = 6
Poultry farming = 7
Fencing = 8
Driver = 9
handicrafts = 10
Cleaning = 11
workshop ass. = 12

Yes= 1
No= 0

A.7 Qualifications:
None = 1
Grade 1-7 = 2
Grade 8-12 = 3
Agric Dip = 4
Agric Degree = 5
OtherDip = 6
Other Degree = 7

B.2 Comments = 1

B.5 Other = 0

B.6
Secretary = 1
Selling;veg management+soil man = 2
Guard = 3
Treasurer = 4
Holding meeting = 5
Divided accord func. = 6
Other = 8

B.8 Other = 0

B.9
Loally = 0
OTK = 1
Starke Ayres = 2
Score+Supermarkets = 3
Mayford = 4
Mayford +Starke Ayres = 6
Doa = 7
Street sellers+cafes = 8
Other = 9

B.11 In rows = 1

B.12 Often = 1

B.13 None = 0

B.17
Trespassers = 1
Normal = 2
Pickers = 3
Cattles = 4
Other = 5

C.1
Never = 0
Little = 1
Moderate = 2
Much = 3

C.2
No. manure = 1
5kg/plot = 2
8kg/200m2 = 3
10kg/plot = 4
200m* 100m = 5

C.3
Soil structure = 0
No funds = 1
Loosen soil = 2
Feed plants = 3
Moisten soil = 4
Increase production = 5
Advised = 6
Soil fertility = 7
Easily available = 8
Other = 9

C.4
cattle = 1
pig = 2
poultry and goats = 3
cattle +pig = 4
sheep = 5
people = 6
goats pig = 7
other = 8

C.6
Increase soil structure = 0
Boost one another = 1
Moisten the soil = 2
Retain moiture = 3
Plants strength = 4
Other = 5

C.9
No measurements = 0
Other = 1

C.10
Unkown = 0
Overapply = 1
Side effects = 2

C.11
None = 0
Straight = 1
Mixed = 2
Other = 3

C.12
no = 0
NPK = 1

C.13
All crops = 2
less than 2 = 1

C.14
increase production = 1
more greenish colour = 2
good growth of leaves and veg = 3
other = 4

C.15
good, fine same = 1
long carrots and beetroots = 2
abnormal side growth = 3
yellowish = 4
other = 5

D.1
fork,spades = 1
Tractor and equipments = 2
all above = 3

D.2
Loosen soil = 1
Cheap = 2
Destroy weeds = 3
Break clods = 4
Save, time and labour = 5
Ease drainage = 6
Other = 7

D.3
Retain moisture = 1
Loosen soil = 2
Destroy weeds = 3
improve infiltration = 4
mix fertilise and manure = 5
Other = 6

D.5 Same = 0

D.6
Tractor disturb irrigation pipes = 1
Time and labour save = 2
Improve soil conditions = 3
tractor plough deep = 4
On big scale = 5
Remove weeds = 6
Tractor plough deep = 7
Other = 8

E.2
Heavy rains = 1
Spades not easy to enter the soil = 2
Loosen soil = 3
Always turned less movem = 4
No traffic = 5
Easily entered by spades = 6
Traffic = 7
Clay soil = 8
Cattle = 9
Other = 10

E.4
Runoff = 1
Very heavy = 2
Disturb seed emergence = 3
Restrict plants develop and growth = 4
Restrict root development = 5
Less Ho2 penetration = 6
Other = 7

E.5
Restrict root developm = 1
Slow vegetative growth = 2
Restrict seed development = 3
Wilting and Dwarfism = 4
Early maturity = 5
Runoff = 6
Other = 7

B.6
sandyloam = 1
Sandy = 2
Loamy = 3
Clay = 4
Clayloam = 5
Other = 6
unkown = 7

E.7
Swells = 1
Sticky = 2
Vision = 3
high infiltration = 4
black = 5
E.9
Sprinkler irrigation = 1
Bucket = 2

Rainfall or no rain
can = 4
other = 5

B.10
Increase growth = 2
Compact the soil = 3
keep beauty plants = 4
Do not irrigate = 5
Other = 6

B.11
Lack of water = 0
Once = 1
Twice = 2
Three = 3
Other = 4
Summer2/day = 7
Winter = 11
No. irriga = 12

E.17
Reduce moisture loss = 1
Soil temp = 2
Protect from sun = 3
Reduce erosion = 4
Improve fertility = 5

F.1
Commercial = 1
Produce more veg = 2
Enlarge market = 3
Learn farming = 4

I.
Poorer = 5
Create employment = 6
Farm stalls = 7
Fertiliser = 8
Stop due to age = 9

G.2
DoA = 1
Boskop = 2
Uniqwa = 3
ESKOM = 4
Acriqwa = 5

G.3
Weak = 0
Very good = 2
Productions = 3
Give skills = 4
Others = 5

G.4
Veg production and management = 1
Record keeping = 2
Pest control = 3
Marketing = 4
Fertiliser application = 5
Management = 6
Crop rotation = 7
No training = 8
Tractor maintenance = 9
Planting dates = 10
Other = 11

G.4
Maize = 1
beetroot = 2
potatoes = 3
cabbage = 4
beans = 5
spinach = 6
raddish = 7
others = 8
peanuts = 9

H.2
no idea = 0
amount of everything = 1
plan cost = 2
keep fan. + phyci. Records = 3
loss or gain = 4
other = 5

H.3
sales and inputs = 2
other = 3

H.5
rainfall = 1
production inputs = 2
temperature = 3

H.6 Other = 0

H.7
Harvested = 1
none = 0
not sure = 2

H.8
Unknown = 0
records = 1
income-input cost = 2
no records = 3
other = 4

I.2
Mayford = 0
Starkeayres = 1
Previous = 2
Supermarkets = 3
Shops = cafes = 4
Other = 5

I.3
TIN /bucket = 0
Seedparkets = 1
Dry on sun = 2
Other = 3

J .1
Important and good = 0
Test knowledge = 1
Realise weak points = 2
Learning = 3
Other = 4

ANNEXURE C

DATA ANALYSIS

Result for Potato data analysis

```
                         General Linear Models Procedure
                             Class Level Information

                        Class      Levels     Values

                        TREATMEN        2     CONTROL TREATED

                        LOCATION        2     LERATVEG MHOVEG

                        BLOCK           2     1 2

                    Number of observations in data set = 96

                                 The SAS System        11:28 Friday, January 1, 1999  10

                         General Linear Models Procedure

Dependent Variable: MASS_G   MASS_G

Source                  DF          Sum of Squares          Mean Square  F Value     Pr > F

Model                    6            141.90145833          23.65024306     0.99     0.4379

Error                   89           2129.11093750          23.92259480

Corrected Total         95           2271.01239583

                  R-Square                    C.V.             Root MSE          MASS_G Mean

                  0.062484                12.84413           4.89107297          38.08020833


Source                  DF             Type III SS          Mean Square  F Value     Pr > F

BLOCK                    1             10.46760417          10.46760417     0.44     0.5100
TREATMEN                 1             92.63010417          92.63010417     3.87     0.0522
LOCATION                 1             21.00010417          21.00010417     0.88     0.3513
TREATMEN*BLOCK           1              2.90510417           2.90510417     0.12     0.7283
LOCATION*BLOCK           1              1.02093750           1.02093750     0.04     0.8368
TREATMEN*LOCATION        1             13.87760417          13.87760417     0.58     0.4483

                                 The SAS System        11:28 Friday, January 1, 1999  11

                         General Linear Models Procedure
                               Least Squares Means

                     TREATMEN         MASS_G        Std Err      Pr > |T|
                                      LSMEAN         LSMEAN . H0:LSMEAN=0

                     CONTROL     39.0625000      0.7059656         0.0001
                     TREATED     37.0979167      0.7059656         0.0001

                     LOCATION         MASS_G        Std Err      Pr > |T|
                                      LSMEAN         LSMEAN    H0:LSMEAN=0

                     LERATVEG    37.6125000      0.7059656         0.0001
                     MHOVEG      38.5479167      0.7059656         0.0001

                TREATMEN   LOCATION        MASS_G        Std Err      Pr > |T|
                                           LSMEAN         LSMEAN    H0:LSMEAN=0

                CONTROL    LERATVEG    38.9750000      0.9983861         0.0001
                CONTROL    MHOVEG      39.1500000      0.9983861         0.0001
                TREATED    LERATVEG    36.2500000      0.9983861         0.0001
                TREATED    MHOVEG      37.9458333      0.9983861         0.0001

                                 The SAS System        11:28 Friday, January 1, 1999  12

                         General Linear Models Procedure

                       Level of             ------------MASS_G-----------
                       TREATMEN     N          Mean                SD

                       CONTROL     48       39.0625000          5.28452679
                       TREATED     48       37.0979167          4.29212488

                       Level of             ------------MASS_G-----------
                       LOCATION     N          Mean                SD

                       LERATVEG    48       37.6125000          6.17998227
                       MHOVEG      48       38.5479167          3.11133751

                  Level of    Level of            ------------MASS_G-----------
                  TREATMEN    LOCATION     N          Mean                SD

                  CONTROL     LERATVEG    24       38.9750000          7.13285418
                  CONTROL     MHOVEG      24       39.1500000          2.48456102
                  TREATED     LERATVEG    24       36.2500000          4.82628672
                  TREATED     MHOVEG      24       37.9458333          3.58499035
```

Result of Carrot data analysis

```
                         General Linear Models Procedure
                             Class Level Information

                        Class      Levels     Values

                        TREATMEN        2     CONTROL TREATED

                        LOCATION        2     LERATVEG MHOVEG

                        BLOCK           2     1 2

                        PLOT            3     1 2 3

                    Number of observations in data set = 240


                         General Linear Models Procedure

Dependent Variable: LENG_CM   LENG_CM

Source                  DF           Sum of Squares          Mean Square   F Value     Pr > F

Model                   14             190.55313889          13.61093849      3.58     0.0001

Error                  225             855.16669444           3.80074086

Corrected Total        239            1045.71983333

                  R-Square                     C.V.             Root MSE           LENG_CM Mean

                  0.182222                 13.79316           1.94954889            14.13416667


Source                  DF              Type III SS          Mean Square   F Value     Pr > F

TREATMEN                 1              71.22001263          71.22001263     18.74     0.0001
LOCATION                 1               7.58364899           7.58364899      2.00     0.1592
BLOCK                    1               6.22227273           6.22227273      1.64     0.2020
PLOT                     2              14.86802778           7.43401389      1.96     0.1438
TREATMEN*LOCATION        1              31.53750000          31.53750000      8.30     0.0044
TREATMEN*BLOCK           1              13.72816667          13.72816667      3.61     0.0586
TREATMEN*PLOT            2               1.54580556           0.77290278      0.20     0.8161
LOCATION*BLOCK           1              31.53750000          31.53750000      8.30     0.0044
LOCATION*PLOT            2               5.89580556           2.94790278      0.78     0.4616
BLOCK*PLOT               2               3.03850000           1.51925000      0.40     0.6710


                         General Linear Models Procedure

Dependent Variable: DIAM_CM   DIAM_CM

Source                  DF           Sum of Squares          Mean Square   F Value     Pr > F

Model                   14              25.04011111           1.78857937      5.94     0.0001

Error                  225              67.73284722           0.30103488

Corrected Total        239              92.77295833

                  R-Square                     C.V.             Root MSE           DIAM_CM Mean

                  0.269907                 15.00968           0.54866645             3.65541667


Source                  DF              Type III SS          Mean Square   F Value     Pr > F

TREATMEN                 1              20.46122475          20.46122475     67.97     0.0001
LOCATION                 1               0.05011364           0.05011364      0.17     0.6837
BLOCK                    1               0.00727273           0.00727273      0.02     0.8766
PLOT                     2               1.25740278           0.62870139      2.09     0.1263
TREATMEN*LOCATION        1               0.34504167           0.34504167      1.15     0.2855
TREATMEN*BLOCK           1               0.30104167           0.30104167      1.00     0.3184
TREATMEN*PLOT            2               0.83573611           0.41786806      1.39     0.2517
LOCATION*BLOCK           1               0.31537500           0.31537500      1.05     0.3072
LOCATION*PLOT            2               0.04773611           0.02386806      0.08     0.9238
BLOCK*PLOT               2               0.11531944           0.05765972      0.19     0.8258
```

```
                                General Linear

Dependent Variable: MASS_G   MASS_G

Source                   DF     Sum of Squares     Mean Square    F Value    Pr > F

Model                    14       407.01771333     29.07269381       2.22    0.0079

Error                   225      2944.20574667     13.08535887

Corrected Total         239      3351.22346000

                   R-Square          C.V.          Root MSE        MASS_G Mean

                   0.121453       9.211885        3.61736905        39.26850000


Source                   DF        Type III SS     Mean Square    F Value    Pr > F

TREATMEN                  1        44.60727475     44.60727475       3.41    0.0662
LOCATION                  1        23.85764091     23.85764091       1.82    0.1783
BLOCK                     1        21.51602475     21.51602475       1.64    0.2011
PLOT                      2       177.82668222     88.91334111       6.79    0.0014
TREATMEN*LOCATION         1        10.43334000     10.43334000       0.80    0.3728
TREATMEN*BLOCK            1        14.88024000     14.88024000       1.14    0.2874
TREATMEN*PLOT             2        27.11074889     13.55537444       1.04    0.3566
LOCATION*BLOCK            1        18.50370667     18.50370667       1.41    0.2356
LOCATION*PLOT             2        24.04845444     12.02422722       0.92    0.4004
BLOCK*PLOT                2        31.19602111     15.59801056       1.19    0.3055
```

```
                     General Linear
                             Least Squares Means

        TREATMEN        LENG_CM      Std Err     Pr > |T|
                         LSMEAN       LSMEAN   H0:LSMEAN=0

        CONTROL      13.6175926    0.1796089        0.0001
        TREATED      14.7171296    0.1796089        0.0001


        TREATMEN        DIAM_CM      Std Err     Pr > |T|
                         LSMEAN       LSMEAN   H0:LSMEAN=0

        CONTROL      3.95879630   0.05054780        0.0001
        TREATED      3.36944444   0.05054780        0.0001


        TREATMEN         MASS_G      Std Err     Pr > |T|
                         LSMEAN       LSMEAN   H0:LSMEAN=0

        CONTROL      39.6252778    0.3332627        0.0001
        TREATED      38.7550926    0.3332627        0.0001


        LOCATION        LENG_CM      Std Err     Pr > |T|
                         LSMEAN       LSMEAN   H0:LSMEAN=0

        LERATVEG     14.3467593    0.1796089        0.0001
        MHOVEG       13.9879630    0.1796089        0.0001


        LOCATION        DIAM_CM      Std Err     Pr > |T|
                         LSMEAN       LSMEAN   H0:LSMEAN=0

        LERATVEG     3.64953704   0.05054780        0.0001
        MHOVEG       3.67870370   0.05054780        0.0001


        LOCATION         MASS_G      Std Err     Pr > |T|
                         LSMEAN       LSMEAN   H0:LSMEAN=0

        LERATVEG     38.8719907    0.3332627        0.0001
        MHOVEG       39.5083796    0.3332627        0.0001


                     General Linear Models Procedure
                           Least Squares Means

  TREATMEN   LOCATION        LENG_CM      Std Err     Pr > |T|
                              LSMEAN       LSMEAN   H0:LSMEAN=0

  CONTROL    LERATVEG     14.1594907    0.2534275        0.0001
  CONTROL    MHOVEG       13.0756944    0.2534275        0.0001
  TREATED    LERATVEG     14.5340278    0.2534275        0.0001
  TREATED    MHOVEG       14.9002315    0.2534275        0.0001


  TREATMEN   LOCATION        DIAM_CM      Std Err     Pr > |T|
                              LSMEAN       LSMEAN   H0:LSMEAN=0

  CONTROL    LERATVEG     3.98212963   0.07132273        0.0001
  CONTROL    MHOVEG       3.93546296   0.07132273        0.0001
  TREATED    LERATVEG     3.31694444   0.07132273        0.0001
  TREATED    MHOVEG       3.42194444   0.07132273        0.0001


  TREATMEN   LOCATION         MASS_G      Std Err     Pr > |T|
                              LSMEAN       LSMEAN   H0:LSMEAN=0

  CONTROL    LERATVEG     39.0985833    0.4702322        0.0001
  CONTROL    MHOVEG       40.1519722    0.4702322        0.0001
  TREATED    LERATVEG     38.6453981    0.4702322        0.0001
  TREATED    MHOVEG       38.8647870    0.4702322        0.0001


                     General Linear Models Procedure

        Duncan's Multiple Range Test for variable: LENG_CM

   NOTE: This test controls the type I comparisonwise error rate, not the
         experimentwise error rate

              Alpha= 0.05  df= 225  MSE= 3.800741

                     Number of Means      2
                     Critical Range  .4960

   Means with the same letter are not significantly different.

        Duncan Grouping              Mean      N  TREATMEN
                      A           14.6933    120  TREATED
                      B           13.5750    120  CONTROL
```

```
              General Linear Models Procedure

     Duncan's Multiple Range Test for variable: DIAM_CM

NOTE: This test controls the type I comparisonwise error rate, not the
      experimentwise error rate

            Alpha= 0.05  df= 225  MSE= 0.301035

                   Number of Means      2
                   Critical Range   .1396

Means with the same letter are not significantly different.

     Duncan Grouping              Mean      N  TREATMEN

                   A           3.95667    120  CONTROL

                   B           3.35417    120  TREATED
```

```
              General Linear Models Procedure

     Duncan's Multiple Range Test for variable: MASS_G

NOTE: This test controls the type I comparisonwise error rate, not the
      experimentwise error rate

            Alpha= 0.05  df= 225  MSE= 13.08536

                   Number of Means      2
                   Critical Range   .9203

Means with the same letter are not significantly different.

     Duncan Grouping              Mean      N  TREATMEN

                   A           39.7487    120  CONTROL

                   B           38.7883    120  TREATED
```

```
              General Linear Models Procedure

     Duncan's Multiple Range Test for variable: LENG_CM

NOTE: This test controls the type I comparisonwise error rate, not the
      experimentwise error rate

            Alpha= 0.05  df= 225  MSE= 3.800741

                   Number of Means      2
                   Critical Range   .4960

Means with the same letter are not significantly different.

     Duncan Grouping              Mean      N  LOCATION

                   A           14.3183    120  LERATVEG
                   A
                   A           13.9500    120  MHOVEG
```

```
              General Linear Models Procedure

     Duncan's Multiple Range Test for variable: DIAM_CM

NOTE: This test controls the type I comparisonwise error rate, not the
      experimentwise error rate

            Alpha= 0.05  df= 225  MSE= 0.301035

                   Number of Means      2
                   Critical Range   .1396

Means with the same letter are not significantly different.

     Duncan Grouping              Mean      N  LOCATION

                   A           3.66833    120  MHOVEG
                   A
                   A           3.64250    120  LERATVEG
```

```
                              General Linear

                   Duncan's Multiple Range Test for variable: MASS_G

               NOTE: This test controls the type I comparisonwise error rate, not the
                     experimentwise error rate

                         Alpha= 0.05  df= 225  MSE= 13.08536

                                Number of Means      2
                                Critical Range  .9203

               Means with the same letter are not significantly different.

                   Duncan Grouping           Mean      N  LOCATION

                                A          39.5437    120  MHOVEG
                                A
                                A          38.9933    120  LERATVEG


Level of   Level of          -----------LENG_CM-----------     -----------DIAM_CM-----------
TREATMEN   LOCATION     N        Mean            SD                Mean            SD

CONTROL    LERATVEG    60     14.1216667      2.04517553        3.98166667      0.40063156
CONTROL    MHOVEG      60     13.0283333      1.88050585        3.93166667      0.47567674
TREATED    LERATVEG    60     14.5150000      1.59541982        3.30333333      0.63325007
TREATED    MHOVEG      60     14.8716667      2.34846446        3.40500000      0.63949795

                Level of   Level of          ------------MASS_G-----------
                TREATMEN   LOCATION     N        Mean            SD

                CONTROL    LERATVEG    60     39.2650000      3.94465203
                CONTROL    MHOVEG      60     40.2323333      3.33191265
                TREATED    LERATVEG    60     38.7216667      3.46557363
                TREATED    MHOVEG      60     38.8550000      4.08724452
```

Results of Soil data analysis

```
                    General Linear Models Procedure
                        Class Level Information

                  Class     Levels    Values

                  TREAT          2    FRESH OVEN

                  SALT           3    NONE OLDSALT SALTED

                Number of observations in data set = 18

                              The SAS System       09:21 Friday, January 1, 1999 124

                    General Linear Models Procedure

Dependent Variable: BDGCM   BDGCM

Source                  DF          Sum of Squares          Mean Square   F Value     Pr > F

Model                    3              0.22620000           0.07540000   2639.00     0.0001

Error                   14              0.00040000           0.00002857

Corrected Total         17              0.22660000

                  R-Square                    C.V.             Root MSE            BDGCM Mean

                  0.998235                0.502686           0.00534522            1.06333333

Source                  DF             Type III SS          Mean Square   F Value     Pr > F

TREAT                    1              0.00500000           0.00500000    175.00     0.0001
SALT                     2              0.22120000           0.11060000   3871.00     0.0001

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                    General Linear Models Procedure

Dependent Variable: PERPORE   PERPORE

Source                  DF          Sum of Squares          Mean Square   F Value     Pr > F

Model                    3            325.08481667         108.36160556   1303.46     0.0001

Error                   14              1.16387778           0.08313413

Corrected Total         17            326.24869444

                  R-Square                    C.V.             Root MSE          PERPORE Mean

                  0.996433                0.481678           0.28832989           59.85944444

Source                  DF             Type III SS          Mean Square   F Value     Pr > F

TREAT                    1              4.79467222           4.79467222     57.67     0.0001
SALT                     2            320.29014444         160.14507222   1926.35     0.0001

                    General Linear Models Procedure
                          Least Squares Means

              TREAT          BDGCM      Std Err       Pr > |T|
                            LSMEAN       LSMEAN    H0:LSMEAN=0

              FRESH     1.04666667   0.00178174         0.0001
              OVEN      1.08000000   0.00178174         0.0001

              TREAT        PERPORE      Std Err       Pr > |T|
                            LSMEAN       LSMEAN    H0:LSMEAN=0

              FRESH     60.3755556    0.0961100         0.0001
              OVEN      59.3433333    0.0961100         0.0001

             SALT            BDGCM      Std Err       Pr > |T|
                            LSMEAN       LSMEAN    H0:LSMEAN=0

             NONE       0.99000000   0.00218218         0.0001
             OLDSALT    1.22000000   0.00218218         0.0001
             SALTED     0.98000000   0.00218218         0.0001

             SALT          PERPORE      Std Err       Pr > |T|
                            LSMEAN       LSMEAN    H0:LSMEAN=0

             NONE       62.6833333    0.1177102         0.0001
             OLDSALT    53.8966667    0.1177102         0.0001
             SALTED     62.9983333    0.1177102         0.0001
```

```
                 General Linea

      Duncan's Multiple Range Test for variable: BDGCM

NOTE: This test controls the type I comparisonwise error rate, not the
      experimentwise error rate

             Alpha= 0.05  df= 14  MSE= 0.000029

                  Number of Means       2
                  Critical Range  .005404

Means with the same letter are not significantly different.

      Duncan Grouping              Mean      N  TREAT

                    A          1.080000      9  OVEN

                    B          1.046667      9  FRESH

                 General Linear Models Procedure

     Duncan's Multiple Range Test for variable: PERPORE

NOTE: This test controls the type I comparisonwise error rate, not the
      experimentwise error rate

             Alpha= 0.05  df= 14  MSE= 0.083134

                   Number of Means     2
                   Critical Range  .2915

Means with the same letter are not significantly different.

      Duncan Grouping              Mean      N  TREAT

                    A           60.3756      9  FRESH

                    B           59.3433      9  OVEN

                 General Linear Models Procedure

      Duncan's Multiple Range Test for variable: BDGCM

NOTE: This test controls the type I comparisonwise error rate, not the
      experimentwise error rate

             Alpha= 0.05  df= 14  MSE= 0.000029

              Number of Means       2       3
              Critical Range  .006619 .006936

Means with the same letter are not significantly different.

       Duncan Grouping              Mean      N  SALT

                     A          1.220000      6  OLDSALT

                     B          0.990000      6  NONE

                     C          0.980000      6  SALTED

                 General Linear Models Procedure

     Duncan's Multiple Range Test for variable: PERPORE

NOTE: This test controls the type I comparisonwise error rate, not the
      experimentwise error rate

             Alpha= 0.05  df= 14  MSE= 0.083134

                Number of Means     2     3
                Critical Range  .3570 .3741

Means with the same letter are not significantly different.

       Duncan Grouping              Mean      N  SALT

                     A           62.9983      6  SALTED
                     A
                     A           62.6833      6  NONE

                     B           53.8967      6  OLDSALT
```

Result of carrot vegetative data analysis

```
                        General Linear Models Procedure
                            Class Level Information

                       Class     Levels     Values

                       TREATMEN       2     CONTROL TREATED

                       LOCATION       2     LERATVEG MHOVEG

                       PLOT           3     1 2 3


                    Number of observations in data set = 48
```

```
                        General Linear Models Procedure

Dependent Variable: VEGLE_CM   VEGLE_CM

Source                  DF         Sum of Squares          Mean Square   F Value     Pr > F

Model                    9            44.13541667           4.90393519      4.72     0.0003

Error                   38            39.48375000           1.03904605

Corrected Total         47            83.61916667

                  R-Square                   C.V.             Root MSE          VEGLE_CM Mean

                  0.527815               31.81283           1.01933608             3.20416667


Source                  DF            Type III SS          Mean Square   F Value     Pr > F

TREATMEN                 1            34.68000000          34.68000000     33.38     0.0001
LOCATION                 1             1.47000000           1.47000000      1.41     0.2416
PLOT                     2             4.30791667           2.15395833      2.07     0.1398
TREATMEN*LOCATION        1             0.18750000           0.18750000      0.18     0.6734
TREATMEN*PLOT            2             2.66375000           1.33187500      1.28     0.2893
LOCATION*PLOT            2             0.82625000           0.41312500      0.40     0.6747
```

```
                        General Linear Models Procedure
                              Least Squares Means

               TREATMEN       VEGLE_CM         Std Err      Pr > |T|
                                LSMEAN          LSMEAN    H0:LSMEAN=0

               CONTROL      2.35416667      0.20807111         0.0001
               TREATED      4.05416667      0.20807111         0.0001


               LOCATION       VEGLE_CM         Std Err      Pr > |T|
                                LSMEAN          LSMEAN    H0:LSMEAN=0

               LERATVEG     3.02916667      0.20807111         0.0001
               MHOVEG       3.37916667      0.20807111         0.0001


         TREATMEN   LOCATION       VEGLE_CM         Std Err      Pr > |T|
                                     LSMEAN          LSMEAN    H0:LSMEAN=0

         CONTROL    LERATVEG     2.11666667      0.29425698         0.0001
         CONTROL    MHOVEG       2.59166667      0.29425698         0.0001
         TREATED    LERATVEG     3.94166667      0.29425698         0.0001
         TREATED    MHOVEG       4.16666667      0.29425698         0.0001
```

```
                        General Linear Models Procedure
                            Class Level Information

                       Class     Levels     Values

                       TREATMEN       2     CONTROL TREATED

                       LOCATION       2     LERATVEG MHOVEG

                       PLOT           3     1 2 3


                    Number of observations in data set = 48
```

```
                          General Linear Models Procedure

Dependent Variable: VEGLE_CM   VEGLE_CM

Source                  DF         Sum of Squares          Mean Square  F Value     Pr > F

Model                    9            44.13541667           4.90393519     4.72     0.0003

Error                   38            39.48375000           1.03904605

Corrected Total         47            83.61916667

                  R-Square                   C.V.             Root MSE         VEGLE_CM Mean

                  0.527815               31.81283           1.01933608            3.20416667


Source                  DF            Type III SS          Mean Square  F Value     Pr > F

TREATMEN                 1            34.68000000          34.68000000    33.38     0.0001
LOCATION                 1             1.47000000           1.47000000     1.41     0.2416
PLOT                     2             4.30791667           2.15395833     2.07     0.1398
TREATMEN*LOCATION        1             0.18750000           0.18750000     0.18     0.6734
TREATMEN*PLOT            2             2.66375000           1.33187500     1.28     0.2893
LOCATION*PLOT            2             0.82625000           0.41312500     0.40     0.6747


                              General Linear Models Procedure
                                    Least Squares Means

                       TREATMEN        VEGLE_CM         Std Err      Pr > |T|
                                         LSMEAN          LSMEAN   H0:LSMEAN=0

                       CONTROL       2.35416667      0.20807111        0.0001
                       TREATED       4.05416667      0.20807111        0.0001


                       LOCATION        VEGLE_CM         Std Err      Pr > |T|
                                         LSMEAN          LSMEAN   H0:LSMEAN=0

                       LERATVEG      3.02916667      0.20807111        0.0001
                       MHOVEG        3.37916667      0.20807111        0.0001


                 TREATMEN   LOCATION          VEGLE_CM         Std Err      Pr > |T|
                                                LSMEAN          LSMEAN   H0:LSMEAN=0

                 CONTROL    LERATVEG        2.11666667      0.29425698        0.0001
                 CONTROL    MHOVEG          2.59166667      0.29425698        0.0001
                 TREATED    LERATVEG        3.94166667      0.29425698        0.0001
                 TREATED    MHOVEG          4.16666667      0.29425698        0.0001
```