THE INFLUENCE OF GARDEN TREATMENTS ON THE NUTRITIONAL PROFILE AND AGRONOMIC PERFORMANCE OF A DARK GREEN LEAFY VEGETABLE GROWN IN A PERI-URBAN SETTING.

by

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DECLARATION OF ORIGINALITY

I, Cayleigh Hepburn, hereby declare that:

I. The research reported in this dissertation, except where otherwise indicated, and is my original research.

II. This dissertation has not been submitted for any other degree or examination at any other university.

III. This dissertation does not contain other persons' data, pictures, graphs or other information unless specifically acknowledged as being sourced from those persons.

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a) Their words have been rewritten but the general information attributed to them has been referenced.

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Signed……………….. Dated………………..

Nicola Wiles (supervisor)………………………

Trevor Hill (co-supervisor)…………………….

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DEFINITION OF TERMS

Anaemia	is a “reduction below normal in the number of red blood cells (RBC) (per cubic millimetre), in the quantity of haemoglobin or in the volume of packed cells per 100ml of blood” (DOH 2013 p6).
Companion planting	is a gardening technique where by two different plants are planted together for a particular purpose, such as to hide, repel or trap pests (Kuepper & Dodson 2001).
Food insecurity	exists when ‘”people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life” (FAO 2014 p50).
Food security	exists when “all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (DOH 2013 p6).
Home food garden	is maintained by one household and is also known as a backyard or kitchen garden (Lyons & Dlamini 2008).
Household food security	is the “access by a household to amounts of food of the right quantity and quality to satisfy the dietary needs of all its members throughout the year” (DOH 2013 p6).
Imifino	is a Zulu/Nguni collective term that refers to various dark-green leaves that are eaten as a vegetable; the leaves either grow wild or come from vegetables such as pumpkin, beetroot and sweet potato (Faber, van Jaarsveld & Laubscher 2007; Faber, Phungula, Venter, Dhansay & Benadé 2002).
Incidence	is the measure of disease that allows us to determine a person’s probability of being diagnosed with a disease during a given period of time. An incidence rate is therefore the number of newly diagnosed cases of a disease (New York State Department of Health 1999).

Inorganic fertiliser	is also known as mineral fertiliser and is excavated from mineral deposits or industrially manufactured through chemical processing (Mtambanengwe, Kosina & Jones 2007).
Inorganic mulch	refers to mulch made from inorganic materials such as rocks and plastic (WCT training material 2016; Extension 2015; McMillen 2013).
Kraal manure	is the layer of organic animal excretions collected from a livestock enclosure and used as organic fertiliser (van Averbeke & Yoganathan 2003).
Malnutrition	results when dietary intake of energy, essential vitamins and trace minerals are too low to meet the minimum requirements for bodily functions causing a poor state of health compromising growth and development, pregnancy and lactation, physical work, cognitive and immunological processes and functions (UNICEF 2016; Luchuo et al 2013; Miller and Welch 2013; Saunders & Smith 2010; Ramakrishnan 2002; Stoltzfus 2001; Fishman, Christian & West 2000).
Morbidity	refers to illness (New York State Department of Health 1999).
Mortality	refers to death, where the mortality rate refers to the number of deaths due to disease divided by the total population (New York State Department of Health 1999).
Nutrition security	exists when “secure access to an appropriately nutritious diet is coupled with a sanitary environment adequate health services and care, in order to ensure a healthy and active life for all household members” (FAO 2014, p50).
Nutritional status	is the “physiological state of an individual that results from the relationship between nutrient intake and requirements and from the body’s ability to digest, absorb and use these nutrients (FAO 2014, p50).

Organic fertiliser	comprises of agronomic and biological as opposed to synthetic materials (WCT training material 2016; FAO 2001).
Organic mulch	is prepared from ecological resources and is applied to the soil surface to inhibit erosion, weed proliferation and water evaporation (WCT training material 2016; Extension 2015).
Prevalence	is used to determine the likelihood of a person having a disease. Therefore, the prevalence of a disease refers to the total number of existing cases of the disease as opposed to incidence which refers to the number of newly diagnosed cases of a disease (New York State Department of Health 1999).
Stunting	is a form of chronic malnutrition which is represented by a low height-for-age (DOH 2013).
Under-nutrition	Is a form of malnutrition which happens “when the body contains lower than normal amounts of one or more nutrients, i.e. deficiencies in macronutrients such as energy and/or micronutrients” (DOH 2013 p7).
Wasting	is a form of acute malnutrition whereby the weight-for-height indicator is between the -3 and -2 z-scores (standard deviations) of the international standard, or the mid-upper arm circumference (MUAC) is between 11.5 cm and 12.5 cm (DOH 2013).

ABBREVIATIONS

ADF	Acid Detergent Fibre
AFSUN	African Food Security Urban Network
AIDS	Acquired Immune Deficiency Syndrome
AOAC	Association of Analytical Chemists
ARC	Agricultural Research Council
BREC	Biomedical Research Ethics Administration
$CaCO_3$	Calcium carbonate
CEBA	Community Ecosystems Based Adaption
CO_2	Carbon dioxide
CRD	Completely Randomised Design
DGLV	Dark Green Leafy Vegetable
DOA	Department of Agriculture
DOH	Department of Health
EC	Eastern Cape
ENGO	Environmental Non-Governmental Organisation
FAO	Food and Agriculture Organization of the United Nations
HDDS	Household Dietary Diversity Scale
HFIAP	Household Food Insecurity Access Prevalence Indicator
HFIAS	Household Food Insecurity Access Scale
HHFI	Household Food Insecurity
HHFS	Household Food Security
HIV	Human Immunodeficiency Virus
HKI	Helen Keller International
HSRC	Human Sciences Research Council
INP	Integrated Nutrition Program
Kg/ha	kilograms per hectare
KZN	KwaZulu-Natal
m	Metre
MAHFP	Months of Adequate Household Food Provisioning indicator
$MgCO_3$	Magnesium carbonate
N_2	Nitrogen

NFCS	National Food Consumption Survey
NFCS-FB-1	National Food Consumption Survey-Fortification-Baseline
^{O}C	Degrees Celsius
PMB	Pietermaritzburg
PVC	Polyvinyl chloride
RCBD	Randomized Complete Block Design
RDA	Recommended Dietary Allowance
SA	South Africa
SANAS	South African National Accreditation System
SANHANES	South African National Health and Nutrition Examination Survey
SASAS	South African Societal Attitudes Survey
SAVACG	South African Vitamin A Consultative Group
SSA	Sub Saharan Africa
TB	Tuberculosis
UKZN	University of KwaZulu-Natal
UNICEF	United Nations Children's Emergency Fund
VAD	Vitamin A Deficiency
WCT	Wildlands Conservation Trust
WHO	World Health Organization

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ABSTRACT

Introduction

Many nutrition interventions have been implemented to try and combat the high prevalence rate of micronutrient malnutrition and food insecurity in South Africa (SA). One of these interventions is home food gardening. Home food gardens growing

Swiss chard, a commonly consumed dark-green leafy vegetable (DGLV) throughout SA, may contribute to food and micronutrient security.

Aim

The aim of this research was to identify, through a home food gardening study, the best affordable method of soil treatment for the production of nutrient dense Swiss chard in KwaZulu-Natal, SA.

Objectives

The objectives of the study were:

1. To determine the effect of fertiliser and mulch treatment combinations on the growth rate (number of days to reach maturity) of Swiss chard.
2. To determine the effect of fertiliser and mulch treatment combinations on the leaf number (yield) of Swiss chard.
3. To determine the effect of fertiliser and mulch treatment combinations on the nutrient profile of Swiss chard.

Methods

The study site was a home food garden in kwaMnyandu, KZN. A two factor Randomised Complete Block Design (RCBD) was used, where fixed factors (mulch and fertiliser garden treatments) were crossed with random factors (the treatment blocks containing Fordhook Giant Swiss chard (*Beta vulgaris var. cicla*) plants). Some of the garden treatments used in the study, organic kraal manure fertiliser and organic grass mulch, were being used at the study site. These garden treatments were available at the study site, free of charge. The other treatments used (inorganic chemical fertiliser and inorganic plastic mulch) may not be accessible by food gardeners in poorer areas due to their price. The nutrient content of Swiss chard was analysed and the garden treatment that produced the best quality of Swiss chard in terms of nutrients was identified

Results

When combined, fertiliser and mulch together did not significantly affect the maturity period of Swiss chard. However individually, organic and inorganic fertiliser and mulch had a significant effect on the maturity period (mean number of days taken to reach maturity) of Swiss chard compared to the control (no treatment). Fertiliser and mulch, applied to the soil in combination or individually, had no effect on the number of leaves present on Swiss chard plants at the study site. Both fertiliser and mulch treatments, independent of each other, significantly altered the nutrient profile of Swiss chard ($p < 0.05$), with fertiliser having a greater effect ($p=0.002$) than mulch ($p=0.0389$). However, experimental treatments containing a combination of fertiliser and mulch treatments, did not significantly affect the nutrient profile of Swiss chard ($p>0.05$).

Conclusion

Adding combinations of fertiliser and mulch to the soil, when growing Swiss chard, is not recommended to shorten the growth rate, improve the leaf number, or improve the nutrient profile of Swiss chard. To grow Swiss chard in the shortest time period (days) the most affordable garden treatment recommended is organic grass mulch. To produce Swiss chard with the best nutrient profile) the most affordable garden treatment recommended is organic kraal manure fertiliser. Considering the relevance of nutrient deficiencies in SA, the significance of the nutrient profile of the Swiss chard grown is more important than the number of days taken for the Swiss chard to reach maturity, and the number of leaves present on the plant. Therefore, the most affordable gardening method to use, to produce the best quality Swiss chard is organic kraal manure fertiliser.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Food insecurity, accelerated by poverty, ultimately leads to nutrient deficiencies and can be as a result of: food unavailability, poor purchasing power, incorrect food distribution and/or inadequate use of food at household level (FAO 2015a; FAO 2014, p50; Luchuo, Paschal, Ngia, Njem, Yelena, Nsah and Ajime; Nuss, Arscott, Bresnahan, Pixley, Rocheford, Hotz, Siamusantu, Chileshe & Tanumihardjo 2012; Shetty 2011; Black, Allen, Bhutta, Caulfield, de Onis, Ezzati, Mathers & Rivera 2008). The consequences of nutrient deficiencies include: increased prevalence of morbidity and mortality, reduced immune and physical function, impaired cognitive development, poor pregnancy outcomes in females, and poor growth and development in children (United Nations Children's Emergency Fund (UNICEF) 2016; Luchuo *et al* 2013; Nuss *et al* 2012, Hendricks & Bourne 2010; Saunders & Smith 2010; Blössner & de Onis 2005; Ramakrishnan 2002; Stoltzfus 2001). Although global hunger decreased from 1990 to 2014, approximately one in nine people worldwide remained food insecure in 2014 (Food and Agricultural Organization of the United Nations (FAO) 2014, p8). An estimated 795 billion individuals worldwide were projected to be food insecure between 2014 and 2015, with a higher hunger prevalence in developing counties (13%) than in the rest of the world (11%) (FAO 2015a; Luchuo, Paschal, Ngia, Njem, Yelena, Nsah & Ajime 2013).

Globally, females of reproductive age and pre-school aged children are the population groups most affected by nutrient deficiencies, particularly vitamin A, zinc, iron and iodine deficiencies (Luchuo *et al* 2013). More than 30% (two billion) of the world's population are anaemic, and 21% (27 million) of children under the age of five are deficient in vitamin A (World Health Organization (WHO) 2016b; Rice *et al* 2004, p249). Together, vitamin A deficiency (VAD) and anaemia have contributed to 40% of global maternal deaths, and approximately 50% of women and 40% of pre-school children in developing countries are anaemic (WHO 2016b; Rice *et al* 2004 p249; West, Eilander & Van Lieshout 2002). In addition, close to 17% of the world's population are at risk of inadequate zinc intake (Wessells & Brown 2012).

In the past, high levels of poverty, concomitant food insecurity and nutrient deficiencies were considered a manifestation of rural Africa, however, consequent of rapid urbanisation; these perceptions have shifted (Frayne, Crush & McLachlan 2014a; Frayne, McCordic & Shilombolen 2014b; Battersby 2012). Currently, one of the main challenges facing South Africa (SA) is rural and urban poverty, and the resultant hunger and malnutrition (Musyoki 2012; Bond 2002). Several studies have stated that a significant percentage of the rural and urban population in SA are food insecure and suffering from micronutrient deficiencies, which has been collectively described as 'hidden hunger' (Frayne *et al* 2014a; Frayne *et al* 2014b; Human Sciences Research Council (HSRC) 2013; Battersby 2012; Harvestplus 2011; Labadarios, Steyn & Nel 2011b; Altman, Hart & Jacobs 2009; Faber, van Jaarsveld & Laubscher 2007; Faber & Wenhold 2007). The 2012 South African National Health and Nutrition Examination Survey (SANHANES-1) reported that as a result of poor dietary diversity, 44% and 11% of children under the age of nine years had VAD and anaemia, respectively (HSRC 2013). Poor dietary diversity contributed significantly to the poor anthropometric status of children, with significant levels of stunting (27%), followed by wasting (12%) and underweight (9%) (HSRC 2013). Within SA, KwaZulu-Natal (KZN) had a high prevalence of VAD (89%) in children less than nine years of age in 2008, raising a major provincial health concern (Labadarios, Swart, Maunder, Kruger, Gericke, Kuzwayo, Ntsie, Steyn, Schloss, Dhansay, Jooste, Dannhauser, Nel, Molefe & Kotze 2008). In addition, more than one quarter (26%) of South African children under the age of nine years of age were food insecure in 2012 (HSRC 2013; Labadarios *et al* 2011b).

To escape poverty, many of the urban poor are involved in green economy initiatives introduced by local environmental non-governmental organisations (ENGO's) (Hlahla, Goebel & Hill 2016). Urban agriculture has been labelled as a possible strategy to address poverty and food insecurity, through the provision of revenue for the unwaged and improved dietary diversity and nutrient intake (Ruysenaar 2013; Rogerson 2011; Zezza 2010). Numerous researchers confirm that poor households reap the benefits of small-scale subsistence farming at a higher intensity than other households, predominantly where social grants and formal food markets are at a minimum (Rogerson 2011; Shisanya & Hendricks 2011; Zezza 2010; Thornton 2008;

Rogerson 2003). In many poor areas, domestic food production in the form of small-scale subsistence farming or home food gardens, are the main providers of food and income for households (FAO 2014, p13). Through the provision of direct access to nutritionally diverse foods, home food gardens, and their role in improving the nutritional and food security status of populations at individual, household and community level are fast gaining momentum (Schreinemachers, Patalagsa, Islam, Uddin, Ahmad, Biswas, Ahmed, Yang, Hanson, Begu & Takagi 2015; Carney, Hamada, Rdesinski, Sprager, Nichols, Liu, Pelayo, Sanchez & Shannon 2012; Masset, Haddad, Cornelius & Isaza-Castro 2012; Faber, Witten & Drimie 2011; Shisanya & Hendriks 2011; Helen Keller International (HKI) 2010; Kortright & Wakefield 2010; Faber *et al* 2007; Faber, Phungula, Venter, Dhansay & Benadé 2002; Welch 2001; Marsh 1998). However, there are many factors that influence the success of home food gardens, therefore an all-inclusive food systems approach is necessary to work towards alleviating food insecurity and nutrient deficiencies through food gardening (Welch & Graham 2005). To obtain sustained participation of communities and individuals in food gardening projects, the involvement of agriculturists and agricultural extension officers is vital, along with the inclusion of nutrition education prior and subsequent to food garden implementation (Schreinemachers *et al* 2015; Carney *et al* 2012; Faber *et al* 2011; HKI 2010; Faber *et al* 2007; Faber *et al* 2002).

Many community based agricultural interventions in South Africa have focused on planting crops high in nutrients that are limited in the diets of those in a particular area (Faber *et al* 2011; Faber & Wenhold 2007). In light of this, crops rich in provitamin A, such as orange-fleshed and dark-green leafy vegetables (DGLVs), have been the focus of many garden initiatives across SA and worldwide (Faber *et al* 2011; Faber *et al* 2002). The current study focuses on DGLVs, particularly Swiss chard, as this nutrient rich DGLV is commonly grown and culturally accepted in KZN (Agricultural Research Council (ARC) 2013b; Faber, Laubscher & Laurie 2013).

Research has shown that the nutrient profile and yield of Swiss chard can be improved through the use of certain organic treatments, nitrogen fertilisers and plant spacings (Echer, Zoz, Rossol, Steiner, Castagnara & Lana 2012; Daiss, Lobo, Socorro, Brückner, Heller & Gonzalez 2008; Smith, Beharee and Hughes 2001). However, it is challenging to apply these findings to poor South African communities due to the controlled environments in which they were conducted. Moreover, many of the experimental treatments applied in these studies are not readily available and/or accessible to poor South Africans. Therefore, the findings of these studies may not be applicable to people of low economic status. Although these factors are common problems that hinder the implementation and success of food gardens, local food gardeners in KZN have access to various readily available soil treatments to promote the growth of their vegetables. These include organic fertilisers and mulches, which are freely obtained from land surrounding their homesteads. However, there is a lack of local research regarding the influence of these treatments on the growth rate, leaf number and nutritional profile of Swiss chard. Therefore, questions arise regarding the effect that various garden treatments would have on these aspects of Swiss chard.

1.2 Statement of the research problem

There is a paucity of research investigating the influence of readily available and accessible soil treatments on the nutritional profile, growth rate and leaf number of Swiss chard grown in home food gardens in poor areas in SA. This study contributes to this knowledge gap by identifying the best soil treatment or treatment combination that would produce Swiss chard containing the highest nutrient levels in a poor peri-urban home food garden in KZN.

1.3 Research aim and objectives

This study aimed to find the best affordable method of soil treatment for the production of Swiss chard with a good nutrient profile in poor peri-urban areas. The study objectives were:

1. To determine the effect of fertiliser and mulch treatment combinations on the growth rate (number of days to reach maturity).

2. To determine the effect of fertiliser and mulch treatment combinations on the leaf number (yield).
3. To determine the effect of fertiliser and mulch treatment combinations on the nutrient profile.

1.4 Study parameters

For the purpose of this study:

- Swiss chard refers to a readily available and accessible DGLV grown in local communities in KZN.
- Swiss chard was the chosen DGLV and was grown in a home food garden in KwaMnyandu, KZN.
- Experimental treatments included fertiliser and mulch only.
- The nutrient profile of Swiss chard was measured/considered in terms of the following nutrients: fat, fibre, crude protein, calcium, magnesium, potassium, sodium, phosphorus, zinc, copper, manganese and iron.

1.5 Assumptions

For the purpose of this study, the following was assumed:

- All Swiss chard seedlings were provided by the same supplier, therefore it was assumed that all seedlings received the same treatment prior to planting.
- The methods for determining soil composition, manure composition and food nutrients were accurate.

1.6 Hypotheses

Swiss chard grown:

- In no-fertiliser and no-mulch control conditions would have the:
    - lowest growth rate
    - lowest leaf number
    - poorest nutrient profile

- The combinations of mulch and fertiliser, when compared to mulch or fertiliser only would result in a:
    - higher growth rate
    - higher leaf number
    - better nutrient profile of Swiss chard

1.7 Conclusion

A significant percentage of South African children younger than nine years, especially those from rural communities, have a poor nutritional status in terms of anthropometric measures and micronutrient deficiencies, due to poor dietary diversity as a result of household food insecurity (HHFI) (HSRC 2013; Labadarios *et al* 2008; Labadarios, Steyn, Maunder, MacIntryre, Gericke, Swart, Huskisson, Dannhauser, Vorster, Nesmvuni & Nel 2005). Many social and agricultural strategies have attempted to improve the food security and nutrient status of South Africans; however, socio-economic constraints remain a major problem hindering the success of these strategies (De Groote, Kimenju & Morawetz 2010).

Home food gardens that produce vegetables high in nutrients (such as DGLVs) have been suggested as a potential strategy to alleviate nutrient deficiencies and improve food security (Maboko & Du Plooy 2013; Labadarios *et al* 2005; Faber *et al* 2002). Swiss chard is a commonly grown and culturally accepted DGLV in SA and KZN, and is thus the focus of this study (ARC 2013b; Faber *et al* 2013). With many international and local studies focusing predominantly on the effect of expensive garden treatments on the nutrient profile and agronomic quality of Swiss chard, there is a need to investigate the effect of locally practised garden treatments on the growth rate, leaf number and nutrient profile of Swiss chard (Echer *et al* 2012; Daiss *et al* 2008; Smith *et al* 2001).

1.8 Referencing style

The referencing style used in this dissertation is that of the Discipline of Dietetics and Human Nutrition.

CHAPTER TWO
LITERATURE REVIEW

2.1 Framework

This chapter develops a theoretical framework for the research by the reviewing literature on the key aspects of the research problem. Part one covers the definition, causes and consequences of malnutrition, with case studies from South Africa. Part two presents the nutritional status of South Africans with a focus on children under nine years of age and women of childbearing age. Next, the food security status of South Africans is reviewed, and the interventions which have been implemented to ensure food security. This is followed by a detailed review on food gardens in a rural setting in terms of their importance in achieving food security, alleviating nutrient deficiencies and their associated benefits and constraints. To conclude, the importance of growing DGLVs in home food gardens, particularly Swiss chard, will be evaluated.

2.2 Introduction

Approximately 805 billion people worldwide were projected to be malnourished between 2014 and 2015, particularly in developing countries (FAO 2015a; Luchuo *et al* 2013). Sub-Saharan Africa (SSA) is home to most of these people where one in four people are malnourished, the highest prevalence of malnutrition in the world after Asia and Latin America (Rosen, Meade & Murray 2015*;* FAO 2014, p8).

Blössner and de Onis (2005) define malnutrition as both under-and over-nutrition, however, the term is often used to refer to under-nutrition alone (Saunders & Smith 2010). For the purpose of this literature review, malnutrition will be considered as under nutrition. This multidimensional condition, malnutrition, is caused by direct, underlying and/or basic factors, predominantly affecting women and children (Orphan Nutrition 2016; UNICEF 2016; Hendricks & Bourne 2010; Saunders & Smith 2010; Blössner & de Onis 2005; Rice *et al* 2004, pp 212-213). Malnutrition negatively affects growth and development in children, pregnancy and lactation in women and physical, cognitive and immunological processes and functions of the body (UNICEF

2016; Luchuo *et al* 2013; Saunders & Smith 2010; Ramakrishnan 2002; Stoltzfus 2001).

These manifestations of malnutrition, specifically of micronutrient malnutrition, are often undetected and are therefore referred to as a ‘hidden hunger’ (Faber & Wenhold 2007). Malnutrition forms part of the quadruple burden of disease in SA, which includes: communicable, non-communicable, perinatal and maternal diseases and injury related disorders (Mayosi, Flisher, Lalloo, Sitas, Tollman & Bradshaw 2009). The co-existence of adult overweight and obesity with child malnutrition (under-nutrition) has been labelled as the ‘double burden of malnutrition’, and raises concern with regards to household food security (HHFS) (Hendriks, Viljoen, Marais, Wenhold, McIntyre, Ngidi, van der Merwe, Annandale, Kalaba & Stewart 2016).

The term ‘food security’ has adopted several definitions, primarily centred on a physical dearth of food (Maxwell 1996; Sen 1981). However Sen (1981) suggested that food inaccessibility rather than food unavailability may be the fundamental cause of food insecurity. Since Sen’s argument in 1981, food insecurity has been internationally recognized as a complex problem encompassing the accessibility and cost of food, and not just the physical availability (WHO 2016a; Arimond, Hawkes, Ruel, Sifri, Berti, Leroy, Low, Brown & Frongillo 2011; Labadarios, Mchiza, Steyn, Gericke, Maunder, Davids & Parke 2011a; Kortright & Wakefield 2010; Maxwell 1996). The Department of Agriculture (DOA) (2002) in South Africa highlights the importance of food reliability, which refers to the use and consumption of safe and nutritious food, requiring sufficient nutritional knowledge (UNICEF 2016; WHO 2016a; DOA 2002). Poor food distribution is a further facet of food insecurity, and results in local food insecure areas within countries who are considered nationally food secure (DOA 2002). Food security was defined at the 1996 World Food Summit in Rome, as a state “when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life” which has since been adopted as the worldwide standard (FAO: World Food Summit 13-17 November 1996).

For interventions to be successful in eliminating food insecurity and nutrient deficiencies, they need to take all the components of the food system into consideration, such as production, marketing, distribution, consumption and nutrition (DOA 2002). In an attempt to improve the food security and nutrition situation in SA, the DOH has developed and implemented numerous nutrition interventions, including: nutrient supplementation, food fortification and dietary diversification and modification (UNICEF 2016; DOH 2013; De Groote *et al* 2010; Blössner & de Onis 2005). There are numerous challenges associated with these interventions, such as socio-economic constraints that limit their effectiveness (De Groote *et al* 2010). To address these problems, multidisciplinary strategies that are sustainable in all socio-economic settings need to be implemented (Gibson 2011; Labadarios *et al* 2005). A strategy that was recommended by the 1999 NFCS as a sustainable intervention to work towards achieving food security and reduced nutrient deficiencies was home food gardening (Labadarios *et al* 2005).

Together with nutrition education, home food gardening has been recognised worldwide for its contribution towards alleviating food insecurity and nutrient deficiencies (Schreinemachers *et al* 2015; Miller & Welch 2013; Carney *et al* 2012; Shetty 2011; HKI 2010; Faber *et al* 2007; Faber *et al* 2002). Home food gardens provide direct access to a variety of nutrient rich foods, translating increased household food production into food security (Schreinemachers *et al* 2015; Carney *et al* 2012; Faber *et al* 2011; HKI 2010; Faber *et al* 2007; Faber *et al* 2002; Marsh 1998). Home food gardens go beyond food security by increasing purchasing power, improving physical and cognitive output, promoting social justice and equality and preserving indigenous knowledge and culture (FAO 2016; Davies, Devereaux, Lennartsson, Schmutz & Williams 2014; Mitchell & Hanstad 2004). A platform to address population specific nutrient deficiencies has been created through home food gardens that grow culturally accepted fruits and vegetables that are high in certain nutrients (Faber *et al* 2011; Faber *et al* 2002).

In SA, common nutrient deficiencies include vitamin A, zinc and iron deficiency. As a result, many home food garden interventions have focused on growing culturally accepted crops rich in these nutrients, such as orange fruits and vegetables and DGLVs (Faber *et al* 2011; Faber *et al* 2002). Against the back drop of the poor nutrient status of South African children and the high prevalence of food insecurity, home food gardens containing DGLVs may have a significant role to play in improving HHFI and nutrient deficiencies (Maboko & Du Plooy 2013; Labadarios *et al* 2005; Faber *et al* 2002). However, the lack of realistic and sustainable infrastructure, social and cultural barriers and a lack of nutritional and agricultural knowledge are some of the challenges that limit the success of food gardens (Faber *et al* 2011; Morton 2007; Faber *et al* 2002; Marsh 1998).

Much agricultural research has focused on increasing the yield size of home food gardens to provide food security, neglecting nutrient deficiencies in terms of the nutritional profile of the produce (Miller & Welch 2013; Arimond *et al* 2011; Shetty 2011). Equal emphasis should be placed on both the quantity and the nutritional profile of the produce as a means to attain and sustain leverage on decreasing the prevalence of food insecurity and nutrient deficiencies in SA (Miller & Welch, Arimond *et al* 2011; Shetty 2011). To close this research gap, many agricultural production strategies to enhance the nutrient content of crops have been explored, such as: fertilisers, cropping systems and biofortification (Miller & Welch 2013; Nuss *et al* 2012; Bouis, Hotz, McClafferty, Meenakshi & Pfeiffer 2011; Gibson 2011; Shetty 2011; Graham, Welch, Saunders, Ortiz-Monasterio, Bouis, Bonierbale, de Haan, Burgos, Thiele, Liria, Meisner, Beebe, Potts, Kadian, Hobbs, Gupta & Twomlow 2007; Welch & Graham 2005). Although these strategies have been shown to improve the nutrient profile and yield size of agricultural produce, they are not always readily available and accessible to the rural and peri-urban poor. Thus, alternate strategies that are more readily available and accessible need to be investigated.

In KZN, Swiss chard is a commonly grown and culturally acceptable DGLV, which is usually eaten as a side dish with a staple food (ARC 2013b; Faber *et al* 2013; Maboko & Du Plooy 2013). Studies have explored the effect of garden treatments on the yield and quality of Swiss chard, however, the treatments used are not affordable to the poor (Echer *et al* 2012; Daiss *et al* 2008; Smith, Beharee & Hughes 2001).

Therefore, it is necessary to investigate the effect of locally available and accessible garden treatments, such as readily available fertilisers and mulch, on the nutritional profile of Swiss chard to contribute towards alleviating HHFI and malnutrition.

2.3 The conceptual framework of malnutrition

The UNICEF Conceptual Framework of Malnutrition (Figure 2.1) was formulated in 1990 as a component of a nutrition strategy to illustrate the complex, dependent relationships between the immediate, underlying and basic causes of malnutrition at individual, community and society level (UNICEF 2016).

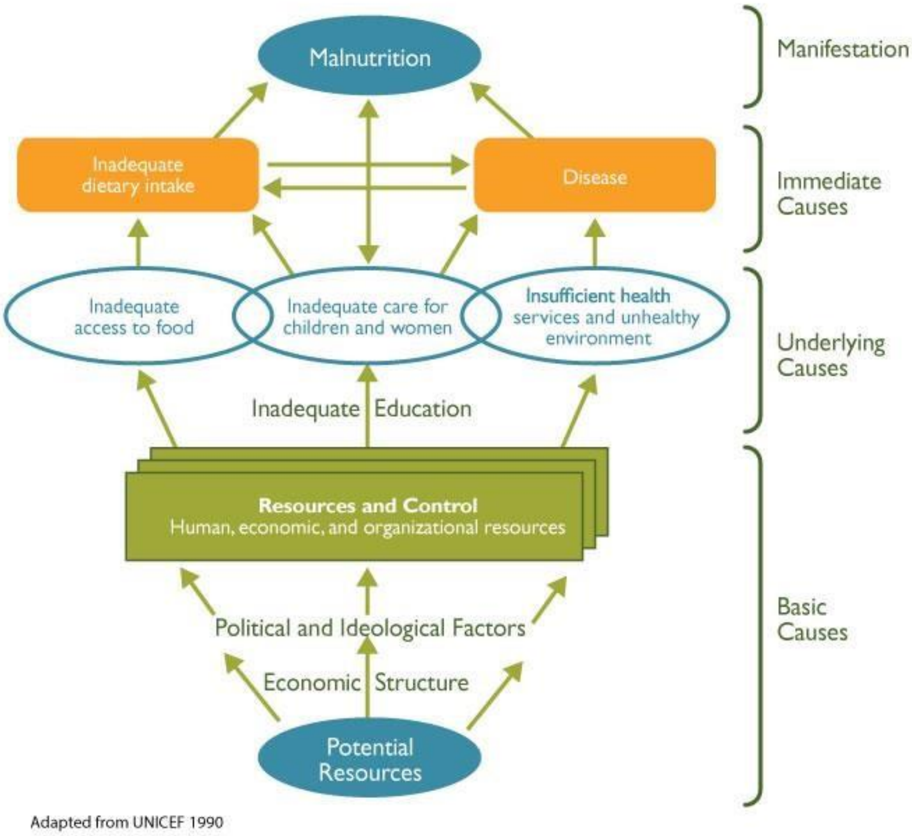

Figure 2.1 The UNICEF conceptual framework

(Source:https://www.springnutrition.org/sites/default/files/publications/reports/ftflandscape_fig7.jpg)

It is essential to have an understanding of the contributory factors of malnutrition to determine its causes in specific populations and for the planning of effective nutrition interventions both nationally and locally (UNICEF 2016; Department of Health (DOH) 2013; Blössner & de Onis 2005). According to the conceptual framework, malnutrition is caused by inadequate dietary intake and poor health, the two immediate causes of malnutrition. Nutrition-related health problems occurring in developing countries are usually due to communicable diseases, such as diarrheal and acute respiratory disease (UNICEF 2016; Saunders & Smith 2010; Blössner & de Onis 2005; Food Security and Nutrition 2016). Ineffectual use of resources result in insufficient access to food, poor health care systems and an “unhealthy” environment. As a result, proper care in households and communities becomes absent, the third component of underlying causes of malnutrition (Food Security and Nutrition 2016). In conclusion, the conceptual framework of malnutrition identifies that human and ecological resources, trade and industry systems and political and ideological factors are basic causes that contribute to malnutrition (Food Security and Nutrition 2016). The major causes of malnutrition are associated with different social-organisational levels. The immediate causes impact individuals, families are affected by underlying causes and basic causes are related to the community and the nation. Therefore, the more ‘secondary’ the causes of malnutrition are, the more widespread the nutritional effect is on a population (Food Security and Nutrition 2016).

2.3.1 Immediate causes of malnutrition

Inadequate dietary intake and disease, the two immediate causes of malnutrition, frequently go hand-in-hand (UNICEF 2016; Saunders & Smith 2010; Blössner & de Onis 2005). These two causes are often referred to as the infection-malnutrition cycle (Figure 2.2), which characterises malnutrition as “both a cause and consequence of disease” (Saunders & Smith 2010, p624). The metabolic changes caused by infections, such as increased requirements and diminished absorption of nutrients, intensify the consequences of inadequate dietary intake resulting in fat, muscle and organ mass loss (UNICEF 2016; Saunders & Smith 2010). Depending on the severity of an infection, poor nutritional intake may lead to a reduced immune response, thereby increasing the risk for, and the duration, of new infections (Orphan Nutrition 2016; Hendricks & Bourne 2010; Blössner & de Onis 2005).

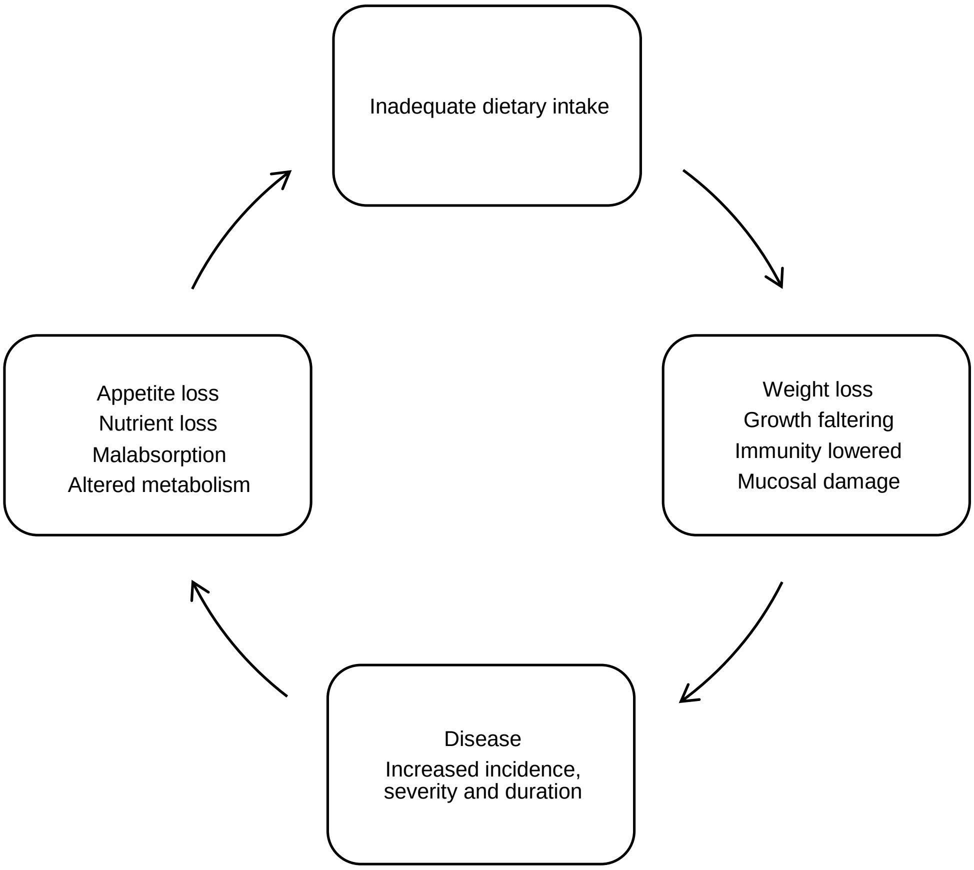

Figure 2.2 Infection-malnutrition cycle (Source: http://www.nzdl.org)

To be disrupted, the infection-malnutrition cycle (Figure 2.2) necessitates professional medical and dietary intervention, a lack of which is part of the underlying causes of malnutrition (UNICEF 2016).

2.3.2 Underlying causes of malnutrition

The three underlying causes of malnutrition are HHFI, inadequate care for women and children, and an unhealthy household environment and lack of health care services (UNICEF 2016). Household decisions concerning the underlying causes of malnutrition are frequently reliant on, and influenced by, interrelated factors such as culture, finances, land availability, education and resources. Therefore, factors that disturb any one of the underlying causes may have major consequences on the other causes of malnutrition (UNICEF 2016).

Considering the various aspects of food security, the DOH in SA has not adopted the definition of food security described by the FAO at the World Food Summit in 1996, but has advocated for two separate definitions for food security at individual and household level. According to these definitions, individual food security exists when "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (DOH 2013, p6). HHFS is the "access by a household to amounts of food of the right quantity and quality to satisfy the dietary needs of all its members throughout the year" (DOH 2013, p6). In contrast to food security, food insecurity has been defined as "a lack of secure access to sufficient amounts of safe and nutritious foods for normal growth and development and an active and healthy life" (FAO 2014, p50). Therefore, to achieve HHFS, food needs to be appropriately utilised and socially, physically and financially available and accessible year-round (Arimond *et al* 2011; Kortright & Wakefield 2010; Maxwell 1996; Sen 1981).

Inadequate care for women and children is the most recent recognised cause of malnutrition, and is often dependent on cultural values and beliefs regarding status, responsibilities, power and education of women (UNICEF 2016; Arimond *et al* 2011). Women are integral to maintaining HHFS, as they are predominantly responsible for purchasing and/or producing, preparing, cooking, preserving and storing food within a household (UNICEF 2016). Malnourished mothers cannot perform vital caring practices optimally such as: breastfeeding, appropriate complimentary feeding, hygienic practices and stimulating and teaching of children, resulting in poor growth and development of children (UNICEF 2016; Arimond *et al* 2011; Hendricks & Bourne 2010; Blössner & de Onis 2005). To prevent the spread of malnutrition through generations, the nutritional status of women and children have been the focal point of many nutrition interventions, such as vitamin A supplementation for children and iron and folic acid supplementation for pregnant women (DOH 2013; Hendricks & Bourne 2010; Blössner & de Onis 2005).

Insufficient health services and unhealthy household environments is the third underlying cause of malnutrition and refer to poor public health (UNICEF 2016). An unhealthy environment in terms of inadequate safe water supply, poor sanitation and unhygienic household conditions has a significant impact on the spread and increased incidence of infectious diseases (UNICEF 2016; Thomson 2011; Hendricks

& Bourne 2010). It is essential for populations to have access to curative and preventative health services that are within a reasonable distance from homes, affordable and of good quality (UNICEF 2016). However, a significant proportion of the world's population still do not have access to health care due to financial constraints (UNICEF 2016).

2.3.3 Basic causes of malnutrition

A lack of access to, and control over, the different resources necessary for sound nutrition is one of the basic causes of malnutrition (UNICEF 2016). Resources such as time and money compete to achieve different aspects of good nutrition, often resulting in malnutrition (UNICEF 2016). Moreover, uncontrollable factors contribute to the basic causes of malnutrition, such as climate change and weather variability, which affects the availability of water for household and agricultural use (Matthews, Rivington, Muhammed, Newton & Hallett 2013).

In addition, political, legal and cultural factors, including religion and tradition may not only hinder households from attaining and sustaining food security and good nutritional status, but may prevent the success of nutrition interventions (Galhena, Freed & Maredia 2013). Some of these factors include: the degree to which the rights of women and children are protected by law and custom, the political and economic system that determines how income and assets are distributed and the ideologies and policies that govern the social sectors (UNICEF 2016; Blössner & de Onis 2005). How available resources are used, distributed and consumed, and who benefits from their income is determined by the economic, political, social and ideological customs of populations (UNICEF 2016). Political factors refer to how the state operates in terms of law enforcement, taxation and subsidization (UNICEF 2016). Individuals of certain religions or races are often excluded from receiving relief services such as food parcels due to political discrimination (UNICEF 2016). For example, black Africans were reported to have the highest risk of experiencing hunger (30%), after coloured Africans (25%), Indian Africans (29%) and white Africans (11%), which is representative of race disparity (HSRC 2013). With this understanding of the multiple interconnected and intricate causes of malnutrition, the nutrition situation in SA will be explored

2.4 Food and nutrition security in South Africa

Accurate accounts of food insecurity and nutrient deficiencies are difficult to obtain due to the challenges involved in collecting large-scale data on food consumption and expenditure. Therefore, simple dietary diversity scores can be used as measures of food security and dietary nutrient adequacy (Caesar, Crush & Hill 2013; Thorne-Lyman, Valpiani, Sun, Semba, Klotz, Kraemer, Akhter, de Pee, Moench-Pfanner, Sari & Bloem 2010; Steyn, Nel, Nantel, Kennedy & Labadarios 2006). Although various nutrient deficiencies exist in SA, there has been a prime focus on VAD and iron deficiency anaemia in the last decade due to the availability of reliable national data, with zinc deficiency recently being included in the focus (Faber & Wenhold 2007).

2.4.1 Dietary intake and nutritional status

There are four major South African surveys that have reported on the nutritional status and/or dietary intake of children. The 1994 South African Vitamin A Consultative Group (SAVACG) survey reported on the prevalence of VAD and anaemia in children between six-and-71 months of age (Labadarios, Van Middelkoop, Coutsoudis, Eggers, Hussey, Ijsselmuiden & Kotze 1995). Thereafter, the 1999 National Food Consumption Survey (NFCS) and 2005 National Food Consumption Survey Fortification Baseline (NFCS-FB-1) were conducted, which explored the nutritional status of 2 894 and 2 469 South African children respectively, aged between one-and nine years (Labadarios *et a*l 2008; Labadarios *et al* 2005). Following the 2005 NFCS, the 2012 SANHANES-1 was conducted, which included individuals of all ages living in SA, except those staying in educational institutions, old-age homes, hospitals, homeless people and uniformed-service barracks. Individuals (n=25 532) completed a questionnaire-based interview (93% interview response rate), had a physical examination by a medical doctor (n=12 025) and provided a blood specimen for biomarker testing (n=8 078).

The diets of poor South Africans are mostly cereal based and nutrient poor, with very few foods of animal origin, vegetables and fruit (Faber, Oelofse, Van Jaarsveld, Wenhold & Jansen van Rensburg 2010). The 1999 NFCS reported that one in 10

South African children aged between one-and-three years had an energy intake of less than half their daily energy needs, and one in four consumed less than two-thirds of their daily energy needs (Labadarios *et al* 2005). Older children, one-to nine years of age, consumed less than 67% of the Recommended Dietary Allowances (RDAs) in energy, calcium, iron, zinc, selenium and vitamins A, D, C, E, B_2, B_3, B_6 and folic acid as a result of a primarily maize based diet, lacking in animal protein, fruit and vegetables (Labadarios *et al* 2005). For adults, it was estimated that 11 million South African males and 13 million females older than 15 years had a low intake of vegetables and fruit in 2000 due to poor access and availability (Schneider, Norman, Steyn & Bradshaw 2007; Labadarios *et al* 2000, p146). Later, Rose, Bourne and Bradshaw (2002, p25) reported that the average South African ate less than half (196g) of the minimum (400g per day) fruit and vegetable intake recommended by the WHO (2016b), for the prevention of diet-related non-communicable diseases. This limited dietary diversity is reflected in the nutrient poor nutrient status of many South African's, particularly children.

The 1994 SAVACG survey reported a high prevalence of VAD (33%) and anaemia (21%) in children between six-and-71 months of age (Labadarios *et al* 1995). The results from the 1994 SAVACG and NFCS's and SANHANES are difficult to compare due to the age difference in their sample population ages, therefore the results of the 1994 SAVACG are reported separately. A decrease was reported in the national prevalence of VAD (from 64% to 44%) and anaemia (28% to 11%) in one-to-nine year old children, and VAD in women of childbearing age (from 27% to 13%) from 1999 to 2012 (HSRC 2013; Labadarios *et al* 2008). These nutrient deficiencies have major health implications and are considered national health concerns irrespective of the decreased prevalence (HSRC 2013; Labadarios *et al* 2008). In addition, although not anaemic, 13% of young South African children had a poor iron status and 45% had a low zinc status, thereby placing them at risk for these deficiencies (Labadarios *et a*l 2008).

Poor dietary diversity has resulted in many nutrient deficient South Africans. Considering that low fruit and vegetable intake has been described by Love, Maunder, Green, Ross, Smale-Lovely and Charlton (2001), as one of the top 10 risk factors contributing to mortality and major nutrient deficiencies worldwide, a strategy to increase fruit and vegetable intake by addressing major constraints that hinder their consumption such as seasonality, affordability and availability (food insecurity) is essential for the health of the South African population (Faber *et al* 2013; Faber *et al* 2010; Faber & Laubscher 2008; Ezzati, Lopez, Rodgers, Vander Hoorn & Murray 2002).

2.4.2 Food security

According to the International Food Security Assessment for 2015-2025, SSA was home to approximately 254 million (28%) food insecure people in 2015 (Rosen *et al* 2015). Within SSA, only a small portion (one in four) of South Africans are food secure, despite residing in a country that has adequate national food production, which is representative of poor food distribution (Frayne *et al* 2014a; Faber *et al* 2011; Hendricks & Bourne 2010; Labadarios *et al* 2008; DOA 2002). The same surveys that reported on the nutrient status and/or dietary intake of children were used to report on food security, expect for the SAVACG survey.

Following the 2005 NFCS, the 2012 SANHANES-1 was conducted, which included individuals of all ages living in SA, except those staying in educational institutions, old age homes, hospitals, homeless people and uniformed-service barracks. One of the aspects that the 2008 SASAS measured was the prevalence of hunger in adults over the age of 16 years (HSRC 2008). However, the randomly selected adults may not have been the carers of children, consequently to parallel the results of the 1999 NFCS and 2005 NFCS-FB-1 with the 2008 SASAS, the secondary data of the 2008 SASAS was restricted to households with children aged between one-and-nine years only (n=1 150) (HSRC 2008). It concluded that the prevalence of food security in children between one-and-nine years of age almost doubled between 1999 (25%) and 2008 (48%), however, declined between 2008 (48%) and 2012 (46%) (Table 2.1) (HSRC 2008; Labadarios *et al* 2008; Labadarios *et al* 2005). Furthermore, the percentage of one-to-nine year old children experiencing hunger has halved between 1999 (52%) and 2012 (26%) (HSRC 2013; 2008; Labadarios *et al* 2008; Labadarios *et al* 2005). Although the prevalence of food security has decreased, the proportion of the population at risk of hunger has increased from 1999 (23%) to 2012 (28%), classifying SA as having a 'moderate' severity of hunger (HSRC 2013). This classification highlights the need for continued interventions to address food insecurity in children.

Table 2.1 National house hold food security status in 1999 and 2012 of children aged one to nine years in South Africa (HSRC 2013; HSRC 2008; Labadarios et al 2008; Labadarios et al 2005).

Indicator	**NFCS (1999) n=2 894 (%)**	**NFCS-FB-1 (2005) n=2 469 (%)**	**SASAS (2008) n=1 150 (%)**	**SANHANES (2012) n=6 306 (%)**
Food secure	25	20	48	46
At risk of hunger	23	28	25	28
Experiencing hunger	52	52	26	26

In the context of a growing population, the unpredictable price and food production levels, coupled with the increasing demand of food, SA requires an increase in food production to meet the dietary requirements of the population (Galhena *et al* 2013; Hendricks & Bourne 2010). To achieve food security effectively and efficiently, the appropriate production, storage and distribution of food needs to take place to overcome susceptibility to market changeability and seasonal variations in access to food (DOA 2002). Food and nutrition security is a basic human right and a financial asset, making the development and implementation of interventions to achieve this, one of the country's primary focuses (DOH 2013; HSRC 2013; DOA 2002).

2.5 Addressing food and nutrition insecurity

In 1995, the DOH initiated the Integrated Nutrition Program (INP), which aimed to ensure optimum nutrition for all South Africans by preventing and managing malnutrition. The objective in terms of micronutrient malnutrition was the eradication of micronutrient deficiencies (DOH 2002, p28). In the past, nutrition interventions focused on nutrient supplementation and food fortification, however, new interventions and strategies have since been introduced including dietary diversification and modification, and bio fortification (Shetty 2011). These interventions are most effective when carried out in combination with other public health strategies such as the control of infectious and parasitic diseases (Gibson 2011; Shetty 2011).

2.5.1 Nutrient supplementation

Micronutrient supplementation involves the administration of synthetic nutrients for the purpose of preventing, reducing or controlling a deficiency, particularly in women and children (Thomson 2011; DOH 2002, p28).

Vitamin A supplementation in particular, is considered one of the most cost effective strategies to address VAD and its co-morbidities (DOH 2013). The vitamin A supplementation programme in SA is intended for children between six-and-59 months of age and it is administered in capsule form (De Groote *et al* 2010). It has been reported to have the potential to decrease death from measles and diarrhoea by 50% and 40% respectively, and overall mortality by 25% (DOH 2013). Other examples of nutrient supplementation programs include: therapeutic zinc supplementation for children with diarrhoea between six and 59 months of age, and iron, folate and calcium supplementation for pregnant women (DOH 2013; WHO 2001, p56).

Although nutrient supplementation has made a significant contribution to ensuring decreased nutrient deficiencies, challenges such as limited access to health facilities, socio-economic constraints and a lack of transportation remain prominent, hindering the success of the programmes (Gibson 2011; Shetty 2011; De Groote *et al* 2010).

2.5.2 Food fortification

Industrial food fortification is an affordable and sustainable food-based approach whereby one or more micronutrients are added to processed food items that are regularly consumed by a substantial proportion of a population (Shetty 2011; Thomson 2011; De Groote *et al* 2010). Food fortification is a strategy used to prevent, reduce or control a deficiency of one or more nutrients in a population (DOH 2002, p28).

Although not a focus of this review, it should be noted that the compulsory iodisation of household salt was introduced through the revised legislation in 1995. Thereafter, the NFCS identified maize meal and wheat flour as the most commonly consumed foods. These foods where therefore recognised as the most suitable vehicles for fortification, and as a result, fortification of maize meal and wheat flour was legislated in October 2003. This forced manufacturers of maize and white bread flour to add iron, zinc, vitamin A, thiamine, riboflavin and vitamin B_6 to their food items (Shetty 2011; Labadarios *et al* 2008). Food fortification, together with other interventions such as dietary diversification and modification, have made a positive impact on VAD and iron deficiency, however, VAD remains a public health problem (HSRC 2013; Labadarios *et al* 2008).

2.5.3 Dietary diversification and modification

Dietary diversification aims to "increase dietary availability, regular access and consumption of vitamin and mineral-rich foods in at-risk and micronutrient deficient groups or populations" through a variety of approaches (DOH 2002, p 28). Dietary modification promotes behaviours that provide adequate intake, and together with ensuring availability of supply, is an affordable and sustainable strategy (Ruel 2001).

Consuming a variety of foods is essential for obtaining a good nutritional status, however the uncertain availability of crops and financial constraints are major limitations associated with this strategy (De Groote *et al* 2010; Gibson, Hotz, Temple, Yeudall, Mtitimuni & Ferguson 2000). Through the adaption of traditional food choice and preparation patterns, the availability of, access to, and utilization of a variety of nutritious foods may be improved (Gibson 2011; Thomson 2011; Gibson *et al* 2000). Understanding the level of nutritional knowledge, food beliefs, preferences and taboos of communities and social marketing and nutrition education play an important role in facilitating behaviour change (DOH 2011; Gibson 2011). Micronutrient supplementation and food fortification are short- to medium-term strategies to address malnutrition, however, in the long-term, dietary diversification through a food-based approach involving agriculture has been proposed as one of the more sustainable options (Kiess, Moench-Pfanner & Bloem 2001).

If all these factors are considered, the strategy becomes a culturally acceptable and financially sustainable way to prevent multiple micronutrient deficiencies, even in resource-poor areas (Gibson 2011). Other benefits, such as empowerment of women and income generation, have been associated with this intervention (Gibson 2011). Dietary diversification and modification, as a food-based approach, has been considered a more suitable long-term strategy to address food insecurity and nutrient deficiencies, rather than short- to medium-term strategies such as nutrient supplementation and food fortification (Kiess *et al* 2001).

2.5.4 Biofortification

Biofortification is the process by which the concentration of essential nutrients in staple foods is enhanced through the use of biotechnology, and is considered a sustainable strategy for addressing micronutrient malnutrition (Nuss *et al* 2012; Bouis *et al* 2011; Gibson 2011; Shetty 2011).

Biofortification through fertiliser, conventional breeding techniques, mutagenesis and transgenic methods improves the nutritional profile of commonly eaten staple foods, providing a cost effective, sustainable means of delivering micronutrients to the poor (Bouis *et al* 2011). Rice, wheat, maize, beans, sweet potato, cassava and pearl millet are most commonly biofortified with provitamin A, iron, and/or zinc (Nuss *et al* 2012; Bouis *et al* 2011). It is a practical way of reducing micronutrient malnutrition, particularly in rural families with limited access to markets, health care facilities, diverse diets, supplements and commercially fortified foods (Bouis et al 2011; Gibson 2011; De Groote *et al* 2010).

The nutritional interventions reviewed (i.e. nutrient supplementation, food fortification, dietary diversity and modification, and biofortifiaction) have played an important role in reducing the prevalence of micronutrient malnutrition and food insecurity (DOH 2013; Nuss *et al* 2012; Bouis et al 2011; Gibson 2011; Shetty 2011; Kiess *et al* 2001). However, there are many constraints hindering their effectiveness including: limited access to health facilities, socio-economic constraints, lack of transport, geographical area, a lack of finances and poor resource availability (Gibson 2011; Shetty 2011; De Groote *et al* 2010). To address these problems, multidisciplinary strategies that are sustainable in all socio-economic scenarios need to be implemented (Gibson 2011; Labadarios *et al* 2005). A strategy that was recommended by the 1999 NFCS as a sustainable intervention to work towards achieving food security and reduced nutrient deficiencies was home food gardening (Labadarios *et al* 2005).

2.6 Home food gardens

The advancement from the hunter-gatherer age to small communities was facilitated by food gardening through the provision of food, fuel, fibre, material and land security (Galhena *et al* 2013; Marsh 1998). Today, home food gardens, also known as 'backyard', 'kitchen', 'mixed', 'farmyard', 'compound' or 'homestead' gardens, form part of typical 'family life', particularly in rural areas, and may be representative of various household needs, such as staple foods, fruits and vegetables (FAO 2016; Galhena *et al* 2013*;* Arimond *et al* 2011; Marsh 1998). The resilience of home food gardens through the ages is evidence of their fundamental economic and nutritional value (Galhena *et al* 2013; Marsh 1998).

Defining home food gardens is difficult due to their different sizes, forms and functions (Arimond *et al* 2011; Lyons & Dlamini 2008). They have been broadly described as any farming systems that have physical, social and economic purpose on the area of land surrounding a homestead. More specifically, they are usually small, irrigated, fertilised and fenced with a diversity of crops that are cultivated continuously (Arimond *et al* 2011; Lyons & Dlamini 2008). Home food gardens may be communal, whereby garden responsibilities and production is shared among a group of individuals (Lyons & Dlamini 2008). However, the primary form of home food gardening that takes place in rural and peri-urban areas in SA is small-scale subsistence farming, which entails food production for consumption rather than income (Africa Development Promise 2014; Baiphethi & Jacobs 2009; Ruel 2001; Nair 1993). In the context of escalating food prices and the global economic recession, home food gardens are considered a potential contributor to food and nutrition security for the rural poor in SA (Faber *et al* 2011). By providing nutritious food, food gardens may improve the health of families, thereby improving their capacity to perform physically and cognitively (Davies *et al* 2014; Mitchell & Hanstad 2004). The impact of home food gardens on the nutrient intake of households in SA was questioned by Webb (2000), and Schmidt and Vorster (1995). However, the importance of home food gardens and nutrition education, and their role in achieving food security and improved nutritional status, has since been recognised worldwide (Schreinemachers *et al* 2015; Carney *et al* 2012; HKI 2010; Faber *et al* 2007; Faber *et al* 2002).

Although home food gardening has the potential for improving both house hold food security and micronutrient malnutrition a clear distinction between home food gardening to improve food security as opposed to improving micronutrient malnutrition needs to be made. According to the FAO (2010), home food gardening can enhance food security by providing: direct access to nutritionally rich foods, increased financial income from sales of garden products and savings on food bills, as well as a contingency supply of food during seasonal lean periods. On the other hand, home food gardening is a long-term strategy to improve micronutrient malnutrition by focusing on provitamin A-rich vegetables, which can contribute to combating vitamin A and other nutritional deficiencies which are of public health significance in developing countries (Faber & Laurie 2011).

2.6.1 Food garden benefits

In America, Heim, Strang and Ireland (2009) designed and implemented a 12-week pilot study which focused on the promotion of fruits and vegetables in children in grades four-to-six who were attending a summer camp. Children (n=93) took part in garden based activities twice weekly and educational activities once weekly. The educational activities included: sensory tests and fruit and vegetable snack preparation. Using pre- and post-surveys, the participant satisfaction and short-term impact of the pilot study were evaluated. In terms of participant satisfaction, high levels of enjoyment in the sensory-testing (98%), preparing fruit and vegetable snacks (94%), working in the garden (96%) and learning about fruits and vegetables (91%) were reported. The short-term impact data expressed an increased number of fruits and vegetables eaten ($p>0.001$), improved vegetable preferences ($p>0.001$) and overall interest in fruit and vegetables at home ($p>0.002$). This pilot study demonstrated that garden-based nutrition education programs can increase fruit and vegetable exposure and improve predictors of fruit and vegetable intake through experimental learning activities. However, it needs to be considered that the study population age was not specified, and grades may not be a meaningful measure in terms of applying the results to other countries because the ages of children in different grades vary worldwide. Moreover, the study was a short-term pilot and in developing countries such as SA where food insecurity and nutrient deficiencies are widespread, educational activities exposing children to fruits and vegetables may not be successful due to a lack of access to, and poor availability of a variety of fruits and vegetables as described by various authors (Faber *et al* 2013; Faber *et al* 2010; Faber & Laubscher 2008; Ezzati *et al* 2002).

As part of a strategy towards alleviating malnutrition, HKI (2010) initiated an on-going nutrition education and homestead food production initiative in Bangladesh, Cambodia, Nepal and the Philippines, in which approximately 300 000 households took part. The initiative aimed to address some of the underlying and direct causes of malnutrition including: a lack of maternal knowledge and education, women's empowerment, community support, access to quality food, food and nutrient intake and health. These issues were addressed through the provision of year-round food availability and variety through homestead food production. The impact of the initiative was evaluated using data collected from a randomly selected representative sample and a control. The baseline data were collected upon the initiation of the project in 2003, and end line surveys were conducted three and four years later, in 2006 and 2007. Apart from Cambodia, both the baseline and end line surveys were carried out at similar times of the year to reduce seasonality production influences. An improved availability and consumption of vegetables, fruit and animal products was synonymous among the four countries. There was an increase in household income, improved involvement of women in household decision making, and a decrease in the prevalence of anaemia in non-pregnant mothers and children aged between six and 59 months. Based on these findings, homestead food production coupled with nutrition education, may have a vital role to play in improving the dietary intake and nutritional status of women and young children (HKI 2010). Arimond *et al* (2011) and Mitchell and Hanstad (2004) are in agreement with the findings regarding the empowerment of women. Having said this, the social, cultural and geographical differences between the Asia-Pacific region and SA need to be taken into consideration, such as the generally plant-based diets of Asians compared to Africans (Faber *et al* 2011).

Carney *et al* (2012), described the impact of a Hispanic community gardening project (n=42 families) on vegetable intake, food security and family relationships. Following an educational programme on planting and maintaining organic gardens, pre- and post-gardening surveys, key informant interviews and observations at community based gardening meetings to assess food security, safety and family relationships took place. The study found that the proportion of adults who said they ate vegetables 'several times a day' increased significantly from 18% to 85% ($p< 0.001$). The number of children who said they ate vegetables "several times a day" increased from 24% to 64%, ($p=0.003$). Before the gardens were initiated, 31% of Hispanic households reported that in the last month, they had "sometimes" and "frequently" worried that their food supply would be depleted before it was financially feasible to buy more. After the gardens were initiated, the sum of the frequencies dropped to 3% ($p=0.006$), and physical, mental, economic and family health benefits were reported. Further, 95% of participants reported that the garden had a positive impact on the health of their families. Thus, in agreement with the conclusions of HKI (2010), the study established that food gardens have the potential to decrease food insecurity by improving dietary intake and availability of vegetables, and strengthen family relationships (Carney *et al* 2012).

Adekunle (2013) explored the role of home food gardens in HHFS in a rural village in the Eastern Cape (EC) of SA. The study focused specifically on crops grown and yields produced in home food gardens, and how the community relied on their own food production to remain food secure. Random stratified sampling was carried out to select 30 individuals from three different villages in the Nkonkobe Municipality. Data were collected using a structured questionnaire by individual interviews. The most commonly grown vegetables were: Swiss chard, cabbage, onion, tomatoes, maize, carrot and butternut. Most of the households (60%) relied on their own food production for HHFS, with 30% of respondents obtaining food at supermarkets and 10% from community vendors. Moreover, 70% of the households relied on their vegetable gardens for adequate vegetable intake, while only 10% and 20% could afford to buy their vegetables from the local producer and supermarkets respectively. It was concluded that home gardening has an indispensable role in HHFS in the three villages studied.

A study conducted by Selepe and Hendriks (2014) set out to determine the impact of home gardens on nutrient intake, access to food and dietary diversity of pre-school children in an informal settlement in Gauteng, South Africa. Caregivers of children aged between two and five years (n=40) who participated in a garden project took part in the study. Data were gathered using: quantitative food frequency, 24-hour recall and dietary diversity questionnaires. The study compared the pre- and post-project food consumption frequencies, dietary diversity and nutrient adequacy. Prior to the home garden project, tomato and onion stew was the sole source of vegetables for the participating children. However, after introducing the gardens, vegetable consumption patterns changed and beetroot, cabbage, carrots and Swiss chard ranked among the top 13 most frequently consumed foods. Similar to the findings of Carney *et al* (2012) and Adekunle (2013), this study found that growing nutrient rich garden produce improved access to, and consumption of, vegetables with a significant increase in dietary diversity and nutrient intake among the participating children.

Considering that home food gardens have been shown to improve dietary intake of vegetables in study communities, it is important to consider the nutrient content of the crops planted. In light of this, many agricultural interventions based in South African communities focus on planting crops high in nutrients that are limited in the diets of those in a particular area (Faber *et al* 2011; Faber & Wenhold 2007). Crops rich in provitamin-A, such as orange-fleshed vegetables and DGLVs, have been the focal crops in many garden initiatives across SA and worldwide (Faber *et al* 2011; Faber *et al* 2002). The 1999 NFCS reported that DGLVs were the 16th most frequently eaten food item in one-to-nine year old South African children, and the 20th in KZN, contributing primarily vitamin A to the diet (HSRC 2013; Labadarios *et al* 2008; Labadarios *et al* 2005). Similarly, a study conducted in adults in Limpopo found that DGLVs were the fifth most consumed food (Steyn, Burger, Monyeki, Alberts & Nthangeni 2001).

2.7 Dark green leafy vegetables

A randomized, double-blind, controlled study was carried out by Takyi (1999) to determine whether the consumption of DGLVs by pre-school children would enhance their serum vitamin A concentration to satisfactory levels. Pre-school children aged between two-and-a-half-years and six years of age (n=5 519) in Saboba, northern Ghana, were randomly assigned to five feeding groups. The groups were fed once daily, seven days a week for three months and received varying amounts of fat and beta-carotene. Various measures were determined before and after the study, however, for the sake of this literature review, serum retinol levels are the focus. Comparative to the baseline serum retinol values, intake of DGLVs in combination with fat significantly (p=0.05) enhanced serum retinol. Thus, the percentage of children with adequate retinol status increased by 20% (from 28% to 48%) after feeding (p=0.05). This study concludes that DGLVs cooked with fat has the potential to provide affordable and sustainable means of reducing or controlling the incidence of VAD in the study area.

Faber *et al (*2002) conducted a study in two neighbouring villages in Ndunakazi, KZN, where the impact of home food gardening and nutrition education on the dietary intake of provitamin –A rich yellow vegetables (butternut squash, carrots and orange-fleshed sweet potatoes) and DGLVs (such as *imifino* and Swiss chard) on serum retinol concentrations of children aged two-to-five years was investigated. *Imifino* is a collective term that refers to various dark-green leaves that are eaten as a vegetable, such as pumpkin and beetroot leaves. The serum retinol concentrations and food consumption of two to five year old children were determined at baseline during a cross sectional survey. Twenty months later, a second cross-sectional survey was done. Children from the experimental village had a significantly higher (p=0.005) consumption frequency of yellow and DGLVs and higher serum retinol concentrations (p=0.0078) than those in the control village (p=0.0148). This study confirmed that DGLVs contributed significantly to the average intake of iron (29%), calcium (29%), vitamin A (55%) and riboflavin (16%) in children (Faber *et al* 2002). The study concluded that together with nutrition education, home food gardens that produce yellow and DGLVs, significantly improve the vitamin A status of children between two and five years of age. The bio-efficacy of provitamin-A carotenoids found in plant foods was previously questioned, however this study by Faber *et al* (2002), and various other studies (Haskell, Jamil, Hassan, Peerson, Hossain, Fuchs & Brown 2004; West *et al* 2002; Takyi 1999), have shown that consuming certain cooked DGLVs improves the vitamin A status of individuals.

Faber *et al* (2010) carried out a study in two provinces in SA, Limpopo and KZN, to determine the availability of, access to nutrition-related African leafy vegetables in rural and urban households. The beta-carotene content of the dominant African leafy vegetable was explored, which will be focused on for the sake of this literature review. The study included a qualitative explorative stage where field walks, semi-structured interviews with key informants and focus group discussions at two rural sites were carried out. A quantitative household survey in the form of a questionnaire was carried out at a rural site in Limpopo (n=100); and a rural (n=101) and urban (n=391) site in KZN. Focus group discussions showed that amaranth (*Amaranthus* spp) was the most regularly eaten African leafy vegetable in both provinces. Fried and boiled amaranth leaves contained 627 µg and 429 µg retinol activity equivalents per 100 grams respectively. Based on this, amaranth can potentially contribute significantly to vitamin A requirements of nutritionally vulnerable communities.

However, availability of, access to, nutrition-related African leafy vegetables are context-specific, with inter- and interprovincial rural/urban differences.

Information collected during small studies within a specific area can therefore not be generalised for all different, defined areas. Moreover, the perceptions of the African leafy vegetables by the study participants in the rural KZN study site need to be considered. They generally regarded African leafy vegetables as a poor person's food, and people who ate imifino were generally judged as 'being poor' and 'having no food'. The aspect of affordability should therefore be avoided or used carefully during promotion, as to avoid the perception that African leafy vegetables are food for the poor. The emphasis should rather be on the potential nutritional and hence health benefits the consumption of these vegetables could offer (Faber *et al* 2010).

Considering the importance of consumer acceptance of crops (Chakravarty 2000), Swiss chard appears to play an important role in home food gardens in KZN and necessitates further investigation.

2.8 Swiss chard

A study in two farm primary schools in a rural area in the North-West Province of SA was conducted by Van der Hoeven, Osei, Greeff, Kruger, Faber & Smut (2013). A sensory evaluation investigated the acceptance of, preference for and intended consumption of dishes made with DGLVs with children (n=98) in grades two-to-four. In the entire group which consisted of 98 children and 29 parents responsible for food preparation for children, Swiss chard was rated statistically significantly higher for smell, taste and overall acceptability than any of the dishes made with African leafy vegetables. Faber *et al* (2013) identified that out of 100 households with home food gardens in the Marianhill area in KZN, the third most commonly grown vegetable was Swiss chard (40%), after pumpkin (81%) and chilli (48%). Adekunle (2013) reported that in a rural village in the Nkonkobe Municipality, EC, Swiss chard was one of the most commonly grown vegetables. A study conducted by Selepe and Hendriks (2014) determined that after implementing a garden initiative in an informal settlement in Gauteng, Swiss chard ranked among the top 13 most frequently consumed foods.

2.8.1 Characteristics of Swiss chard

Swiss chard (*Beta vulgaris subsp. vulgaris.)* is an important part of both commercial and subsistence farming in SA (ARC 2013b). Often confused for spinach *(Beta vulgaris var. cicla)*, Swiss chard belongs to the beet family and has thicker leaves than spinach (Starke Ayres 2016; Maboko & Du Plooy 2013). It is able to withstand high soil salinity, making it suitable for soil conditions that limit the growth of many other pH sensitive vegetables (Okluda & Uben 2002; Shannon, Grieve, Lesch & Draper 2000). Even though Swiss chard is a cool weather crop (12°C to 24°C), it is well adapted to hot conditions and extended daylight of the summer months, which makes this crop resilient to weather variability (ARC 2013a; Niederwieser 2001, p140). Swiss chard thrives in a wide variety of soils, such as well-drained sandy, loamy and clay loam soils (Starke Ayres 2016; ARC 2013a). All of these characteristics classify Swiss chard as an 'easy-to-grow' crop, which is an important aspect to consider when planting crops, particularly in poor areas (Chakravarty 2000).

In Africa, Swiss chard leaves and stalks or whole leaf blades are eaten as a vegetable side dish with a staple food after being shredded and boiled or sautéed (Maboko & Du Plooy 2013). It is highly nutritious and contains plant proteins, fibre, iron, calcium, magnesium, sodium, zinc, potassium, phosphorus, copper, vitamin A, vitamin B_1 (thiamine), B_2 (riboflavin) B_3 (niacin) B_6 (pyridoxine), folic acid and vitamin C, all of which are important for good health (Starke Ayres 2016; United States National Library of Medicine 2015; Thomson 2011; Balch 2010 pp7-39;; FAO 2001; Kruger, Sayed, Langenhoven & Holing 1998). The diversity of nutrients provided by cooked Swiss chard and their functions in the body may have an important role to play in alleviating not only highly prevalent nutrient deficiencies such as vitamin A, zinc and iron deficiency, but other less explored deficiencies (Faber *et al* 2011; Smith *et al* 2001; Kruger *et al* 1998).

The importance of growing Swiss chard in home food gardens is clear. However, practices that improve the quality of Swiss chard need to be explored.

2.8.2 Garden treatments (fertiliser applications) and Swiss chard

Smith *et al* (2001), conducted a greenhouse experiment on the effects of organic composts on the total leaf fresh mass of Swiss chard and the common bean. The study entailed applying two different organic composts (garden refuse only and a combination of market and garden refuse) at different turning frequencies (0x and 6x) and different rates (0%, 25%, 50% (m/m)) to a sandy soil with and without low applications of inorganic fertiliser. Swiss chard grown in a combination of market and garden refuse produced the highest total leaf fresh mass. Turning of the compost and increasing the proportion of compost from 25% to 50% significantly increased the yield. However, adding chemical fertiliser had no significant effect on the total yield of Swiss chard. Although beans are not included in this study, it must be noted that the common bean showed a contrasting response as a result of differences in crop nutrient and salinity requirements. This shows that for maximum yields, garden treatments need to be suited to specific crop requirements. Although a combination of market and garden refuse produced the highest total leaf fresh mass of Swiss chard, it must be considered that most Swiss chard production in SA is carried out in open field cultivation and not in controlled environments such as greenhouses (Maboko & Du Plooy 2013). Moreover, the nutritional profile of the Swiss chard in terms of its potential contribution to nutrient deficiencies was not investigated.

Daiss *et al* (2008) determined the effect of different organic pre-harvest treatments on the physical, chemical and nutritional properties of Swiss chard using a randomised block design. The organic treatments evaluated included: effective microorganisms, a mixture of effective microorganisms with fermented organic matter and an auxiliary soil product made up of organic salts, organic acids, plant extracts, polysaccharides, minerals and polyelectrolytes. The Swiss chard was analysed 8 and 19 weeks after sowing. The treatments did not notably modify the physical and chemical quality of the chard when compared with control plants. Swiss chard harvested 19 weeks after sowing showed greater differences in the nutritional profile than chard harvested 8 weeks after sowing. Although certain organic treatments improved the nutritional profile of Swiss chard in terms of phosphorus, calcium and magnesium, these treatments are not affordable to poor community members in peri-urban areas. Therefore, there is a need to explore the effects of locally available and readily accessible garden treatments on the nutritional profile of Swiss chard. In addition, Daiss *et al* (2008) shows that the harvesting time of the Swiss chard may have an important role to play in the nutritional profile. However, home food gardeners growing Swiss chard in poor areas do not harvest Swiss chard according to an agricultural time line. Rather, Swiss chard is most often harvested in communities when it is thought to be mature, which is determined by leaf size. Therefore, there is a need to conduct more studies on the nutritional profile of Swiss chard harvested according to the timeline of a target community.

High concentrations of nitrogen fertilisers have often been applied to Swiss chard to increase its production. Little is known about the optimum levels and influence of different nitrogen sources on Swiss chard under South African conditions. To close this gap in knowledge, Engelbrecht, Ceronio and Motseki (2010) conducted a pot trial in the greenhouses of the Department of Soil, Crop and Climate Sciences at the University of the Free State, Bloemfontein, South Africa. This experiment aimed to determine the integrated effects of nitrogen level and source on the yield and quality of Swiss chard. A randomised complete block design (RCBD) was used for the pot trial. The response of Swiss chard cultivar Fordhook Giant to six nitrogen sources and nine nitrogen levels (0, 100, 200, 300, 400, 500, 600, 700 and 800 kg/ha) were investigated. The six nitrogen sources were ammonium nitrate, calcium nitrate, potassium nitrate, ammonium sulphate, urea ammonium nitrate and urea. A total of fifty-four treatment combinations were applied and each combination was replicated four times. The number of leaves harvested, leaf area, fresh and dry leaf mass, and leaf nitrogen content increased with increasing nitrogen levels up to 800 kg/ha. However, much like the study conducted by Smith *et al* (2001), the nutritional profile of the Swiss chard was not investigated. Additionally, the study was conducted in greenhouses using expensive treatments, making the application of the results to rural communities challenging. This emphasises the need for determining the effects of locally available and readily accessible garden treatments on the nutritional profile of Swiss chard grown in a community setting.

A study by Echer *et al* (2012) in Brazil evaluated the effect of plant spacing and nitrogen fertilization on Swiss chard's yield in a randomized block design using split-plots, with four replications. Each plot was allocated two plant spacing's (30 cm and 50 cm) and the subplots were allocated nitrogen fertiliser (0, 40, 80, 120 and 160 kg/ha). After harvesting the crop after 90 days, it was found that the 50cm plant spacing provided increased production of total fresh weight of shoot and marketable weight. However, the highest total yield and marketable yield was achieved with a 30 cm spacing. The nitrogen rates increased the total and marketable production of fresh mass of shoots, the total and marketable yield, the nitrogen content and accumulation in the shoots of Swiss chard on the evaluated plant spacing's. Similar to the study conducted by Engelbrecht *et al* (2010), this study concludes the importance of nitrogen fertiliser on improving the yield of Swiss chard; however, it highlights the importance of the spacing of the plants.

The effects of various garden treatments, plant spacing and harvesting time on different aspects of Swiss chard such as yield, quality and nutritional profile have been explored (Engelbrecht *et al* 2010; Daiss *et al* 2008; Smith *et al* 2001). However, these studies have predominantly been conducted in controlled environments such as greenhouses, neglecting the fact that most Swiss chard production in SA is carried out in open fields and not in controlled environments (Maboko & Du Plooy 2013). In addition, the garden treatments used in these studies are not readily available or accessible to the rural and peri-urban poor. These factors make it difficult to implement the results of these studies in poor communities. Therefore, to close these gaps in knowledge, the effect that readily available and accessible garden treatments have on Swiss chard, cultivated, maintained and harvested within the target community, according to their practices, need to be investigated. However, before investigating this, the constraints that food gardeners experience in a South African context need to be explored. By identifying these constraints, strategies can be put in place to overcome them, improving the chances of food garden success.

2.8.3 Food garden constraints

Faber and Laurie (2011, p176), described limitations experienced in garden projects in three different places in SA. The main limitation was limited irrigation water, followed by (in no particular order) limited: fencing, finances, fertiliser, seeds, pesticides and garden tools.

Against the backdrop of climate change, many regions are experiencing higher temperatures and changes in precipitation patterns, which necessitate an adaption in crop management systems (Matthews *et al* 2013). A common, readily available and accessible method to address this challenge is mulching, which entails covering the soil around plants with protective material, preventing soil-water evaporation, increasing soil moisture retention and decreasing the need for irrigation (Maughan & Drost 2016; Relf, McDaniel & Freeborn 2015; Africa Development Promise 2014; Galhena *et al* 2013; Matthews *et al* 2013; McMillen 2013). A financially feasible and sustainable practice which is carried out in resource poor community's is organic mulch production using agricultural by-products such as wheat, straw, grass and leaves (McMillen 2013).

Limited resources such as fertilisers prevents food gardens from fulfilling their potential role in achieving HHFS (Galhena *et al* 2013; Faber & Laurie 2011, p176; Aliber & Hart 2010; Sikhakhane 2007). To achieve optimum crop growth and quality of crops in home food gardens, it is essential to fertilise the soil. When fertilisers are added to soil, they have the ability to affect the amount of micronutrients available to plants by changing the chemical, physical and biological characteristics of the soil (Miller & Welch 2013; Welch & Graham 2005; Place, Barrett, Ade Freeman, Ramisch & Vanlauwe 2003; FAO 2000). Vegetables grown in fertile soils are known to contain more nutrients than vegetables grown in soils that are stressed (Gibson 2011; Shetty 2011; Welch 2001). Large-scale farmers in SA purchase chemical fertilisers to ensure optimum crop growth, however, in rural and peri-urban areas, chemical fertilisers are rarely used due to financial constraints and limited transport (van Averbeke & Yoganathan 2003). Nonetheless, readily available and accessible alternatives to expensive chemical fertilisers, such as manure fertilisers, are available and were practised by farmers worldwide prior to the production of chemical fertiliser (Galhena *et al* 2013; van Averbeke & Yoganathan 2003; Marsh 1998).

Hendriks, Viljoen, Marais, Wenhold, McIntyre, Ngidi, van der Merwe, Annandale, Kalaba and Stewart (2016) investigated the consumption and production patterns of rural households in four of the poorest areas in the EC, KZN, Limpopo and North West Province. The study sites were randomly selected from a list of census enumeration areas and included two sites from Ingquza Hill, Maruleng and Ratlou municipalities and one site from Jozini. Qualitative and quantitative data were collected between October 2013 and November 2015 using key informant interviews and a two-round panel survey. Home food gardeners communicated that agricultural inputs and extension services were inaccessible and/or unsuitable to them. In several communities, subsistence farmers spoke about the inappropriateness of adapting commercial crop inputs to local conditions. Farmers reported that they felt obligated to implement these crop inputs and had high levels of crop failure.

The socio-cultural customs of communities, which often determines the participation of individuals (particularly women) in home food gardens may also be a constraint (Mitchell & Hanstad 2004). Aliber and Hart (2010) reported that women form the bulk (61%) of the approximate 3 million small-scale farmers in SA who produce food solely for household consumption, as it is considered a culturally accepted activity for women. In light of this, constraints of home food gardens related to gender disparities such as access to, and control over, land, finances, markets and time, need to be addressed (Mitchell & Hanstad 2004). Furthermore, some communities associate food gardens with poverty, having tuberculosis (TB), Human Immunodeficiency Virus (HIV) and Acquired Immune Deficiency Syndrome (AIDS). This stigma attached to home food gardening may prevent individuals from participating in home food gardens (Sikhakhane 2007). Furthermore, the under-developed market in rural areas makes it difficult for gardeners to sell their surplus, limiting their ability to re-invest in new inputs to sustain production levels (FAO 2015b; Low, Arimond, Osman, Cunguara, Zano & Tschirley 2007; The Footprints Network 2005).

Lastly, Chinsamy and Koitsiwe (2016) conducted out a case study in the Lekgophung village in the North West Province, SA. The study explored the sustainability of indigenous knowledge-based vegetable garden projects in this village. In agreement with some of the findings of Hendriks *et al* (2016) and Faber and Laurie (2011, p176) the study found that the sustainability of the food gardening projects were hindered by a lack of: garden management, youth participation, financial accountability, sustainable support from government and other developmental agencies and garden tool and produce theft.

2.9 Conclusion

The high prevalence of malnutrition and food insecurity in SA is a national health concern (Bouis *et al* 2011; Labadarios *et al* 2011a; Labadarios *et al* 2008; Labadarios *et al* 2005). With the increase in the number of people at risk of hunger, classifying SA as having a 'moderate' severity of hunger, multidisciplinary interventions need to be put in place (HSRC 2013). Nutrition interventions, such as nutrient supplementation, food fortification, dietary diversification and modification and biofortification have been effective in reducing certain nutrient deficiencies and HHFI (Shetty 2011). However, their effectiveness has often been restricted by resource constraints. In the context of escalating food prices and the global economic recession, home food gardens are considered a potential contributor to food security and improved nutritional status of the rural poor in SA (Maboko & Du Plooy 2013; Faber *et al* 2011; Labadarios *et al* 2005).

DGLVs, particularly Swiss chard, is commonly consumed throughout SA (Adekunle 2013; Faber *et* al 2013; HSRC 2013; Labadarios *et al* 2008; Labadarios *et al* 2005; Steyn *et al* 2001) and therefore the potential contribution that it can make towards food security and improved nutrient status needs to be explored. Currently, much research has focused on the effects of various financially unavailable and inaccessible (to the rural poor) garden treatments on Swiss chard grown in controlled environments and maintained and harvested according to agricultural guidelines (Engelbrecht *et al* 2010; Daiss *et al* 2008; Smith *et al* 2001). Considering that most Swiss chard production in SA is done in open fields (Maboko & Du Plooy 2013), and rural individuals have very limited or no access to agricultural guidelines, the effect that readily available and accessible garden treatments have on Swiss chard, cultivated, maintained and harvested within the target community, according to their practices, need to be investigated.

This study attempted to close this gap in knowledge by growing Swiss chard in a local home food garden in a poor peri-urban community in KZN. The next chapter will describe the methods used to conduct the study.

CHAPTER THREE
METHODS

3.1 Introduction

This chapter provides the framework of the research methods that were followed to achieve the study objectives. First, the study site will be described in terms of its food security status, the subsidising Environmental Non-Governmental Organisation (ENGO) and the existing home food garden. Thereafter two block designs will be defined and the study design chosen will be applied to the experimental garden. Subsequently, the soil profile of the experimental garden and its implications regarding the research methods will be explored. The methods and materials of the experimental soil treatments, and the planting, maintenance and harvesting of crops will be outlined. Following this, the methods and materials used to determine the nutritional profile and leaf number of the produce will be described. Thereafter, the variables included in the study, data capturing and statistical analysis will be discussed. Lastly, data quality control and ethical considerations will be presented.

3.2 Study site

Pietermaritzburg (PMB), the capital city of KZN is governed by the uMgungundlovu District Municipality in which the local Municipality, Msunduzi is located (Caesar *et al* 2013). Msunduzi is one the seven local municipalities that fall under the uMgungundlovu district, and has the fourth highest prevalence of malnutrition in KZN (Caesar *et al* 2013). Much like the rest of SA, PMB has experienced increased poverty and unemployment rates, resulting in the unequal development in townships and rural settlements (National Treasury: Msunduzi Municipality 2012). It has been reported by Thurlow, George and Gow (2009), that the already higher than average national unemployment and poverty rates in KZN, are rising more rapidly than any other province in the country. This has resulted in many households within the Msunduzi municipality living below the poverty line, with high rates of poverty, unemployment and crime in densely populated formal and informal settlements (Msunduzi Municipality 2012; Statistics South Africa 2011).

3.2.1 Food security status of the Msunduzi district

To gain insight into the food security status of major cities in SA, the African Food Security Urban Network (AFSUN) conducted a baseline food insecurity survey using systematic sampling on 556 households, in 11 cities, of nine countries across southern Africa in 2008 and 2009 (Frayne *et al* 2014b; Caesar *et al* 2013). The large sample and area size was representative of a variety of lower income areas ranging from informal settlements to peri-urban areas (Crush & Caesar 2014). HHFS was measured using the Household Food Insecurity Access Scale (HFIAS), Household Food Insecurity Access Prevalence Indicator (HFIAP), Household Dietary Diversity Scale (HDDS) and Months of Adequate Household Food Provision Indicator (MAHFP) (Caesar *et al* 2013).

With an average HFIAS score of 11.3, Msunduzi recorded high overall levels of food insecurity in relation to other cities such as Cape Town (10.7) and Johannesburg (5.7). According to the HFIAP indicator, up to 60% and 27% of households in Msunduzi were severely and moderately food insecure, respectively, with only 7% considered entirely food secure (Caesar *et al* 2013). The dietary quality element of food insecurity was reported by the HDDS, which showed that more than half (53%) of the surveyed households ate five or fewer of the 12 major African food groups, indicative of poor dietary diversity (Caesar *et al* 2013). A statistically significant ($p< 0.001$) relationship was found between food security and dietary diversity: as dietary diversity decreased, so food insecurity increased (Caesar *et al* 2013). Annual household food supply was assessed by the MAHFP indicator, which reported that almost 70% of the households in Msunduzi lacked year round food security. Overall, 87% of the surveyed households in Msunduzi were severely or moderately food insecure. Thus, it can be concluded from the various measures, that Msunduzi has high overall levels of house hold food insecurity (HHFI) (Caesar *et al* 2013).

In light of the poor food security status of the Msunduzi municipality, Wildlands Conservation Trust (WCT), a local ENGO, launched a green economy initiative targeting the area (WCT 2012).

3.2.2 Wildlands Conservation Trust (WCT)

WCT was established in 2005 and is based in Hilton, KZN. This registered ENGO developed a green economy initiative to create 'a sustainable future for all' (WCT 2016). Their projects are developed around the Community Ecosystems Based Adaption (CEBA) model, which focuses on the dependent relationship between human well-being and environmental health. The CEBA projects allow community members to be a part of the green economy and overall environmental sustainability through "green-preneurship", a form of green job creation (WCT 2016; WCT 2012). Green economy initiatives empower women, economically and socially through poverty alleviation, and contribute towards urban food security and sustainability (Hlahla *et al* 2016).

Green-preneurship includes a triad of 'waste-preneurship', 'tree-preneurship' and, 'food-preneurship' (WCT 2012). Waste-preneurs are required to collect recyclable waste from their surrounding communities and tree-preneurs are taught how to identify and grow indigenous trees. Waste- and tree-preneurs are paid in vouchers by WCT according to the weight of waste collected and the height of the trees grown, respectively. These vouchers can be redeemed at WCT's 'Green Future Stores', which sell food and other necessities (Hlatswayo 2016; WCT 2011a). Waste- and tree-preneurs who excel in their work are promoted to 'food-preneurs' hip (WCT 2011b).

'Food-preneurship' allows a member to grow vegetables for household use and generate extra income. They receive a 'starter-pack', which includes 30 metres of chicken mesh, a 10 litre watering can and various vegetable seedlings that are sponsored by Sunshine Seedling Services (Hlatswayo 2016; WCT 2011b). They attend training courses where their knowledge of sustainable crop production and nutrition are assessed and built upon. These training courses are necessary for agriculture to make a significant impact on improving food security as shown by the studies conducted by Schreinemachers *et al* (2015), Carney *et al* (2012), HKI (2010), Faber *et al* (2007) and Faber *et al* (2002). Topics included in the nutrition education are food safety and hygiene and the food based dietary guidelines (Hlatswayo 2016). 'Food-preneurs' are trained regarding the advantages of permaculture, which has been defined as the process of caring for an environment that in turn will care for its inhabitants (WCT training material 2016). Permaculture encourages rural and peri-urban community members to obtain valuable resources from the environment for the upkeep of their gardens (Mollison 1979).

3.2.3 Existing home food garden

The study site was an existing home food garden situated in kwaMnyandu, a peri-urban area in Msunduzi, KZN (Figure 3.1). The existing home food garden at the study site was established by five widows who excelled in the WCT 'tree-preneurship' initiative and were promoted to 'food-preneurship'.

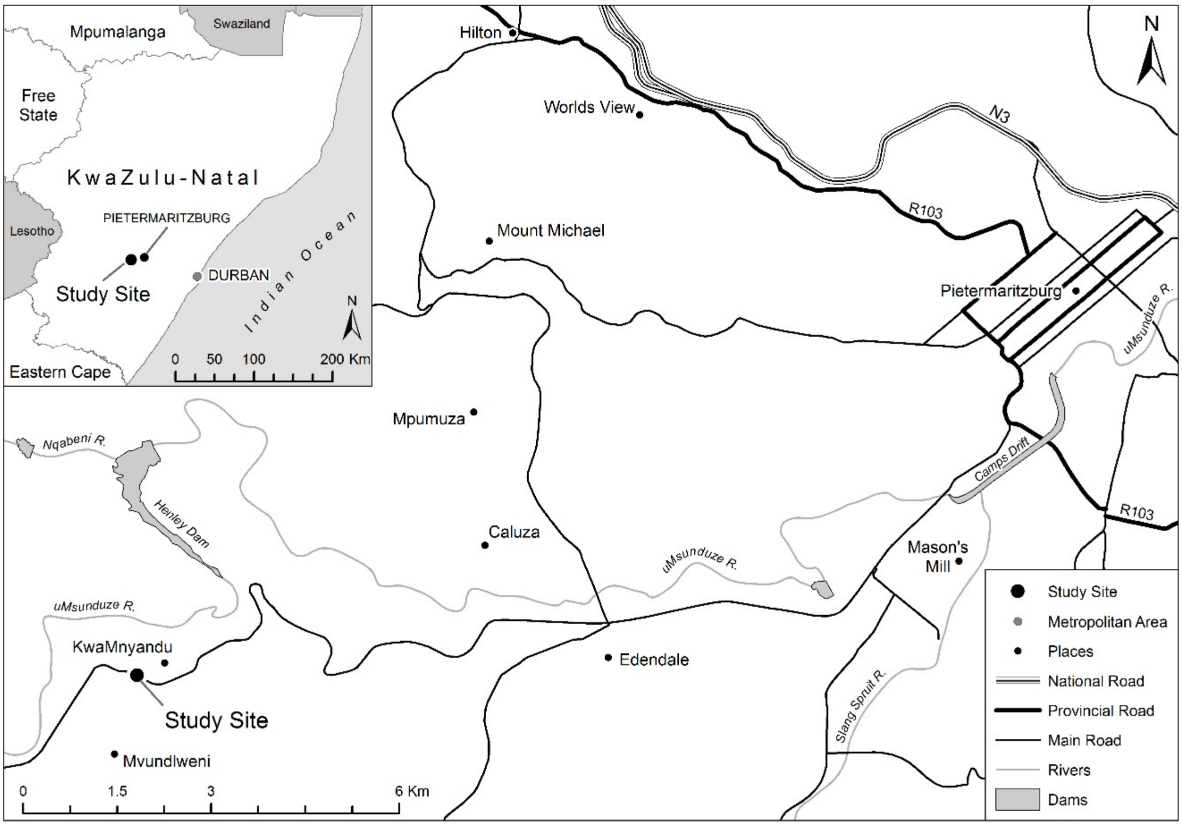

Figure 3.1 Map of study site in kwaMnyandu, KZN

The training courses carried out by WCT equipped these female 'food-preneurs', both theoretically and practically, to implement and sustain a home food garden using a combination of resources that were readily available and accessible to them and resources provided by WCT (Hlatswayo 2016).

The readily available and accessible resources at the existing home food garden included: access to clean running water through an outside tap, abundant fenced off land, kraal manure fertiliser and grass mulch. The resources provided by WCT included vegetable seedlings, garden tools, agricultural and nutritional training, and frequent visits by an agricultural field worker trained in permaculture. It was anticipated that the constraints experienced by home food gardeners in SA would be prevented through the combination of these readily available and provided resources. Access to clean and running tap water enabled the female 'food-preneurs' to irrigate garden crops as required, unlike other gardeners in SA where a lack of irrigation water is common, and prevents the success of food gardens (Faber & Laurie 2011, p176). The plot of land on which the existing garden was situated was free of livestock and domestic animals, and enclosed by a large fence with a lockable gate, protecting the produce against theft and damage through foot and livestock traffic.

Moreover, poor purchasing power renders many underprivileged gardeners unable to procure fertilisers, pesticides, seeds and/or seedlings and garden tools for the sustainment and maintenance of their food gardens (Faber & Laurie 2011, p176). Through the provision of seedlings and garden tools by WCT, the female 'food-preneurs' were able to plant, grow, maintain and harvest a variety of vegetables continually. With direct access to unrestricted amounts of kraal manure fertiliser from a local cattle farmer, and grass mulch from the surrounding land, the female 'food-preneurs' were able to fertilise and mulch their soil to ensure optimum growing conditions for vegetables, free of charge. Companion planting was used as a form of permaculture-based pest repellent, learnt by the female 'food-preneurs' through the WCT permaculture training. Companion planting is generally a small-scale agricultural gardening technique whereby two different plants are planted together to hide, repel or trap pests, thereby protecting other vegetable plants (ARC 2013a; McClure, Roth, Ondra, Hager, Fox, Ross & Fretz 1999). The female 'food-preneurs' planted onions in and around their vegetable to mask the scent of other vegetables, thus deterring pests.

Furthermore, the regular visits of the agricultural fieldworker, employed by WCT, gave the female 'food-preneurs' access to suitable agricultural inputs, unlike the constraints reported by Hendriks *et al* (2016). Food gardening constraints related to gender disparities, such as access to and control over land, finances, markets and time (Mitchell & Hanstad 2004), were not applicable to this home food garden as the homestead consisted of women only. The under-developed markets in rural areas described by a number of authors (FAO 2015b; Low *et al* 2007; The Footprints Network 2005) did not affect the female ‘food-preneurs’ as unsold produce surplus was collected by the agricultural field worker and sold on behalf of the female ‘food-preneurs’.

Through the elimination of various commonly encountered problems experienced by South African food gardeners, the experimental garden had a high probability of being successful.

3.3 Study design

Two experimental designs commonly used in agricultural field studies were explored as potential study designs for this study, the completely randomised design (CRD) and the randomised complete block design (RCBD) (Krebs 2013, p432).

3.3.1 Introduction to the experimental designs

The CRD involves strict randomization of treatments, whereas the RCBD involves grouping similar experimental units into blocks or replicates and has often been described as the gold standard design for agricultural experiments (Web Centre for Social Research Methods 2016; Krebs 2013, p432; Grant 2010; Dallal 2005). The RCBD has shown to be more accurate and efficient than the CRD study design, as more information can be inferred from it (Rangaswamy 1995, p281). It is not limited to a certain number of treatments or replicates, and allows for missing plots to be easily estimated (Grant 2010; Rangaswamy 1995, p281). On the other hand, RCBDs may not be as effective as CRDs, if there are too few treatments, the error degrees of freedom is smaller compared to the CRD (Grant 2010). However, a large error term may result if there are large variations between experimental units, and if there are too many treatments in blocks that are very large, it may be difficult to maintain homogeneity within blocks, increasing the experimental error (Grant 2010; Rangaswamy 1995, p282).

When using the CRD, treatments are assigned randomly to an entire plot, so that each treatment unit has the same chance of receiving any one treatment. However, the RCBD involves grouping experimental material into homogenous sub-groups or 'blocks' consisting of a set of treatments (Figure 3.2) (Grant 2010).

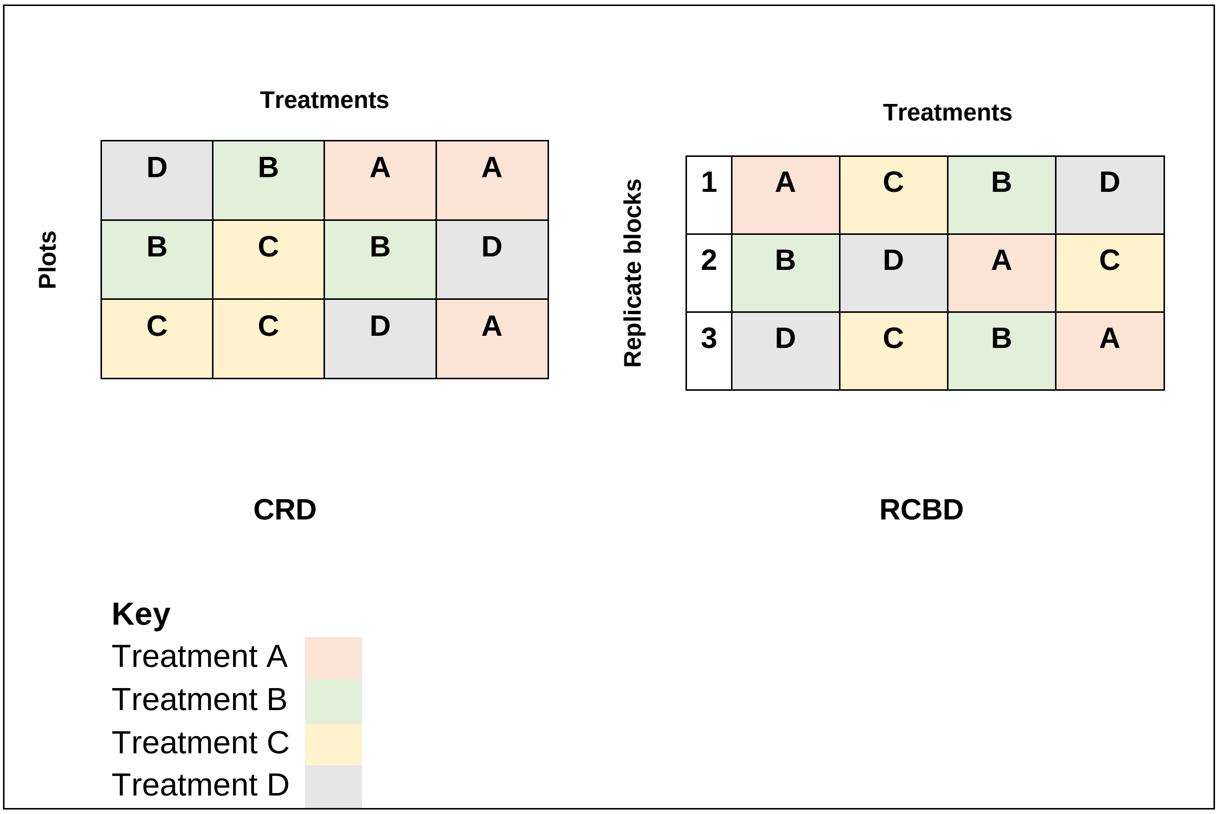

Figure 3.2 A CRD verses a RCBD using four treatments (Adapted from Grant 2010; Dallal 2000).

3.3.2 The randomised complete block design

This study was a two factor study where the fixed factors (treatments) were crossed with the random factors (the blocks) (Dallal 2005) (Table 3.1). The vegetable species studied was Fordhook Giant Swiss chard (*Beta vulgaris var. cicla*), to which fertiliser and mulch treatments were applied. The fertiliser treatment factor had three components:

- No fertiliser (control)
- Organic fertiliser (kraal manure)
- Inorganic fertiliser (2:3:4(38))

Similarly, the mulch treatment factor had three components:

- No mulch (control)

- Organic mulch (grass)
- Inorganic mulch (plastic)

The combination of the two factors resulted in a three-by-three factorial experiment with nine treatments (Table 3.1) arranged in a RCBD, with three replication blocks.

Table 3.1 Experimental treatment combinations and control

		Factor 1: Fertiliser		
		Inorganic fertiliser	Organic fertiliser	No fertiliser
Factor 2: Mulch	Inorganic mulch	Inorganic fertiliser and inorganic mulch	Organic fertiliser and inorganic mulch	No fertiliser and inorganic mulch
	Organic Mulch	Inorganic fertiliser and organic mulch	Organic fertiliser and organic mulch	No fertiliser and organic mulch
	No mulch	Inorganic fertiliser and no mulch	Organic fertiliser and no mulch	No fertiliser and no mulch

Key	
	Treatment A
	Treatment B
	Treatment C
	Treatment D
	Treatment E
	Treatment F
	Treatment G
	Treatment H
	Treatment I (control)

The different treatments were assigned randomly within the three replicate plots using Microsoft Excel (Appendix A, p105) (Grant 2010). Variation within the experiment was controlled by taking the soil profile differences within each replicate plot into account (Table 3.2), therefore, the effects of the treatments applied to each block were more accurate as they were measured within each block (RCBD) as opposed to measuring the effects of the treatments across the entire plot (CRD) (Web Centre for Social Research Methods 2016; Grant 2010).

The three replicates protected the study from chance events that could have interfered with observations (such as weather variability) and allowed the accurate assessment of statistical significance through ‘experimental error’ (Krebs 2013, p431; Dallal 2005; Grant 2010). In this experiment, the treatments were replicated independently in blocks, thereby avoiding pseudo replication (Knezevic 2009). In addition, the units of analysis (the garden treatments) and the units of replication (the garden plots) were clearly defined to ensure that replicates were independent to avoid pseudo replication (Knezevic 2009). Pseudo replication refers to “the use of inferential statistics to test for treatment effects with data from experiments where either treatment is not replicated (though samples maybe) or replicates are not statistically independent” (Hurlbert 1984, p187). The most common type of pseudo replication occurs when there is a single replicate per treatment; however this was not applicable to this study due to three replicates of each treatment (Krebs 2013, p436). Sacrificial pseudo replication was avoided by ensuring that data for replicates were not grouped together before statistical analyses (Krebs 2013, p436). By randomizing treatment combinations within the replicate blocks, independent observations were ensured and bias was avoided (Krebs 2013, p430).

3.3.3 Experimental garden layout

The experimental garden was situated in an area of the existing home food garden allocated to the research by the female ‘food-preneurs’. Although the female ‘food-preneurs’ did not practice the same layout in their existing garden, a strict experimental garden blueprint had to be followed according to the study design for the study to be scientifically sound. The experimental garden measured 7 metres (m) long and 5 m wide. Using a Roto-Sure measuring wheel, this area was divided into three uniform plots separated by 0.5 m walkways. The walkways aimed to protect the crops from foot traffic damage during irrigation, weeding and harvesting. They also allowed for the treatment blocks to be measured. Each of the three plots were divided into nine treatment blocks measuring 60 x 100 cm using a tape measure, which were separated by 20 cm gaps, to prevent the treatments from mixing. Each treatment block contained an allocated treatment (represented by alphabetical letters) (Figure 3.2).

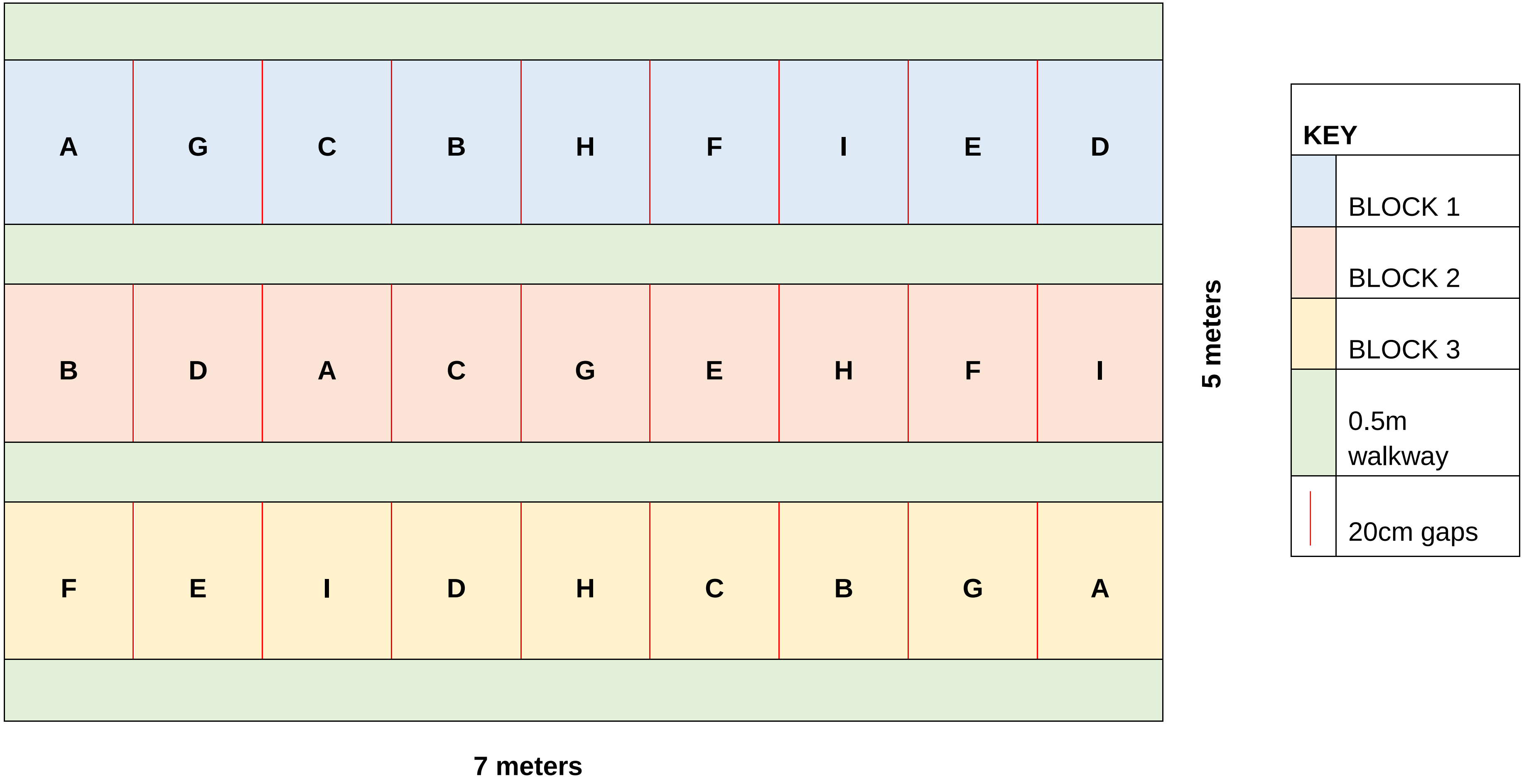

Figure 3.3 Study garden layout

3.4 Study site soil profile and planting plan

Considering the importance of home food gardens growing vegetables (as outlined in Chapter Two), a needs assessment in the form of key informant interviews in terms of what vegetable crops the female ‘food-preneurs’ wanted to grow, was carried out. It was unanimous (n=5) that they needed and wanted to grow chillies, Swiss chard, and carrots. The female ‘food-preneurs’ specified that they used chillies in small amounts in a tomato relish, commonly eaten with a traditional maize meal staple dish called ‘pap’. Although chillies are high in vitamin A and C, calcium and iron, the contribution that chillies make to the nutrient intake and food security status of the female ‘food-preneurs’ was questionable due to the small amounts they are eaten in. At the study site, Swiss chard and carrots are both boiled and eaten as a vegetable side dish with added fat such as margarine or oil, or they are added to stews and curries. With a prime focus on the nutritional value, marketability, growth potential and cultural acceptability of the produce, the study intended to grow carrots (*Duacus carota L*.) and Swiss chard (*Beta vulgaris var. cicla*), and excluded chillies (*Capsicum annuum L.*).

Soil sampling is a rare practice in poor areas due to financial constraints; therefore, prior to this study soil sampling had not been undertaken. However, to ensure that the soil conditions at the study site were able to support the growth of Swiss chard and carrots for the success of the study, soil sampling prior to planting was essential (Simmons 2014; Fery & Murphy 2013; Peters & Laboski 2013; Clewer & Scarisbrick 2001, p5).

3.4.1 Soil sampling

Soil samples need to be representative of the study site, as unrepresentative samples may result in misleading recommendations for improved soil output (Alberta Agriculture and Forestry 2016; Muchaonyerwa 2016; Simmons 2014; Fery & Murphy 2013; Peters & Laboski 2013; Clewer & Scarisbrick 2001, p5). It was suggested by Muchaonyerwa (2016) and Fery and Murphy (2013) that a minimum of 15 to 20 random soil cores within a study site should be taken. Clewer and Scarisbrick (2001, p5) suggest that soil cores should be taken in a "W" shape with six to 10 soil cores being taken on each arm of the "W" (between 24 and 40 cores), for a more representative sample.

In this study the 'W' soil sampling method was used, taking four cores from each arm of the 'W' (16 cores) in each replicate plot (plot 1, 2 and 3). For a sample from each plot to be truly representative, the samples were collected at a depth of 15 cm by a soil scientist, using a bucket hand-auger (Fery & Murphy 2013; Clewer & Scarisbrick 2001, p5). The samples were mixed thoroughly in three separate containers labelled plot 1, 2 and 3 and a smaller sample (500g) free of mulch and grass, was extracted from each bucket and placed into clean plastic bags marked with labels indicating the plot number, date and depth of soil sampling (Muchaonyerwa 2016; Simmons 2014; Fery & Murphy 2013). Samples were air-dried in soil trays and sieved through a 2 mm sieve.

Thereafter the samples were packaged, labelled and taken to Cedara Agricultural College for soil fertility testing. Recommendations were made on how to achieve optimum soil conditions to support the growth of Swiss chard and carrots (Simmons 2014; Fery & Murphy 2013).

Figure 3.4 The "W" soil sampling method (Adapted from Agriculture Victoria 2011).

* Where **X** represents where the soil cores were taken.

3.4.2 Soil analysis

At Cedara Agricultural College, soil samples were spread out in drying trays, and room temperature air was forced over them, drying the soil. Once the soil was dry, it was crushed in the middle of rubber belts on a soil crusher, and delivered through a 1 millimetre (mm) filter. Material coarser than 1 mm, which could not pass through the filter, such as stones, were rejected (Manson & Roberts 2011). When the soil was ready for analysis, samples were placed into trays which each held 11 polyvinyl chloride (PVC) cups (70 millilitres (ml)). Nine of these cups were filled with unknown samples of soil, one cup was filled with a standard soil sample for quality control, and the other cup was blank. To determine soil density a 10 ml scoop of dried and milled soil was used, and the density was measured (Manson & Roberts 2011).

Phosphorus, potassium, zinc and manganese were determined using the Ambic-2 extracting solution, which consisted of 0.25 M NH_4CO_3, 0.01 M Na_2EDTA, 0.01 M NH_4F and 0.05 g L^{-1} Superfloc (N100), adjusted to a pH of 8 with a concentrated ammonia solution. The Ambic-2 solution (25 ml) was added to 2.5 ml of soil and stirred for 10 minutes using a multiple stirrer. Thereafter the extracts were filtered using Whatman number one paper. A 2 ml fraction of filtrate was used to determine phosphorus, using a variation of the Murphy and Riley (1962) molybdenum blue procedure (Hunter 1975). Potassium was determined by atomic absorption on a 5 ml fraction of the filtrate after diluting it with 20 ml de-ionised water. The remaining diluted filtrate was used to determine zinc and magnesium (Manson & Roberts 2011).

The soil calcium, magnesium and exchangeable acidity were determined by scooping 2.5ml of soil into sample cups, and adding 25ml of 1 M KCl solution. The suspension was stirred at 400 revolutions per minute for 10 minutes with a multiple stirrer. The extracts were filtered using Whatman number one paper. Thereafter 5ml of the filtrate was diluted with 20ml of 0.0358 M $SrCl_2$, and calcium and magnesium were determined by atomic absorption. The acidity was determined by diluting 10ml of the filtrate with 10ml of de-ionised water containing 2-4 drops of phenolphthalein, and titrating with 0.005 M NaOH (Manson & Roberts 2011).

Soil pH was determined by scooping 10ml of soil into sample cups and adding 25ml of 1 M KCl. The suspension was stirred at 400 revolutions per minute for five minutes using a multiple stirrer and allowed to stand for 30 minutes. The pH was then measured using a gel-filled combination glass electrode while stirring (Manson & Roberts 2011). The clay content of the soil was measured using mid-infrared reflectance (Manson & Roberts 2011).

The Automated Dumas dry combustion method using a LECO TruSpec CN analyser was used to determine total carbon and nitrogen levels. This entailed placing between 0.3 and 0.5 g of soil into a tin foil cup into a vertical furnace. A stream of oxygen burnt the samples at 950 ^{O}C (degrees Celsius) and the resultant gases were passed through an infrared cell to determine carbon (as carbon dioxide (CO_2). The gases were subsequently swept through a thermal conductivity cell where nitrogen was determined (as N_2). Organic carbon was determined using the Walkley-Black method which is based on the procedure by Allison (1965), and measures the readily oxidisable organic carbon. The organic matter was oxidised by potassium dichromate in a sulphuric medium and the excess dichromate was determined by titrating with standard ferrous sulphate solution.

3.4.3 Soil results and implications

The soil analysis results formed a vital part of determining the final methods for the study and are therefore reported as part of methods rather than results.

The analytical soil fertility results and Mid-Infrared Estimates (Table 3.2) showed large variation in the soil composition of each replicate plot (plot 1, 2 and 3) in terms of pH, phosphorus, potassium and calcium. All three replicate plots contained more than 50% clay, which would hinder the growth of carrots, which need deep, well-drained and loose sandy loam soil to grow (Starke Ayres 2016; ARC 2013b; Allemann & Young 2008). Faber *et al* (2011) mentioned the importance of encouraging own production when considering crop choice. The gardeners at the study site may have become despondent and less motivated to grow their own carrots if the carrots in the experimental home food garden did not grow optimally. Due to the high clay content of the soil (54%-55%), and the potentially poor response rate to growing carrots that would have resulted, carrots were excluded from this study and Swiss chard alone was planted in the experimental home food garden.

Table 3.2 Summary of analytical soil fertility results and Mid-Infrared Estimates

Variable	**Unit**	**Plot 1**	**Plot 2**	**Plot 3**
Density	g/ml	0.72	0.74	0.73
Phosphorus	mg/l	10	4	4
Potassium	mg/l	98	64	69
Calcium	mg/l	502	665	688
Magnesium	mg/l	217	221	208
Zinc	mg/l	2.1	2.1	1.8
Manganese	mg/l	10	9	8
Exchangeable Acidity	cmol/l	0.91	0.82	0.61
pH	(KCl)	4.08	4.24	4.28
Mid-Infrared Estimates				
Organic Carbon	%	5.8	6	5.9
Nitrogen	%	0.38	0.35	0.38
Clay	%	54	55	54

3.5 Soil treatment methods and materials

This study used a combination of experimental treatments: previously practised, readily available and accessible treatments and new, financially unavailable and inaccessible treatments. This combination was in-line with what was carried out at the existing home food garden in terms of their garden maintenance. The female ‘food-preneurs’ utilised both readily available and accessible resources to maintain their food garden, provided to them by their surrounding environment and financially unavailable resources provided to them by WCT. By including the financially unavailable and inaccessible experimental treatments in the study, it equipped WCT with the knowledge on their effect/s on the growth rate, nutritional profile and leaf characteristics of Swiss chard. This knowledge may be used in future ‘food-preneurship’ initiatives and adapted to current initiatives. The previously practised, readily available and accessible experimental treatments included kraal manure fertiliser and grass mulching. The new, financially unavailable and inaccessible experimental treatments included chemical fertiliser and plastic mulch.

3.5.1 Dolomitic lime

KZN has been described to have naturally acidic soils, which increases the risk of aluminium and manganese toxicity, and renders numerous nutritional soil elements unavailable to plants, making the application of fertiliser treatments potentially ineffective (van Averbeke & Yoganathan 2003). Soils that take on this profile necessitate lime application for optimum growth and yield of plants.

Although soil lime application is not a financially feasible practice in poor areas (such as the study site), for the sake of the scientific soundness of this study it was essential to apply lime to the soil to ensure pH homogeneity throughout each plot. By doing so, changes in the dependent variables could not be attributed to pH variations in the soil. The analytical soil fertility results and Mid-Infrared Estimates (Table 3.2) were translated into soil lime recommendations specific to Swiss chard for each replicate plot (plot 1, 2 and 3) by Cedara Agricultural College. The lime required at the study site was to correct the acidity (pH) of the soil at the study site to suit Swiss chard (pH 6-7) was dolomitic lime at a rates of 3.0 kg/ha, 2.5 kg/ha and 1.5kg/ha to plot 1, 2 and 3 respectively.

The lime was weighed on a calibrated digital scale and placed into clear plastic bags labelled with the weight of the lime and the plot number, prior to applying it to the soil at the study site. This was done for accuracy purposes, as adding too much lime to the soil would render the soil too alkaline and nutrients such as iron, manganese, zinc and phosphorus inaccessible to Swiss chard (DOA 2000). Gromor Dolomitic lime was applied to each of the three replicate plots at the required rates, six weeks prior to planting the Swiss chard seedlings (Starke Ayres 2016; ARC 2013a). The lime was thoroughly incorporated into the soil at a depth of 20cm by ploughing (DOA 2000).

3.5.2 Kraal manure fertiliser

Kraal manure is readily available and accessible in many rural and peri-urban areas where animal husbandry is practised (van Averbeke & Yoganathan 2003). A kraal is described as "an enclosure in which livestock are kept during the night, providing protection against theft and wild animals" (van Averbeke & Yoganathan 2003, p2). A layer of organic manure consisting of animal dung and urine accumulates on the floor of the kraal, this layer is removed and used as organic fertiliser. Using kraal manure as an organic fertiliser was practised by many farmers prior to the production of chemical fertilisers. It remains one of the most abundantly used organic fertilisers in areas where chemical fertilisers are not physically or financially accessible (Place *et al* 2003; van Averbeke & Yoganathan 2003). Kraal manure significantly improves the soil structure and the ratio of large pore spaces to small pore paces so that there is a gaseous exchange between the soil and the atmosphere and this helps improve the soil water holding capacity (van Averbeke 1997). Kraal manure contains adequate nutrients for plant growth including nitrogen, phosphorus and potassium, however they may not exist in the correct proportions (van Averbeke & Yoganathan 2003; van Averbeke 1997). For this reason, a 500g composite sample of the kraal manure used at the existing home food garden was randomly taken and sent for analysis at Cedara Agricultural College, KZN. Although analysing kraal manure is not commonly practised in poor areas, it was essential for the sake of the study to determine the appropriate application rates of kraal manure for each plot, specific to the requirements of Swiss chard.

The manure samples were handled as described in the soil analyses techniques previously. The manure sample was dried at 75°C, and milled to pass through a 0.84 mm sieve. Subsamples were dry ashed at 450°C overnight and taken up in 1 M HCl. The phosphorus concentration of the manure was determine calorimetrically by the same method used for soil samples, and potassium, sodium, calcium, magnesium, copper, manganese and zinc were determined through atomic absorption. The nitrogen concentration of the manure was determined by the Automated Dumas dry combustion method using a LECO CNS 2000. This involved placing the manure into a ceramic crucible to which 0.5g of vanadium pentoxide was added as a combustion catalyst. The crucible was placed into a horizontal furnace, where a stream of oxygen burnt it at 1 350°C. The nitrogen gas produced was passed through a thermal conductivity cell and the concentration was reported as N_2.

The analytical results of kraal manure (Table 3.4), form an integral part of determining the final methods for kraal manure application and are therefore reported as part of study methods, rather than results. According to the analytical results of kraal manure (Table 3.3), the kraal manure was considered low in all nutrients including: phosphorus, magnesium, calcium, potassium, nitrogen, copper, zinc, manganese and sodium. This suggests that the manure was well composted, which was desired to prevent Swiss chard seedlings from being burnt (Department of Agriculture, Forestry and Fisheries 2011, p3).

Table 3.3 Summary of analytical results of kraal manure (100% dry matter basis)

Component	Unit	Result
Phosphorus	%	0.27
Magnesium	%	0.44
Calcium	%	0.81
Potassium	%	1.00
Nitrogen	%	1.79
Copper	mg/kg	43.2
Zinc	mg/kg	120
Manganese	mg/kg	535
Sodium	mg/kg	598.8

To apply the correct rates of kraal manure fertiliser to each plot, Cedara Agricultural College made recommendations based on the soil profile of the study site. Based on these recommendations, kraal manure was applied at rates of 20t/ha in plot 1 and 30t/ha in plot 2 and 3. By applying the recommended amounts of kraal manure to each plot, the effect of kraal manure on the dependent variable could not have been attributed to the amount of kraal manure applied, but rather the composition of the kraal manure applied. Much like the lime, kraal manure was weighed on a calibrated digital scale and placed into clear plastic bags labelled with the weight of the manure and the plot number, prior to applying it to the soil at the study site. The manure was spread evenly in the required treatment blocks and worked into the soil to a depth of 10cm with garden forks and spades (van Averbeke & Yoganathan 2003).

3.5.3 Chemical fertiliser

Nitrogen, phosphorus and potassium are macronutrients that are essential for plant growth (FAO 2000, p4). Nitrogen is absorbed from the soil either as nitrate (NO_3) or ammonium (NH_4), and forms between 1% and 4% of plant dry matter (FAO 2000, p4). Nitrogen is involved in the formation of amino acids and proteins in plants, which are essential for plant development and yield formation (FAO 2000, p4). In addition, the absorption of various other nutrients is dependent on plant nitrogen supply. Phosphorus plays an important role in photosynthesis and other chemico-physiological processes in plants, and makes up 0.1% to 0.4% of plant dry matter (FAO 2000, p4). It is essential for cell differentiation and tissue development, which form the growing point of plants. Lastly, potassium is needed for the function of over 60 enzymes, and it forms a vital part of carbohydrate and protein synthesis. Much like nitrogen, potassium makes up 1% to 4% of plant dry matter. Plants that have a good potassium supply are more tolerant to drought, frost, salinity and disease (FAO 2000, p4).

Based on the soil profile of the study site, soil nutrient requirements specific to Swiss chard (Table 3.4) were described by Cedara Agricultural College and fertiliser recommendations were made.

Table 3.4 Soil nutrient requirements specific to Swiss chard

Variable	**Unit**	**Plot 1**	**Plot 2**	**Plot 3**
Nitrogen	kg/ha	100	100	100
Phosphorus	kg/ha	185	250	250
Potassium	kg/ha	255	340	330

The use of 2:3:4(38) chemical fertiliser at rates of 29.1 bags/ha in plot 1 and 39.4 bags/ha in plot 2 and 3 were recommended. The first three numbers in the name of the fertiliser (2:3:4), refer to the ratio of nitrogen, phosphorus and potassium respectively, and the bracketed number (38) refers to the total percentage (%) of nutrients in the fertiliser. The recommended rates of 2:3:4(38) were applied to each plot, supplying more than sufficient nitrogen, and sufficient phosphorus and potassium for the optimum growth and yield of Swiss chard.

Similarly to the concept used in lime and kraal manure application, by applying the recommended amounts of chemical fertiliser to each plot, the effect of chemical fertiliser on the dependent variables could not be attributed to the amount of chemical fertiliser applied. The 2:3:4(38) fertiliser was uniformly broadcast into the soil by hand, which entails applying the fertiliser to the surface of the soil and incorporating it into the entire plough layer, using garden hoes (FAO 2000 p19).

3.5.4 Grass mulch

Grass mulch is an organic mulch that insulates the soil, thereby regulating soil temperatures (Relf *et al* 2015). As the grass clippings decompose, they add nitrogen and humus to the soil which improves plant growth and soil moisture holding capacity (Relf *et al* 2015). Moreover, mulching prevents the proliferation of weeds, improves root growth, prevents soil erosion and improves soil fertility (Maughan & Drost 2016; WCT training material 2016; Relf *et al* 2015; McMillen 2013).

Fresh grass clippings were collected from the land surrounding the study site, and dried in the sun before application. This was according to the methods that the female 'food-preneurs' at the study site used in their existing food garden. Drying the grass out prevents heat and odour release from the grass, which slows down the decomposition of organic materials (Relf *et al* 2015). Prior to applying mulch to the required treatment blocks, the soil was irrigated in accordance with what was practised in the existing home garden. Mulch application may prevent rain or irrigation water filtration; therefore it is important to irrigate the soil before applying mulch to prevent soil compaction (Relf *et al* 2015). The mulch was spread evenly across the soil in five centimetre thick layers before planting the Swiss chard seedlings, a method taught to 'food-preneurs' by WCT (WCT educational material 2016; Relf *et al* 2015).

3.5.5 Black plastic mulch

Plastic mulch is available in various colours such as black, clear and white, with black plastic mulch being the most commonly used and least expensive (Maughan & Drost 2016). Black plastic mulch is a pliable, odourless, nontoxic and inorganic polyethylene plastic that increases soil temperatures, moisture retention and crop yield, and prevents weed proliferation, nutrient leaching, and soil erosion (Cedar Circle Farm 2016; Relf *et al* 2015; Sanders 2001).

According to Maughan and Drost (2016), the increased soil temperature caused by plastic mulch trapping solar radiation, may cause plants to mature sooner due to increased early plant growth. Water is unable to permeate the black plastic, and therefore soil moisture is unable to evaporate, significantly reducing water loss and nutrient leaching, and increasing water conservation (Maughan & Drost 2016). The decrease in weed proliferation reduces the competition for nutrients and water between crops and weeds, resulting in a healthier crop and decreased labour in terms of weeding (Maughan & Drost 2016). The plastic protects the soil from rainfall and foot traffic, thereby preventing erosion, encouraging better root growth for increased water and nutrient absorption by plants (Maughan & Drost 2016). Moreover, plastic mulch is impermeable to carbon dioxide, therefore it builds up under the plastic and escapes through the holes made for the seedlings, creating a ‘chimney effect’, which results in localized concentrations of abundant carbon dioxide for actively growing leaves (Sanders 2001).

Inorganic and/or organic fertiliser experimental treatments were applied to treatment blocks according to the study design, prior to mulch application. Thereafter the soil was watered using a watering can to prevent compaction and to supply adequate moisture for plant growth (Cedar Circle Farm 2016; Relf *et al* 2015). Due to the financial constraints of using machinery to apply the plastic mulch and the relatively small area size, it was applied by hand (Cedar Circle Farm 2016; Relf *et al* 2015; Sanders 2001). The plastic was placed onto moist soil that was free of debris and well tilled, in such a way that it was in close contact with the soil but care was taken not to stretch or tear the plastic (Cedar Circle Farm 2016; Maughan & Drost 2016; Relf *et al* 2015; Sanders 2001). The plastic was not tilled into the soil as it is not biodegradable (Sanders 2001).

Lastly, the sides of the plastic was secured into the soil and then covered with top soil (Cedar Circle Farm 2016; Relf *et al* 2015). Holes were made in the black plastic using a long-handed bulb setter to ensure that the Swiss chard seedlings had less contact with the plastic and to avoid making slits or “X” shaped cuts in the plastic which are prone to stretching (Maughan & Drost 2016). The holes were made large enough so that the seedlings did not touch the plastic, to prevent leaf and/or stem burning (Maughan & Drost 2016).

3.6 Methods and materials for growing Swiss chard

For the study results to be directly applicable to the study community, planting, maintenance and harvesting of Swiss chard was done in accordance with the methods used by the female ‘food-preneurs’ at the study site prior to implementing the experimental garden. These methods were taught to the female ‘food-preneurs’ through generations of knowledge and the WCT ‘food-preneurship training program.

3.6.1 Planting

The Swiss chard seedlings were planted in winter 2016 (late in June). Each plot was tilled to a depth of 20 cm (the length of the fork on a large garden fork) using hand hoes and garden forks. Stones, roots and weeds were removed from the plots, resulting in a smooth soil, free of debris. Each of the 27 treatment blocks contained 20 Swiss chard seedlings, which were planted in two rows of 10. The seedlings were planted approximately 15 cm apart (the distance between the tip of the thumb and the tip of the smallest or ‘pinky’ finger on an outstretched hand) and the rows were planted approximately 30 cm apart (double the distance between the tip of the thumb and the tip of the last finger on an outstretched hand) (Figure 3.5).

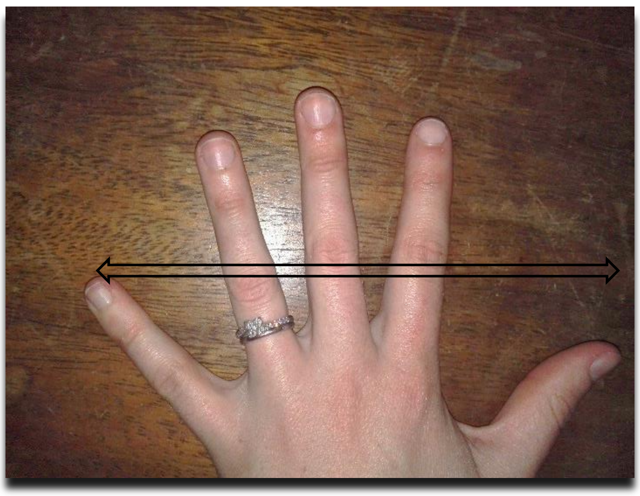

Figure 3.5 The distance between the tip of the thumb and the tip of the smallest or finger on an outstretched hand

Although planted in accordance with what the female 'food-preneurs' had learnt from WCT, Starke Ayres (2016) and the ARC (2013a) suggested the same plant and row spacing. The seedling and row spacing's were measured and marked with wooden stakes, using the same woman's hand for consistency. Thereafter, 5 cm ('four fingers') deep holes were made using a wooden stake marked with a 5 cm mark, and seedlings were planted.

After planting the Swiss chard seedlings, onion seedlings were planted around each treatment block as a means of companion planting, which was carried out by the female 'food-preneurs' prior to implementing the experimental garden.

3.6.2 Maintenance

The Swiss chard was watered by the female 'food-preneurs' using 10 litre watering cans. When irrigating their existing home food garden, the female 'food-preneurs' did not ensure that their produce beds were evenly irrigated. However, for changes in the dependent variables to be attributed to the experimental treatments, and not irrigation variation, it was ensured that each treatment block received 10 litres of water at each watering. Although the amount of irrigation water at each watering was kept constant, irrigation frequency was dependent on the female 'food-preneurs' judgement. The female 'food-preneurs' stated that irrigation frequency was weather dependent. In hot and humid weather, the Swiss chard was irrigated more frequently (between three to five times a week) than in wet weather (between once and three times a week). The experimental garden was inspected for weeds during irrigation. Weeds were removed as required using garden forks to remove their roots.

During the Swiss chard maintenance period, theft of both garden produce and tools occurred, despite the garden being enclosed by a fence and lockable gate. As previously discussed in the literature review, theft is a common constraint experienced in many gardens in SA. Shortly after initiating the experimental garden, six rain gauges were stolen along with three entire blocks of Swiss chard. The Swiss chard in plot three, specifically treatments D (kraal manure fertiliser and plastic mulch), F (kraal manure fertiliser and no mulch) and I (no fertiliser and no mulch), were stolen. The study design (RCBD) and plot replicates, however, allowed for statistical inference of the stolen Swiss chard plots.

3.6.3 Harvesting and sampling

Swiss chard is reported to be ready for harvest within 56 to 70 days after sowing seedlings, or when the outermost leaves are approximately 20 cm high (South African Department of Agriculture, Forestry and Fisheries 2011, p3; Rubatzky and Yamaguchi 1997, p470). Many studies conducted on Swiss chard follow strict harvesting times according to agricultural guidelines; however, the results of these studies may not be applicable to poor communities, who harvest their produce according to their own instincts or knowledge. Thus, for the sake of the study Swiss chard harvesting was dependent on when the female 'food-preneurs' would consider the crop was ready for cooking, to allow the study results to be directly applicable to the female 'food-preneurs'.

To have a crop sample completely representative of each treatment block, all the Swiss chard grown in each block was harvested, leaving two mature Swiss chard leaves on each plant. The mature Swiss chard in each treatment block was harvested by removing the outer matured leaves using a sharp knife approximately 'four fingers' (5cm) above the soil. This method protected the Swiss chard plants from being damaged (ARC 2013a; Maboko & Du Plooy 2013; Department of Agriculture, Forestry and Fisheries 2011, p3; Rubatzky and Yamaguchi 1997, p470).

The harvested Swiss chard was packaged into bags, labelled with the plot number and treatment number, and then moved to a secure venue where they were soaked and thoroughly washed with distilled water three times to remove soil debris. The leaves were air-dried on absorbent paper at room temperature for two hours. The stems were removed and the leaves were cut into smaller pieces and homogenised using a household food processer. From this, 50 g portions were randomly taken and transferred into plastic containers with screw caps, labelled with the date, plot number and treatment number (Clewer & Scarisbrick 2001 p6). Thereafter the samples were transported to Cedara Agricultural College for nutrient analyses.

For each treatment block, the number of leaves were counted and the leaf width and height were measured using a ruler. The number of leaves and leaf width and height were averaged for each treatment block.

3.7 Analysis of nutritional profile

For the sake of this study, the nutritional profile refers to the moisture, fat, fibre, crude protein, calcium, magnesium, phosphorus, sodium, potassium, zinc, copper and iron content of the Swiss chard only. The analyses were done on a double blind basis in a South African National Accreditation System (SANAS) accredited laboratory. Reference samples form part of the daily routine in these laboratories to assure the quality of results. Accepted standardized techniques were used for nutrient analysis.

After initial standardisation of techniques, 27 samples were treated identically for each test where single measurements were done. Three samples per treatment were analysed, one sample from each treatment block.

The nutritional profile of the Swiss chard was measured using the following techniques:

3.7.1 Fibre content

The crude fibre content was determined after chemical digestion and solubilisation. The sample was treated with diluted sulphuric acid and sodium hydroxide. The fibre mass was corrected for ash content after ignition. The final sample was weighed to determine the fibre content. This was done according to the Association of Analytical Chemists (AOAC) Official Method 973.18 (AOAC 2003) (Appendix B, p106) and calculated using the following equation:

$$\text{Acid detergent fiber (ADF) (\%)} = \frac{(W_3 - W_1)}{W_2} \times 100$$

Where:

W_1 – Mass of a crucible (g).

W_2 – Mass of the original sample (g).

W_3 – Mass of residue in crucible after drying (g)

3.7.2 Protein content

The protein content of the Swiss chard was measured by the Dumas method (AOAC 2003). Using the LECO machine, three samples of 0.2 g were measured out, and placed on the arm of the furnace. The sample was then heated to 1 353ºC in the furnace. The sample was combusted in an oxygen rich atmosphere and helium gas served as a carrier gas in the furnace. As a result, nitrogen and sulphur were available to analyse, to determine the protein content, the following equation was used: $N_2/6.25$ = protein (g)

3.7.3 Fat content

The fat content was measured by the Soxhlet method according to the AOAC Official Method 920.39 (AOAC 2003). Using the Buchi 810 Soxhlet Extractor, ether was heated in a flask until it boiled. One half of the water provided steam from the bottom and the other half provided cool water that dropped onto the sample. The sample was then placed into an extraction thimble. Fat extracted by ether dropped back into the flask, as the ether evaporated from the flask the fat was left behind. The fat content was calculated using the following equation:

$$\text{Crude Fat (\%)} = \frac{W_3 - W_2}{W_1} \times 100$$

Where:

W_1 – Mass of a sample (g)

W_2 – Mass of the Buchi fat beaker (g)

W_3 – Mass of the Buchi fat beaker with extracted residue (g)

3.7.4 Mineral (ash) content

A 1 g sample was placed in a crucible, which was marked at the bottom. The organic matter of the sample was removed by heating the sample in a furnace to 550ºC. The remaining residue consisted of ash. The ash percentage was calculated by weighing and recording the mas of the organic matter before and after heating. This was done according to the AOAC Official Method 942.05 (AOAC 2003) (Appendix B, p106) and calculated using the following equation:

$$\text{Ash (\%)} = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

Organic Matter (OM) % = 100 – Ash (DM) %

Where:

W_1 = mass of pre-dried crucible.

W_2 = mass of sample + crucible.

W_3 = mass of sample + crucible after ashing.

3.8 Variables, data capturing and statistical analysis

3.8.1 Independent and dependent variables

Independent variables are manipulated in an experiment to observe the effect on the dependent variable/s (Patel 2009). The following were considered independent variables in this study:

- Vegetable seedlings planted (Swiss chard)
- Experimental treatments applied

The change in a dependent variable is influenced by the manipulation on the independent variable/s. It is this change that researchers attempt to explain (Patel 2009). The following were considered dependent variables in this study:

- Nutrient profile of Swiss chard
- Growth rate of Swiss chard
- Leaf number of Swiss chard

3.8.2 Data capturing and analysis

The data were entered into the Statistical Package for Social Sciences (SPSS) programme, version 22.0, on two separate occasions and then compared to ensure accuracy. A p value ≤ 0.05 indicated statistical significance. Statistical analyses (Table 3.5) included the following tests:

- A multivariable Redundancy analysis (RDA) explored the patterns of change in the nutrient profile of Swiss chard according to the experimental treatments used.
- An Analysis of Variance using a two-way ANOVA table where the effect of the experimental treatments (fertiliser and mulch) on the growth rate, leaf number and nutrient profile of Swiss chard was determined. The ratio of variance was thereafter detected by calculating the F-statistic.
- A Fisher's Least Significant Difference (LSD) was done after the ANOVA, to determine the smallest difference between means (according to the ANOVA) that is required for significance at a stated level of significance, for example p = 0.05. Any differences smaller than the LSD are not significant (Dodge 2008).
- A Permutation Analysis of Variance (PERMANOVA), which is similar to the ANOVA done on single variables, however it examines how all the variables together (jointly), vary within and between treatments, and tests main effects (fertiliser and mulch) and their interaction (fertiliser x mulch) using permutation tests (Clarke & Gorley 2006).

Table 3.5 Statistical analyses of variables pertaining to study objectives

The effect of experimental treatments on these aspects of Swiss chard:	**Independent variable**	**Dependent variable**	**Statistical analyses**
Nutritional profile	Swiss chard grown and experimental treatments	Moisture, ash, fat, fibre, protein, fat, Ca, Mg, P, Na, K, Zn, Cu and Fe.	Canoco: RDA (ter Braak & Šmilauer 2012). Primer 6: PERMANOVA (Clarke & Gorley 2006).
Growth rate		Growth rate	Genstat 14: ANOVA table
Leaf number		Leaf number	Genstat 14: ANOVA table

*where RDA: Redundancy Analysis, PERMANOVA: Permutations Analysis of Variance, ANOVA: Analysis of Variance

3.9 Data quality control

3.9.1 Pilot study

A pilot study is necessary to test the research instruments and to consider limitations with the research procedure (Kothari 2004, p101). However, for the purpose of this study a pilot study was not carried out due to the nature of the study being an intervention as well as financial constraints.

3.9.2 Reliability and validity of data

Reliability and validity were considered throughout the study. Reliability refers to the ability of the research tool to produce consistent results (Kothari 2004, p70). Validity is the degree to which a tool measures what it was intended to measure (Kothari 2004, p69). Accuracy was also considered. Accuracy is the extent to which the measurement actually reflects the true value of the feature being measured and is affected by both reliability and validity (Kothari 2004, p65). Both reliability and validity were ensured by having three repetitions of each study block. In addition, each study block had a control.

Additionally, The AOAC methods used for determination of the nutritional composition of Swiss chard were standardised.

3.9.3 Reduction of bias

The researcher collected the data for this study. This does create risk of bias, however, to remove all temptation of subjectivity, treatments were assigned to garden plots randomly using the =RAND() function on Excel (Table 3.6).

Table 3.6 Excel randomised treatments

Plot 1								
A	G	C	B	H	F	I	E	D
Plot 2								
B	D	A	C	G	E	H	F	I
Plot 3								
F	E	I	D	H	C	B	G	A

3.10 Ethical considerations

Gate keeper's permission (Appendix C, p115) was received from WCT prior to implementing the study garden in KwaMnyandu. Ethical clearance (Appendix D, p116) to conduct the study was obtained from the Biomedical Research Ethics Administration (BREC) at the University of KwaZulu-Natal (UKZN) (Reference number EXM289/16).

CHAPTER FOUR
RESULTS

4.1 Introduction

This chapter serves to present the research findings. The effect of specific mulch and fertiliser treatments on the growth rate, leaf number and the nutrient profile of Swiss chard are reported.

4.2 The effect of fertiliser and mulch on the growth rate of Swiss chard

An analysis of variance (ANOVA) was done on the data for the average leaf number, height and width of Swiss chard (Table 4.1).

Table 4.1 Leaf number, average height and average width of Swiss chard

Treatment	Block	Leaf number (n)	Total mean leaf number (n)	Average leaf height (cm)	Total mean leaf height (cm)	Average leaf width (cm)	Total mean leaf width (cm)
A	1	19		20.8		12.5	
	2	21	24.3	21.3	21.2	12.2	12.9
	3	33		21.5		14.1	
B	1	16		20.7		11.9	
	2	*	18.8	*	23.0	*	12.6
	3	24		22.6		12.2	
C	1	17		22.6		12.4	
	2	22	18.7	24.5	22.4	14.6	13.2
	3	17		20.0		12.7	
D	1	30		11.6		8.4	
	2	19	25.2	22.5	16.5	15.2	11.7
	3	*		*		*	
E	1	36		11.6		7.2	
	2	20	25.0	26.0	18.0	14.6	10.3
	3	19		16.4		9.0	
F	1	40		13.0		8.0	
	2	11	26.2	11.7	11.8	6.6	7.2
	3	*		*		*	
G	1	18		22.5		14.0	
	2	25	24.3	25.2	23.7	14.9	14.6
	3	30		23.3		15.0	
H	1	23		23.5		15.6	
	2	21	20.3	25.0	23.4	15.0	15.1
	3	17		21.7		14.6	
I (control)	1	19		12.6		8.4	
	2	33	26.7	16.0	13.8	9.7	9.0
	3	*		*		*	
Grand mean			23.3		19.3		11.8

While the effect/s of inorganic and organic fertiliser and mulch treatments on the growth rate of Swiss chard (mean days taken to reach maturity) were statistically significant ($p<0.05$), the interactions between fertiliser and mulch treatments were not ($p>0.05$) (Table 4.2).

Table 4.2 The Analysis of Variance (ANOVA) between mean days to maturity and experimental treatments

Source of variation	**d.f**	**s.s**	**m.s**	**F-value**	**P-value**
Block stratum	2	341.7	170.9	1.04	
Treatments					
Fertiliser	2	10403.7	5201.8	31.64	**<0.001**
Mulch	2	2792.8	1396.4	8.49	**0.005**
Fertiliser x mulch	4	1441.3	360.3	2.19	0.132
Residual	12	1973.1	164.4		
Total	22	13568.9			

*Where d.f. stands for Degrees of freedom, s.s for Sum of the squares and m.s for Mean of squares. Significant p-values are emboldened.

The standard error of means (Table 4.3) does not include fertiliser and mulch treatment combinations due to the insignificance thereof. Only the ± standard error of means (Table 4.1) for the two treatment levels of fertiliser applied (organic kraal manure and inorganic chemical fertiliser) were averaged across the two levels of mulch applied (organic grass and inorganic plastic mulch) and the ± standard error of means for the two levels of mulch applied were averaged across the two treatment levels of fertiliser applied.

Table 4.3 The effect of fertiliser and mulch on the growth rate of Swiss chard (mean days)

Treatment	**LSD**	**None**	**Organic**	**Inorganic**
Fertiliser	13.17	91.6 ^{a}	106.9 ^{b}	59.7 ^{c}
Mulch	13.17	100.4 ^{a}	80.4 ^{b}	77.5 ^{b}

*Different letters in the same rows denote significant differences according to the Least Significant Difference (LSD) test ($p< 0.05$).

In comparison to the no fertiliser-control, inorganic fertiliser lowered the maturity period of Swiss chard by 35% (32 days). In contrast, organic kraal manure fertiliser, when compared to the no fertiliser-control, had a 16 % higher maturity period of Swiss chard (15 days).

Both mulch treatments (organic grass and inorganic plastic) lowered the maturity period of Swiss chard by 20% (21 days) when compared to the no mulch-control. Therefore, mulched Swiss chard grew an average of 13% faster than unmulched Swiss chard (control). Numerically, Swiss chard grown in inorganic plastic mulch matured approximately three days faster than Swiss chard grown in grass mulch, however the difference was not significant ($p>0.05$).

4.3 The effect of fertiliser and mulch on the leaf number of Swiss chard

Neither the combination of fertiliser and mulch or individual fertiliser and mulch treatments had a significant effect on the number of leaves (yield) produced on a Swiss chard plant grown at the study site (Table 4.2).

4.4 The effect of fertiliser and mulch on the nutrient profile of Swiss chard

Permutation Analysis of Variance (PERANOVA) tables between Swiss chard nutrient profile and experimental treatments were carried out on the data collected on the nutrient profile of Swiss chard (Table 4.4 and Table 4.5).

Table 4.4 Data on the effect of garden treatment combinations on the fibre and crude protein content of Swiss chard (g/100g dry basis)

Treatment	**Block**	ADF	NDF	Crude protein
A	1	12.6	22.9	39.4
	2	15.3	25.1	42.2
	3	12.8	28.6	41.7
B	1	15.2	25.9	41.0
	2	*	*	*
	3	14.9	26.8	41.6
C	1	11.6	27.4	38.6
	2	14.1	27.2	39.7
	3	14.1	22.5	41.6
D	1	15.8	36.9	24.7
	2	11.9	25.2	37.7
	3	*	*	*
E	1	14.1	36.9	*20.0
	2	25.5	36.8	32.2
	3	13.0	34.4	19.1
F	1	12.7	36.2	21.5
	2	11.1	33.1	18.7
	3	*	*	*
G	1	16.4	36.9	37.4
	2	14.0	29.7	33.5
	3	11.4	26.3	37.7
H	1	14.7	35.5	38.0
	2	26.4	31.7	31.9
	3	16.0	24.5	39.8
I	1	16.0	40.7	24.9
	2	3.5	35.9	18.7
	3	*	*	*

Table 4.5 Data on the effect of garden treatment combinations on the nutrient content of Swiss chard (g/100g dry basis)

Treatment	Block	Ca	Mg	K	Na	P	Zn	Cu	Mn	Fe
A	1	0.7	1.6	4.1	1.6	0.8	35	7	516	220
	2	0.6	1.3	4.5	1.1	0.7	40	9	435	276
	3	0.7	1.5	4.0	1.3	0.9	40	13	358	257
B	1	0.8	1.4	4.2	1.0	0.6	35	11	229	229
	2	*	*	*	*	*	*	*	*	*
	3	0.6	1.5	3.6	1.4	0.8	46	8	337	276
C	1	0.7	1.5	5.2	1.4	0.6	32	9	349	224
	2	0.6	1.2	4.1	1.1	0.5	50	13	314	801
	3	0.7	1.4	4.9	1.4	0.6	45	9	329	223
D	1	1.6	2.0	3.7	1.6	0.2	177	11	924	690
	2	0.5	0.9	4.3	1.1	0.5	84	9	460	574
	3	*	*	*	*	*	*	*	*	*
E	1	2.7	2.3	2.9	1.6	0.1	100	11	801	575
	2	1.6	1.6	1.6	2.3	0.5	69	14	378	665
	3	2.4	2.2	2.2	1.4	0.1	171	13	769	610
F	1	2.2	2.3	2.9	1.5	0.2	149	12	834	700
	2	1.0	1.0	0.9	0.8	0.0	62	4	499	446
	3	*	*	*	*	*	*	*	*	*
G	1	0.9	1.4	4.1	1.2	0.5	51	8	388	683
	2	1.2	1.8	3.5	1.8	0.4	60	10	380	786
	3	0.7	1.7	2.8	1.5	0.6	58	10	388	637
H	1	1.0	1.7	2.7	1.5	0.5	38	12	337	665
	2	1.7	1.7	1.6	2.5	0.4	77	14	452	789
	3	0.7	1.4	4.5	1.1	0.6	56	12	276	601
I (control)	1	1.7	1.7	1.9	1.8	0.2	117	10	931	795
	2	2.2	2.2	1.5	1.9	0.2	144	11	1038	940
	3	*	*	*	*	*	*	*	*	*

Table 4.6 Permutation Analysis of Variance between Swiss chard nutrient profile and experimental treatments

Source	d.s	s.s	m.s	Pseudo-F	P-value
Fertiliser	2	109.53	54.764	5.686	**0.0002**
Mulch	2	35.392	17.696	1.8373	**0.0389**
Fertiliser x mulch	4	49.983	12.496	1.2974	0.1761
Res	14	134.84	9.6314		
Total	22	330			

*Where d.s stands for the d statistic, s.s for Sum of the squares and m.s for Mean of squares.
Significant p-values are emboldened

Both fertiliser and mulch treatments, independent of each other, significantly altered the nutrient profile of Swiss chard ($P < 0.05$), with fertiliser having a greater effect ($p=0.002$) than mulch ($p=0.0389$) (Table 4.6). However, the interaction between fertiliser and mulch (fertiliser x mulch) did not significantly affect the nutrient profile of Swiss chard ($p>0.05$). Therefore, experimental treatments containing a combination of fertiliser and mulch treatments, did not significantly affect the nutrient profile of Swiss chard.

Table 4.7 Permutation Analysis of Variance between fertiliser treatments and the nutrient profile of Swiss chard

Fertiliser		
	T-value	**P-value**
Inorganic and organic (chemical and kraal manure)	2.8712	**0.0011**
Inorganic (chemical)	3.118	**0.0008**
Organic (kraal manure)	1.0858	0.3195
Mulch		
Inorganic and organic (plastic and grass)	1.1904	0.2188
Inorganic (plastic)	1.4845	0.0592
Organic (grass)	1.3748	0.0830

*Numbers written in bold represent significant values ($p< 0.05$)

Overall, fertiliser, specifically inorganic chemical fertiliser, significantly affected the nutrient profile of Swiss chard ($p<0.05$). However, organic kraal manure fertiliser alone did not significantly affect the nutrient profile of Swiss chard (p>0.05) (Table 4.7). In contrast to fertiliser, mulch did not have a significant effect on the nutrient profile of Swiss chard (p>0.05). A Summary of the effect of mulch and fertiliser on the number of days taken to reach maturity and nutrient profile of Swiss chard is presented in Table 4.8.

Table 4.8 Summary table of the effect of mulch and fertiliser on the number of days taken to reach maturity and nutrient profile of Swiss chard

Dependent variable	Statistical test	P-value	Explanation (compared to control)
		Fertiliser	
Days to maturity	ANOVA	**<0.001**	Inorganic fertiliser lowered and organic fertiliser made higher the mean number of days taken for Swiss chard to reach maturity.
Nutrient profile	PERMANOVA and RDA	**0.0002**	Overall, fertiliser, specifically inorganic chemical fertiliser, significantly affected the nutrient profile of Swiss chard.
		Mulch	
Days to maturity	ANOVA	**0.005**	Organic or inorganic mulch lowered the maturity period (days) of Swiss chard.
Nutrient profile	PERMANOVA and RDA	**0.0389**	Mulch significantly altered the nutrient profile of Swiss chard, with fertiliser having a greater effect.
		Fertiliser x mulch	
Days to maturity	ANOVA	0.132	The combination of fertiliser and mulch did not significantly affect the maturity period (days) or nutritional profile of Swiss chard.
Nutrient profile	PERMANOVA and RDA	0.176	

*Numbers written in bold represent significant values (p< 0.05) and Sig. stands for significance

To further investigate the effect of mulch and fertiliser treatments on the nutrient profile of Swiss chard, a multivariable Redundancy Analysis (RDA) was carried out. The results of the RDA (Table 4.9) was translated into an image for clear understanding (Figure 4.2).

Table 4.9 The percentage of nutrients explained on Redundancy Analysis axes

Nutritional component (g/100g dry basis)	Percentage explained by RDA axis 1	Percentage explained by RDA axis 2
Moisture	8.8	31.3
Ash	0.2	0.2
Fat	44.5	9.9
ADF	2.9	24.8
NDF	*61.4	0.1
CP	*73.1	6.8
Ca	*64.7	0.4
Mg	21.2	2.6
K	*54.9	0.0
Na	12.4	15.0
P	*69.4	3.6
Zn	*67.1	1.7
Cu	1.2	25.1
Mn	*52.5	6.8
Fe	*51.3	9.8

*represents nutrients which have more than 50% of their variation explained on RDA Axis

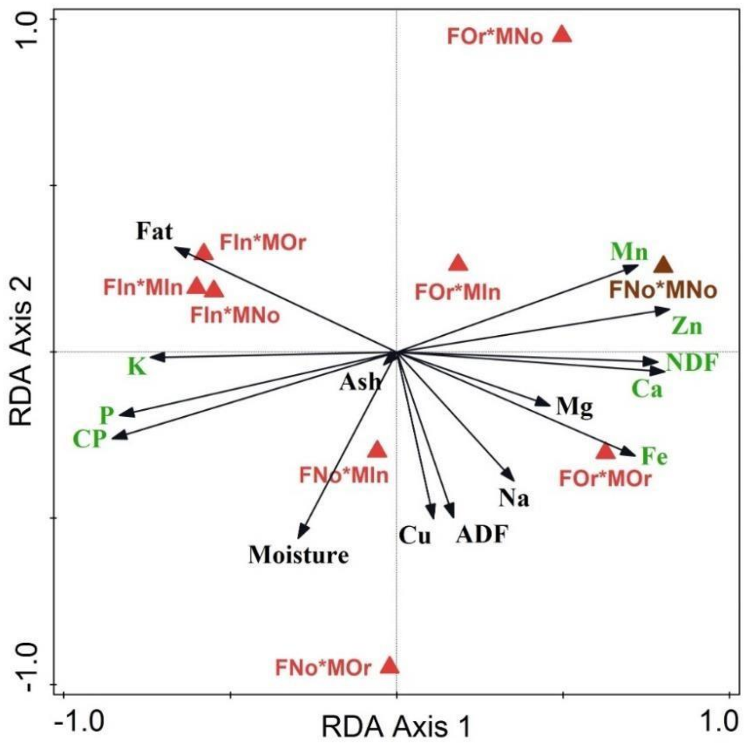

Figure 4.1 Redundancy Analysis showing how treatment combinations affect the nutrient profile of Swiss chard

Key	
↘	Arrows indicate direction of increasing amount in that nutrient
△	Triangles represent the average position (centroid) of treatment combinations on the gradient.
▲ (brown)	Control
▲ (red)	Experimental treatments
F	Fertiliser
M	Mulch
In	Inorganic
Or	Organic
No	None
■ (green)	Nutrients depicted in green had 50% or more of their variation explained on RDA Axis 1.
■ (black)	Nutrients depicted in black had less than 50% of their variation explained on RDA Axis 1.

Replications did not vary significantly in mean nutrient profile across plots (p=0.402) (there was no spatial variation between plots), therefore joint variation in nutrients was measured as opposed to investigating each nutrient separately. The RDA Axis 1 (Figure 4.1) represents a macro-to-micronutrient gradient, showing differences in variation. Nutrients (represented by arrows indicating direction of increase) are influenced by the average effects of fertiliser (F) and mulch (M) and their nine combinations, in red, relative to the average of the control (no fertiliser and no mulch), in brown.

The distance rule applies to the triangles, whereby those closest to each other have a similar nutrient profile, and those further apart (in particular along axis 1) differ most in their overall nutrient profile. Neutral detergent fibre (NDF), crude protein, calcium (Ca), potassium (K), phosphorus (P), manganese (Mn) and iron (Fe) have more than 50% of their variation explained on RDA Axis 1, meaning that these nutrients had the highest response rates to experimental soil treatments applied. On all axes, both fertiliser and mulch, and their interaction significantly influenced the nutrient profile of Swiss chard ($P < 0.005$) compared to the control (no fertiliser and no mulch). The effects of individual experimental treatments on the nutrient content of Swiss chard (g/100g dry basis) were also investigated (Table 4.10)

Table 4.10 The effects of individual experimental treatments on the nutrient content of Swiss chard (g/100g dry basis)

Nutrient	**g/100g**	**NF (Control)**	**OF**	**IF**	**NM (Control)**	**OM**	**IM**
Fat	%	3	2	5	4	3	3
ADF		15	16	14	14	18	14
NDF		34	33	26	32	31	30
Crude protein		25	33	41	29	35	36
Ca		2	1	1	1	1	1
Mg		2	2	1	2	2	2
K		3	3	4	3	3	4
Na		2	2	1	1	2	1
P		0	0	1	0	1	1
Zn	mg/kg	8	12	4	9	7	7
Cu		1	1	1	1	1	1
Mn		54	67	34	61	40	51
Fe		77	61	33	59	58	56

*Where F stands for fertiliser, M for mulch, N for none, O for organic and I for inorganic.

4.4.1 Fat, fibre and crude protein

When compared to the no-fertiliser control, organic fertiliser lowered the fat percentage of Swiss chard slightly (by 1%). In contrast, Swiss chard fertilised with inorganic chemical fertiliser had almost doubled the percentage of fat compared to the no fertiliser-control. Swiss chard grown in no mulch-control contained a marginally higher fat percentage (1% higher) than Swiss chard grown in the two treatment levels of mulch (organic grass and inorganic plastic).

In terms of fibre, organically fertilised Swiss chard contained marginally more Acid Detergent fibre (ADF) (1%) than the no fertiliser-control, whereas inorganically fertilised Swiss chard contained marginally less ADF (1%). The ADF content of Swiss chard was 4% higher grown in organic mulch, and inorganic mulch did not affect the ADF content of Swiss chard when compared to the no mulch-control. In terms of NDF, both fertiliser and mulch treatments (organic and inorganic) lowered the NDF content (%) of Swiss chard. Compared to the no fertiliser-control, organic and inorganic fertiliser lowered the NDF content by 2% and 8% respectively. Similarly, organic and inorganic mulch lowered the NDF content by 1% and 2% respectively. With regard to total fibre content (ADF and NDF), organic kraal manure had no effect on the total fibre content of Swiss chard. Inorganic fertiliser however lowered the total fibre content by 5%. The total fibre content of Swiss chard was marginally higher (2%) with organic mulch and inorganic mulch lowered the content marginally (1%) when compared to the no mulch-control.

The protein content (%) of Swiss chard was higher in all fertiliser and mulch treatments (organic and inorganic) versus the control (no mulch and no fertiliser). The crude protein content was 8% and 16% higher respectively, grown in organic and inorganic fertiliser, when compared with the no fertiliser-control. Therefore, Swiss chard grown in either inorganic chemical or organic kraal manure fertiliser contained an average of 1.5 times more crude protein than Swiss chard grown without fertiliser. The application of organic and inorganic mulch made higher the crude protein content of Swiss chard by 6% and 7% respectively, when compared to the no mulch-control. Therefore mulching in general resulted in a 1.3 times higher crude protein content of Swiss chard.

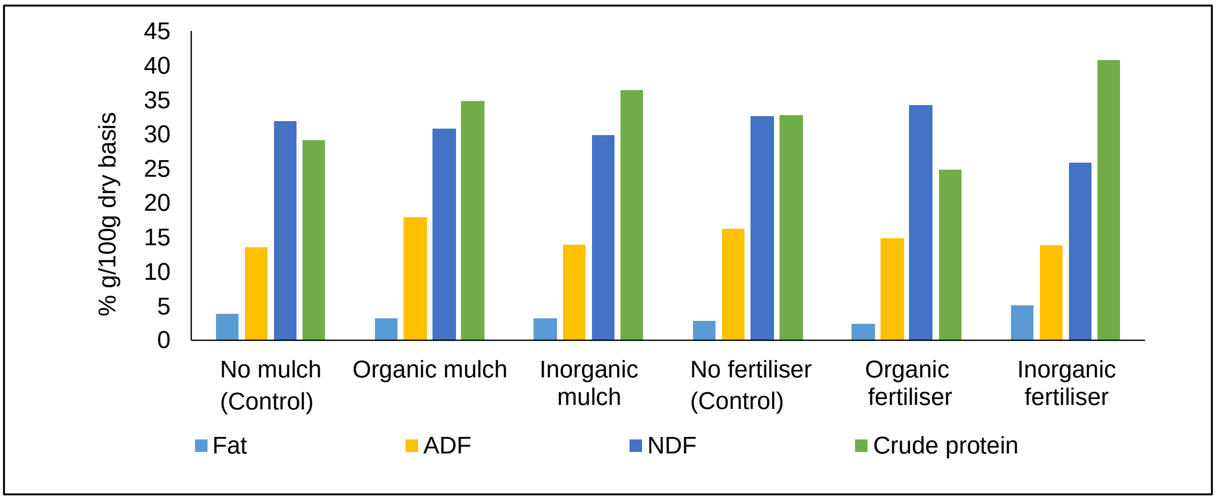

Figure 4.2 The effect of different levels of fertiliser and mulch treatments on the macronutrient content of Swiss chard (g/100g (%), dry basis)

4.4.2 Micronutrients

When compared to the no fertiliser-control, organic and inorganic fertiliser lowered the calcium content of Swiss chard by a marginal 1%. Compared to the no mulch control, mulch treatments had no effect on the calcium content of Swiss chard. The magnesium content of Swiss chard was not affected by experimental mulch or fertiliser treatments.

The potassium content of Swiss chard by was 2% higher grown in inorganic chemical fertiliser, whereas organic fertiliser had no effect on the potassium content of Swiss chard in contrast to the no fertiliser-control. Organic mulch had no effect on the potassium content of Swiss chard whereas the potassium content was 1% higher in inorganic mulch compared to the no mulch-control.

Organic fertiliser had no effect on the phosphorus content of Swiss chard, and inorganic fertiliser made it higher by 1% when compared to the no fertiliser-control. Compared to the no-mulch control the phosphorus content of Swiss chard was 1% higher in Organic and inorganic mulch.

Organic fertiliser left the sodium content of Swiss chard unchanged where it was 1% higher in inorganic in comparison to the no fertiliser-control. In terms of mulch, inorganic mulch had no effect on the sodium content of Swiss chard compared to the no mulch-control, whereas the sodium content was 1 % higher in organic mulch.

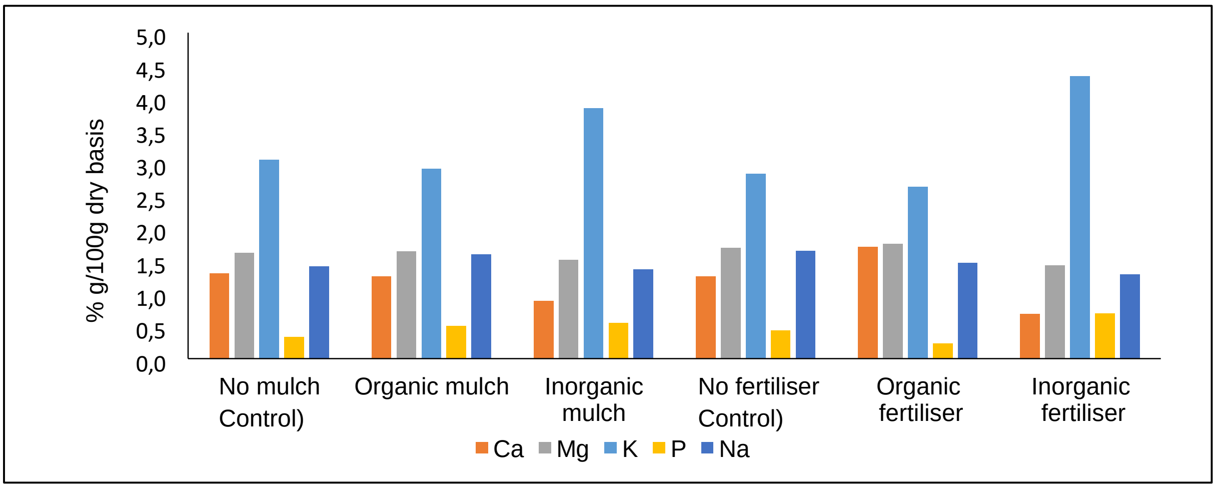

Figure 4.3 The effect of different levels of fertiliser and mulch treatments on the calcium, magnesium, potassium, phosphorus and sodium content of Swiss chard (g/100g (%), dry basis).

Swiss chard grown in organic kraal manure fertiliser contained approximately 1.5 times more zinc than plants grown in no fertiliser (control). Inorganic fertiliser halved the zinc content of Swiss chard compared to the no fertiliser-control. The two mulch treatments, organic and inorganic, lowered the zinc content of Swiss chard compared to the no mulch-control. The copper content of Swiss chard remained unaffected by experimental treatments of mulch or fertiliser.

The manganese content of Swiss chard was less than 1% higher when organic kraal manure fertiliser was added. Inorganic fertiliser lowered the manganese content by less than 1% when compared to the absence of fertiliser all together (control). Both treatments of mulch lowered the manganese content of Swiss chard, inorganic plastic mulch by less than 1%.

The two treatment levels of fertiliser and mulch, (organic and inorganic) lowered the iron content of Swiss chard compared to the no fertiliser-control. Organically fertilised Swiss chard contained 1.3 times less iron than the no fertiliser-control. Inorganic fertiliser more than halved the iron content of Swiss chard. In terms of mulch, organic and inorganic mulch lowered the iron content of Swiss chard compared to the no mulch-control, marginally (less than 1%).

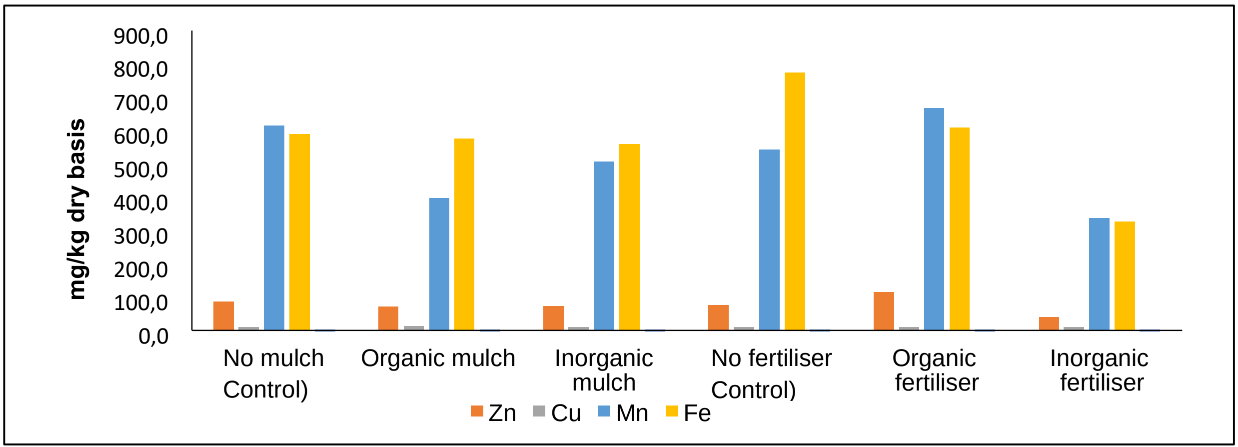

Figure 4.4 The effect of different levels of fertiliser and mulch treatments on the zinc, copper, manganese and iron content of Swiss chard (g/100g (%), dry basis).

Table 4.11 Summary table of the effect of fertiliser and mulch treatments on the nutrient content of Swiss chard

Treatments	Fibre	Crude protein	Ca	Mg	K	Na	P	Zn	Cu	Mn	Fe
					Fertiliser						
Organic	0	+	-	0	0	0	0	+	0	+	-
Inorganic	+	+	-	-	+	-	+	-	0	-	-
					Mulch						
Organic	-	+	0	0	0	+	0	-	0	-	+
Inorganic	-	+	0	0	+	0	0	-	0	-	-

*where + represents an increase in nutrients, - represents a decrease in nutrients and 0 represents no change in nutrient content compared to the control (none).

4.5 Summary

Fertiliser and mulch treatment combinations did not significantly affect the maturity period of Swiss chard. However, on an individual level, fertiliser and mulch (organic and inorganic) significantly affected the maturity period of Swiss chard compared to the control (no treatment). Inorganic chemical fertiliser lowered the maturity period of Swiss chard whereas organic kraal manure fertiliser lengthened the maturity period of Swiss chard. Organic grass and inorganic plastic mulch, lowered the maturity period of Swiss chard when compared to the no mulch-control.

The number of leaves present on Swiss chard plants at the study site was not significantly affected by fertiliser or mulch at combination or individual level.

Both fertiliser and mulch treatments, independent of each other, significantly altered the nutrient profile of Swiss chard ($p< 0.05$), with fertiliser having a greater effect ($p=0.002$) than mulch ($p=0.0389$). However, experimental treatments containing a combination of fertiliser and mulch treatments, did not significantly affect the nutrient profile of Swiss chard ($p>0.05$). Overall, fertiliser, specifically inorganic chemical fertiliser, significantly affected the nutrient profile of Swiss chard ($p< 0.05$). However, organic kraal manure fertiliser alone did not significantly affect the nutrient profile of Swiss chard ($p>0.05$). In contrast to fertiliser, mulch on all levels did not have a significant effect on the nutrient profile of Swiss chard ($p>0.05$).

CHAPTER FIVE
DISCUSSION

5.1 Introduction

This chapter analyses and discusses the results of the study. Furthermore, the findings of this study will be compared with those of similar studies reported in the relevant literature.

5.2 The effect of fertiliser and mulch on the growth rate of Swiss chard

Inorganic chemical fertiliser lowered the overall maturity period of Swiss chard (mean days) by a mean of 29% when compared to the no fertiliser-control. This may be attributed to the increased nitrogen, phosphorus and potassium provided from the chemical fertiliser. These nutrients are involved in plant development, nutrient absorption, photosynthesis, cell differentiation and tissue development, therefore an increase in these nutrients may have hastened the plant growth. Organic kraal manure fertiliser had conflicting results, increasing the overall maturity period of Swiss chard by 20% when compared to the control. Although kraal manure has been described to have many benefits such as the improvement of soil structure and water holding capacity, the nutrient levels may have been insufficient to promote rapid foliar growth of Swiss chard plants (van Averbeke 1997). Even though well composted, the kraal manure used at the study site was low in many nutrients such as phosphorus, magnesium, calcium, potassium, nitrogen, copper, zinc, manganese and sodium (See Chapter Three, Table 3.4). The low level of nutrients, overall, in the kraal manure used at the study site may have been a contributing factor to the lower growth rate (mean number of days) of the Swiss chard plants grown in organic fertiliser.

Swiss chard grown in organic grass or inorganic plastic mulch grew an average of 13% faster than the no-mulch control. This result is in agreement with Maughan and Drost (2016), who stated that mulch has the potential to shorten the maturity period of plants due to increased soil temperature caused by trapped solar radiation (Relf *et al* 2015). Moreover, mulch (plastic in particular) is impermeable to carbon dioxide, causing the gas to accumulate underneath the mulching material. This carbon dioxide gas escapes through the seedling holes in the mulch, creating a ‘chimney effect’ resulting in localized concentrations of abundant carbon dioxide for growing Swiss chard leaves (Sanders 2001). In addition, mulched Swiss chard may have matured faster than unmulched plants due to moisture retention, significantly reducing plant and soil water loss and nutrient leaching (Maughan & Drost 2016).

The interactions between fertiliser and mulch treatments (fertiliser x mulch) were not significant ($p>0.05$); therefore the combination of inorganic fertiliser and organic mulch did not have a significant effect on the growth rate of Swiss chard. Based on these findings, the following hypotheses are therefore rejected:

- Swiss chard grown in no-fertiliser and no-mulch control conditions would have the slowest growth rate.
- Swiss chard grown in combinations of mulch and fertiliser, when compared to Swiss chard grown in mulch or fertiliser only would have a faster growth rate.

Although inorganic chemical fertiliser and organic grass or inorganic plastic mulch lowered the maturity period (mean number of days) of Swiss chard, the total yield of Swiss chard may not be larger.

5.3 The effect of fertiliser and mulch on the leaf number of Swiss chard

Engelbrecht, Ceronio and Motseki (2010) conducted a pot trial in the greenhouses of the Department of Soil, Crop and Climate Sciences at the University of the Free State, Bloemfontein, South Africa. Engelbrecht *et al* (2010) discovered that the leaf number of Swiss chard plants increased with increasing nitrogen levels. One of the aspects this study investigated was the effect of nitrogen level and source on the number of leaves harvested off Swiss chard plants. Based on the study by Engelbrecht *et al* (2010), it would have been expected that Swiss chard plants grown in fertiliser would have had a higher number of leaves due to the increased nitrogen content in fertiliser as opposed to none (control).

However, the findings of the current study are not in accordance of expectations that were based on the findings of Engelbrecht *et al* (2010), but rather this study is in agreement with Smith *et* al (2001), who found that the addition of chemical fertiliser had no significant effect on the total yield of Swiss chard. Fertiliser x mulch treatment combinations, or individual treatments, did not have a significant effect on the number of leaves produced on Swiss chard plants grown at the study site. Therefore, the following hypotheses were rejected:

- Swiss chard grown in no-fertiliser and no-mulch control conditions would have the lowest leaf number.
- Swiss chard grown in combinations of mulch and fertiliser, when compared to Swiss chard grown in mulch or fertiliser only would have the lowest leaf number.

According to Allen (2003), the quality of food, determined by the micronutrient profile, makes a stronger contribution to nutritional status rather than the quantity of food. Therefore, the leaf number of Swiss chard plants may not be important in terms of nutritional contribution.

5.4 The effect of fertiliser and mulch on the nutrient profile of Swiss chard

Daiss *et al* (2008) determined the effect of different organic pre-harvest treatments on the nutritional profile of Swiss chard using a randomised block design. It was found that Swiss chard harvested 19 weeks after sowing showed greater differences in nutritional profile than chard harvested 8 weeks after sowing. Therefore, it may be necessary for future studies to harvest Swiss chard grown in different treatments at different times. However, this study, aimed to plant, maintain and harvest the Swiss chard as per the community practices, thereby getting a true reflection of the nutrient content of the Swiss chard when it would be eaten.

Although the concentration of individual nutrients in Swiss chard is important, it is difficult to rank individual nutrients according to level of importance when looking at the importance of total dietary intake. Nutrients are all needed in a specific quantity and micronutrient deficiencies are often a result of other nutrients deficiencies like a domino effect. Therefore, it is important to look at the general nutrient profile of Swiss chard as a whole, and how the experimental treatments affected the general profile as opposed to single nutrients. It is important to note that children do not rely solely on Swiss chard to provide dietary nutrient requirements.

5.4.1 Fibre and crude protein

Sufficient dietary fibre intake ensures a healthy digestive system and helps to prevent constipation. The consumption of fibre rich foods in a healthy, balanced diet can reduce the risk of cardiovascular disease, type 2 diabetes and colorectal cancer (British Nutrition Foundation 2018).

The addition of inorganic fertiliser lowered the total fibre content of Swiss chard. Swiss chard grown in organic kraal manure fertiliser contained the same amount of total fibre (%) as Swiss chard grown without fertiliser (control). On the other hand, inorganic chemical fertiliser lowered the total fibre content of Swiss chard. Mulching with organic grass enhanced the total fibre content of Swiss chard and inorganic plastic lowered the total fibre content of Swiss chard.

If Swiss chard formed part of the total daily dietary intake of children and adults, more inorganically fertilised Swiss chard would have to be consumed, compared to organically fertilised or untreated Swiss chard, to meet their DRI of fibre per day (25g/day, 38g/day for men and 25g/day for women). Therefore, in terms of total fibre, the application of kraal manure or chemical fertiliser to Swiss chard grown at the study site may be of little value. The use of organic grass mulch can be recommended as an affordable way to increase the total fibre content of Swiss chard slightly.

Kolahdozz, Spearing and Sharma (2013) did a cross-sectional study assessing dietary adequacy from 24-hour dietary recalls of 136 adults older than 19 years, who were randomly selected, from Empangeni, KwaZulu-Natal, South Africa. Most of the study population consumed enough protein, however, the majority of protein was obtained from plant-based foods. A link has been found between diets lacking in animal source foods and micronutrient deficiencies, including iron, zinc, vitamin B-12, riboflavin, calcium and vitamin A (Murphy and Allen 2003). Due to the statistical links reported between the intake of animal sources of food and improved growth, cognitive function, activity, pregnancy outcome and morbidity, the intake of animal sources of food has been described as a strong predictor of functional capacity in children (Neumann, Bwibo, Murphy, Sigman, Whaley, Allen, Guthrie, Weiss & Demment 2003).

Swiss chard grown in inorganic and organic fertiliser and mulch, particularly inorganic, had a higher crude protein content (%). For children and adults who consume Swiss chard as part of their daily dietary intake, they would have to consume less Swiss chard (g/day) to meet their RDA for protein (19 g/day for children, 56g/day for men and 46g/day for women), if it was treated inorganic or organic fertiliser and mulch.

In poor communities where chemical fertiliser may not be financially feasible, organic kraal manure fertiliser would be recommended. In terms of mulch, either two treatments of mulch used could be recommended as they both caused a higher crude protein content of Swiss chard within one percentage of each other. In poor communities, organic grass mulch would be the foremost recommendation due to its availability and accessibility.

5.4.2 Macro minerals

Kolahdozz *et al* (2013) showed that more than 90% of their study population in KZN consume less than 70% of the calcium DRI. In rural Africa, the intake of dairy products is low, and diets are typically high in phytates, oxalates and tannins, which all reduce calcium absorption (Prentice, Schoenmakers, Jones, Jarjou and Goldberg 2009). Based on this, the lack of calcium fortification in staple foods is a cause for concern in rural SA. Additionally, dietary calcium absorption is reduced by as much as 20 to 30% in diets low in meat sources of food (Venti & Johnston 2002). Moreover, a diet low in calcium promotes the oxidation of fat and favors a decrease in energy intake (Tremblay & Gilbert 2011; Zemel, Richard, Milstead and Campbell 2005).

Experimental treatment levels of fertiliser lowered the calcium content of Swiss chard plants slightly. In terms of mulch, the application of experimental mulch treatments left the calcium content of Swiss chard unchanged when compared to the control. Swiss chard grown in organic or inorganic fertiliser would result in children and adults having to consume more marginally more Swiss chard (g) per day as part of their total dietary intake, to meet their calcium DRI (1g/day for children and adults). Although the addition of fertiliser and mulch experimental treatments did not increase the calcium content of Swiss chard, the benefits of these treatments to the soil are indispensable considering the marginal decrease of calcium in Swiss chard fertilised with experimental treatments.

Magnesium is a cofactor in more than 300 enzymatic reactions that control numerous biochemical reactions in the body, including protein synthesis, muscle and nerve function and blood glucose and blood pressure regulation (Rude 2012 pp 159-75; Rude 2010 pp 527-37; Institute of Medicine 1997). Processes such as the production of energy, oxidative phosphorylation, glycolysis and RNA and DNA synthesis rely on magnesium. Magnesium. The transportation of calcium and potassium across cell membranes also relies on magnesium. This process is important for nerve impulse conduction, muscle contraction and normal heart rhythm (Rude 2012 pp 159-75).

Organic fertiliser did not change the magnesium content of Swiss chard compared to the control, and inorganic fertiliser halved the magnesium content. As part of their total dietary intake, children and adults would have to eat more Swiss chard (mg/day) fertilised with inorganic fertiliser as opposed to untreated (control) or organically fertilised soil to meet their DRI (130mg/day for children, 400 mg - 420 mg for men and 310 mg - 320 mg for women). In terms of magnesium, organic kraal manure fertiliser may be preferable over inorganic chemical fertiliser. The addition of either organic grass or inorganic plastic mulch to the soil had no effect on the magnesium content of Swiss chard. Even though mulch may not increase the magnesium content of Swiss chard, it may still be recommended that either organic or inorganic mulch be added to the soil to reap the soil-related benefits of these treatments such as soil temperature regulation, lowered weed proliferation, improved root growth and soil fertility, lowered nutrient leaching and improved soil structure (Cedar Circle Farm 2016; Maughan & Drost 2016; WCT training material 2016; Relf *et al* 2015; McMillen 2013; Sanders 2001).

Potassium is vital for glycogenesis, acid-base balance, regulation of osmotic pressure, conduction of nerve impulse, muscle contraction (the cardiac muscle in particular), and cell membrane function (Soetan, Olaiya C, Oyewole 2012).

Overall, the addition of chemical fertiliser resulted in slightly higher potassium levels in Swiss chard and organic fertiliser left the potassium content of Swiss chard unchanged when compared to the control. Organic grass mulch did not affect the potassium content of Swiss chard whereas inorganic plastic mulch resulted in a slightly higher potassium content, when compared with the no mulch-control. For Swiss chard to contribute to the potassium RDA for adults and children, if Swiss chard formed part of their total daily dietary intake, they would have to consume more Swiss chard (g) per day grown without fertiliser or in organic fertiliser as opposed to grown in chemical fertiliser. Moreover, they would need to consume more Swiss chard (g/day) as part of their total dietary intake if it was mulched with organic mulch compared or no mulch (control) compared to inorganic mulch. However, it must be considered that from a nutritional perspective, a dietary deficiency in potassium is not a national health concern.

One of the leading estimated health risks worldwide is an excess of dietary sodium intake (Campbell, Johnson and Campbell 2012). Kolahdozz *et al* (2013) reported that sodium intake exceeded the DRI's by 300 mg to 700 mg, in all age and gender groups. A diet high in sodium may result in high blood pressure, stroke, coronary heart disease, and heart failure have been linked to the hormonal and cellular responses that result from excess dietary sodium intake (Mohan & Campbell 2009; Sanchez-Castillo & James 2005).

Inorganic fertiliser application lowered the sodium content of Swiss chard and organic fertiliser application left the sodium content of Swiss chard unchanged. The sodium content was 1% higher in Swiss chard grown in organic grass mulch. Based on the negative health benefits associated with an excess intake of dietary sodium, Growing Swiss chard lower in sodium may be beneficial. However, experimental treatments did not alter the sodium content of Swiss chard enough to support a certain treatment in growing Swiss chard lower in sodium.

Phosphorus is one of the most abundant minerals in the body that makes up one percent of a person's total body weight. It is present in every cell of the body, and is found mostly in the bones and teeth. Phosphorus mainly aids in bone and teeth formation, but also plays a role in how the body uses fats and carbohydrates and protein and ATP synthesis. Dietary phosphorus is mainly obtained from protein sources of food (United States National Library of Medicine 2017).

Organic kraal manure fertiliser did not change the phosphorus content of Swiss chard and was 1% higher in inorganic chemical fertiliser. In terms of mulch, the addition of inorganic or organic mulch improved the phosphorus content of Swiss chard (1% higher). Based on these findings it can be recommended to use either organic or inorganic mulch on the soil, or inorganic chemical fertiliser. However a dietary deficiency of phosphorus is not common due to its abundance in the body.

5.4.3 Micro minerals

Kolahdozz et al (2013) found that, in spite of the food fortification programme, 72% of females, and only 41% of males consumed adequate daily intakes of zinc. This may be due to diets low in meat sources of food. Zinc functions as an intracellular molecule for immune cells, in the body. Zinc deficiency can result in growth retardation, cognitive damage, infection, inflammation and many other chronic diseases as a result of an impaired immune response (Prasad 2009a;, Prasad 2009b).

Compared to the no fertiliser-control, organic kraal manure fertiliser produced Swiss chard with a 1.6 times higher zinc content, whereas inorganic chemical fertiliser halved the zinc content. The addition of inorganic plastic and organic grass mulch, equally lowered the zinc content of Swiss chard when compared to the control. If children and adults consumed Swiss chard as part of their daily dietary intake, they would have to eat more Swiss chard per day to meet their zinc DRI (5mg/day for children, 11mg/day for men and 8mg/day for women) if it was fertilised with inorganic fertiliser as opposed to the no fertiliser (control).

Although organic kraal manure fertiliser produced Swiss chard with a higher zinc content, it must be taken into account that the phytic acid in Swiss chard, a main inhibitor if zinc bioavailability, renders the zinc less bioavailable than in meat sources of food (Gautam, Platel and Srinivasan 2011). Moreover, zinc bioavailability may be reduced by as much as 20% from a diet low in meat (Venti and Johnston 2002).

Manganese is a trace mineral in the body that is needed for several enzymatic processes. Manganese is mostly found in the bones, but is also distributed in tissues of the pancreas, kidneys, liver, adrenal glands and pituitary gland (Merrell 2017).

The manganese content of Swiss chard, compared to the no fertiliser-control, was higher in organic kraal manure and lower in inorganic fertiliser. The two treatment levels of mulch lowered the manganese content of Swiss chard, particularly organic mulch. Considering that manganese deficiency is very rare (Merrell 2017), it may be beneficial to consider the interactions of the soil treatments on other, more nutritional important nutrition's (in terms of deficiencies).

Iron is an indispensable nutrient needed for the synthesis of haemoglobin and myoglobin, and is essential for health (Saunders, Craig, Baines and Posen 2012). A large percentage of human iron requirements are met through the recycling of iron in red blood cells (Samman 2007). Iron deficiency manifests in three levels (in increasing order of severity): depleted iron stores, early functional iron deficiency and iron deficiency anaemia (Saunders *et al* 2012). It has been previously thought that the oxalic acid in DGLV's may inhibit iron absorption, however a study by Genannt Bonsmann, Walczyk, Renggli and Hurrell (2008) suggests that its effects are insignificant.

Fertiliser lowered the iron content of Swiss chard, particularly chemical fertiliser. Children and adults would have to eat more Swiss chard per day, as part of their total dietary intake, if it were fertilised (organically or inorganically), to meet their DRI (10mg/day for children, 8mg/day for men and 18mg/day for women) as opposed to unfertilised Swiss chard. The iron content of the Swiss chard was slightly higher in organically mulched Swiss chard. Inorganic mulch lowered the iron content of Swiss chard slightly. Therefore, the production of Swiss chard rich in iron requires no fertiliser or mulch, or organic mulch. However, in terms of the iron content of Swiss chard in the study area, inorganic fertiliser should be avoided as it more than halves the iron content of Swiss chad compared to the control.

5.4.4 Overall nutrient profile

Both fertiliser and mulch treatments, independent of each other, significantly affected the nutrient profile of Swiss chard ($P < 0.05$), with fertiliser having a greater effect ($p=0.002$) than mulch ($p=0.0389$) (Table 4.3).

Overall, for children between the ages of six months and eight years to meet their AI or DRI for fibre, crude protein, calcium, magnesium, potassium, sodium, phosphorus, zinc, copper, manganese and iron through the consumption of Swiss chard as part of their daily dietary intake, organically fertilised Swiss chard would require double the consumption (g/day) compared to the unfertilised (control) or inorganically fertilised Swiss chard. The addition of inorganic fertiliser to the soil resulted in a marginal increase in the nutrient profile of Swiss chard when compared to the control. Therefore, in terms of poor communities, the marginal difference in the nutrient profile of Swiss chard does not warrant the expense of inorganic chemical fertiliser.

The addition of mulch, particularly inorganic mulch, to the soil improved the overall nutrient profile of Swiss chard. Children between the ages of six months and eight years would have to eat times more Swiss chard (g/day) to meet their AI or DRI for fibre, crude protein, calcium, magnesium, potassium, sodium, phosphorus, zinc, copper, manganese and iron if the soil was unmulched, compared to soil mulched in plastic mulch if Swiss chard was part of their daily dietary intake,. In conclusion, in poor areas growing Swiss chard, the soil should be mulched with either grass mulch or inorganic plastic mulch. Therefore, based on these results, the application of inorganic fertiliser or inorganic mulch resulted in the most nutrient dense Swiss chard.

The interaction between fertiliser and mulch treatments did not significantly affect the nutrient profile of Swiss chard ($p>0.05$).

5.5 Summary

The absence of fertiliser and application of organic grass mulch took the most average number of days to reach maturity. There was no significant interaction between mulch and fertiliser treatments ($p=0.05$). Swiss chard grown in inorganic mulch grew 1.3 times faster than Swiss chard grown in no mulch (control).

Fertiliser and mulch treatment combinations, or individual treatments, did not have a significant effect on the number of leaves produced on Swiss chard plants grown at the study site. In terms of nutrient profile, the interaction between fertiliser and mulch treatments did not significantly affect the nutrient profile of Swiss chard ($p>0.05$).

Overall, for children and adults to meet their AI or DRI for fibre, crude protein, Ca, Mg, K, Na, P, Zn, Cu, Mn and Fe through the consumption of Swiss chard as part of their daily nutritional intake, fertilised with organic kraal manure, they would have to eat more Swiss chard (g/day) compared to if it was unfertilised (control) or inorganically fertilised. This result is unexpected as vegetables grown in fertile soils are known to contain more nutrients than vegetables grown in poor soils (Gibson 2011; Shetty 2011; Welch 2001).

Areas with a high demand for Swiss chard (such as school gardens or large homesteads) may benefit from fertilising the soil with inorganic chemical fertiliser rather than organic kraal manure fertiliser, or mulching the soil with either organic grass or inorganic plastic mulch. However, inorganic fertiliser may be financially inaccessible, in which case organic kraal manure would not be recommended as it decreases the nutritional profile of Swiss chard and increases the mean number of days it takes to reach maturity. It would be better for Swiss chard in terms of growth rate and nutrient profile to be grown in control conditions in terms of fertiliser (no fertiliser) than adding organic kraal manure fertiliser. However, the long term benefits of kraal manure on the soil quality must be considered. In terms of mulch, organic grass and inorganic plastic mulch lowered the number of days that Swiss chard took to reach maturity and improved the nutrient profile of Swiss chard (inorganic mulch slightly more than organic mulch). However, the improvement of the nutrient profile of Swiss chard grown in mulch was not significant ($p>0.05$).

For home food gardens in the study area, it can be recommended that they use either inorganic fertiliser or plastic mulch. In the case that these garden treatments are financially inaccessible, it would be recommended that community members leave the soil untreated as opposed to applying kraal manure fertiliser or use inorganic grass mulch instead of plastic mulch. The nutrient profile was not significantly higher when mulch was applied, however mulching is beneficial to the soil. Therefore, it would still be recommended to mulch the soil.

CHAPTER SIX
CONCLUSION

6.1 Introduction

Malnutrition and food insecurity are highly prevalent in SA (HSRC 2013; Bouis *et al* 2011; Labadarios *et al* 2011a; Labadarios *et al* 2008; Labadarios *et al* 2005). To decrease their prevalence, multiple nutrition interventions were implemented. However, they were often hindered by extreme resource constraints (Shetty 2011). Home food gardens may be a sustainable intervention to improve food security and nutrient status of the rural poor in SA (Maboko & Du Plooy 2013; Faber *et al* 2011; Labadarios *et al* 2005).

With Swiss chard being commonly consumed throughout SA (Adekunle 2013; Faber *et* al 2013; HSRC 2013; Labadarios *et al* 2008; Labadarios *et al* 2005; Steyn *et al* 2001), it may have a significant contribution toward food security and improved nutrient status. Much research to date has investigated the effects of expensive garden treatments on Swiss chard grown, maintained and harvested in controlled environments according to agricultural guidelines (Engelbrecht *et al* 2010; Daiss *et al* 2008; Smith *et al* 2001). However, the majority of SA's Swiss chard is cultivated in open fields (Maboko & Du Plooy 2013), and maintained and harvested according to community practices.

The aim of this research was to identify, through a home food gardening study, the best affordable method of soil treatment for the production of nutrient dense Swiss chard in SA. The Swiss chard was cultivated, maintained and harvested according to the study community's practices. Therefore, the conclusions are directly related and implementable to the study community.

6.2 Conclusions

6.2.1 Experimental treatments and growth rate of Swiss chard

At an individual treatment level, organic and inorganic fertiliser and mulch had a significant effect on the maturity period (mean number of days taken to reach maturity) of Swiss chard compared to the control (no treatment). Inorganic chemical fertiliser and organic kraal manure fertiliser had contrasting effects on the maturity period of Swiss chard. Inorganic fertiliser lowered and organic fertiliser lengthened the maturity period of Swiss chard. Both organic grass and inorganic plastic mulch lowered the maturity period of Swiss chard when compared to the no mulch-control.

Therefore it would not be beneficial to add the combinations of fertiliser and mulch used in the current study (organic kraal manure and inorganic chemical fertiliser and organic grass and inorganic plastic mulch) to shorten the growth rate of Swiss chard. To produce Swiss chard with the shortest maturity period, inorganic chemical fertiliser or, either inorganic plastic or organic grass mulch may be used. However, when considering the affordability aspect of the study aim, inorganic chemical fertiliser and mulch is not affordable to poor communities. It may be recommended then, that organic grass mulch be used as the most affordable treatment method to grow Swiss chard with the fastest maturity period.

6.2.2 Experimental treatments and the leaf number of Swiss chard

This study determined that experimental treatments did not significantly affect the number of leaves on the Swiss chard plants.

In terms of leaf number of Swiss chard plants in terms of fertiliser and mulch, the most affordable gardening method to use would be the control methods (no fertiliser and no mulch).

6.2.3 Experimental treatments and the nutrient profile of Swiss chard

It was found that independently, experimental treatments significantly altered the nutrient profile of Swiss chard ($p<0.05$). Fertiliser, specifically inorganic, had a greater effect ($p=0.002$) than mulch ($p=0.0389$). Fertiliser and mulch combination experimental treatments did not significantly affect the nutrient profile of Swiss chard ($p>0.05$).

Therefore, the addition of the current study's treatment combinations (fertiliser x mulch) to the soil is not recommended in terms of the nutrient profile of Swiss chard, or the affordability of the treatments applied. It may be recommended to apply fertiliser, rather than mulch, to the soil to produce Swiss chard with the best nutrient profile. In particular, organic kraal manure fertiliser, which was obtained by the garden owners free of charge, may be recommended to use to grow Swiss chard with the best nutrient profile.

In conclusion, the addition of the current study's treatment combinations (fertiliser x mulch) to the soil, when growing Swiss chard, is not recommended to shorten the growth rate of, improve the leaf number of, or improve the nutrient profile of Swiss chard. The most affordable gardening treatments used in the study were organic kraal manure fertiliser and organic grass mulch. Both of these treatments are easily obtainable by gardeners at the study site, without charge. To grow Swiss chard in the shortest time period (days) the most affordable garden treatment recommended is organic grass mulch. To produce Swiss chard with the best nutrient profile) the most affordable garden treatment recommended is organic kraal manure fertiliser. The importance of the nutrient profile of Swiss chard, takes preference over the number of days taken for the Swiss chard to reach maturity, and the number of leaves present on the plant. Therefore, in conclusion, the most affordable gardening method to use, to produce the best quality Swiss chard is organic kraal manure fertiliser.

6.3 Critique of the study

6.3.1 Study limitations and recommendations

- The effect of different garden treatments on the vitamin A content of Swiss chard was not investigated due to financial constraints. Therefore vitamin A should be considered for analysis in future studies.
- Despite the plot having security measures in place, petty theft resulted in two experimental treatments and one control plot being stolen. However, this was overcome through the use of a RCBD, which allowed for statistical inference for missing plots.
- The community members at the study site did not have all the necessary resources required to initiate and maintain a food garden. This limitation was overcome through funding, which provided the financial means to equip the female 'food-preneurs' with these resources.
- A language barrier existed between the home food gardeners and the researcher. Therefore an isiZulu translator had to be appointed and attended all visits to the home food garden to ensure open and effective communication channels.

- Children do not rely solely on Swiss chard to provide dietary nutrient requirements. Future studies should compare the nutrient content of the average portion size of Swiss chard eaten by children fertilised and mulched in different experimental treatments.

6.4 Recommendations for nutrition practice

Swiss chard grown in inorganic fertiliser reached maturity the fastest and had the best nutrient profile when compared to the no fertiliser-control and organic kraal manure fertiliser. Therefore, ENGO's such as WCT should consider providing 'food-preneurs' with inorganic chemical fertiliser according to the soil analyses of the garden sites. By doing so, 'food-preneurs' will grow their Swiss chard faster, which will translate into a higher income, which may improve household food security due to the increased money available for food.

Globally, women of reproductive age and pre-school aged children are mostly affected by a number of deficiencies, including zinc (Luchuo *et al* 2013; Nuss *et al* 2012; Rice, West Jr & Black 2004, p213). Therefore, the findings of this study may be applied to grow Swiss chard higher in zinc to target this particular deficiency. In terms of fertiliser, Swiss chard fertilised with organic kraal manure fertiliser contained approximately 1.5 times more zinc than plants grown in no fertiliser (control). Inorganic fertiliser almost halved the zinc content of Swiss chard compared to the no fertiliser-control. Therefore, it may be recommended that areas with a high prevalence of zinc deficiency should fertilise their Swiss chard with organic kraal manure to produce Swiss chard with the highest zinc content.

More than two billion people worldwide are anaemic (World Health Organization (WHO) 2016b; Rice *et al* 2004, p249). Therefore, to work towards reducing the number of anaemic people in the study area, soil should remain unfertilised and unmulched because fertiliser and mulch (organic and inorganic) lowered the iron content of Swiss chard compared to the no fertiliser-control. This research can be applied to different areas, whereby analyses on the soil and garden treatments available in certain areas may be done. Thereafter recommendations can be made on how much of each treatment to apply to Swiss chard crops to improve its iron content. However, this process would be financially unfeasible to poor communities and would therefore need to be funded by government or non-government organizations.

Moreover, growing Swiss chard may increase vegetable consumption and dietary diversity, a limitation of which has resulted in many nutrient deficient South Africans (Love *et al* 2001).

6.5 Implications for further research

Food gardens can act as a buffer against extreme poverty and therefore play an important part in maintaining food security. However, there are a number of guidelines that need to be considered when carrying out further research:

- The study was short-term, and the effects of the experimental treatments on the quality of the soil could therefore not be investigated. Future long-term studies taking place during multiple seasons should be conducted to investigate this.
- This study focused on Swiss chard only, future studies should focus on growing a variety of vegetables in one plot in order to determine the effect of experimental garden treatment in terms of crop size and nutritional quality on other vegetables.
- This study only analysed the soil at the study site before experimental treatments were applied, it should be considered in future studies to analyse the soil before and after applying experimental treatments in order to determine the effects of the experimental treatments on the soil condition.
- The results of the study are only applicable to the study site and therefore further research should include a study area representative of larger areas of KZN.
- Although Swiss chard is resilient to weather variability (ARC 2013a; Niederwieser 2001 p140), future studies should investigate the effect of weather/season on the nutritional profile of Swiss chard.
- An important component to investigate for further research is a discussion on the differences in nutrient content in an average portion size of Swiss chard, with and without fertiliser and mulching.

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APPENDIX A: AOAC Methods

ASH CONTENT

1. Application

This method is used for the determination of ash or organic matter in animal feed and plant tissue samples.

2. Principle

Organic matter of a sample is removed by heating to a temperature of 550ºC. The remaining residue is ash.

3. Analytical procedure

3.1 Safety precautions

- Crucibles are hot, use the crucible clamp to handle them.
- Use heat resistant gloves when removing crucibles from the oven.

3.2 Apparatus

Analytical Balance, accurate to 0.0001g

Porcelain crucibles and lids

Stainless steel tray for furnace

Desiccator

Forced air oven

Furnace

Spatula

Crucible clamps

3.3 Procedure

Note: Sample must be ground to pass 1mm sieve.

1. Dry crucibles and lids in an oven at 90 - 105ºC overnight.
2. Place them in the desiccator to cool.
3. Weigh crucible and lid, and record the combined mass ($\mathbf{W_1}$).
4. Weigh approximately 1g of well-mixed dry sample and record the mass, i.e.

Combined mass of crucible, lid and sample (**W_2**).

5. Replace lid onto crucible and place in the furnace set at 550ºC, overnight.

Allow furnace to cool to less than 200ºC before attempting to remove tray.

6. Place in the desiccator to cool.
7. Weigh and record the mass (**W_3**).

3.4 Calculation

$$\text{Ash (\%)} = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

Organic Matter (OM) % = 100 – Ash (DM) % Where:

W_1 = mass of pre-dried crucible.

W_2 = mass of sample + crucible.

W_3 = mass of sample + crucible after ashing.

4. Reference

AOAC Official Method 942. 05

CRUDE FAT (SOXHLET METHOD)

1. Application

This method is used for the determination of crude fat in animal feed and plant tissue samples.

2. Principle

Ether is heated in a flask until it boils. Cool water condenses the vapours and it drops onto the sample placed into an extraction thimble. The fat is extracted by the ether, which drops back into the flask. The ether is evaporated from the flask, leaving the fat behind.

3. Analytical procedure

3.1 Safety Precautions

- Wear respirator when using petroleum ether.
- Petroleum ether is a highly flammable solvent; extraction should be done in the fume cupboard, if not possible, extraction must take place in a well-ventilated area to remove ether vapors.
- Open flames are not allowed in the area of the extraction apparatus.

3.2 Apparatus

Analytical Balance

Oven at 90 - 105ºC

Desiccator

Cellulose extraction thimbles 25mm x 100mm

Spatula

Absorbent cotton wool

Buchi fat flasks

Buchi 810 Soxhlet Fat Extractor

3.3 Reagents

Petroleum ether, boiling point of 40 - 60ºC, AR

3.4 Procedure

Note:

- **Switch on the Buchi 810 Soxhlet Fat Extractor 15 minutes before loading samples.**

- **Sample must be ground to pass 1mm sieve.**

8. Place Buchi fat beakers in the oven to dry, overnight.
9. Place them in the desiccator to cool.
10. Place a thimble on the balance and tare the balance to read zero.

    Weigh approx 5g sample into the thimble and record the mass of a sample (**W_1**).
11. Place in the oven to dry for 1 hour (**fat extraction must be done on a dry sample**).
12. Weigh the Buchi fat beaker and record the mass (**W_2**).
13. Pair each thimble to a flask for numbering purposes.
14. Plug the thimbles with cotton wool, and then pour petroleum ether into the beakers approx ¾ full.
15. Place thimbles, one into each Soxhlet extractor.
16. Place the beakers onto the heating spaces. Close up and seal the 3 glass sections together.
17. Turn on the cooling water supply and check for leaks.
18. Allow extraction to take place for 4 hours.
19. Divert flow of refluxed **fat-free** solvent to collect in container at the back of the machine.
20. When flasks all appear to be free of solvent, open up the whole system and remove thimbles and beakers.

    Leave overnight on the bench for residual solvent to evaporate.
21. Dry beakers in the oven at 90^{o}C for an hour.
22. Allow to cool in the desiccator, weigh and record the mass (**W_3**).

3.5 Calculation

$$\textbf{Crude Fat (\%)} = \frac{W_3 - W_2}{W_1} \times 100$$

Where:

W_1 – Mass of a sample (g)

W_2 – Mass of the Buchi fat beaker (g)

W_3 – Mass of the Buchi fat beaker with extracted residue (g)

4. Reference

AOAC Official Method 920. 39 **ACID DETERGENT FIBRE (ADF)**

1. Application

This is a rapid method for lignocellulose determination in grains, feeds, silages and other plant material. The ADF procedure is used as a preparatory step for the determination of acid detergent lignin (ADL) and acid detergent insoluble protein (ADIN).

2. Principle

The ADF is a fraction of the feedstuff cell wall that consists of cellulose, lignin, cutin and silica, i. e. the difference between NDF and ADF is an estimate of hemicelluloses content. The sample is extracted with acid detergent solution and the remaining residue is dried.

3. Analytical procedure

3.1 Safety precautions

- Crucibles are hot, use the crucible clamp to move them.
- Use respirator mask and gloves when handling cetyl trimethyl ammonium bromide (CTAB) and acid.
- Do not use acetone in the Dosi-fibre machine.

3.2 Apparatus

Dosi fibre or Fibretec system

Balance, accurate to 0. 0001g

Forced Air Oven at 95ºC

Muffle furnace

Sintered glass crucibles, porosity 1 or 2

Desiccator

Crucible clamp

3.3 Reagents

Cetyl trimethyl ammonium bromide (CTAB).

Sulphuric acid, H_2SO_4, 0. 5M, 1N.

Dekalin (anti-foaming agent).

Acetone.

Acid detergent solution (ADS)

1. Weigh 98. 08g of 98% Sulphuric acid (1N H_2SO_4).
2. Add acid **slowly** to about 1000ml of distilled water and make volume up to 2000ml.

   Standardise.
3. Weigh 40g of CTAB into 3000ml Erlenmeyer flask, and then add 2000ml of 1N H_2SO_4 (from above) and stir to dissolve.

3.4 Determination

Note: Sample must be milled to pass 1mm sieve. If fat content is more than 10%, sample must be defatted prior to determination.

23. Dry crucibles in an oven overnight.
24. Place crucibles in a desiccator to cool, and then weigh (**W_1**).
25. Weigh about 1g of dry sample into each crucible and record the mass (**W_2**).
26. Place the crucibles in the extraction unit. Lower the fixing lever to **close the system up**.

    Ensure that crucibles fit snuggly, i.e. cannot be easily turned by hand.
27. **Put all the valves in the closed (OFF) position**, and turn on the condenser cooling water at a flow rate of about 1 litre per minute.
28. Add 100ml of cold ADS and 2ml of dekalin, to each crucible.
29. Check for leakages and then fit the cover in front of the heating section.
30. Turn the main switch ON, and turn the heater up to 90ºC. Bring it to boil, then adjust the heater to ±60ºC and allow samples to boil gently for 60 minutes.
31. Turn the heater OFF.
32. Open the tap of the water suction pump and switch the valves to the suction position.
33. When filtration is complete, close the valves. Rinse with hot water at least 3 times and filter until all material has been rinsed off the walls of the condenser tube. If drainage through the crucible becomes difficult due to blocked pores, switch the pressure pump ON and briefly turn the valve to the blow position.

34. Close all valves: Switch the water suction pump, pressure pump, power switch and the water tap off.
35. Transfer crucibles to the rack mounted at the front of the machine, by inserting the crucible clamp around the crucibles and free them using the release lever.
36. Soak the sample residue in acetone for 2 minutes.
37. Using a suitable rubber adaptor, place crucibles in the Buchner flask attached to the water suction pump. Apply suction and rinse once more with acetone. **Do not use acetone in the dosi-fibre machine.**
38. Dry in a 95ºC forced air oven, overnight.
39. Place in the desiccator to cool and weigh (**W_3**).

3.5 Calculation

$$\textbf{ADF (\%)} = \frac{(W_3 - W_1)}{W_2} \times 100$$

Where:

W_1 – Mass of a crucible (g).

W_2 – Mass of the original sample (g).

W_3 – Mass of residue in crucible after drying (g).

Note: If sample has been defatted then apply calculation to correct for fat loss.

4. Reference

AOAC Official Method 973.18

APPENDIX B: Gate keeper's permission

WILDLANDS™

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Email info@wildlands.co.za.
P.O. Box 1138 | Hilton | 3245 | South Africa

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07 March 2016
Miss Cayleigh Hepburn (SN 212546354)
School of Agricultural, Earth and Environmental Sciences
College of Agriculture, Engineering and Science
UKZN

Emial: cayleigh.hepburn@gmail.com

Dear Miss Hepburn

RE: PERMISSION TO CONDUCT RESEARCH

Gatekeeper's permission is hereby granted for you to conduct research at the kwaMnayndu homestead garden, towards your postgraduate studies. We note the title of your research project is:

"The Influence of Organic Verses Inorganic Mulching and Fertilizer on the Quality of Vegetables Grown in a Homestead Garden in Kwamnyandu, Msunduzi".

It is noted that you will be planting vegetables in the kwaMnyandu community garden and applying organic and inorganic mulching and fertilizer techniques to four different vegetable beds. It is also noted that thereafter samples of vegetables will be taken for nutrient analysis.

Yours Sincerely

Dr Roelie Kloppers
Executive Director

APPENDIX C: Ethical clearance

UNIVERSITY OF
KWAZULU-NATAL

INYUVESI
YAKWAZULU-NATALI

RESEARCH OFFICE
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Website: http://research.ukzn.ac.za/ResearchEthics/BiomedicalResearchEthics.aspx

24 May 2016

Ms Cayleigh Hepburn
School of Agricultural, Earth and Environmental Science
College of Agriculture, Engineering and Science
Cayleigh.hepburn@gmail.com

Dear Ms Hepburn

Study Title: "*The influence of garden treatments on the nutritional quality of vegetables grown in a peri-urban setting*"
Degree: *MSc*
BREC REF NO.: *EXM289/16.*

I refer to your application to BREC received on 09 May 2016 and wish to advise that exemption is granted for the above-mentioned study.

Site permission letter from Wildlands to conduct your research at the kwaMnayndu homestead garden has been noted by BREC.

This approval will be noted at the Biomedical Research Ethics Committee meeting to be held on 14 June 2016.

Yours sincerely

PROFESSOR J TSOKA-GWEGWENI
Chair: Biomedical Research Ethics Committee

cc: Dr Nicola Wiles (Supervisor)
Postgraduate Office